MONITORING AND REPORTING WORKPLAN

AND

MONITORING WELL INSTALLATION AND SAMPLING PLAN

PHASE 1:

INITIATION OF REPRESENTATIVE GROUNDWATER MONITORING NETWORK DESIGN &

MONITORING PROGRAM

EXISTING MILK COW DAIRIES – STANISLAUS AND MERCED COUNTIES, CALIFORNIA

FINAL

Prepared for

Central Valley Dairy Representative Monitoring Program

January 11, 2012

LUHDORFF AND SCALMANINI, CONSULTING ENGINEERS
WOODLAND, CA

Monitoring And Reporting Workplan

and

Monitoring Well Installation and Sampling Plan

Phase 1:

Initiation of Representative Groundwater Monitoring Network Design & Monitoring Program

Existing Milk Cow Dairies – Stanislaus and Merced Counties, California

Prepared for

Central Valley Dairy Representative Monitoring Program

January 11, 2012

Final

PROFESSIONAL GEOLOGIST TILL ERIC ANGERMANN No. 7789 01-11-2012 STATE OF CALIFORNIA

PROFESSIONAL GEOLOGIST TILL ERIC ANGERMANN No. 853 CERTIFIED HYDROGEOLOGIST 01-11-2012 STATE OF CALIFORNIA

This document is the finalized version of the June 16, 2011 *Public Review Draft* without changes. The *Public Review Draft* was conditionally approved by the Executive Officer September 9, 2011.

Vicki Kretsinger
Principal Hydrologist

Till Angermann
Senior Hydrogeologist

FOR Barbara Dalgish
Project Hydrogeologist

LSCE File No. 09-1-075

Table of Content

Tables, Figures, and Attachments

Acronyms

ASTM	American Society for Testing and Materials
COC	chain of custody
CVDRMP	Central Valley Dairy Representative Monitoring Program
CVHM	Central Valley Hydrologic Model
CVRWQCB	Central Valley Regional Water Quality Control Board (CVRWQCB)
DWR	California Department of Water Resources
GTAC	Groundwater Technical Advisory Committee
LSCE	Luhdorff and Scalmanini, Consulting Engineers
MAC	Multidisciplinary Advisory Committee
MCL	Maximum Contaminant Level
MRP	Monitoring and Reporting Program
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
SDFP	Sustainable dairy farming plan
QA	quality assurance
QC	quality control
RMP	Representative Groundwater Monitoring Program
TDS	total dissolved solids
TID	Turlock Irrigation District
TKN	Total Kjeldahl Nitrogen
UCCE	University of California Cooperative Extension
USCS	Unified Soil Classification System

1 Executive Summary

This document was prepared for the Central Valley Dairy Representative Monitoring Program (CVDRMP), and in response to the Central Valley Regional Water Quality Control Board's (CVRWQCB) *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies* (General Order) and its revised Monitoring and Reporting Program (revised General Order MRP). The CVDRMP is a coalition of more than 960 member dairies formed in 2010 to conduct and manage a Representative Monitoring Program. CVDRMP is a non-profit California corporation managed by a 12-member board of directors to administer the Representative Groundwater Monitoring Program (RMP). CVDRMP is presently in the process of creating a comprehensive sustainable dairy farming plan (SDFP). Components of the SDFP provide for rigorous peer review of RMP data collection, analyses, and interpretations, by two technical advisory committees, stakeholder input, and ongoing identification of research, extension and consulting needs, and funding sources necessary to support those needs. The CVDRMP also proposes to implement the RMP in a minimum of two phases with ongoing refinement as the program proceeds.

- Phase 1 RMP refers to the initiation of a network of dedicated monitoring wells in Stanislaus and Merced Counties, and associated comprehensive data collection, analysis, and reporting. The document herein is referred to as the Phase 1 RMP Workplan.
- Phase 2 RMP refers to the geographic expansion of the RMP to all San Joaquin Valley Counties, and selected counties in the Sacramento Valley, where dairy farming occurs. Phase 2 will be addressed in a separate Phase 2 Workplan.

The goal of the RMP is to identify dairy farm practices protective of groundwater quality (including practices currently employed in response to the General Order) using a data collection and analysis effort that targets a subset of Central Valley dairy farms. This Phase 1 RMP Workplan aims to satisfy the regulatory requirements for both the Monitoring and Reporting Workplan and the Monitoring Well Installation and Sampling Plan identified in the revised General Order MRP.

1.1 Area Selection for Phase 1 RMP Initiation

Luhdorff and Scalmanini, Consulting Engineers (LSCE) evaluated dairy farm characteristics along with environmental parameters to determine the area most sensitive to dairy management practices in the *Report of Results* (LSCE, 2010). This area was selected based on delineation of those areas in the Central Valley where high groundwater nitrogen and salt concentrations are thought to be substantially attributable to dairy operations and where changes in water quality are most likely to be detected quickly due to adoption of management practices required by the General Order. The analysis included comparison of key information such as relative dairy farm/milk cow densities and other historical livestock operations data, historical average depths to groundwater, soil permeability, historical recharge to groundwater, observed historical groundwater nitrate and total dissolved solids (TDS) concentrations, and whole farm nitrogen balances submitted to the CVRWQCB in response to the General Order. Based on the above criteria, the *Report of Results* recommended that the representative groundwater monitoring be initiated in Stanislaus and Merced Counties (i.e., from the Stanislaus River in the north and the Chowchilla River in the south) between the San Joaquin River and Highway 99. This area is referred to as the high priority area, and is characterized by predominantly coarse-grained, highly permeable soils, and shallow depth to groundwater.

The high priority area will facilitate understanding of the causal link between groundwater quality changes (as observed with the network of dedicated monitoring wells) in response to modifications to dairy management practices. The shorter the response time the sooner conclusions can be drawn from the data, and the higher the confidence in the identified linkage between management practices and groundwater quality trends. To increase the representativeness of the Phase 1 data collection effort, the Phase 1 RMP Workplan also includes dairy farms west of the San Joaquin River in an area of shallow groundwater and clay-rich, low permeability soils.

1.2 Selection of Phase 1 Dairy Farms

There are two key components involved in the transfer of nutrients and salts from the land surface to underlying soil and groundwater, specifically, the rate of deep percolation and constituent concentrations of the infiltrate. Accordingly, surface processes (including management practices) in combination with soil properties in the very shallow zone (e.g., the crop root zone of manure application areas) are important factors for groundwater quality analysis and interpretation. The relationship between these factors and the extrapolation of results from the RMP to non-monitored dairy farms is described below.

Physical Parameters

Physical parameters (e.g., soil texture, depth to groundwater, irrigation depth, manure and fertilizer application, and crop type and rotation) directly support the analysis and interpretation of groundwater quality data and the extrapolation of results from the RMP to non-monitored dairy farms. These parameters are key to the representativeness of the RMP, and dairy farms were selected accordingly for participation in the Phase 1 RMP.

Dairy Farm Infrastructure and Operational Characteristics

In contrast to physical parameters, dairy farm infrastructure and operational characteristics (e.g., dairy farm size; number of lactating milk cows, dry cows, heifers, calves, and bulls; and the relationship between annual manure exports and imports of synthetic fertilizers) do not have direct bearing on the analysis and interpretation of groundwater quality data, because they do not provide information on actual subsurface loading rates. Dairy farm characteristics were considered to assemble an initial group of dairy farms that is intended to be sufficiently representative of a cross section of typical dairy farms and a wide range of typical operational management practices for purposes of initiating the Phase 1 RMP. Therefore, from an infrastructure and operational standpoint, non-monitored dairies exhibiting similar characteristics are expected to be able to implement similar management practices that are determined to result in groundwater quality improvements on monitored farms. As such, the diversity of these parameters in the group of monitored dairy farms is key to the implementability of identified management practices on non-monitored dairy farms. It is expected that through the process of RMP refinement, initial data gaps will be identified and addressed during Phase 2.

Other Important Considerations

Only CVDRMP member dairy farms were considered because these farms are contractually bound to permit groundwater monitoring to occur on their property as part of the RMP. After reviewing the CVRWQCB's files, aerial photography was used to identify potential candidate farms. The owners/operators of these dairy farms were informed by mail, and also follow-up phone calls, that their dairy farms had been selected as a potential site to install RMP monitoring wells. These owners/operators were invited to an informational meeting on April 8, 2011 to introduce them to the RMP, the CVDRMP board of directors, and next steps. At the meeting, 23 site visits were scheduled.

Prior to the site visits, major selection criteria were the size and geometry of dairies' management units with regard to the inferred, prevailing regional groundwater flow direction. For example:

- Large management units are favorable to groundwater monitoring efforts on dairy farms.
- The geometry of the management unit should be such that the expected source area for the to-be-constructed monitoring well(s) would take full advantage of the management unit's extent.
- Clear separation between management units.

1.3 Representativeness of the Representative Groundwater Monitoring Effort

The ability to extrapolate monitoring results from dairy farms monitored under the RMP to non-monitored dairy farms rests on the selection of physical parameters that directly support the analysis and interpretation of groundwater quality data. For example, dairy practices on coarse-grained/sandy soils over shallow groundwater that result in groundwater quality improvements beneath cropped manure application fields that are part of the RMP are expected to produce similar results beneath non-monitored fields of similar soil types in areas of similar precipitation patterns. The same rationale applies to corrals and liquid manure storage ponds.

Since increased depths to groundwater and increased seasonal variability of groundwater level elevations do not exert control on subsurface salt loading rates, Phase 1 and subsequent phase results will also be applicable to areas with these characteristics without necessitating additional data collection efforts. Although response times between dairy management practices (and associated changing nutrient and salt loading characteristics) and potential groundwater quality changes in areas of deep first encountered groundwater will be significantly prolonged, there remains a potential for long-term impact and also improvement related to modified practices. Additionally, data analysis and interpretation in such areas are exacerbated by the difficulty to delineate (with a reasonable degree of confidence) contributing source areas and, ultimately, establish a causal link between groundwater quality results and the range of management practices by management unit. Consequently, measures to avoid groundwater quality impacts would likely not occur in these areas for a potentially very long time unless a proactive approach is taken via extrapolation of RMP results.

1.4 Groundwater Monitoring on Dairies

Groundwater monitoring efforts will target the uppermost zone of first encountered groundwater beneath three distinct management units, i.e., the liquid manure storage ponds, corrals, and manure applied forage fields.

There are two significant differences between traditional groundwater monitoring of regulated units and groundwater monitoring on dairy farms:

- Traditional regulated units are designed to not recharge groundwater, whereas irrigated agriculture depends on sufficient leaching of salt residue beyond the crop root zone to avoid increasing soil salinity and associated soil degradation and crop losses (and some recharge is also expected from corrals and liquid manure storage ponds). In the case of dairy farms, groundwater samples retrieved from both upgradient and downgradient monitoring wells will not originate from the same source areas but from different source areas.
- Typically, constituents of concern related to traditional regulated units are not commonly found in natural groundwater systems (e.g., petroleum products), and a detection in a downgradient well provides evidence that the regulated unit leaks (given that this constituent is not detected in the upgradient well). This is in contrast to irrigated agriculture, where constituents of concern (i.e., mainly nitrate and other salts) are ubiquitous in groundwater systems.

RMP Monitoring Well Design, Data Collection, and Data Interpretation

The circumstances under which groundwater monitoring is conducted in areas of irrigated agriculture have the following implications for monitoring well design, data collection, and data interpretation:

- RMP monitoring wells positioned downgradient of a management unit are aimed to be constructed such that they intercept groundwater, which originates under that targeted management unit, only.
- Groundwater sampling should occur in the upper few feet of the groundwater column to avoid mixing of (younger) groundwater originating under the targeted management unit with (older) groundwater from source areas upgradient of the targeted management unit.
- As a corollary to the above, the concept of comparing downgradient to upgradient groundwater quality as a means to determine potential groundwater degradation loses its utility in recharge-dominated systems.

The Phase 1 RMP attempts to address the above design challenges using a two-pronged approach:

- The Phase 1 RMP areas are characterized by very shallow groundwater. Also, irrigation water needs in most of these areas are largely satisfied with surface water deliveries from local water purveyors. This translates into less agricultural demands on groundwater resources and less pumping-induced seasonal groundwater level fluctuations.

- Most monitoring wells will be constructed as nested wells (i.e., two well casings with relatively short well screens located at different depth intervals, constructed in one bore hole).

Nested Monitoring Well Design

The nested monitoring well design planned for most of the Phase 1 sites provides monitoring facilities that:

- address uncertainty regarding the extent of the upgradient area contributing flow to the well (i.e., the source area);
- is less vulnerable to seasonal and longer-term groundwater level fluctuations than single-completion monitoring wells;
- is suitable for the installation of shorter screen lengths (e.g., 5-15 feet), which helps avoid potential groundwater quality bias due to vertical flow components in the wells; and
- can be used for chemical groundwater profiling including isotopic groundwater age dating.

The proposed nested design also (i) increases data quality and the confidence in analysis and interpretations, (ii) increases the flexibility for analytical approaches, and (iii) avoids or decreases the need for potential future well replacements, for example, as a result of groundwater level declines causing a well to go “dry”.

1.5 Proposed Phase 1 Network of Dedicated Monitoring Wells

This Phase 1 RMP Workplan proposes a network of 135 dedicated monitoring well locations distributed over 18 dairy farms in Stanislaus and Merced Counties, and associated comprehensive data collection, analysis, and reporting. Eighteen (18) of the proposed monitoring wells already exist and wells at 117 locations are proposed for installation. Eighty-six (86) monitoring well locations are distributed over 10 dairy farms located in the high priority area. Forty-nine (49) monitoring well locations are distributed over 8 dairy farms located in the area west of the San Joaquin River in Stanislaus and Merced Counties.

Most of these wells will be installed as nested wells (i.e., two wells of different depth and construction installed in one borehole). Therefore, the proposed 135 monitoring well locations actually symbolize a much larger number of individual monitoring facilities (possibly upwards of 200). However, for ease of communication, each well location is referred to as one well herein, regardless of whether or not it will be completed as a nested well.

1.6 Monitoring and Reporting

The monitoring activities proposed herein exceed requirements of the revised General Order MRP. This includes high frequency groundwater level measurements to evaluate potentially important seasonal intricacies of groundwater flow conditions, and comprehensive baseline sampling, subsequent quarterly sampling for a reduced set of constituents, and annual sampling for an expanded set of constituents.

A Monitoring Well Installation Completion Report will be prepared in compliance with Item C, Attachment A of the revised General Order MRP.

RMP Annual Reports will be prepared in compliance with the revised General Order MRP and applicable Standard Provisions and Reporting Requirements of the General Order, and in accordance with the goal of the RMP. The reports will present cumulative groundwater level and quality data collected to date and utilize tables and figures to communicate the dairies’ layout and infrastructure, monitoring results, pertinent observations, and data trends. The reports will provide geologic/lithologic conceptualization of the shallow subsurface, hydrogeologic analysis (e.g., groundwater level hydrographs, groundwater level contour maps, groundwater quality data, trend analyses, and statistical analyses) and comparative evaluations in view of variable land uses and dairy operations. Further, the reports will present and evaluate any information pertinent to the operation and management of the specific investigated dairy management units. Analytical tools may include statistical procedures such as:

- cluster analysis to assess the *a priori* hypothesis of differences in groundwater quality between management units;

- assessment of statistical sample distributions and spatial and temporal autocorrelations between groundwater samples to aid, for example, in the delineation of appropriate analytical approaches, sampling frequencies, and placement of additional monitoring wells;
- statistical intervals such as upper tolerance bounds or prediction intervals with associated confidence levels;
- concentration averaging specific to management unit and comparison against recharge and loading estimates;
- farm-scale averaging to assess overall farm performance; and
- group comparisons using, for example, analysis of variance (parametric or nonparametric).

1.7 Future Activities

CVRWQCB approval of this Phase 1 RMP Workplan will trigger several activities.

Within 3 months:

- Complete Phase 1 RMP well installation

Within 6 months:

- Advisory committees to CVDRMP (i.e., the Groundwater Technical Advisory Committee and the Multidisciplinary Advisory Committee) will be formed.
- Initiate a dialogue with the CVRWQCB regarding the overall scope of the Phase 2 RMP and cooperatively work with the advisory committees on the details to be incorporated in the Phase 2 RMP Workplan.
- A public stakeholder meeting will be held (location, time and agenda to be coordinated with CVRWQCB staff).

Ongoing Activities:

- ongoing data analysis and interpretation
- annual reporting
- RMP refinement (i.e., continuous improvement of the work effort, for example, via identification of data gaps)

A Summary Report (as described in the revised General Order MRP) will be prepared within 6 years of initiating Phase 1 sampling activities to provide a comprehensive synthesis of RMP monitoring activities (Phase 1 and subsequent phases), results, and findings related to dairy management practices historically and currently employed by the monitored dairy farms, the effects of those practices on groundwater quality, and observed groundwater quality trends in response to modified practices during the first 6 years of the program.

The Summary Report is intended to serve as a technical basis for evidence-based regulatory decision-making. In this capacity, the Summary Report will analyze and discuss the effectiveness of dairy management practices and provide information that will be applicable to both monitored and non-monitored dairy farms.

2 Introduction

This document was prepared for the Central Valley Dairy Representative Monitoring Program (CVDRMP), the administrative body managing the Representative Groundwater Monitoring Program (RMP). It is referred to as the Phase 1 RMP Workplan and aims to satisfy the regulatory requirements for both the Monitoring and Reporting Workplan and the Monitoring Well Installation and Sampling Plan identified in the revised General Order MRP. Phase 1 RMP refers to the initiation of a network of dedicated monitoring wells in Stanislaus and Merced Counties, and associated comprehensive data collection, analysis, and reporting. Phase 2 RMP refers to the geographic expansion of the RMP to all San Joaquin Valley Counties, and selected counties in the Sacramento Valley, where dairy farming occurs.

CVDRMP is presently in the process of creating a comprehensive sustainable dairy farming plan (SDFP). Components of this plan provide for rigorous peer review of RMP data collection, analyses, and interpretations, by two technical advisory committees, stakeholder input, and ongoing identification of research, extension and consulting needs, and funding sources necessary to support those needs.

Background

On May 3, 2007, the Central Valley Regional Water Quality Control Board (CVRWQCB) adopted *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies* (General Order) (CVRWQCB, 2007). The General Order defines an existing milk cow dairy as a dairy that (i) was operating as of October 17, 2005, (ii) filed a complete Report of Waste Discharge in response to the CVRWQCB's August 8, 2005 Report of Waste Discharge Request Letter, and (iii) has not expanded since October 17, 2005 (i.e., its herd size has not increased by more than 15%). The General Order regulates waste discharges to land at the majority of 1,429 existing dairies[1] of all sizes and imposes significantly more stringent requirements than in the past.

Relative to groundwater monitoring, the General Order and its accompanying Monitoring and Reporting Program (MRP) specify two requirements: (1) monitoring of domestic and agricultural supply wells at dairies, and (2) additional groundwater monitoring. The latter requirement is presently implemented by the Executive Officer by ordering individual dairies to install monitoring wells ("site-by-site approach"). However, the General Order also authorizes the Executive Officer to approve alternative monitoring methods. The Information Sheet (page IS-8) states:

> "In the future, the Executive Officer or Central Valley Water Board may determine that a proposed alternative method of environmental monitoring is appropriate to determine if groundwater protection is being achieved. One suggested alternative has been to allow regional groundwater monitoring as a substitute for groundwater monitoring at individual dairies. Any proposed alternative will require sufficient details for consideration by either the Executive Officer or Central Valley Water Board. The Executive Officer or the Central Valley Water Board must issue a monitoring and reporting program order for any alternative environmental monitoring."

To further the development of an alternative environmental monitoring method, Dairy Cares (www.dairycares.com) submitted a proposal on October 5, 2009 (Dairy Cares, 2009) to the CVRWQCB Executive Officer for the development of a collaborative plan that would allow a representative groundwater monitoring approach to satisfy the additional groundwater monitoring requirements in lieu of the site-by-site approach of the General Order MRP.

At the February 4, 2010 stakeholder meeting held at the CVRWQCB's offices in Rancho Cordova, Luhdorff and Scalmanini, Consulting Engineers (LSCE) presented an initial outline of the representative groundwater monitoring approach, which was developed based on a regional monitoring approach proposed by Dr. Thomas Harter of the University of California Cooperative Extension (UCCE) in September 2008 (Harter, 2008). The monitoring approach was discussed in greater detail at the March 9, 2010 meeting of the CVRWQCB's Groundwater Advisory Workgroup, also held at the CVRWQCB's offices in Rancho Cordova.

[1] As of January 2010 (personal communication with J.P. Cativiela, Dairy Cares, April 2, 2010).

Concurrently, LSCE evaluated dairy farm characteristics along with environmental parameters to determine the area most sensitive to dairy management practices in the *Report of Results* (LSCE, 2010; **Attachment 1**). This area (which is the primary focus in this document) was selected for initiating the RMP based on delineation of those areas in the Central Valley where high groundwater nitrogen and salt concentrations are thought to be substantially attributable to dairy operations and where changes in water quality are most likely to be detected quickly due to adoption of management practices required by the General Order. The analysis included comparison of key information such as relative dairy farm/milk cow densities and other historical livestock operations data, historical average depths to groundwater, soil permeability, historical recharge to groundwater, observed historical groundwater nitrate and total dissolved solids (TDS) concentrations, and whole farm nitrogen balances submitted to the CVRWQCB in response to the General Order. This work effort recommended that the representative groundwater monitoring be initiated in Stanislaus and Merced Counties (i.e., from the Stanislaus River in the north and the Chowchilla River in the south) between the San Joaquin River and Highway 99 (this area is referred to as the high priority area). Results of this work effort were presented at the April 5, 2010 stakeholder meeting held at the CVRWQCB's offices in Rancho Cordova.

Subsequently, two concurrent work efforts ensued. One was the formation of an administrative body to manage the RMP. This occurred on May 17, 2010 with the founding of the CVDRMP. The other effort concerned the modification of the MRP to provide regulatory support for the RMP. The revised General Order MRP was issued by the Central Valley Executive Officer on February 23, 2011 (CVRWQCB, 2011).

3 CVDRMP's Sustainable Dairy Farming Plan

CVDRMP is presently in the process of creating a comprehensive sustainable dairy farming plan (SDFP). The SDFP is tentatively composed of the following components:

- Phase 1 – Initiation of the RMP including a detailed network of dedicated monitoring wells located in Stanislaus and Merced Counties;
- Phase 2 – Geographic expansion of the RMP to include dairy farms in all counties in the San Joaquin Valley plus some dairies between Sacramento and Tehama Counties in the Sacramento Valley;
- formation of a Groundwater Technical Advisory Committee;
- formation of a Multidisciplinary Advisory Committee;
- stakeholder input and external review; and
- ongoing identification of research, extension and consulting needs (and funding sources necessary to support those needs) to ensure dairy practices are protective of water quality.

A detailed description of the Phase 1 RMP is presented in this Phase 1 RMP Workplan. This Phase 1 RMP Workplan also conceptually outlines Phase 2 by (i) quantifying its overall scope (i.e., general location and number of participating dairy farms) and (ii) providing a time table to develop a detailed Phase 2 RMP Workplan. The remaining SDFP components are outlined below.

3.1 RMP Administration

The CVDRMP is a coalition of more than 960 member dairies formed in 2010 to conduct and manage a Representative Monitoring Program. CVDRMP is a non-profit California corporation managed by a 12-member board of directors to administer the RMP. CVDRMP was officially formed on May 17, 2010, following a series of more informal scoping and planning meetings. Important duties for the board of directors in the near term are:

- solicitation of membership in the program from dairy operators/owners and collection and management of membership fees (962 members as of May 20, 2011);
- submission of an acceptable Phase 1 RMP Workplan to the CVRWQCB; and
- upon CVRWQCB approval of this Phase 1 RMP Workplan, selection and hiring of personnel to drill and install monitoring wells, collect groundwater level and quality data, compile, organize, analyze, and interpret data, and prepare annual monitoring reports.

3.2 Groundwater Technical Advisory Committee

The purpose of the Groundwater Technical Advisory Committee (GTAC) is to ensure adequacy of the RMP data collection effort, soundness of analytical tools, and interpretations. The GTAC will be formed within 6 months of CVRWQCB approval of this Phase 1 RMP Workplan. It is envisioned that this committee will include, for example, hydrologists, statisticians with experience in environmental applications relevant to this work effort, members of the University of California Cooperative Extension Hydrology Program, dairy farm representatives, and CVRWQCB staff and additional professionals as determined appropriate by CVDRMP. Members of the GTAC will be asked to critically review and formally comment on draft annual reports before their finalization. The GTAC review and comment process is to facilitate delivery of comprehensive work products (particularly Annual Reports) submitted to the CVRWQCB for its review, comment, and ultimate approval.

3.3 Multidisciplinary Advisory Committee

The MAC will be formed within 6 months of CVRWQCB approval of this Phase 1 RMP Workplan. It is envisioned that this committee will include professionals providing background in agronomy, economy, animal nutrition, irrigation, plant biology, hydrology, and civil engineering (with emphasis on liquid manure storage pond design, pond liners and covers, wastewater treatment, and digester technology), members of the University of California Cooperative Extension Hydrology Program, dairy farm representatives, and CVRWQCB staff, and others as deemed appropriate by CVDRMP.

The purpose of the Multidisciplinary Advisory Committee (MAC) is to:

- Aid in the compilation of a list of existing management practices, which will be used in the refinement of the RMP and affect both the extrapolation of RMP findings to non-monitored facilities and the expansion of the RMP;
- identify innovative methodologies[2], approaches, and analytical tools (e.g., whole farm nitrogen use efficiency modeling, modeling of nitrogen and salt movement in the root zone, and groundwater modeling) to support the RMP and its goals;
- review and evaluate results from implemented methodologies, approaches, and analytical tools;
- identify potential research needs; and
- identify potential solutions in response to findings of the RMP[3].

3.4 Stakeholder Input and External Review

Public stakeholder meetings will be held on a semi-annual basis starting upon approval of this Phase 1 RMP Workplan. The purpose of these stakeholder meetings will be to:

- inform stakeholder groups of the progress and development of the RMP and the overarching SDFP;
- inform stakeholder groups on key findings of the RMP that are presented in Annual Reports;
- provide a platform to discuss findings and answer questions on the SDFP; and
- provide a platform for public input and external review from interested parties.

[2] An example of a promising methodology to assess the seepage rate of working liquid manure storage ponds was identified as part of a systematic literature review (LSCE, 2008). A demonstration project including the application of this methodology to five liquid manure storage ponds in winter 2010/11 in conjunction with an outreach program has been funded by the U.S. Department of Agriculture (USDA) and California Department of Food and Agriculture/Dairy Cares and is presently being carried out. Results from this demonstration project will be submitted to the MAC for critical review and comment.

[3] It is fully expected that such developed management practices will be relevant to both CVDRMP member dairy farms and also to non-member dairy farms.

4 Purpose and Scope

The purpose of this Phase 1 RMP Workplan is to seek CVRWQCB approval to proceed with the implementation of the RMP. Specifically, this document aims to satisfy the regulatory requirements for both the Monitoring and Reporting Workplan and the Monitoring Well Installation and Sampling Plan identified in the revised General Order MRP. The remainder of this document is structured as follows:

- *Section 5* provides detailed discussions of RMP components and underlying rationale controlling the design of the Phase 1 well network. This includes:
    - *Section 5.1* – a discussion of similarities and differences between traditional groundwater monitoring for regulatory compliance and groundwater monitoring in irrigated agricultural settings,
    - *Section 5.2* – a description of anticipated data collection efforts the RMP will pursue to facilitate interpretation of groundwater quality trends beneath management units,
    - *Section 5.3* – key features of the RMP,
    - *Section 5.4* – a summary of how the high priority area was identified,
    - *Section 5.5* – a discussion of key parameters used in the selection of dairy farms,
    - *Section 5.6* – the rationale for the proportional distribution of proposed monitoring wells,
    - *Section 5.7* – the rationale for extrapolating monitoring results to non-monitored dairy farms,
    - *Section 5.8* – the process of ongoing RMP refinement, which aims to improve the representativeness and overall performance of the RMP, and
    - *Section 5.9* – the process of Phase 2 expansion of the RMP.
- *Sections 6-8* present information for the Monitoring Well Installation and Sampling Plan portion of the Phase 1 RMP Workplan, i.e., detailed information on proposed well locations, preliminary well design, well development, wellhead surveying, and groundwater sampling procedures.
- *Sections 9* and *10* present a detailed monitoring and reporting program that exceeds requirements set forth in the General Order.
- *Section 11* proposes a schedule for the installation of the monitoring well network described herein through the submittal of a Monitoring Well Installation Completion Report to the CVRWQCB. It also provides a conceptual process schedule, including timelines for the creation of technical advisory committees, RMP refinement, and RMP expansion (Phase 2).
- *Section 11* – References

5 Representative Groundwater Monitoring Program

The goal of the RMP is to identify dairy farm practices protective of groundwater quality using a data collection effort that targets a subset of Central Valley dairy farms. To reach this goal, the RMP aims to:

- examine current groundwater conditions and how they relate to historical dairy management practices and recent changes to those practices; and
- generate results and recommendations for additional changes to waste management and utilization practices that are applicable beyond areas of monitored dairies (to non-monitored dairies).

5.1 Framework

Nearly the entire acreage of a typical Central Valley dairy constitutes a potential source of manure-related waste discharge, including the corrals or exercise yards, the freestalls with their flush lanes, underground waste conveyance facilities, solid and liquid waste storage facilities, areas for manure drying and feed storage, and all crop land receiving manure applications, including elaborate irrigation and drainage systems of pipes, canals, and ditches. In addition, the adjacency of different management units (with different loading characteristics) and the large size of dairies (i.e., hundreds to sometimes thousands of acres) makes groundwater monitoring, as the sole means to enforce compliance with water quality objectives, ineffective and very expensive. Many dairies apply manure and commercial fertilizer to grow feed for their animals on 10 to 20 or more individual fields. Crop types, cropping patterns (including crop rotations within a year and year-to-year), irrigation practices, manure application rates, and other variables may vary substantially from field to field. Highly variable application rates may also occur within individual fields. While many of these fields are adjacent to each other, many fields may also be distant from the production area[4]. There may also be significant changes from year to year, as land leases expire and new land is acquired. In light of the inherent complexity of dairy operations and their sheer geographic extent, groundwater monitoring can feasibly occur only on a small fraction of the manure application areas and other management units. In an effort to respond to the challenges outlined above, the Phase 1 RMP was developed and includes an extensive groundwater monitoring network consisting of new and existing dedicated monitoring wells.

For the purposes of extensive groundwater quality research, California dairy farms have previously been conceptualized to consist of three main management units, the land application areas, corrals, and liquid manure holding ponds (CVRWQCB, 2007; Harter et al., 2001a; Harter, 2008; van der Schans et al., 2009). These management units have been documented to exhibit distinctly different subsurface loading characteristics and are often large enough to support targeted groundwater quality monitoring. Therefore, this concept has been incorporated into the RMP.

It is useful to compare traditional groundwater monitoring of regulated units (e.g., underground storage tanks, mining operations, refineries, dry cleaners, and landfills) to groundwater monitoring on dairy farms. In either case, the monitoring effort targets the uppermost zone of first encountered groundwater, i.e., the shallowest existing groundwater. However, there are two significant differences with important implications regarding monitoring well design, data collection, and data interpretation.

1. Traditional regulated units are designed to not recharge groundwater. This is accomplished by roofing, asphalt and concrete surfaces, synthetic liners, and possibly leachate collection systems. As a result, monitoring wells placed upgradient and downgradient of the unit may have an essentially identical source area (i.e., the area which supplies groundwater to the well). Under this traditional concept, the comparison of upgradient (i.e., ambient or background) groundwater quality to downgradient groundwater quality is critical in the determination of potential groundwater degradation. In contrast, irrigated agriculture depends on sufficient leaching of salt residue beyond the crop root zone to avoid increasing soil salinity and associated soil degradation and crop losses. In this case, samples retrieved from both upgradient and downgradient monitoring wells will not originate from essentially identical source areas but from completely different source areas. In this scenario, the emphasis for purposes of the assessment of potential impact to groundwater quality is now shifted to the downgradient well.

[4] The production area encompasses the actual dairy facility where animals are bred, housed, and fed including support infrastructure such as barns, feed and waste handling and storage facilities, and the milk barn.

2. Typically, constituents of concern related to traditional regulated units are not commonly found in natural groundwater systems (e.g., petroleum products, volatile or aromatic organics, pesticides, and other chemicals), or not in as high of concentrations (e.g., heavy metals). This has important implications regarding groundwater quality interpretation. For example, if a groundwater sample retrieved from a monitoring well downgradient of a gas station in an urban/industrial setting shows any detection of benzene (regardless of how small it might be), and the upgradient well has no such detections, it is determined that the unit is leaking. The fact that the leachate is much diluted has no effect on the conclusion that the unit leaks. If, however, the upgradient well shows similar benzene concentrations, this conclusion is not warranted (i.e., following the paradigm of “no groundwater quality change”). This is in contrast to irrigated agriculture in general and dairy farms in particular, where constituents of concern (i.e., mainly nitrate and other salts) are ubiquitous in groundwater systems[5]. In this case, the traditional concept provides an unsatisfactory interpretation, because a given nitrate or salt concentration in a downgradient monitoring well could be the result of any number of (i) management unit subsurface loading rates, (ii) upgradient subsurface loading rates, and (iii) proportional representations of both management unit and upgradient contributions.

The above has the following implications for monitoring well design, data collection, and data interpretation:

- RMP monitoring wells positioned downgradient of a management unit are aimed to be constructed such that they intercept groundwater which originates under that targeted management unit, only.
- Groundwater sampling should occur in the upper few feet of the groundwater column (i.e., shorter well intake screen) to avoid mixing of (younger) groundwater originating under the targeted management unit with (older) groundwater from source areas upgradient of the targeted management unit.
- As a corollary to the above, the concept of comparing downgradient to upgradient groundwater quality as a means to determine potential groundwater degradation loses its utility in recharge-dominated systems.

The above also highlights the challenge of installing monitoring wells for purposes of the RMP or likewise, the regulatory site-by-site approach on dairy farms. The monitoring effort needs to focus on the upper few feet of the groundwater column. Since the well screen (for groundwater intake) is placed according to field observations during drilling (i.e., lithology, initial and equilibrated groundwater levels), even moderately fluctuating groundwater levels (i.e., seasonal or longer-term fluctuations) have the potential to render a monitoring well useless. Longer well screens (commonly used in domestic and agricultural supply wells) would address this issue. However, this is counter to the needs for above *Item 1*.

The Phase 1 RMP attempts to address the above design challenges using a two-pronged approach.

1. The Phase 1 RMP areas are characterized by very shallow groundwater. Also, irrigation water needs in most of these areas are largely satisfied with surface water deliveries from local water purveyors. This translates into less agricultural demands on groundwater resources and less pumping-induced seasonal groundwater level fluctuations.
2. Most monitoring wells will be constructed as nested wells (i.e., two well casings with relatively short well screens located at different depth intervals, constructed in one bore hole).

5.2 Additional Data Collection

In addition to the collection of groundwater level and quality data, the RMP will pursue other data collection efforts necessary to interpret groundwater quality trends beneath management units. Specifically, information currently submitted to the CVRWQCB in response to the General Order will be complemented by additional data to fully analyze and interpret current groundwater quality and also quality changes beneath manure application areas, corrals, and liquid manure storage ponds. For these management units, detailed study and recordation of on-farm practices will be necessary. For example, in the case of the manure application areas, results from tile drain water analyses will be

[5] This may be different in the vicinity of liquid manure storage ponds where ammonium has been documented in some monitoring wells.

included in the evaluation. Also, more detailed tracking of irrigation water, manure, and fertilizer applications in relation to crop demands specific to crop type and species/sub-species (trade name if genetically engineered) will be collected to more effectively interpret groundwater quality. In the case of corrals, more detailed tracking of corral conditions and management (e.g., soil type, methods/degree of soil compaction, slope and drainage, observations of precipitation ponding, animal hours spent on the corral, frequency of manure scraping) will be collected to more effectively interpret groundwater quality. In the case of liquid manure storage ponds, more detailed tracking of pond conditions and management (e.g., waste depth, nutrient and salt concentrations, berm conditions, periodic draining and sediment removal) will be collected to more effectively interpret groundwater quality.

The data collection effort described above will commence upon CVRWQCB approval of this Phase 1 RMP Workplan. This effort will likely involve consultants that already routinely provide services to the dairy farms regarding the collection and compilation of information in response to the General Order. Data collection efforts will be refined as potential data gaps or redundancies are identified.

5.3 Key Features

The following are key features of the RMP:

- monitoring effort focused on three distinct management units (i.e., crop fields, corrals, and liquid manure storage ponds);
- individual well design based on local predominant gradients, hydraulic conductivities in the shallow groundwater zone, and estimated recharge rates;
- network of monitoring facilities encompassing many dairies (group approach);
- systematic development of a comprehensive data set;
- centralized data collection and compilation;
- uniform quality assurance (QA) and control (QC);
- comprehensive data analysis and evaluation;
- rigorous peer review by Groundwater Technical Advisory Committee (GTAC);
- rigorous peer review and independent work by Multidisciplinary Advisory Committee (MAC); and
- comprehensive reporting.

Fundamentally, the RMP monitoring well network is more comprehensive than the traditional site-by-site monitoring well networks and groundwater investigations at individual dairy farms, because the RMP network optimizes well installation efforts and emphasizes the systematic development of a comprehensive data set. Through this integrative approach, the total number of monitoring wells and their relative distribution over application areas, corrals, and liquid manure storage ponds is determined by balancing the need for a sufficiently large data set to capture the existing variability within management units and between dairies with the expected variability of groundwater quality changes in response to future modifications to current management practices.

5.4 Area Selection for Monitoring Well Network

It is critical to the success of the RMP that a causal link be established between groundwater quality changes (as observed with the network of dedicated monitoring wells) in response to modifications to dairy management practices. The shorter the response time the sooner conclusions can be drawn from the data, and the higher the confidence in the identified linkage between management practices and groundwater quality trends. Therefore, the emphasis for the Phase 1 RMP implementation was placed on an area of high aquifer sensitivity (i.e., highly permeable soils and shallow depth to groundwater), as summarized below.

In the northern San Joaquin Valley, the area in Stanislaus County between the San Joaquin River and Highway 99, and extending south into Merced County, emerged as an area of very high dairy farm density and milk cow density (**Attachment 1**). These two counties have consistently had the second and third largest overall herd size while other livestock operations have been comparatively minor. Based on the California Department of Water Resources (DWR) depth-to-groundwater contour maps and the U.S. Geological Survey's Central Valley Hydrologic Model (CVHM) (Faunt, 2009) groundwater level output, the above Stanislaus/Merced dairy farm area overlies very shallow groundwater (i.e., <20 feet, below ground surface). Soil data indicate a prevalence of high permeability soils in this area, and CVHM groundwater recharge estimates for this area indicate moderate to moderately high annual recharge. Greatly elevated groundwater nitrate-N concentrations occur in this area, and an overall increase of nitrate-N concentrations is apparent since the 1980s. According to CVRWQCB files, the results from the recent (2007-2008) dairy-specific nitrate monitoring also show elevated groundwater nitrate concentrations in this area. Lastly, Stanislaus and Merced Counties are characterized by relatively high N-balances in comparison to other San Joaquin Valley dairy farms.

In the southern San Joaquin Valley, the area west and east of Highway 99 in Kings and Tulare Counties also emerged as an area of very high dairy farm density and milk cow density (**Attachment 1**). Tulare County has always had the largest herd size (1.8 times larger than Merced County's herd size in 2005) and has experienced substantial growth of the milk cow population over the last two decades while other livestock operations have been very minor. Kings County has also experienced large increases in cow population and ranks fourth in terms of its herd size; other livestock operations have been very minor. Based on the DWR depth-to-groundwater contour maps and the CVHM groundwater level output, the depth to groundwater beneath the Tulare/Kings dairy farm cluster is deeper and more heterogeneous (ranging mainly from 40 to 80 feet, bgs) than beneath the high density dairy farm area in Stanislaus and northern Merced Counties, with shallower groundwater beneath dairies near the Tulare lakebed and substantially deeper groundwater south of Tule River. CVHM recharge estimates for this area indicate predominantly high annual recharge. These model results are consistent with the prevalence of high permeability soils in this area. The area of low permeability soils west of Highway 99 in Tulare County also roughly corresponds to deeper water levels. Groundwater nitrate-N concentrations from the 1990s compared to those from the 2000s indicate an increasing trend. This increase occurred during a time when the herd size in Tulare County more than doubled. The results from the recent (2007-2008) dairy-specific nitrate monitoring also indicate elevated nitrate-N concentrations in this area. Lastly, N-balances in this area are similar to the rest of the San Joaquin Valley.

Only 3 percent of the Central Valley milk cow population resides in the Sacramento Valley, cow populations have remained fairly stable in the Sacramento Valley, and milk cows constitute a comparatively small proportion of all livestock. Contours of equal depth to groundwater in the unconfined aquifer of the Sacramento Valley were not available from DWR. Based on CVHM groundwater level output only, dairies in Sacramento County and most other places in the Sacramento Valley are situated on very shallow groundwater. However, the recent maximum nitrate-N concentrations in agricultural and domestic wells located on dairy farms in the Sacramento Valley are predominantly below the Maximum Contaminant Level (MCL).

The prevalence of high permeability soils in combination with very shallow depths to groundwater, high nitrate-N concentrations, and relatively high N-balances present favorable baseline conditions, as future changes in field and dairy management practices are likely to positively affect groundwater quality more rapidly than in other regions. Therefore, this region was recommended as the high priority area to initiate the representative groundwater monitoring program approach. To increase the representativeness of the Phase 1 data collection effort, the Phase 1 RMP Workplan is comprised of dairy farms located in both the high priority area and west of the San Joaquin River in an area of shallow groundwater and clay-rich, low permeability soils (**Table 1**, **Figure 1**).

5.5 Selection of Initial Dairy Farms

5.5.1 Key Parameters

The selection of dairy farms for the initiation of the RMP was based on two types of parameters:

- physical parameters that control subsurface loading; and
- dairy farm infrastructure and operational characteristics.

The subsurface loading rate is determined by the product of its two components, the rate of deep percolation (i.e., the amount of infiltrated water reaching first encountered groundwater) and the constituent concentration of the infiltrate. It is a chemical flux that describes a particular management unit's performance. This concept is applicable to any management unit, and is described in more detail by management unit in *Sections 5.5.1.1 – 5.5.1.3* and further discussed in *Section 5.5.1.4.*

Physical parameters directly support the analysis and interpretation of groundwater quality data and the extrapolation of results from the RMP to non-monitored dairy farms. As such, these parameters are key to the representativeness of the RMP. Some physical parameters are largely independent of dairy operational decisions and management, and they cannot be readily changed by individual dairy farm practices. These parameters are referred to as “static” in this context (**Table 2**). Examples are soil texture (i.e., the proportional grain size distribution of soil particles) and precipitation. The overall depth to groundwater is also a physical parameter, which is largely independent of individual farmers’ dairy operational decisions and management[6]. However, the depth to groundwater does not control subsurface loading, it merely affects the travel time of the infiltrate through the unsaturated zone and, thus, exerts control on the response time between surface processes and groundwater quality responses[7]. Similarly, the age of an existing management unit does not control subsurface loading. However, knowledge of the age of an existing management unit may aid in the evaluation of the lag time between commencement of operation and downgradient groundwater quality effects.

Other parameters are subject to change. The irrigation rate and duration, fertilizer application, and crop type are examples of parameters important in relation to manure application areas. Examples for corrals are ground surface slope (to provide drainage), degree of compaction, and maintenance thereof. Examples for liquid manure storage ponds are ultimately (and most directly) seepage rate and constituent concentrations (i.e., the components of the chemical flux). These parameters can be addressed via management practices; therefore, they are referred to as “dynamic” in this context.

To establish basic parameters that have bearing on the direct analysis and interpretation of groundwater quality data and the extrapolation of results from the RMP to non-monitored dairy farms, it is useful to recognize and focus on the two components involved in subsurface loading, i.e., the rate of deep percolation and constituent concentration of the infiltrate. From this, it is clear that surface processes (including management practices) in combination with soil properties in the very shallow zone (e.g., the crop root zone of manure application areas) are key elements for groundwater quality analysis and interpretation.

In contrast to physical parameters, dairy farm infrastructure and operational characteristics do not have direct bearing on the analysis and interpretation of groundwater quality data, because they do not provide information on actual subsurface loading rates. Dairy farm characteristics used to assemble an initial group of dairy farms that is intended to be representative of a cross section of typical dairy farms and a wide range of typical operational management practices are discussed in *Section 5.5.1.5*. Examples include (i) the dairy farm size, (ii) number of lactating milk cows, dry cows, heifers, calves, and bulls, and (iii) the relationship between annual manure exports and imports of synthetic fertilizers. Specifically, dairy farm size (including the total cropping area available for manure application) in absolute terms or in relation to the total number of animals on the farm does not provide an indication of actual nitrogen and salt application rates occurring on particular forage fields. Similarly, the relationship between annual manure exports and imports of synthetic fertilizers is not sufficient to explain any particular constituent concentration in a groundwater sample obtained from a particular monitoring well.

Dairy farm characteristics were considered to assemble an initial group of dairy farms that is intended to be sufficiently representative of a cross section of typical dairy farms and a wide range of typical operational management practices for purposes of initiating the Phase 1 RMP. Therefore, from an infrastructure and operational standpoint, non-monitored dairies exhibiting similar characteristics are expected to be able to implement similar management practices that are determined to result in groundwater quality improvements on monitored farms. As such, the diversity of these parameters in the group of monitored dairy farms is key to the implementability of identified management practices on

[6] It is recognized that irrigated agriculture can and does affect groundwater levels on a regional scale.

[7] In the case of nitrogen components, reactive transport such as denitrification may also play a significant role in some localized subsurface environments (particularly in clay-rich soils), although denitrification rates may overall be less significant, even in deep vadose zone environments, than previously hypothesized (Harter et al., 2006). This is a very active field of research, and estimates of denitrification rates usable for consideration in the selection of dairy farms are currently not available. Similarly, sorption and desorption processes were not considered in this context, as quantification of these do not relate to actual subsurface loading (but merely to constituent fate and transport rates once introduced to the subsurface).

non-monitored dairy farms. However, it is fully expected that through the process of RMP refinement, initial data gaps will be identified and addressed during Phase 2 (and possibly later phases) and also the activities of the GTAC and MAC.

5.5.1.1 Physical Parameters – Manure Application Areas

For purposes of interpreting groundwater quality beneath cropped manure application areas, the primary focus is on soil texture, irrigation and precipitation, and the application rate and fate of nutrients. Soil texture, and particularly its clay content, relates to the infiltration rate and its rate of change during individual irrigation and precipitation events (and consecutive events). For example, soil properties in conjunction with the rate of irrigation application (e.g., in a furrow irrigated system) relate to the spatial variability of deep percolation losses along the furrow profile. Irrigation types (e.g., furrow, flood, impact or micro sprinkler) and practices (e.g., rate of irrigation application, timing and duration of irrigation events) are often chosen to complement particular soil types. Likewise, the frequency and rate of fertilizer applications to satisfy a particular crop's demand depends, in part, on the soil. Precipitation, while typically not a major contributor to deep percolation beneath crop fields in the San Joaquin Valley, poses a complicating variable to the farmer, as it can affect decisions relating to the timing of sowing, planting, harvest, irrigation, and manure/fertilizer applications. In addition, it can potentially cause unwanted flushing of the root zone. Since the long-term sustainability of irrigated agriculture depends on the flushing of excess salts below the root zone (to prevent a detrimental accumulation of salts), it becomes apparent that the interaction between the soil, irrigation and precipitation, and manure/fertilizer application is key to the interpretation of groundwater quality beneath cropped manure application fields.

Farming practices on coarse-grained/sandy soils and fine-grained/clay-rich soils that result in groundwater quality improvements beneath cropped manure application fields that are part of the RMP are expected to produce similar results on non-monitored fields of similar soil types in areas of similar precipitation patterns. Consequently, for purposes of selecting dairy farms (and particularly the associated manure application areas) for the initiation of the RMP, the primary focus was on soil texture and precipitation. Specifically, regarding static physical parameters, the emphasis was to initiate a large data set related to application fields on coarse-grained soils and on fine-grained soils in an area of shallow groundwater occurrence and similar annual precipitation. In terms of dynamic physical parameters, Phase 1 dairy farms were selected to include forage crops typical for the industry (e.g., corn, oats, alfalfa, sudan, pasture, and wheat) as well as two less typical, yet not insignificant crops (e.g., almonds). Likewise, the initial dairy farm group employs typical irrigation practices for their forage crops, namely flood and furrow irrigation. Lastly, crop fertilization occurs by use of synthetic fertilizers, and both liquid and dry manure.

5.5.1.2 Physical Parameters – Corrals

Corrals are designed (or should be designed) to minimize infiltration and deep percolation. For purposes of interpreting groundwater quality beneath corrals, the primary focus is on soil texture, precipitation, and the rate and fate of nitrogen and salt excretions onto the corral surface. Naturally, these parameters are very similar to parameters discussed for the application areas, because the fundamental components (i.e., liquid and chemical flux) that control subsurface loading are the same. The liquid flux is largely determined by soil texture and precipitation, and it can be reduced by management practices such as compaction of the soil and sloping of the corral surface to provide positive drainage and reduce pooling of water during the rainy season[8]. The mass input (i.e., the excretion rate) can be controlled by management practices relating to the total amount, rate, and timing of nitrogen and salt excretions. The fate of excretions can be controlled by the frequency and timing of manure removal (e.g., via scraping).

Management practices (as outlined above) on coarse-grained/sandy corrals and fine-grained/clay-rich corrals that result in groundwater quality improvements beneath corrals that are part of the RMP are expected to produce similar results on non-monitored corrals of similar soil types in areas of similar precipitation patterns. Consequently, for purposes of selecting dairy farms (and particularly the associated corrals) for the initiation of the RMP, the primary focus was on soil texture and precipitation. Specifically, regarding static physical parameters, the emphasis was to initiate a large

[8] Good maintenance to of a sloped corral surface during the rainy season is important in order to reduce pooling and infiltration, but may be difficult to achieve, for example, in saturated clay-rich soils. This highlights the importance to continuously monitor corral surface conditions.

data set related to corrals on coarse-grained soils and fine-grained soils in an area of shallow groundwater occurrence and similar annual precipitation. In terms of dynamic physical parameters, dairy farmers are currently implementing practices as prescribed in the General Order but reliable, quantitative information was not available for this work effort. For example, dry manure may be scraped from corrals several times a year, followed by some grading and compaction effort. However, the degree of drainage from corral surfaces during the rainy season may vary widely between dairies as the soft, organics-rich soil is constantly turned over and worked into the ground by the cows. Actual rainy season maintenance efforts appear important to understanding potential recharge from corrals; and regular visual observations may prove to be the most useful tool to evaluate these efforts in the future. Site visits were used to select a group of Phase 1 RMP Workplan dairy farms, including corrals with very thick manure cover and others with well-scraped and graded surfaces.

5.5.1.3 Physical Parameters – Liquid Manure Storage Ponds

Similar to corrals, liquid manure storage ponds are designed (or should be designed) to minimize infiltration and deep percolation (referred to as seepage in the context of ponds). For purposes of interpreting groundwater quality beneath ponds, the primary focus is on soil texture, pond seepage, and the nitrogen and salt concentrations in the waste liquor near the bottom of the pond. Again, these parameters are very similar to parameters discussed for the application areas and corrals, because the fundamental components (i.e., liquid and chemical flux) that control subsurface loading are the same. Site-specific information on pond seepage is currently not available and information on the chemical composition is very sparse. The latter is also highly variable depending on the amount of dilution with fresh flush water and can vary considerably between seasons as affected by direct precipitation. Soil texture appears to not typically control the seepage rate of liquid manure storage ponds (especially not those filled with cow manure) that are operated as anaerobic basins in all but the most extreme cases (e.g., gravel deposits or macro fissures in limestone) (LSCE, 2008). However, the presence of clay beneath such ponds has been found to significantly affect the movement of ammonium in the subsurface; and ion exchange processes involving clay minerals can significantly affect groundwater quality (LSCE, 2008).

Management practices pertaining to ponds that are operated as anaerobic basins are essentially limited to the maintenance of the berms and a steady waste depth, and the degree of solids separation. Waste depth and the solids content may relate to the chemical environment in the vertical waste profile. Information on the solids content in the ponds is currently very sparse. However, CVRWQCB files often identify settling basins and mechanical solids separators.

Management practices (as outlined above) pertaining to ponds on coarse-grained/sandy soils and fine-grained/clay-rich soils that result in groundwater quality improvements beneath ponds that are part of the RMP are expected to produce similar results beneath non-monitored ponds on similar soil types. Consequently, for purposes of selecting dairy farms (and particularly the associated liquid manure storage ponds) for Phase 1 of the RMP, the primary focus was on soil texture. A secondary focus was on precipitation, as it can relate to seasonal differences of the chemical composition of the waste liquor. Specifically, regarding static physical parameters, the emphasis was to initiate a large data set related to ponds on coarse-grained soils and fine-grained soils in an area of shallow groundwater occurrence and similar annual precipitation. Additional emphasis was placed on older liquid manure storage ponds such as to favor ponds with a history of nitrogen and salt loading. In terms of dynamic physical parameters, Phase 1 RMP dairy farms were selected to include the most typically encountered pond system where liquid manure passes through one or more settling basins prior to entering the main storage pond[9]. Some of the selected dairy farms utilize mechanical solids separators in addition to settling basins. Others operate a mechanical separator with a single liquid manure storage pond. Solids removal from settling basins occurs mostly via scooping off the dry top layer but may also include more complete drying and/or deeper excavation. Solids from the main storage ponds are removed either via agitation and pumping, or excavation, or may not yet have been necessary at the time of the site visit. Phase 1 RMP Workplan dairy farms were selected to include earthen liquid manure storage facilities ranging in depth from 4 to over 20 feet. These facilities were constructed prior to 2007, and many are older than 10 years.

[9] During site visits and direct communication with dairy farmers, it was found that this system is not always strictly operated in series, but also in parallel or switched back and forth (i.e., one settling basin is used until full while the other is dried out).

5.5.1.4 Physical Parameters – Discussion

Physical parameters directly support the analysis and interpretation of groundwater quality data and the extrapolation of results from the RMP (Phase 1 and subsequent phase(s)) to non-monitored dairy farms. As such, these parameters are key to the representativeness of the RMP.

Future changes in field and management practices are likely to positively affect groundwater quality more rapidly in areas of coarse-grained/sandy soils and shallow groundwater depths than in any other areas. Practices specific to management units in these conditions that result in groundwater quality improvements on dairy farms that are part of the RMP are expected to produce similar results beneath non-monitored dairy farms that operate in similar conditions including similar precipitation patterns. Consequently, for purposes of selecting dairy farms for the initiation of the RMP, the primary focus was on static physical parameters, including soil texture, depth to groundwater, and precipitation. Specifically, the emphasis was to initially generate a large data set for an area of coarse-grained/sandy soils, shallow groundwater, and moderate precipitation (e.g., about 7 to 10 inches annual precipitation, which applies to most dairy farms in the San Joaquin Valley). This is consistent with conditions in the high priority area (i.e., the area in Stanislaus and Merced Counties from the Stanislaus River in the north and the Chowchilla River in the south, between the San Joaquin River and Highway 99). In addition, the Phase 1 RMP Workplan includes several dairy farms west of the San Joaquin River (outside of the high priority area), where groundwater also occurs at shallow depths and annual precipitation is similar, but soils are predominantly fine-textured (e.g., clay loams and clays). These dairies were selected to broaden the initial range of hydrogeologic conditions and potential dairy management practices investigated within the Phase 1 RMP well network.

For the selection of corrals and liquid manure storage ponds, additional emphasis was placed on older management units such as to favor those with a history of nitrogen and salt loading. In an effort to obtain improved pond construction documentation, some younger liquid manure storage ponds were also selected.

5.5.1.5 Dairy Farm Infrastructure and Operational Characteristics

As discussed in *Section 5.6.1*, dairy farm infrastructure and operational characteristics do not have direct bearing on the analysis and interpretation of groundwater quality data, because they do not provide information on actual subsurface loading rates. However, they were invoked to assemble an initial group of dairy farms that is intended to be representative of a cross section of typical dairy farms and a wide range of typical operational management practices for purposes of initiating the RMP. Therefore, from an infrastructure and operational standpoint, non-monitored dairies exhibiting similar characteristics are expected to be able to implement similar management practices that are determined to result in groundwater quality improvements on monitored farms. As such, the diversity of these parameters in the group of monitored dairy farms is key to the implementability of identified management practices on non-monitored dairy farms. The following is a list of characteristics exhibited by the selected initial group of dairy farms for the Phase 1 RMP:

- distinct management units (corrals, liquid manure holding ponds, land application areas);
- dairy farm size ranges from approximately 550 to 5,500 mature milk cows;
- animal housing occurs to approximately equal portions under roofed areas (freestalls) and open lots;
- additional infrastructure includes separate areas for heifers, calves, dry cows, bulls, and sick animals; milk barn; loading docks and roads; hay and commodity barns; outside silage storage; manure drying/stacking areas; farm equipment yards and machine shops; residential housing; ditches and underground pipelines; and tailwater recovery systems;
- mature milk cows constitute approximately half of all animals on the dairy farms;
- predominant waste management via flush lanes but also substantial manure drying;
- proportion and absolute volume of manure exports vary widely between dairies;
- the overall size of the land application areas vary widely between dairies and is not correlated to the number of animals; and
- reported whole farm nitrogen-balances range from less than 1.00 to over 3.00.

A summary of herd sizes, manure application areas, and whole farm nitrogen balances for dairy farms that were selected to be part of the Phase 1 RMP network is presented in **Table 3**. The information shown in this table was obtained from files that were submitted by dairy farm owners/operators to the CVRWQCB to maintain compliance with the General Order. It is recognized that these data are not flawless (e.g., inaccuracies in the computation on the whole farm nitrogen balance are not uncommon). During the site visits, information regarding irrigation methods, crop types and rotations, field ownership or expiring leases, plans for new infrastructure, liquid manure storage facility operation, and other miscellaneous items as they arose out of individual discussions, was gathered. Since the overall diversity of the initial group of dairies is important to the success of the Phase 1 RMP, not the combination of individual characteristics on any one dairy farm, it is expected that any potential biases in the initial group of dairy farms (to be identified via continued interaction with dairy farmers and analyses in the first annual report) will be readily addressed as the monitoring network will be expanded. For example, dry scrape and pasture dairies were considered but ultimately not included in Phase 1, because they constitute a very small fraction of all Central Valley dairies. Their inclusion will be considered again during the process of refinement and the Phase 2 RMP expansion.

5.5.2 Monitoring Well Siting and Other Considerations

Only CVDRMP member dairy farms were considered because these farms are contractually bound to permit groundwater monitoring to occur on their property as part of the RMP. After reviewing the CVRWQCB's files, aerial photography was used to identify potential candidate farms. The owners/operators of these dairy farms were informed by mail, and also follow-up phone calls, that their dairy farm had been selected as a potential site to install RMP monitoring wells. The owners/operators of these dairy farms were informed by mail, and also follow-up phone calls, that their dairy farms had been selected as a potential site to install RMP monitoring wells. These owners/operators were invited to an informational meeting on April 8, 2011 to introduce them to the RMP, the CVDRMP board of directors, and next steps. At the meeting, 23 site visits were scheduled.

Prior to the site visits, major selection criteria were the size and geometry of dairies' management units with regard to the inferred, prevailing regional groundwater flow direction. For example:

- Large management units are favorable to groundwater monitoring efforts on dairy farms.
- The geometry of the management unit should be such that the expected source area for the to-be-constructed monitoring well(s) would take full advantage of the management unit's extent.
- Clear separation between management units.

An example of a less favorable condition is the existence of a management unit of potentially high infiltration located upgradient of a management unit of potentially small infiltration (e.g., a large liquid manure storage pond upgradient of a small corral).

Site visits and communication with dairy farmers were invaluable in the effort to place the proposed monitoring wells. In many cases, locations that appeared promising based on the inspection of aerial photography proved to be not usable. Examples were:

- Unstable road conditions – many of the field roads are simple dirt paths, tentative in nature and subject to being plowed-over and modified during the seasons.
- Open areas next to liquid manure storage ponds that are periodically used for excavators and trucks during solids removal.

Underground facilities (e.g., irrigation and flush water pipes, tailwater recovery systems, residential sewer systems, and gas and telephone lines) put substantial constraints on monitoring well placement. In many cases, the most promising location for a monitoring well was directly under above-ground telephone or power lines. As a result, and due to rough field conditions, many wells will need to be installed using specialized limited-access equipment.

5.6 Rationale for the Proportional Distribution of Monitoring Wells

The total number of monitoring wells and their relative distribution over application areas, corrals, and liquid manure storage ponds was determined by balancing the need for a sufficiently large data set to capture the existing variability within management units and between dairies with the expected variability of groundwater quality changes in response to future modifications to current management practices.

Land Application Area

The land application area constitutes by far the largest proportion of a dairy and has been shown to be the largest contributor to subsurface loading of salts and fertilizers (van der Schans et al., 2009). In addition, the land application areas provide the most promising opportunity to control leaching of excess salts and fertilizer through a variety of potential management adjustments, including methods of application, application rate and timing, irrigation practices, crop types and cropping patterns, installation of tile drains, and return water recycling systems (Mathews et al., 2001; Harter et al., 2001b). As a result, the overall groundwater quality responses to management modifications are expected to be most diverse in the land application areas.

Corrals

In comparison to field management, dairy corral management offers less flexibility. Open-lot corrals do not feature animal housing with impermeable floors and manure removal systems, but they may have simple shade structures. Management of these corrals may include the frequency of manure removal (scraping) and its timing in relation to dry and wet seasons, and overall maintenance of the surface to provide positive drainage and reduce infiltration. Many corrals are associated with freestalls (i.e., roofed animal housing with concrete floors and manure removal systems) where animals spend most of their day.

Liquid Manure Storage Ponds

Management of liquid manure storage ponds offers relatively little flexibility for the dairy farmer. Probably the single most important management tool for unlined and earthen-lined ponds is to minimize seasonal stage elevation changes and to always maintain a minimum liquid depth. This ensures the maintenance of anaerobic conditions in the manure liquor and helps keep non-organic nitrogen in the form of ammonium, which sorbs to clay particles in the subsurface. In contrast, oxidizing conditions in the manure liquor support conversion of ammonium to nitrate, which is highly mobile in groundwater systems.

In accordance with the above observations, the largest proportion of monitoring facilities in the proposed representative groundwater monitoring well network is dedicated to land application areas.

5.7 Extrapolation of Monitoring Results to Non-Monitored Dairies

The ability to extrapolate monitoring results from dairy farms monitored under the RMP to non-monitored dairy farms rests on the selection of physical parameters that directly support the analysis and interpretation of groundwater quality data. For example, dairy practices on coarse-grained/sandy soils over shallow groundwater that result in groundwater quality improvements beneath cropped manure application fields that are part of the RMP are expected to produce similar results beneath non-monitored fields of similar soil types in areas of similar precipitation patterns. The same rationale applies to corrals and liquid manure storage ponds.

Notably, increased depths to groundwater and increased seasonal variability of groundwater level elevations do not exert control on subsurface salt loading rates. Consequently, Phase 1 and subsequent phase results will also be applicable to areas with these characteristics without necessitating additional data collection efforts. Although response times between dairy management practices (and associated changing nutrient and salt loading characteristics) and potential groundwater quality changes in areas of deep first encountered groundwater will be significantly prolonged, there remains a potential for long-term impact and also improvement related to modified practices. Additionally, data analysis and interpretation in such areas are exacerbated by the difficulty to delineate (with a reasonable degree of confidence) contributing source areas and, ultimately, establish a causal link between groundwater quality results and the range of management practices by management unit. Consequently, measures to avoid groundwater quality impacts would likely not occur in these areas for a potentially very long time unless a proactive approach is taken via extrapolation of RMP results.

5.8 Refinement of Representative Groundwater Monitoring Program

This Phase 1 RMP Workplan proposes to install an initial network of monitoring wells on a group of dairy farms to initiate the RMP. The RMP will be assessed on an annual basis and dynamically modified through a process of peer review, input from technical advisory committees (GTAC and MAC), and stakeholder input. Input requested from reviewers will, for example, pertain to:

- any technical aspects of the RMP Annual Reports (e.g., monitoring well locations and construction, selection of dairy farms, sampling protocol, any data collection and compilation efforts, analyses, interpretations, and recommendations);
- identification of potential solutions in response to findings of the RMP (Phase 1 and subsequent phase(s));
- identification of innovative methodologies, approaches, and analytical tools;
- review and evaluation of results from implemented methodologies, approaches, and analytical tools; and
- identification of potential research needs, and most generally, the ability of the RMP to reach its goals.

5.9 Expansion of Representative Groundwater Monitoring Program

The Phase 2 RMP Workplan will expand the RMP to include a total of 50-100 dairies. Three distinct components of the Phase 2 RMP expansion are identified:

- *High Priority Area* The well network will be expanded in the high priority area (i.e., the primary focus of the initial Phase 1 RMP; the area defined by the Stanislaus River in the north, the Chowchilla River in the south, the San Joaquin River in the west, and Highway 99 in the east).
- *West Side Expansion* The well network will be expanded in the area west of the San Joaquin River in Stanislaus and Merced Counties (i.e., a secondary focus of the initial Phase 1 RMP), which is characterized by fine-grained/clay-rich soils and the occurrence of shallow groundwater.
- *Central Valley Coverage* The well network will be expanded to include dairy farms in all San Joaquin Valley counties plus dairy farms between Sacramento and Tehama Counties in the Sacramento Valley. This effort will include a survey of dairy farms that already conduct groundwater monitoring to assess their potential to effectively contribute to Central Valley wide groundwater evaluation beneath dairies and their associated management units.

Additional expansion of the monitoring network and program will continue to be evaluated, under consideration of the input from the advisory committees, in regulatory annual monitoring reports; and will depend, most generally, on the success of the RMP.

6 Proposed Phase 1 Representative Monitoring Well Network

The proposed Phase 1 dedicated monitoring well network consists of 18 dairy farms and 135 dedicated monitoring well locations (**Table 4**, **Figure 2**). 18 of these monitoring wells already exist (**Attachment 2**), and 117 are proposed for installation. Most of these wells will be installed as nested wells (with possible exceptions being very large irrigated forage fields). This means that most proposed locations for monitoring well installation will actually have two wells of different depth and construction installed in one borehole. However, for ease of communication, each well location is referred to as one well regardless of whether or not it will be completed as a nested well). 86 of these monitoring wells are distributed over 10 dairy farms located in the high priority area characterized by predominantly sandy coarse-textured permeable soils and shallow groundwater occurrence (the depth to groundwater is commonly less than 20 feet below ground surface and often less than 5 feet below ground surface). Regionally, shallow groundwater flow directions range from southwest to northwest. This was supported via anecdotal evidence in conversations with dairy farmers and confirmed with site specific groundwater elevation data where available. 49 monitoring wells are distributed over 8 dairy farms located in the area west of the San Joaquin River in Stanislaus and Merced Counties characterized by clay-rich, low-permeability soils and shallow groundwater (similar to the high priority area). Regionally, shallow groundwater flow directions range from southeast to northeast. This was supported via anecdotal evidence in conversations with dairy farmers and confirmed with site specific groundwater elevation data where available.

Monitoring well locations were identified in cooperation with dairy farmers during site visits carried out from April 11 to May 6, 2011 (**Figures 3** to **21**), and final locations will be identified during the well drilling permit process.

Existing production area infrastructure (e.g., existing water wells, corrals, shade structures, hay and milk barns, silage storage areas, liquid manure storage areas, and settling basins) was compiled from annual dairy reports and is included in these figures. All selected dairy farms have monitoring wells proposed near a liquid manure storage pond. In the high priority area, the selected dairy farms have monitoring wells distributed over all three target management units. On the west side, the number of CVDRMP member dairies is rather limited and, as a result, the availability of favorable monitoring conditions is similarly limited. As a result, the corrals of one dairy farm and the fields of two dairy farms are not monitored in that area.

7 Monitoring Well Construction

Well construction in Stanislaus County is permitted through the Stanislaus County Department of Environmental Resources, Office of Environmental Health. A qualified California licensed professional well drilling contractor (C-57 license) will be selected through a competitive screening process. The drilling contractor will be responsible for adherence to trade-specific health and safety measures during drilling, installation, and site cleanup. In addition, a safety meeting will be held in the field before commencing work; local emergency telephone numbers and directions to the nearest medical facilities will be distributed.

In accordance with the expected shallow completion of the monitoring wells and unconsolidated nature of subsurface materials in the project area, direct push and/or auger methods will be employed for the advancement of the boreholes. The machinery will be sized commensurate to the tasks. Drilling and construction oversight will be provided by a licensed California professional geologist or professional civil engineer with experience in the water well construction business or under the direct supervision of such a professional.

Subsurface materials will be described and logged in the field by a California professional geologist or under his/her direct supervision. Subsurface materials will be sampled at least every 5 feet and at the terminus of the boreholes. The description of the samples will follow the American Society for Testing and Materials (ASTM) Unified Soil Classification System (USCS). Material samples will be archived for a minimum of one year from the date of retrieval.

7.1 Monitoring Well Design

Monitoring wells will be constructed such that the well screen intersects the uppermost zone of first encountered groundwater. Consequently, the final monitoring well design (e.g., total well depth, depth and length of the well screen, depth of the transition seal, depth and length of the surface seal) will be determined based on field observations made during drilling (e.g., depth to first encountered groundwater and type of subsurface materials). Most monitoring wells will be constructed as nested wells (i.e., two well casings with well screens located at different depth intervals, constructed in one borehole (**Figure 22**). This design provides a monitoring facility that:

- addresses uncertainty regarding the extent of the upgradient area contributing flow to the well (i.e., the source area);
- is less vulnerable to seasonal and longer-term groundwater level fluctuations than single-completion monitoring wells;
- is suitable for the installation of shorter screen lengths (e.g., 5-15 feet), which helps avoid potential groundwater quality bias due to vertical flow components in the wells; and
- can be used for chemical groundwater profiling including isotopic groundwater age dating.

The proposed nested design also (i) increases data quality and the confidence in analysis and interpretations, (ii) increases the flexibility for analytical approaches, and (iii) avoids or decreases the need for potential future well replacements, for example, as a result of groundwater level declines causing a well to go "dry". An alternative single well construction profile is shown in **Figure 23**. Figures **22** and **23** show a traffic valve box for below-grade completion. However, such construction is planned for only two locations (NUN-MW3 and 4), where the newly poured concrete feed lane provides a better location than the steep escarpment leading into the adjacent field to the east. A more typical surface completion with casing stick-up and bollards is shown in **Figure 24**. Other options for surface completions include flexible posts with reflective sheeting or the use of a 1.5 to 2-feet section of 4 to 6-feet diameter prefabricated concrete pipe such as used in the construction of manholes to protect the wellhead. The actual configuration of the surface completion will be determined prior to drilling based on local conditions surrounding the well location and communication/consensus with the appropriate party (i.e., property owner and/or dairy farm operator).

7.2 Monitoring Well Development

The monitoring wells will be developed as the drilling program progresses and the last monitoring well will be developed within two weeks of its installation.

The purpose of well development is to remove drilling fluids and to develop the gravel pack and aquifer to ensure that proper groundwater samples can be obtained from the monitoring facility. Since the proposed drilling methods do not utilize drilling fluids, the overall monitoring well development efforts are expected to be relatively straightforward.

Monitoring wells will be initially bailed to remove any fill that may have accumulated in the well casing during installation. The gravel envelope will be cleaned of fluids, cake, and substances that would impair the flow of water into the well and the quality thereof. Cleaning will be accomplished by surging and pumping opposite the screen interval until the gravel has been cleaned and consolidated. The pumping operations will be conducted until the screen section is fully developed and the well discharges clean groundwater. Fill that may have accumulated in the well casing during development will be removed using bailing or pumping methods.

The development will continue until the well produces water free of sand and the following turbidity guidelines can be achieved:

- For monitoring wells that produce less than 2 gpm, a turbidity of 10 NTU within two casing volumes of purging.
- For monitoring wells that produce at least 2 gpm, a turbidity of 5 NTU within two casing volumes of purging.

It is recognized that the limited yield, typical for small diameter monitoring wells, can substantially affect the progress and overall success of well development. Ultimately, the professional overseeing the well development will decide when well development efforts will be terminated based on the logged progress in the field.

7.3 Wellhead Survey

A California licensed professional (licensed land surveyor or civil engineer with land surveying experience) will be selected through a competitive screening process. To ensure adequate measurement accuracy and precision, the horizontal and vertical position of the top of the well casings of the new monitoring wells will be determined in accordance with the National Oceanic and Atmospheric Administration's (NOAA) *National Geodetic Survey User Guidelines for Single Base Real Time GNSS Positioning* (Henning, 2010) using a professional-grade global navigation satellite system. Wellhead elevations will be determined with an accuracy of 0.01 foot and their horizontal position will be determined with an accuracy of 0.02 foot.

8 Groundwater Sampling

This section describes guidelines for:

- the retrieval of groundwater level measurements and groundwater quality samples from dedicated groundwater monitoring wells;
- purging protocol;
- instrumentation and its calibration and decontamination;
- sample handling and recordation; and
- quality assurance procedures.

8.1 Sampling Procedures and Instrumentation

The sampling procedures will comply with the provisions set forth in the General Order.

8.1.1 Groundwater Level Measurements

Prior to sampling a monitoring well, the static water level is measured. An electric sounder is used to measure the depth to groundwater from a specified reference point (usually the top of the well casing). Wellhead reference points will be marked to provide consistency between measurements. Measurements are recorded to the nearest 0.01 foot. The static water level in conjunction with well construction information is used to calculate the volume of water in the well. This information is used to determine the minimum volume of water to be purged prior to sample collection.

8.1.2 Purging Protocol

Monitoring wells are be purged and sampled using a portable submersible sampling pump. A discharge hose is attached to the top of the pump assembly through which purge water is discharged. Smaller-diameter tubing for sample collection is also attached to the top of the pump assembly. Discharge and sample collection tubings are attached to a manifold and are isolated from each other by a check valve.

Monitoring wells are purged of at least three wet casing volumes and until indicator parameters have stabilized prior to sample retrieval. Stabilization is defined as three consecutive readings at 5-minute intervals where parameters do not vary by more than 5 percent. Purged groundwater is disposed of by spreading it on the ground at a reasonable distance from the sampled well to avoid the potential for purge water to enter the well casing again during the purging process.

The following indicator parameters are monitored during the well purging:

- temperature (°C)
- pH (standard pH-units)
- electrical conductivity (µS/cm)
- dissolved oxygen (percent saturation)
- oxygen reduction potential (mV)
- turbidity (NTU)

Visual (color, occurrence of solids), olfactory (odor) and other observations (e.g., wellhead conditions, well access, ground conditions, weather) are noted as appropriate.

8.1.2.1 Instrumentation

The following equipment is used during purging and sampling activities:

purging:	submersible pump with discharge hose[10]
sample retrieval:	clean food-grade polyethylene tubing (to bypass the discharge hose)
depth-to-water:	*Durham Geo Slope Indicator* electrical sounder (or similar)
pH, temperature, electrical conductivity:	*YSI* instrumentation (Model 63) (or similar)
turbidity:	*Orbeco-Hellige* Model 966 portable turbidity meter (or similar)

[10] Alternatively, it may be elected to use an inertial pump, peristaltic pump, or comparable equipment.

- dissolved oxygen: *YSI* instrumentation (Model 55) (or similar)
- oxygen reduction potential: *Oakton ORPTestr* (or similar)

8.1.2.2 Calibration

Field calibration of instrumentation is conducted following the manufacturer's instructions and standard solutions prior to a sampling event and once on every day of the event. The thermometer is factory calibrated and is not field calibrated.

8.1.2.3 Decontamination

The pump assembly and discharge hosing will be thoroughly flushed with tap water between well visits. If additional analyses are incorporated into the program in the future (e.g., microbial analyses, volatile organic compounds, low-level metal analyses, pharmaceuticals, or isotopic speciation), decontamination procedures will be appropriately adjusted to include, for example:

- use of new sampling hose between each well,
- purging of the pump with a dilute Clorox© solution and subsequent rinsing with clean tap water,
- washing the portion of the electrical sounder that has entered a well with a dilute Clorox© solution and subsequent rinsing with tap water, and
- double bagging procedures.

8.2 Sample Handling and Recordation

After completion of purging activities, groundwater quality samples are filtered in the field to remove turbidity and collected in laboratory-supplied bottles with or without preservative (depending on analyses to be conducted) without headspace. Bottles are labeled with laboratory-supplied labels, immediately placed on ice, and kept in a dark ice chest (at 4 °C) until delivered to the laboratory. Samples are delivered to a laboratory certified through the State of California (Department of Health Services Environmental Laboratory Accreditation Program) with the proper chain-of-custody documentation within the required holding time. A chain-of-custody (COC) form is used to record sample identification numbers, type of samples (matrix), date and time of collection, and analytical tests requested. In addition, times, dates, and individuals who had possession of the samples are documented to record sample custody.

A field sheet is used to document equipment calibration, water level measurements, well purging activities, and the measurement of indicator parameters; an example is provided in **Attachment 3**.

8.3 Quality Assurance Procedures

Quality assurance (QA) is an overall management plan used to guarantee the integrity of data collected by the monitoring program. This includes the discussed guidelines for groundwater level measurements, purging protocol, and sample handling and recordation. Quality control (QC) is a component of QA that includes analytical measurements used to evaluate the quality of the data. A brief discussion of field QC is followed by a discussion of laboratory QC requirements.

8.3.1 Field Quality Control

"Blind" duplicate field samples are collected to monitor the precision of the field sampling process and to assess laboratory performance. Blind duplicates are collected from at least 5 percent (1 in 20) of the total number of sample locations. The true identity of the duplicate sample is not noted on the COC form, rather a unique identifier is provided. The identities of the blind duplicate samples are recorded in the field sheet, but the sampling locations of the blind field duplicates will not be revealed to the laboratory.

8.3.2 Laboratory Quality Control

Quality assurance and quality control samples (e.g., spiked samples, blank samples, duplicates) are employed by the laboratory to document the laboratory performance. Results of this testing are provided with each laboratory report.

8.3.3 Review of Laboratory Data Reports

Data validation includes a data completeness check of each laboratory analytical report. Specifically, this review includes:

- review of data package completeness (ensuring that required QC and analytical results are provided);
- review of the required reporting summary forms to determine if the QC requirements were met and to determine the effect of exceeded QC requirements on the precision, accuracy, and sensitivity of the data;
- review of the overall data package to determine if contractual requirements were met; and
- review of additional QA/QC parameters to determine technical usability of the data.

In addition, the data validation includes a comprehensive review of the following QA/QC parameters:

- holding times (to assess potential for degradation that will affect accuracy);
- blanks (to assess potential laboratory contamination);
- matrix spikes/matrix spike duplicates and laboratory control samples (to assess accuracy of the methods and precision of the method relative to the specific sample matrix);
- internal standards (to assess method accuracy and sensitivity);
- compound reporting limits and method detection limits; and
- field duplicate relative percent differences.

9 Groundwater Monitoring Program

This section discusses the proposed monitoring program for the representative groundwater monitoring approach. The monitoring program consists of groundwater level and quality sampling and exceeds monitoring requirements set forth in the General Order. The groundwater level monitoring is proposed to be initially conducted at a relatively high frequency to evaluate potentially important seasonal intricacies of groundwater flow conditions. The proposed groundwater quality monitoring consists of comprehensive baseline sampling, subsequent quarterly sampling for a reduced set of constituents, and annual sampling for an expanded set of constituents.

9.1 Groundwater Levels

Depth-to-water measurements will be obtained on a monthly schedule from the monitoring wells in the network for a period of 2 years following well installation. After 24 monthly water level measurements, the data collection frequency will be reduced to a quarterly schedule if, upon review of the water level data record, such reduced collection frequency is adequate to meet the goals of the RMP. Groundwater level measurements will be coordinated by area within the region in order to collect data over a relatively short time period (i.e., within days rather than weeks).

9.2 Groundwater Quality

Groundwater samples will be regularly retrieved from the network locations. However, at a given location of a nested well, a groundwater sample will only be retrieved from the well casing that intersects the uppermost portion of first encountered groundwater. For example, if the screen of well casing “a” is 60 percent below the groundwater table and the screen of well casing “b” is 100 percent below the groundwater table, then a sample will be retrieved from well casing “a”.

Additional analytical testing will be performed on an ad-hoc basis as needs are identified. For example, some chemical profiling in a subset of nested wells will begin in the first year of monitoring to complement the regulatory monitoring effort. Monitoring frequencies and laboratory analytical testing are summarized in **Table 5**. Analytical methods and reporting limits are summarized in **Table 6**. The scope of monitoring frequencies and laboratory analytical testing will be annually evaluated and modified, as needed, through a process of ongoing RMP refinement.

9.2.1 Initial Sampling

The first groundwater quality samples will be retrieved within one month of the completion of well development. Samples will be laboratory analyzed for total dissolved solids (TDS), nitrate, and ammonia (i.e., identical to quarterly sampling).

9.2.2 Expanded Sampling

During the second groundwater sampling campaign, samples will be laboratory analyzed for general minerals (i.e., sodium, potassium, magnesium, calcium, chloride, sulfate, alkalinity suite (bicarbonate, carbonate, and hydroxide alkalinity), phosphate, and TDS), nitrate, nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN).

9.2.3 Quarterly Sampling

Groundwater quality samples will be retrieved on a quarterly schedule (e.g., November, February, May, August) from the monitoring wells in the network. These samples will be laboratory analyzed for TDS, nitrate, and ammonia.

9.2.4 Annual Sampling

An expanded suite of constituents will be analyzed during the annual sampling event (scheduled for the third quarter sampling event), including the same general mineral suite as used during the second monitoring campaign and select nitrogen components. Nitrite analysis will not be repeated in wells where samples were previously reported as below the reporting limit or otherwise negligibly small. Similarly, TKN analysis will not be repeated in wells where the comparison of TKN and ammonia results indicates that organic nitrogen concentrations are negligibly small in groundwater.

10 Reporting

10.1 Monitoring Well Installation Completion Report

A Monitoring Well Installation Completion Report will be prepared in compliance with Item C, Attachment A of the General Order's MRP, including:

- detailed location and site maps;
- narrative and chronology of pertinent field activities;
- identification of contractors, geologists, engineers, and other key personnel;
- description of drilling methods;
- detailed monitoring well information (planned and actual locations, as-built drawings);
- driller's logs and lithologic logs;
- depth-to-groundwater measurements;
- field notes;
- monitoring well construction summary table;
- records and results of the well development and well survey;
- purging records and indicator parameter measurements; and
- laboratory data reports.

10.2 Annual Reporting

RMP Annual Reports will be prepared in compliance with the revised General Order MRP and applicable Standard Provisions and Reporting Requirements of the General Order, and in accordance with the goal of the RMP. The reports will present cumulative groundwater level and quality data collected to date and utilize tables and figures to communicate the dairies' layout and infrastructure, monitoring results, pertinent observations, and data trends. The reports will provide geologic/lithologic conceptualization of the shallow subsurface, hydrogeologic analysis (e.g., groundwater level hydrographs, groundwater level contour maps, groundwater quality data, trend analyses, and statistical analyses) and comparative evaluations in view of variable land uses and dairy operations. Further, the reports will present and evaluate any information pertinent to the operation and management of the specific investigated dairy management units. Analytical tools may include statistical procedures such as:

- cluster analysis to assess the *a priori* hypothesis of differences in groundwater quality between management units;
- assessment of statistical sample distributions and spatial and temporal autocorrelations between groundwater samples to aid, for example, in the delineation of appropriate analytical approaches, sampling frequencies, and placement of additional monitoring wells;
- statistical intervals such as upper tolerance bounds or prediction intervals with associated confidence levels;
- concentration averaging specific to management unit and comparison against recharge and loading estimates;
- farm-scale averaging to assess overall farm performance; and
- group comparisons using, for example, analysis of variance (parametric or nonparametric).

In accordance with the goal of the RMP and based on the cumulative data record, the Phase 1 RMP Annual Report (and reports for subsequent phases) will assess current groundwater conditions and how they relate to historical operations, as possible. The Phase 1 RMP Annual Report and following RMP Annual Reports will assess how dynamically changing dairy management practices (e.g., in response to regulatory requirements specified in the General Order) affect groundwater quality trends.

Subsequent RMP Annual Reports will supplement the data record and are expected to strengthen statistical and interpretive analyses and confidence in conclusions. Following the rationale formulated in *Section 5.7*, results generated and conclusions drawn from a relatively small subset of dairy farms will be adequate to formulate management practices that are relevant and applicable to a much larger number of dairy farms throughout the Central Valley. The MAC will delineate management practices in response to findings communicated in RMP Annual Reports and evaluate their technical and economic feasibility. Subsequent implementation of management practices by the RMP will ultimately show whether they are protective of groundwater quality.

10.3 Summary Report

A Summary Report will be prepared within 6 years of initiating Phase 1 sampling activities to provide a comprehensive synthesis of the RMP monitoring activities (Phase 1 and subsequent phases), results, and findings related to dairy management practices historically and currently employed by the monitored dairy farms, the effects of those practices on groundwater quality, and observed groundwater quality trends in response to modified practices during the first 6 years of the program. Similar to the RMP Annual Reports, the Summary Report will be prepared in compliance with the revised General Order MRP and applicable Standard Provisions and Reporting Requirements of the General Order, and in accordance with the goal of the RMP. The Summary Report will include the same components as the RMP Annual Reports, complemented by additional analyses of groundwater conditions and trends in relation to historical and/or modified management practices.

The Summary Report is intended to serve as a technical basis for evidence-based regulatory decision making. In this capacity, the Summary Report will analyze and discuss the effectiveness of dairy management practices and provide information that will be applicable to both monitored and non-monitored dairy farms.

11 Schedule

11.1 Estimated Schedule for Monitoring Well Construction and Reporting

It is the intent of the CVDRMP to start the Phase 1 RMP well installation in August 2011, complete the installation within 3 months and submit the Monitoring Well Installation Completion Report within 2 months following conclusion of the installation project.

11.2 Proposed Schedule for Other Elements of the RMP

Formation of:

Groundwater Technical Advisory Committee	within 6 months of Phase 1 RMP Workplan approval
Multidisciplinary Advisory Committee	within 6 months of Phase 1 RMP Workplan approval
Stakeholder Input/External Review	semi-annually upon CVRWQCB approval of Phase 1 RMP Workplan

11.3 Proposed Schedule for RMP Refinement and Expansion

Begin Phase 2 RMP Workplan Development	within 6 months of Phase 1 RMP Workplan approval. Initiate a dialogue with the CVRWQCB regarding the overall scope of the Phase 2 RMP and cooperatively work with the advisory committees on the details to be incorporated in the Phase 2 RMP Workplan.
RMP Refinement	following release of the first Phase 1 RMP Annual Report and annually thereafter, as needed
Phase 2 Implementation	Following immediately upon CVRWQCB approval of Phase 2 RMP Workplan
Subsequent Phase(s)	as needed, pending Phase 2 results and findings and activities of GTAC and/or MAC

The refinement and expansion of the RMP will occur on a continuous basis through the preparation of the milestone 6-year Summary Report. As peer review and collaboration with a multidisciplinary group of experts (GTAC and MAC) will continue throughout the duration of the RMP, it is expected that dynamic changes will continue to be implemented after the submittal of the Summary Report. Therefore, the mechanisms for RMP refinement and expansion will continue to operate throughout the duration of the RMP.

12 References

Central Valley Regional Water Quality Control Board. **2007**. *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies*. May 3, 2007.

Central Valley Regional Water Quality Control Board. **2009**. *Evaluation of Alternative Groundwater Monitoring Options at Dairies Operating under Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies (Draft)*. June 4, 2009.

Central Valley Regional Water Quality Control Board. **2011**. Revised Monitoring and Reporting Program Order No. R5-2007-0035 General Order for Existing Milk Cow Dairies. February 23, 2011.

Dairy Cares. **2009**. *Proposal for collaborative plan development, to allow representative groundwater monitoring networks to satisfy the additional groundwater monitoring requirements of General Order R5-2007-0035*. Letter by J.P. Cativiela (Dairy Cares Program Coordinator) to Pamela Creedon (CVRWQCB Executive Officer, Region 5). October 5, 2009.

Faunt, Claudia C., ed. **2009**. *Groundwater Availability of the Central Valley Aquifer, California*. U.S. Geological Survey Professional Paper 1766, 225 p.

Harter, Thomas, Harley Davis, Marsha C. Mathews, Roland D. Meyer. **2001a**. *Monitoring Shallow Groundwater Nitrogen Loading from Dairy Facilities with Irrigated Forage Crops*. American Society of Agricultural Engineers Meeting Paper No. 01-2103.

Harter, Thomas, Marsha C. Mathews, Roland D. Meyer. **2001b**. *Effects of Dairy Manure Nutrient Management on Shallow Groundwater Nitrate: A Case Study*. American Society of Agricultural Engineers Meeting Paper No. 01-2192.

Harter, Thomas, Roland D. Meyer, Marsha C. Mathews. **2002**. *Nonpoint Source Pollution from Animal Farming in Semi-Arid Regions: Spatio-Temporal Variability and Groundwater Monitoring Strategies*. In: Ribeiro, L. (Ed.), 2002, *Future Groundwater Resources at Risk, Proceedings of the 3rd International Conference, Lisbon, Portugal, June 2001*; p. 363-372.

Harter, Thomas, Yuksel S. Onsoy, Katrin Heeren, Michelle Denton, Gary Weissmann, Jan W. Hopmans. **2006**. Deep Vadose Zone Hydrology Demonstrates Fate of Nitrate in Eastern San Joaquin Valley. California Agriculture, Vol. 59(2): 124-132.

Harter, Thomas. **2008**. *Proposal for Groundwater Monitoring at Existing Dairies for Purposes of Meeting the Waste Discharge Requirements*. Post-Discussion Draft. University of California Cooperative Extension - Davis. September 5, 2008.

Henning, William. **2009**. *National Geodetic Survey User Guidelines for Single Base Real Time GNSS Positioning*. Version 1.1. May 2010.

Luhdorff and Scalmanini, Consulting Engineers. **2008**. *Liquid Animal Waste Lagoons, Input Loading to Subsurface Soils and Groundwater*. Technical Memorandum. In cooperation with University of California Cooperative Extension. September 2, 2008.

Luhdorff and Scalmanini, Consulting Engineers. **2010**. *Report of Results – Delineation of an Area for the Design and Initiation of a Representative Groundwater Monitoring Network for Existing Milk Cow Dairies, Central Valley, CA*. Prepared for Dairy Cares; August 31, 2010.

Mathews, Marsha C., Eric Swenson, Thomas Harter, Roland D. Meyer. **2001**. *Matching Dairy Lagoon Nutrient Application to Crop Nitrogen Uptake Using a Flow Meter and Control Valve*. American Society of Agricultural Engineers Meeting Paper No. 01-2105.

Van der Schans, Martin, Thomas Harter, Anton Leijnse, Marsha C. Mathews, Roland D. Meyer. **2009**. *Characterizing sources of nitrate leaching from an irrigated dairy farm in Merced County*. Journal of Contaminant Hydrology 110 (2009) 9-21.

Tables

Table 1
Dairy Farm Selection for Monitoring Well Installation
Phase 1 Representative Groundwater Monitoring Workplan

Dairy Farm	Address	City, State, Zip Code	Facility Detail
East Side			
Albert Mendes Dairy	1100 Ruble Rd	Crows Landing, CA 95313	Figure 3
Anchor J. Dairy	24507 First Ave	Stevinson, CA 95374	Figures 5 and 7
Bettencourt and Marson Dairy	18128 American Ave	Hilmar, CA 95324	Figure 10
Frank J. Gomes Dairy #1	5301 N. DeAngelis Road	Stevinson, CA 95374-9726	Figures 5 and 6
Gallo Cattle Company Bear Creek	15751 W. Hwy. 140	Livingston, CA 95334	Figure 11
Gallo Cattle Company Cottonwood	10561 Hwy. 140	Atwater, CA 95301	Figures 12 and 13
Gallo Cattle Company Santa Rita	91 S. Bert Crane	Atwater, CA 95301	Figures 12 and 14
P. & L. Souza Dairy	20633 Crane Ave	Hilmar, CA 95324	Figure 8
Paul Caetano Dairy	9436 Griffith Ave	Delhi, CA 95315	Figure 9
Robert Gioletti and Sons Dairy	118 N. Blaker Road	Turlock, CA 95380	Figure 4
West Side			
Antone L. Gomes and Sons Dairy	515 E. Stuhr Rd	Newman, CA 95360	Figure 16
Correia Family Dairy Farms	26380 W. Fahey Rd	Gustine, CA 95322	Figure 19
Frank J. Gomes Dairy #2	890 Kniebes Rd	Gustine, CA 95322	Figure 17
Godinho Dairy	12710 S. Wilson Rd	Los Banos, CA 93635	Figure 21
John Machado Dairy	22495 W. China Camp	Los Banos, CA 93635	Figure 20
Jose Nunes Dairy	22484 W. China Camp Rd.	Los Banos, CA 93635	Figure 20
Moonshine Dairy	22922 Kilburn Rd	Crows Landing, CA 95313	Figure 15
Tony L. Lopes Dairy LP	27500 Bunker Road	Gustine, CA 95322	Figure 18

Table 2
Physical Parameter Types for Dairy Farm Selection by Management Unit
Phase 1 Representative Groundwater Monitoring Workplan

	Physical Parameter (1)	
Management Unit	Static	Dynamic
Manure Application Area	Soil Texture Precipitation Depth to Groundwater (2)	Irrigation Manure and Fertilizer Application Crop Type and Rotation
Corral	Soil Texture Precipitation Depth to Groundwater (2) Age (2)	Slope, Soil Compaction, Maintenance Rate of Manure Excretion Rate of Manure Removal
Liquid Manure Storage Pond	Soil Texture Precipitation Depth to Groundwater (2) Age (2)	Waste Depth Solids Content Chemistry Seepage Rate

(1) Static: Existing conditions that are not readily changed by individual dairy farm practices; Dynamic: Items that can be addressed by dairy farm practices specific to management unit.
(2) These parameters do not control subsurface loading, but are important considerations with respect to groundwater quality analysis as affected by travel time of nitrogen components and salt in the subsurface.

Table 3
Dairy Farm Herd Size, Manure Application Area, and Whole Farm Nitrogen Balance
Phase 1 Representative Groundwater Monitoring Workplan

Dairy Farm	Maximum Number of Animals (head)			Animal Housing (head)		Manure Application Area (acres)	Whole Farm Nitrogen Balance
	Mature Milk Cows	Other (1)	Total	Freestall	Open Lot		
East Side							
Albert Mendes Dairy	1,700	1,450	3,150	1,700	1,450	379	1.67
Anchor J. Dairy	2,600	500	3,100	2,600	500	4,456	0.79
Bettencourt and Marson Dairy	1,244	1,104	2,348	1,244	1,104	649	1.32
Frank J. Gomes Dairy #1	1,250	1,680	2,930	1,250	1,680	252	2.32
Gallo Cattle Company Bear Creek	3,955	6,706	10,661	5,456	5,205	3,115	1.56
Gallo Cattle Company Cottonwood	5,500	687	6,187	0	6,187	1,463	1.63
Gallo Cattle Company Santa Rita	3,200	459	3,659	0	3,659	**tbd**	1.04
P. & L. Souza Dairy	457	630	1,087	**tbd**	**tbd**	426	1.06
Paul Caetano Dairy	640	280	920	**tbd**	**tbd**	120	2.40
Robert Gioletti and Sons Dairy	2,000	650	2,650	2,000	400	1,600	0.84
West Side							
Antone L. Gomes and Sons Dairy	520	563	1,083	671	412	150	2.28
Correia Family Dairy Farms	850	1,349	2,199	1,080	1,119	137	3.87
Frank J. Gomes Dairy #2	2,300	2,750	5,050	3,775	1,275	582	2.46
Godinho Dairy	1,258	1,140	2,398	1,490	908	492	1.60
John Machado Dairy	760	500	1,260	760	500	282	1.66
Jose Nunes Dairy	1,200	1,400	2,600	1,380	1,220	1,053	1.59
Moonshine Dairy	2,000	1,950	3,950	2,400	1,550	425	1.15
Tony L. Lopes Dairy LP	2,175	2,293	4,468	2,175	2,293	919	1.62

Data from most recent available Annual Dairy Report (i.e., calendar year 2009) at the time of February 2011 file review.
tbd = to be determined
(1) Dry cows, bred heifers (15-24 months), heifers (7-14 months), and calves (<6 months).

Table 4
Number and Distribution of Monitoring Wells
Phase 1 Representative Groundwater Monitoring Workplan

Dairy Farm	Dedicated Shallow Monitoring Well Locations (1)					
				Assigned To (2)		
	Existing	New	Total	Pond	Corral	Field
East Side						
Albert Mendes Dairy	-	7	**7**	2	3	2
Anchor J. Dairy	4	5	**9**	4	2	3
Bettencourt and Marson Dairy	-	8	**8**	1	3	4
Frank J. Gomes Dairy #1	-	9	**9**	1	2	6
Gallo Cattle Company Bear Creek	-	8	**8**	1	3	4
Gallo Cattle Company Cottonwood	10	4	**14**	2	3	9
Gallo Cattle Company Santa Rita	-	10	**10**	3	3	4
P & L Souza Dairy	-	7	**7**	2	3	2
Paul Caetano Dairy	-	6	**6**	1	3	2
Robert Gioletti and Sons Dairy	-	8	**8**	2	3	3
West Side						
Antone L. Gomes and Sons Dairy	-	6	**6**	1	3	2
Correia Family Dairy Farms	-	5	**5**	1	4	0
Frank J. Gomes Dairy #2	-	6	**6**	1	2	3
Godinho Dairy	-	7	**7**	1	2	4
John Machado Dairy	-	5	**5**	2	0	3
Jose Nunes Dairy	-	4	**4**	1	3	0
Moonshine Dairy	4	4	**8**	2	3	3
Tony L. Lopes Dairy LP	-	8	**8**	2	3	3
		Total	135	30	48	57

(1) Strictly speaking, this table enumerates well locations, not wells. Most of the proposed new dedicated monitoring facilities will be constructed as nested wells with two individual wells completed in one borehole. As a result, the total number of new monitoring wells will be approaching or exceeding 200.

(2) The assignment indicates the management unit targeted for groundwater quality assessment. All wells are used for hydraulic control. Many wells serve multiple purposes (e.g., downgradient hydraulic control/groundwater quality from application field and upgradient hydraulic control for corral).

Table 5
Groundwater Quality Monitoring Program and Laboratory Analyses
Phase 1 Representative Groundwater Monitoring Workplan

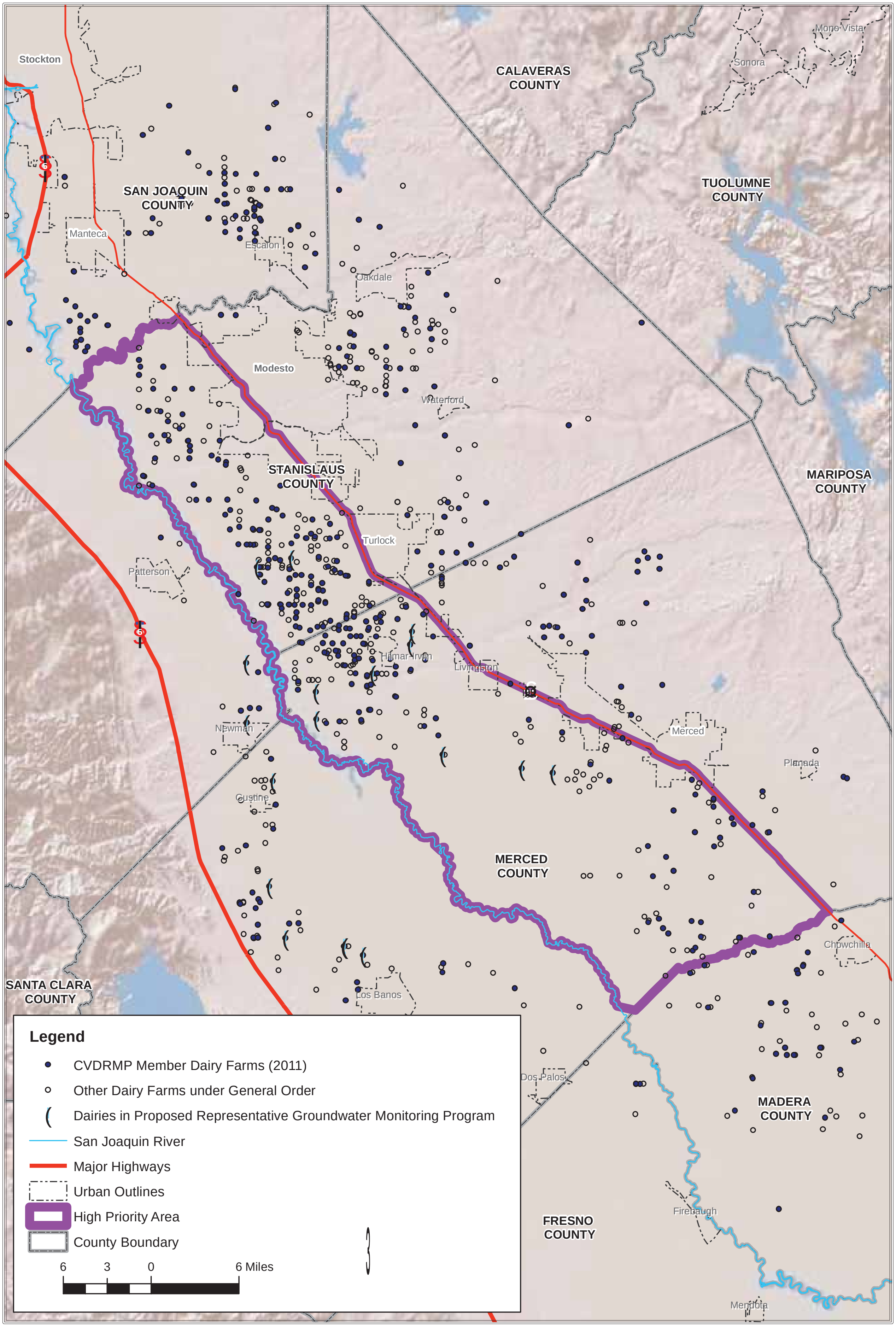
Quarter (1)	Sampling Event	Laboratory Analyses
Year 1 Q1	initial sampling	TDS, nitrate, ammonia
Year 1 Q2	**expanded sampling**	general minerals, nitrate, nitrite, ammonia, TKN
Year 1 Q3	quarterly	TDS, nitrate, ammonia
Year 1 Q4	quarterly	TDS, nitrate, ammonia
Year 2 Q1	quarterly	TDS, nitrate, ammonia
Year 2 Q2	quarterly	TDS, nitrate, ammonia
Year 2 Q3	**annual**	general minerals, nitrate, nitrite, ammonia, TKN (2)

General Minerals = sodium, potassium, magnesium, calcium, chloride, sulfate, alkalinity suite (bicarbonate, carbonate, and hydroxide alkalinity), phosphate, total dissolved solids.
TKN = total Kjeldahl nitrogen (sum of ammonia and organic nitrogen)
TDS = total dissolved solids
ammonia = sum of ammonium and ammonia
(1) Generic quarters are given for purposes of demonstration.
(2) Nitrite analysis will not be conducted in wells where baseline sampling indicate concentrations below the reporting limit or otherwise negligibly small concentrations. TKN analysis will not be conducted in wells where the comparison of TKN and ammonia baseline results indicate negligibly small organic nitrogen concentrations in groundwater.

Table 6
Laboratory Methods and Reporting Limits
Phase 1 Representative Groundwater Monitoring Workplan

Constituent	Analytical Method	Reporting Limit (mg/L)
Sodium	EPA 200.7	1.0
Potassium	EPA 200.7	1.0
Magnesium	EPA 200.7	1.0
Calcium	EPA 200.7	1.0
Chloride	EPA 300.0	0.5
Sulfate	EPA 300.0	1.0
Bicarbonate (as CaCO3)	SM2310B	5.0
Carbonate (as CaCO3)	SM2310B	5.0
Hydroxide (as CaCO3)	SM2310B	5.0
Phosphate (as PO4)	SM4500-PE	0.15
Total Dissolved Solids	SM2540C	10
Nitrate-N	EPA 300.0	0.5
Nitrite-N	EPA 300.0	0.4
Ammonia-N	EPA 350.2 or SM4500-NH3C	0.1
Total Kjeldahl Nitrogen-N	EPA 351.3 or SM4500-NH3C	0.2

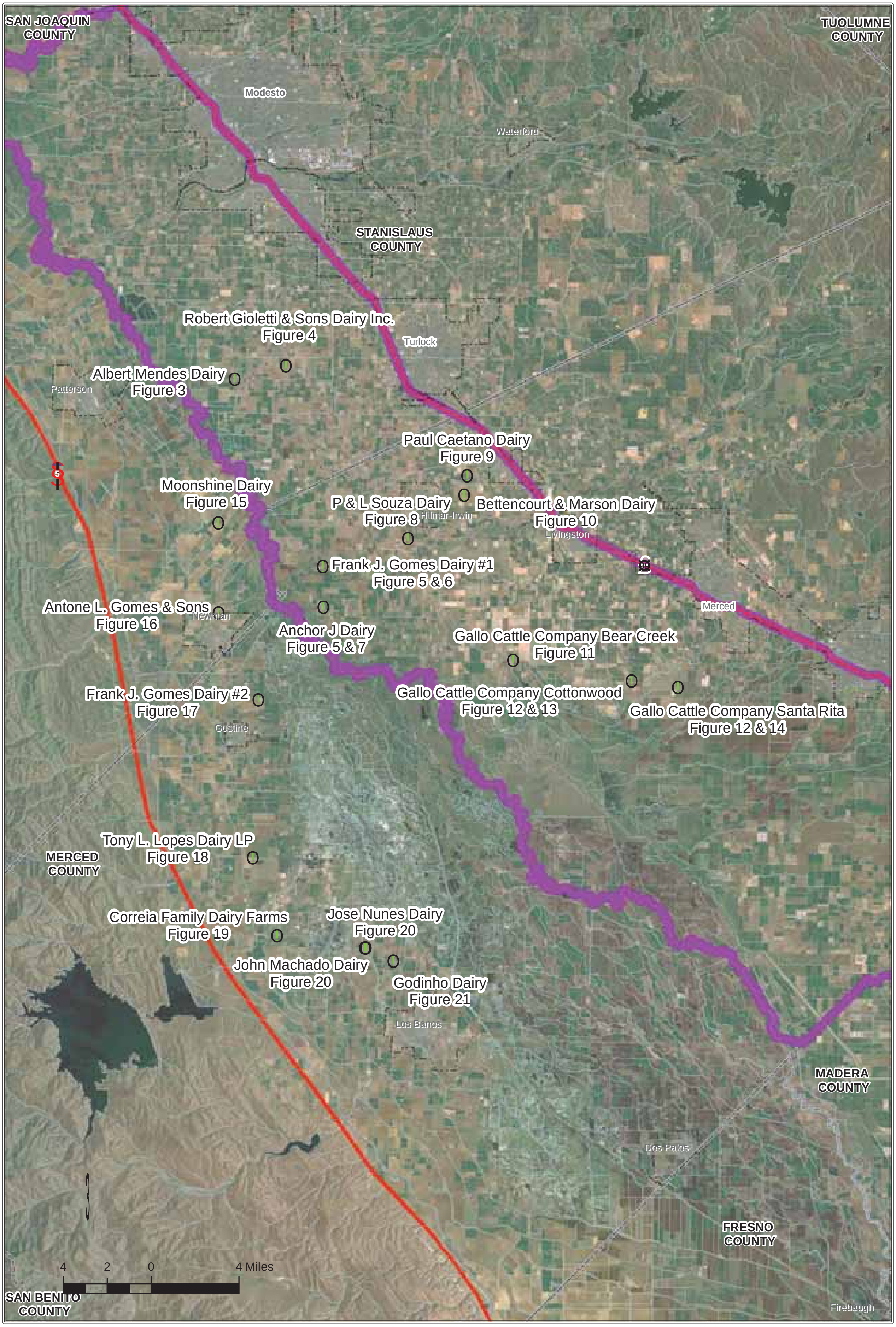
Figures



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\HiPriArea_1.mxd Date: 8/3/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

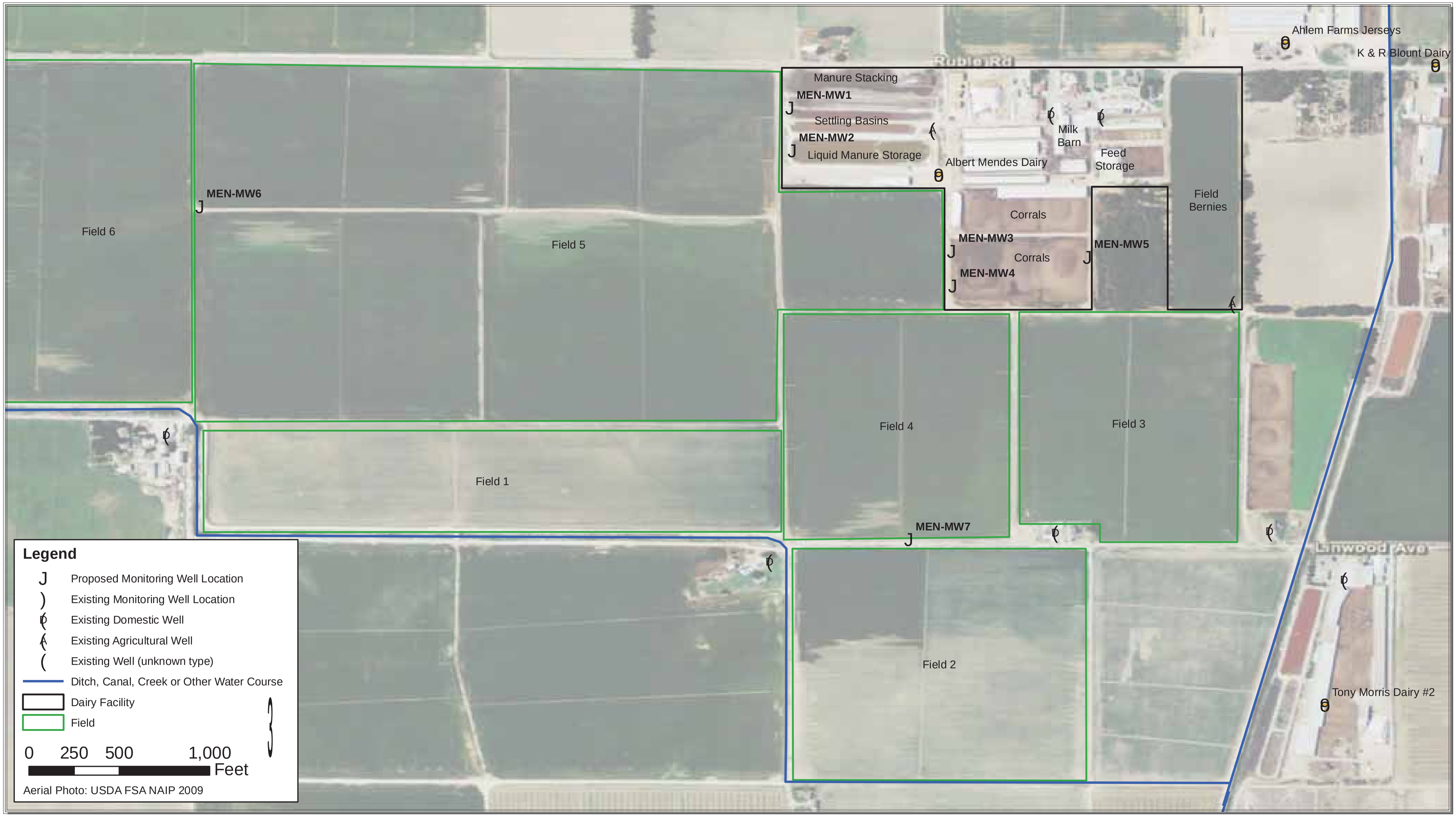
Figure 1
Location Map - Selected Dairy Farms
Phase 1 Representative Groundwater Monitoring Program



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\HiPriArea_1.mxd Date: 8/3/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 2
Index Map - Selected Dairy Farms
Phase 1 Representative Groundwater Monitoring Program



File: GIS/Jeanette/Jeanette 5.2.2011

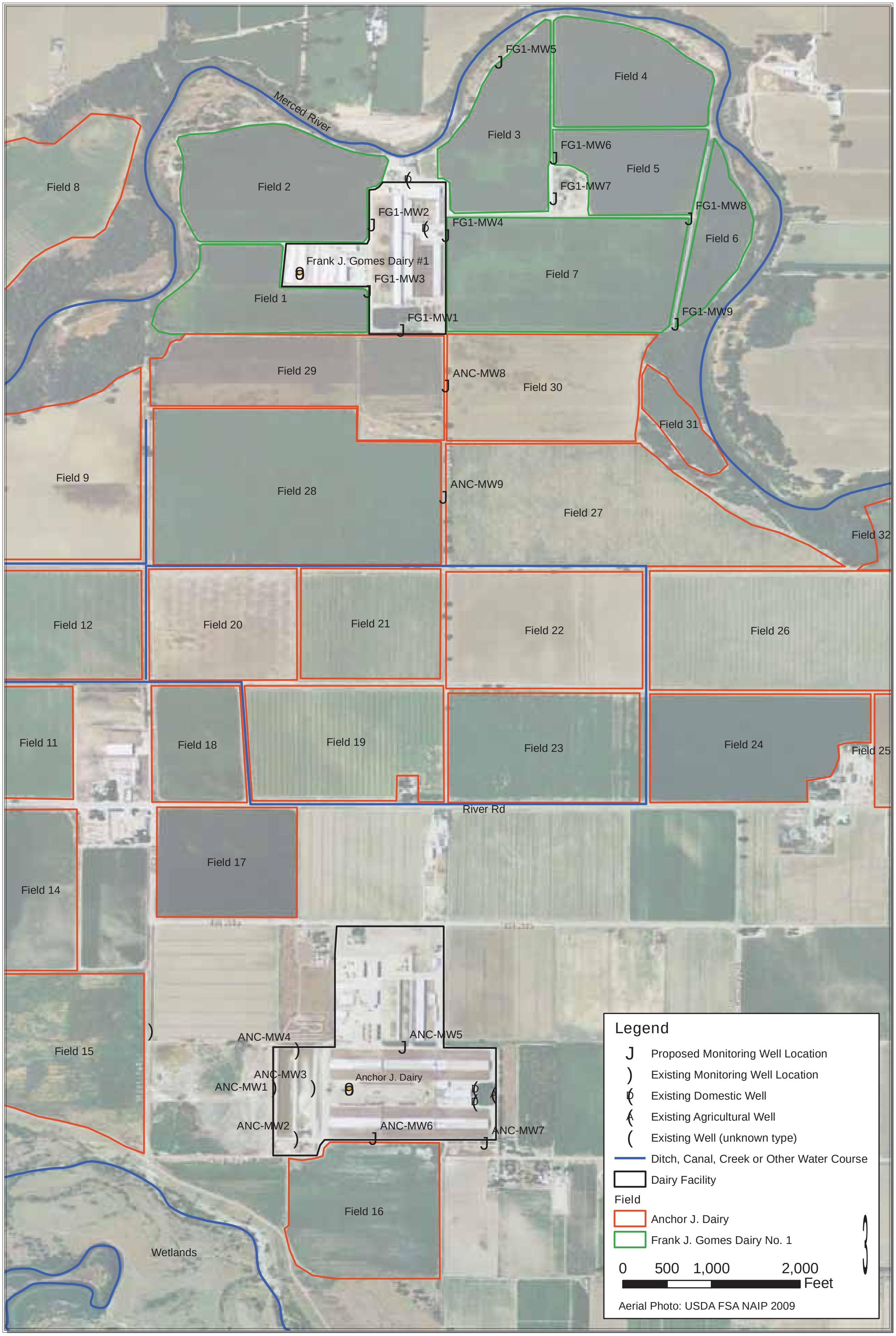
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 3
Albert Mendes Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 4
Robert Gioletti and Sons Dairy
Proposed Monitoring Well Locations



File: GIS/Jeanette/Jeanette5.2.2011

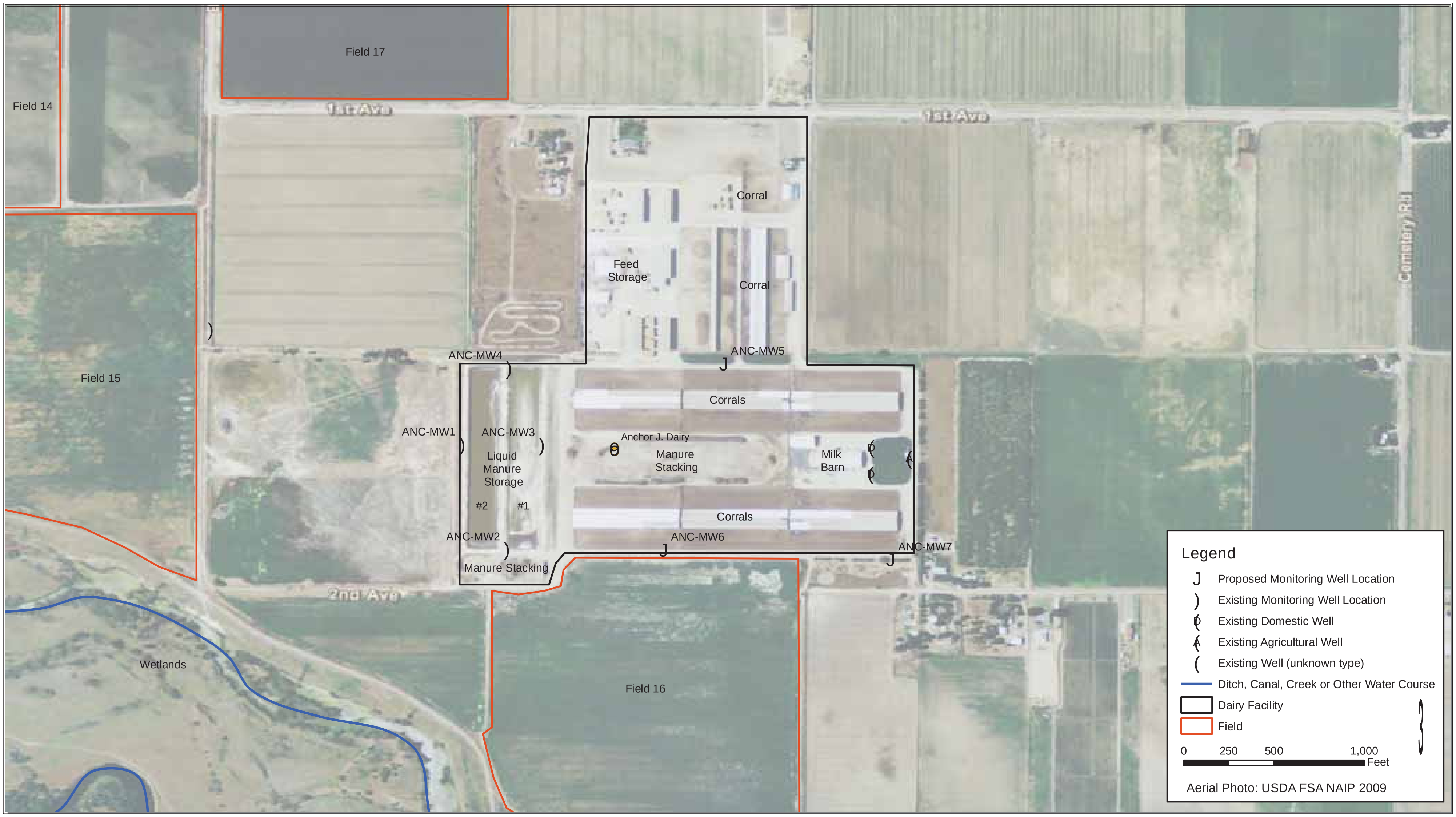
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 5
Index Map for Frank J. Gomes # 1 and Anchor J. Dairies

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 6
Frank J. Gomes Dairy # 1
Proposed Monitoring Well Locations



File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 7
Anchor J. Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 8
P. and L. Souza Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 9
Paul Caetano Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

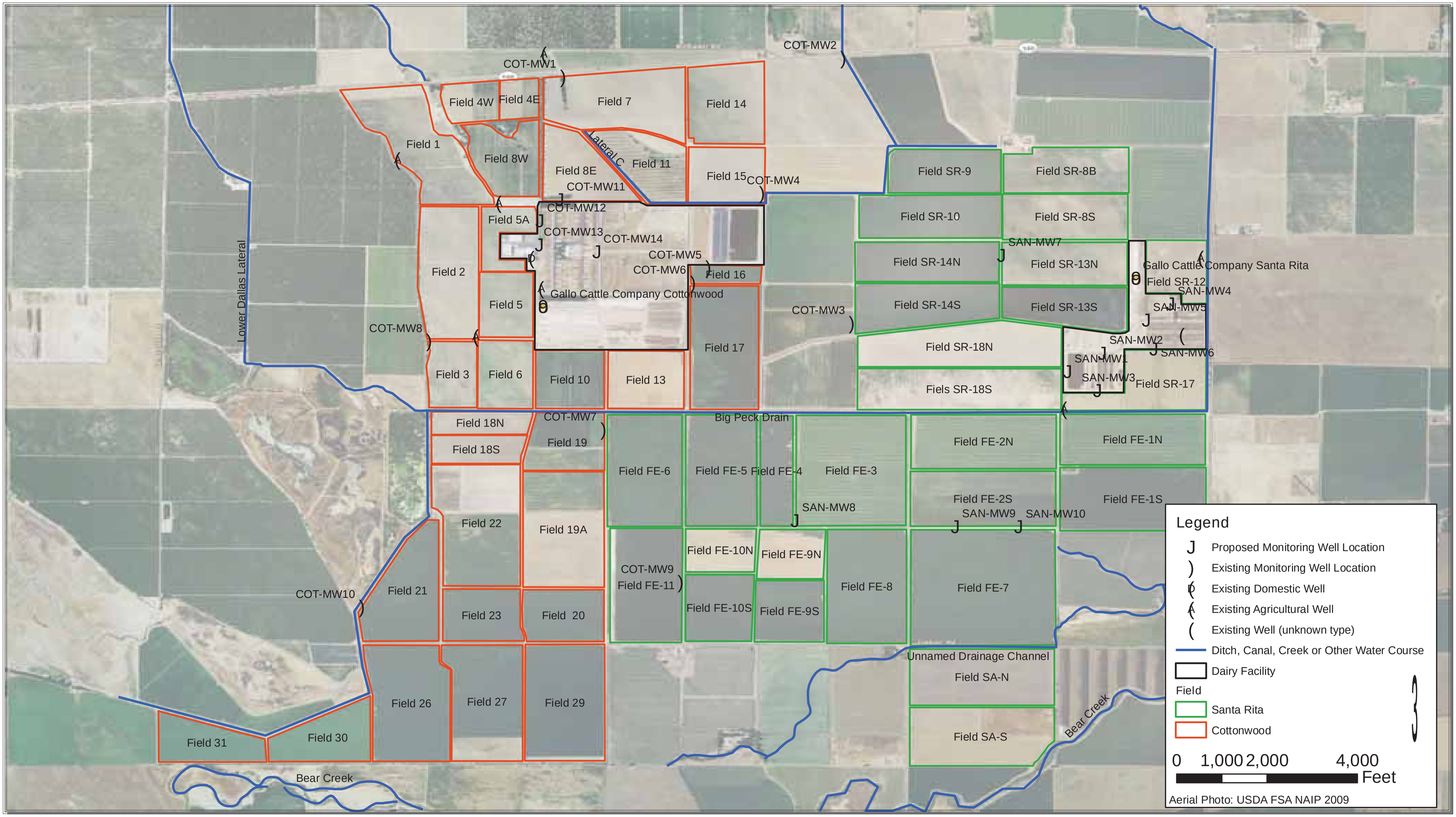
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 10
Bettencourt and Marson Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 11
Gallo Cattle Company, Bear Creek Dairy
Proposed Monitoring Well Locations



File: GIS/Jeanette/Jeanette 5.2.2011

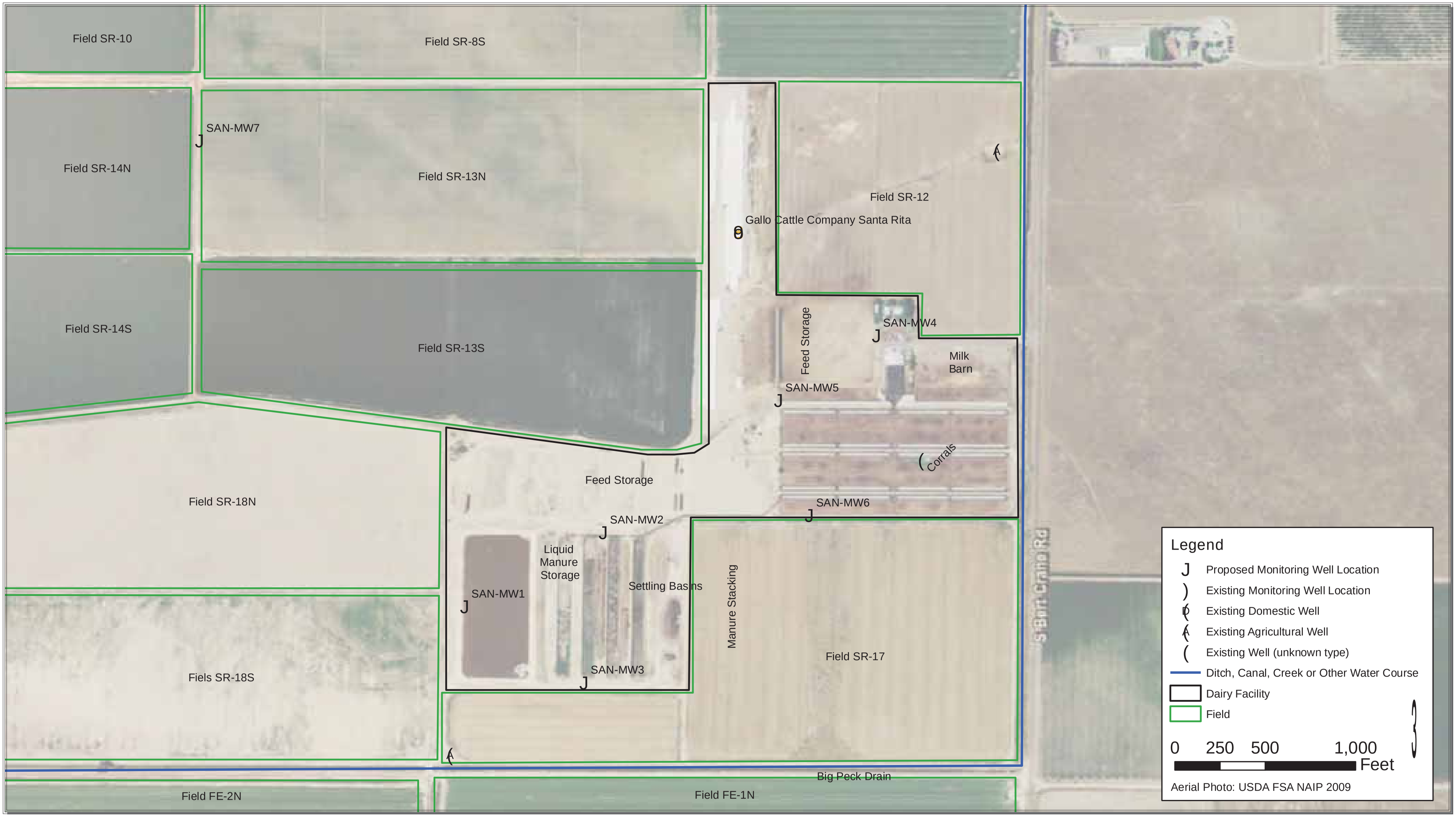
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 12
Index Map for Gallo Cattle Company, Cottonwood and Santa Rita Dairies

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

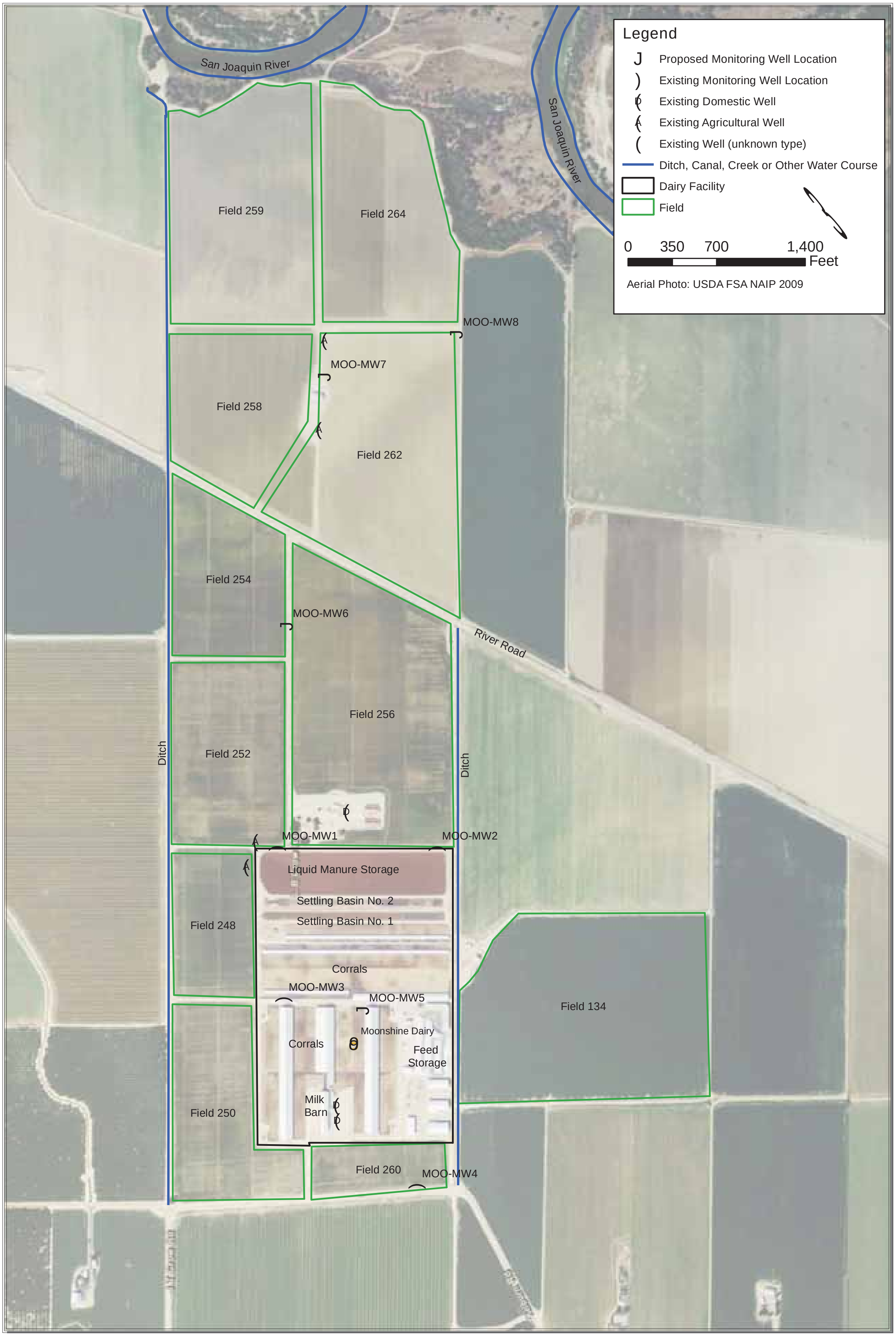
Figure 13
Gallo Cattle Company, Cottonwood Dairy
Proposed Monitoring Well Locations



File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 14
Gallo Cattle Company, Santa Rita Dairy
Proposed Monitoring Well Locations



File: GIS/Jeanette/Jeanette 5.12.2011

Figure 15
Moonshine Dairy
Proposed Monitoring Well Locations

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 16
Antone L. Gomes and Sons Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 17
Frank J. Gomes Dairy #2
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 18
Tony L. Lopes Dairy LP
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Figure 19
Correia Family Dairy
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

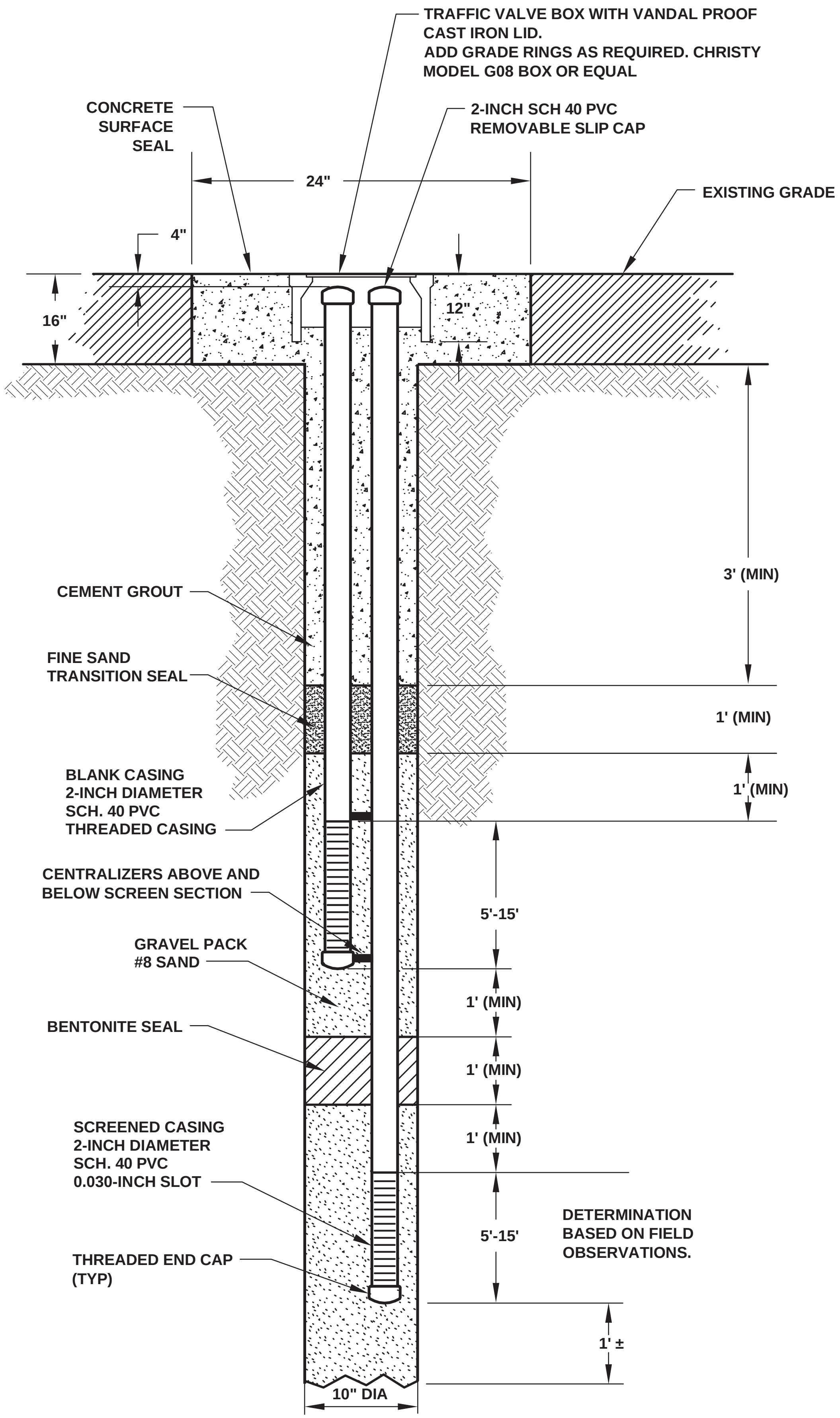
LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 20
Jose Nunes and John Machado Dairies
Proposed Monitoring Well Locations

File: GIS/Jeanette/Jeanette 5.2.2011

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

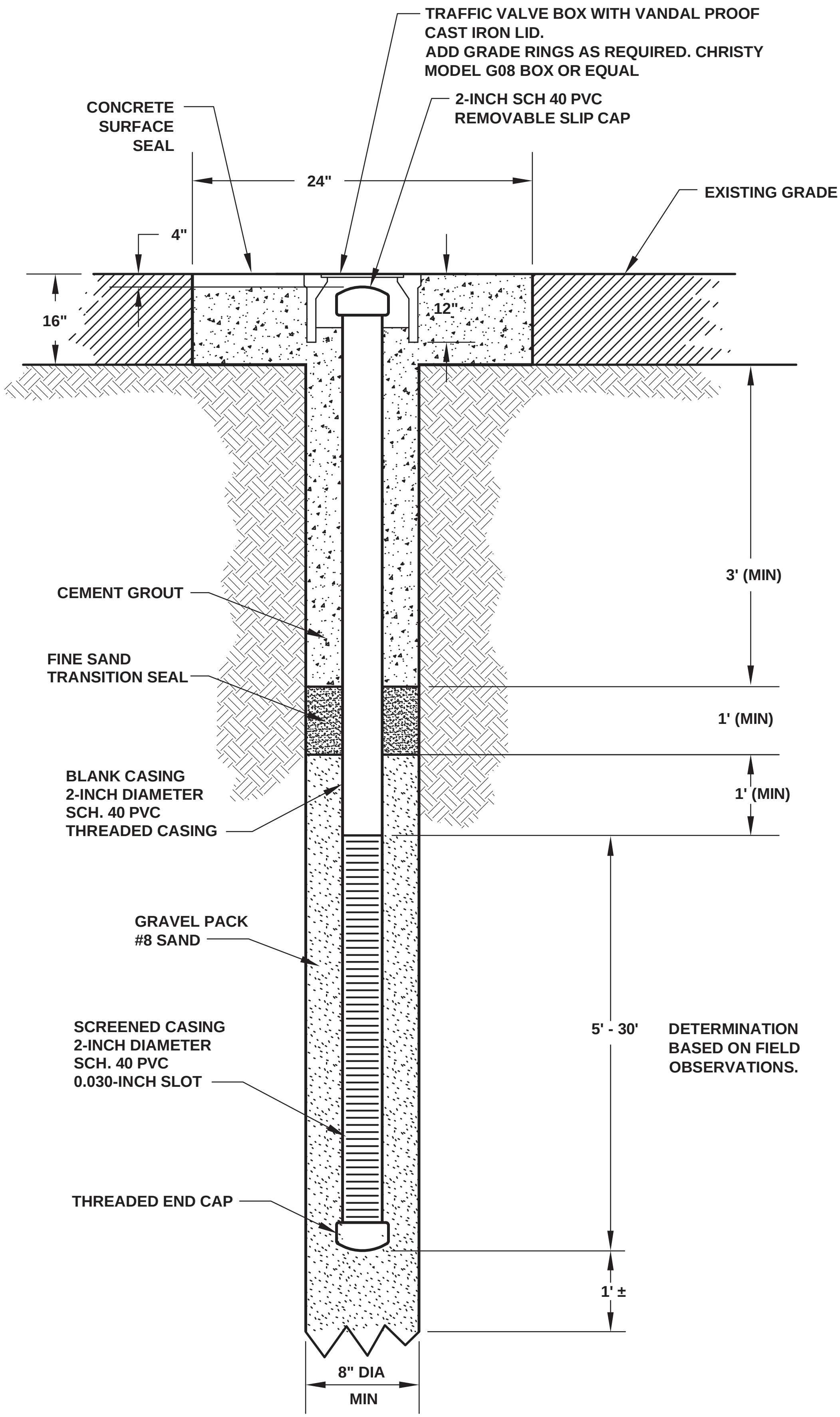
Figure 21
Godinho Dairy
Proposed Monitoring Well Locations



CAD FILE: G:/Projects/Dairy Cares/09-1-075/Figure 22.dwg CFG FILE: LSCE2500.PCP_MRG DATE: 06-16-11 2:33pm

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

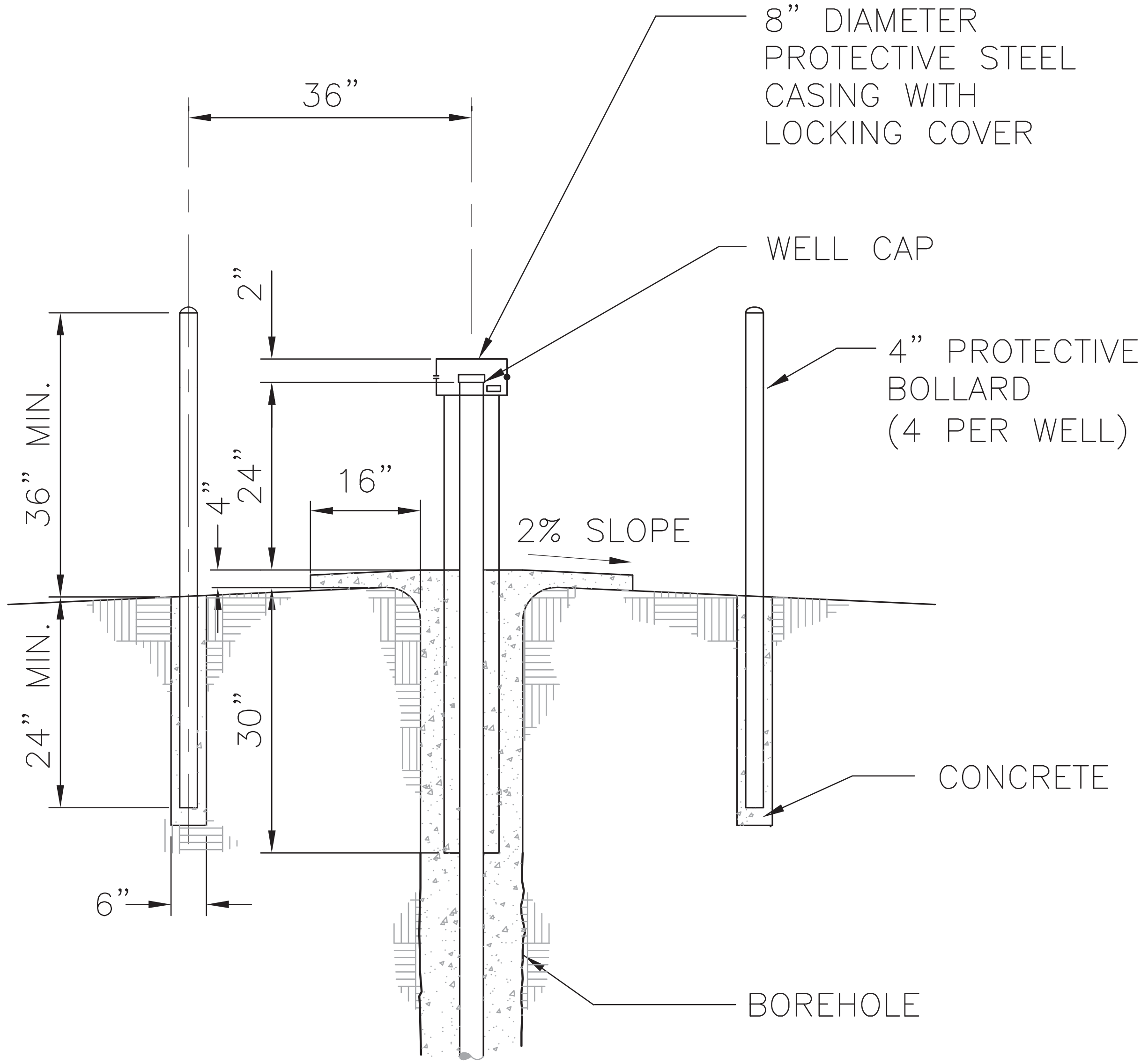
Figure 22
Typical Nested Groundwater Monitoring Well Profile



CAD FILE: G:/Projects/Dairy Cares/09-1-075/Figure 23.dwg CFG FILE: LSCE2500.PCP_MRG DATE: 06-16-11 2:23pm

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Figure 23
Typical Groundwater Monitoring Well Profile



NOTE:

DIMENSIONS OF CONCRETE PAD SUBJECT TO LOCAL REQUIREMENTS.

CAD FILE: G:/Projects/Dairy Cares/09-1-075/Figure 24.dwg CFG FILE: LSCE2500.PCP_MRG DATE: 05-13-11 1:57pm

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 24
Typical Above Grade Surface Completion Detail

Attachment 1

Report of Results – Delineation of an Area for the Design and Initiation of a Representative Groundwater Monitoring Network for Existing Milk Cow Dairies, Central Valley, CA.

REPORT OF RESULTS

DELINEATION OF AN AREA RECOMMENDED FOR THE DESIGN AND INITIATION OF A REPRESENTATIVE GROUNDWATER MONITORING NETWORK FOR EXISTING MILK COW DAIRIES, CENTRAL VALLEY, CA

Prepared for

Dairy Cares

August 31, 2010

LUHDORFF AND SCALMANINI, CONSULTING ENGINEERS
WOODLAND, CA

REPORT OF RESULTS

DELINEATION OF AN AREA RECOMMENDED FOR THE INSTALLATION OF A PILOT GROUNDWATER MONITORING NETWORK DESIGNED FOR A GROUP OF EXISTING DAIRIES, CENTRAL VALLEY, CA

Prepared for

Dairy Cares

August 31, 2010

Representing LSCE:
Vicki Kretsinger, Principal Hydrologist
Till Angermann, Project Hydrogeologist, P.G. 7789, C.Hg. 853
Barbara Dalgish, Staff Hydrogeologist, P.G. 8714

LSCE FILE NO. 09-1-075

Table of Content

Tables – Figures – Attachments

1 EXECUTIVE SUMMARY

On May 3, 2007, the Central Valley Regional Water Quality Control Board (CVRWQCB) adopted *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies* (General Order). The General Order regulates waste discharges to land at the majority of 1,429 existing dairies of all sizes and imposes significantly more stringent requirements than in the past.

Relative to groundwater monitoring, the General Order and its accompanying Monitoring and Reporting Program (MRP) specify two requirements: (1) monitoring of domestic and agricultural supply wells at dairies, and (2) additional groundwater monitoring. The latter requirement can be implemented by the Executive Officer ordering individual dairies to install monitoring wells on a phased basis. However, the General Order also authorizes the Executive Officer to approve alternative monitoring methods. The Information Sheet (page IS-8) states:

> "In the future, the Executive Officer or Central Valley Water Board may determine that a proposed alternative method of environmental monitoring is appropriate to determine if groundwater protection is being achieved. One suggested alternative has been to allow regional groundwater monitoring as a substitute for groundwater monitoring at individual dairies. Any proposed alternative will require sufficient details for consideration by either the Executive Officer or Central Valley Water Board. The Executive Officer or the Central Valley Water Board must issue a monitoring and reporting program order for any alternative environmental monitoring."

Dr. Thomas Harter of the University of California Cooperative Extension (UCCE) prepared a formal proposal outlining an alternative groundwater monitoring approach for regulatory compliance, and presented it to CVRWQCB staff and stakeholders in September 2008. A central aspect of Dr. Harter's proposal was the concept that groundwater monitoring would not be performed on every single dairy in the Central Valley, but rather be performed on a representative subset of dairies.

The CVRWQCB is presently proceeding with implementation of the General Order by issuing directives, under California Water Code Section 13267, to individual dairies that require the installation of groundwater monitoring wells. In October 2009, and parallel to this ongoing process, Dairy Cares submitted a proposal to the Executive Officer for the development of a collaborative plan that would allow representative groundwater monitoring networks to satisfy the additional groundwater monitoring requirements of the General Order.

Dairy Cares commissioned Luhdorff and Scalmanini, Consulting Engineers (LSCE) to further develop the concept of representative groundwater monitoring. LSCE presented an initial outline of the representative groundwater monitoring approach and the process for selecting a geographic region well-suited to initiate this approach to CVRWQCB staff and stakeholders in February 2010. Subsequently, the monitoring approach was presented and discussed in greater detail with the CVRWQCB's Groundwater Advisory Workgroup in March 2010.

This report discusses the technical approach that leads to the recommendation of a particular geographic region well-suited to initiate the representative groundwater monitoring approach. The technical approach (i.e., methodology), individual data components employed in the analysis, their sources, their benefits and limitations, analytical methods, and limitations of the analysis are described herein. In general, the methodology invokes parameters that are either widespread (e.g., groundwater quality data, whole farm nitrogen balance) or were derived via extensive data collection, analysis, and scaled averaging by others (e.g., recharge to groundwater, depth to groundwater, soil survey information). Therefore, the methodology places little significance on any individual data point. Instead, it places emphasis on regional comparisons.

Based on the data and analysis provided herein, the area in Stanislaus and Merced Counties between the San Joaquin River and Highway 99, is recommended as the region to initiate the representative groundwater monitoring program approach for a group of to-be-selected dairies. This region emerged as an area of very high dairy farm density and milk cow density. These two counties have consistently had the second and third largest overall herd size while other livestock operations have been comparatively minor. Based on California Department of Water Resources depth-to-groundwater contour maps and the groundwater level output from the Central Valley Hydrologic Model (CVHM), this dairy farm area overlies very shallow groundwater (i.e., <20 feet below ground surface). Soil survey data indicate a prevalence of high permeability soils in this area, and CVHM groundwater recharge estimates for this area indicate moderate to moderately high annual recharge. Greatly elevated groundwater nitrate-N concentrations occur in this area, and an overall increase in nitrate-N concentrations is apparent since the 1980s. The recent (2000-2008) dairy-specific nitrate monitoring, most of which has predominantly been conducted in accordance with the General Order, also show elevated groundwater nitrate concentrations in this area. Lastly, Stanislaus and Merced Counties are characterized by relatively high nitrogen balances in comparison to other San Joaquin Valley dairy farms.

In coordination with Dairy Cares, UCCE, and the CVRWQCB, a group of approximately 15 to 20 dairy farms would be selected for the design and initiation of the representative groundwater monitoring program in the Stanislaus/Merced County area between the San Joaquin River and Highway 99. The dairy farms would be selected based on the review of the dairies' Preliminary Dairy Facility Assessment, Waste Management Plan, Nutrient Management Plan, Salinity Report, Annual Reports, and other pertinent documents as appropriate. Considerations in the selection process would include (but not necessarily be limited to) facility layout, facility infrastructure and operation, existing groundwater monitoring facilities and data records, and adjacent land uses. The work effort would include the retrieval and processing of site maps from potentially several dozen dairy farms.

For the selected group of dairy farms, a comprehensive monitoring well network would be designed and proposed to the CVRWQCB in a Representative Groundwater Monitoring Network Well Installation and Sampling Plan, which would be prepared in compliance with General Order Attachment A, Item B – including (but not limited to) mapped well locations, specific monitoring objectives for each well and preliminary well design(s).

It is anticipated that a comprehensive data request can be placed 2 weeks after approval to proceed. Further, it is anticipated that the Representative Groundwater Monitoring Network Well Installation and Sampling Plan can be submitted in draft format to Dairy Cares within approximately 4-6 weeks following receipt of information summarized above.

2 INTRODUCTION AND BACKGROUND

On May 3, 2007, the Central Valley Regional Water Quality Control Board (CVRWQCB) adopted *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies* (General Order) (CVRWQCB, 2007). The General Order defines an existing milk cow dairy as a dairy that (i) was operating as of October 17, 2005, (ii) filed a complete Report of Waste Discharge in response to the CVRWQCB's August 8, 2005 Report of Waste Discharge Request Letter, and (iii) has not expanded since October 17, 2005 (i.e., its herd size has not increased by more than 15%). The General Order regulates waste discharges to land at the majority of 1,429 existing dairies[1] of all sizes and imposes significantly more stringent requirements than in the past.

Relative to groundwater monitoring, the General Order and its accompanying Monitoring and Reporting Program (MRP) specify two requirements: (1) monitoring of domestic and agricultural supply wells at dairies, and (2) additional groundwater monitoring. The latter requirement can be implemented by the Executive Officer ordering individual dairies to install monitoring wells on a phased basis. However, the General Order also authorizes the Executive Officer to approve alternative monitoring methods. The Information Sheet (page IS-8) states:

> "In the future, the Executive Officer or Central Valley Water Board may determine that a proposed alternative method of environmental monitoring is appropriate to determine if groundwater protection is being achieved. One suggested alternative has been to allow regional groundwater monitoring as a substitute for groundwater monitoring at individual dairies. Any proposed alternative will require sufficient details for consideration by either the Executive Officer or Central Valley Water Board. The Executive Officer or the Central Valley Water Board must issue a monitoring and reporting program order for any alternative environmental monitoring."

A formal proposal outlining an alternative groundwater monitoring approach for regulatory compliance was prepared by Dr. Thomas Harter of the University of California Cooperative Extension (UCCE) (Harter, 2008). This included a recommendation for the replacement of numerous site-by-site investigations in favor of a targeted regional monitoring approach that accounts for dairy management units (e.g., corral, manure storage lagoon, and cropland receiving manure applications) and the hydrogeologic region characterized by similar soil, climate, and hydrogeologic conditions (e.g., soil type, aquifer material, irrigation efficiency/net recharge, depth to groundwater, and groundwater flow dynamics). A

[1] As of January 2010 (personal communication with J.P. Cativiela, Dairy Cares, April 2, 2010.

central aspect of Dr. Harter's proposal was the concept that groundwater monitoring would not be performed on every single dairy in the Central Valley. Monitoring would rather be performed on a subset of dairies that would be representative of both a range of pertinent hydrogeologic conditions encountered in the Central Valley and common management practices. Dr. Harter formally presented his alternative groundwater monitoring approach to the CVRWQCB at the September 4, 2008 stakeholder meeting held at the CVRWQCB's offices in Rancho Cordova, CA. In the June 4, 2009 draft staff report on alternative groundwater monitoring options, the CVRWQCB found Dr. Harter's proposal to be infeasible, chiefly due to legal, enforcement, and funding challenges; no technical objections were raised (CVRWQCB, 2009).

The CVRWQCB is presently proceeding with the enforcement of the General Order by issuing directives, under California Water Code Section 13267, to individual dairies that require the installation of groundwater monitoring wells. Parallel to this ongoing process, Dairy Cares submitted a proposal on October 5, 2009 (Dairy Cares, 2009) to the Executive Officer for the development of a collaborative plan that would allow representative groundwater monitoring networks in a region to satisfy the additional groundwater monitoring requirements of the General Order.

Dairy Cares commissioned Luhdorff and Scalmanini, Consulting Engineers (LSCE) to further develop the concept of representative groundwater monitoring. At the February 4, 2010 stakeholder meeting held at the CVRWQCB's offices in Rancho Cordova, LSCE presented an initial outline of the representative groundwater monitoring approach and the process for selecting a geographic area well-suited to initiate the approach. Subsequently, the monitoring approach was presented and discussed in greater detail at the March 9, 2010 meeting of the Groundwater Advisory Workgroup, also held at the CVRWQCB's offices in Rancho Cordova.

3 PURPOSE OF THIS REPORT

The primary purposes of this report is to recommend a favorable area for initiating the representative groundwater monitoring approach, by identifying those areas of the Central Valley where high groundwater nitrogen and salt concentrations are thought to be substantially attributable to dairy operations and where changes in water quality are most likely to be detected quickly due to adoption of management practices required by the General Order.

A secondary purpose of the work described herein is to identify areas of relatively lower priority where subsequent efforts could expand the representative groundwater monitoring approach.

4 METHODOLOGY

This section describes the methods employed to identify a favorable area where the representative groundwater monitoring program approach would be initiated. The methodology includes the (i) use and organization of readily available pertinent data, (ii) identification of favorable conditions in an area where monitoring well installation would begin, (iii) utilization of spatial analyses which use a Geographic Information System (GIS) database and mapping tool, and (iv) application of non-spatial analyses.

The methodology was developed with the recognition that existing groundwater quality conditions are the result of historical processes. It invokes parameters that are either widespread (e.g., groundwater quality data, whole farm nitrogen balance) or were derived via extensive data collection, analysis, and scaled averaging by others (e.g., recharge to groundwater, depth to groundwater, soil survey information). Therefore, the methodology places little significance on any individual data point. Instead, it places emphasis on regional comparisons.

4.1 Data Components

The following seven data components were considered:

1. Dairy locations and population densities of dairy cows
2. Non-dairy land use information
3. Depth to groundwater
4. Recharge to groundwater
5. Soil survey information
6. Shallow groundwater nitrate and salt concentrations
7. Whole farm nitrogen balance

These data components are further described below.

4.1.1 Dairy Locations and Population Densities of Dairy Cows

Rationale

Given similar management practices and hydrogeologic conditions, the number of dairy farms and the number of dairy cows in specific areas (i.e., population densities) give an indication of where impacts to groundwater are most likely to occur (i.e., in high population, high density areas) and where impacts are less likely to occur (i.e., in low population, low density areas).

Sources

- CVRWQCB
- USDA NASS

Data Description

Map coordinates for dairy farms were obtained by CVRWQCB staff via site visits and Geographic Positioning System (GPS) measurements. Dairy operators provided the maximum number of mature cows residing at their dairy to the CVRWQCB in a Report of Waste Discharge in response to the 2005 Report of Waste Discharge Request Letter[2]. Historical information on herd sizes per county is available from the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS)[3].

Benefits

1. Knowledge of the location of dairy cow populations is critical to the spatial analysis of proportional contribution to existing groundwater quality conditions.
2. Data are widespread throughout the Central Valley (i.e., good coverage).
3. Large data volume moderates the significance of individual values and facilitates statistical evaluation.
4. Historical data record available.

Limitations

1. Knowledge of individual dairy herd sizes is not conducive to dairy-specific assessment (e.g., a small, poorly operated dairy may pose a greater risk to groundwater quality than a large, well operated dairy).
2. Total dairy sizes (i.e., their acreages) were not available for the computation of dairy-specific population densities. Population densities were approximated using a spatial algorithm.

4.1.2 Non-Dairy Land Use Information

Rationale

Human activities associated with certain land uses unrelated to dairies have been identified as potentially contributing to nutrient and salinity increases in groundwater, including non-dairy agriculture, ranches, and other livestock operations (e.g., beef, hog, sheep, and poultry farms). Consideration of non-dairy land use types is useful in the evaluation of the proportional non-dairy contribution to existing groundwater conditions.

Sources

- USGS's CVHM
- DWR
- USDA NASS

Data Description

[2] A comprehensive spreadsheet was received from CVRWQCB containing dairy farm map coordinates and herd sizes. Values for herd sizes submitted to different RWQCB offices in the Central Valley were uniformly entered in the spreadsheet.

[3] Data accessed December 1, 2009 at http://www.nass.usda.gov:80/Statistics_by_State/California/index.asp

The U.S. Geological Survey's (USGS) Central Valley Hydrologic Model (CVHM) (Faunt, Claudia C., ed., 2009) includes model input files with extensive land use information.[4] In addition, the California Department of Water Resources (DWR) gathers and compiles land use information on a county-wide basis. This information is available for some counties but inter-county differences exist between land use categorization, scales and mapping accuracy, and the times of the mapping efforts. USDA NASS maintains annual records by county on livestock herd sizes (e.g., beef cows, hogs, sheep and lambs).

Benefits
1. Facilitates the evaluation of the proportional non-dairy contribution to existing groundwater conditions.
2. Land use data are available for the entire Central Valley (i.e., good coverage).
3. Large-scale averaging ensures representation of majority land use types and facilitates regional analysis.
4. Historical data record available.

Limitations
1. Spatial accuracy of data varies.
2. Uncertain relationship between land use and proportional groundwater effects.
3. CVHM land use coverages do not differentiate dairies from feedlots and other livestock operations.
4. DWR county-wide data require substantial pre-processing prior to input to the GIS database.

4.1.3 Depth to Groundwater

Rationale
The depth to first encountered groundwater gives an indication of the thickness of the unsaturated zone. The thickness of the unsaturated zone can give an indication of the comparative sensitivity of groundwater to surface water percolation. For example, a thin unsaturated zone may be expected to provide less protection for groundwater resources than a thick unsaturated zone, which provides greater opportunity for natural attenuation to occur (other variables constant). The thickness of the unsaturated zone can also provide an indication of the relative travel time of vertical unsaturated flow to reach groundwater. Therefore, the depth to groundwater is an important component within the framework of the proposed methodology.

Sources
- USGS's CVHM
- DWR

Data Description
Hydraulic head output files from CVHM and DWR's mapped contours of equal depth to first encountered groundwater (identified as the unconfined aquifer).

Benefits
1. CVHM output synthesizes the relative effects of a large number of environmental variables estimated over the entire Central Valley (e.g., three-dimensional subsurface grain size distribution, vertical hydraulic conductivities, evaporation, topography (slope and aspect), precipitation, streamflow, land use, irrigation applications, and crop root depths).
2. Numerical values available (i.e., facilitates quantitative analysis as opposed to categorical comparison).
3. Simulated groundwater levels from CVHM were checked against field measurements during calibration.
4. Data record (1960 – 2003) supports historical assessment.

Limitation
1. CVHM output and DWR data are not applicable for site-specific assessment due to large-scale averaging.

4.1.4 Recharge to Groundwater

Rationale

[4] CVHM's land use input files are a comprehensive source of information as they were compiled from many different sources such as California Department of Water Resources (DWR), USGS Geographic Information Retrieval and Analysis System (GIRAS), and USGS North American Land Class Data.

The rate of recharge represents the link between surface water and groundwater and gives an indication of aquifer vulnerability to surface water percolation. Under certain assumptions and a given constituent concentration, the rate of recharge determines the constituent's mass loading rate to groundwater. For example, an area of low groundwater recharge is expected to be less vulnerable to contamination from surface water percolation than an area of high recharge (other variables constant). Therefore, knowledge of the vertical flux to groundwater is a useful component within the framework of the proposed methodology.

Source
- USGS's CVHM

Data Description
Vertical flux output files from CVHM[5].

Benefits
1. Synthesizes the relative effects of a large number of environmental variables over the entire Central Valley (e.g., three-dimensional subsurface grain size distribution, vertical hydraulic conductivities, evaporation, topography (slope and aspect), precipitation, streamflow, land use, irrigation applications, and crop root depths).
2. Numerical values available (i.e., facilitates quantitative analysis as opposed to categorical comparison).
3. Data record (1960 – 2003) supports historical assessment.

Limitations
1. Simulated recharge not checked against field measurements during calibration.
2. Extraction and compilation of cell-by-cell output data is very time consuming.
3. Not applicable for site-specific assessment because the modeled quantity is subject to large-scale averaging.

4.1.5 Soil Survey Information

Rationale
Soil survey information includes soil textural data that can be related to the soil's permeability. Farming practices may vary according to soil type, and soil permeability plays a key role affecting irrigation practices and efficiencies, the potential for leaching, and the availability of oxygen in shallow groundwater, which affects the fate of nitrogen components. Therefore, soil survey information was used to complement recharge rates simulated with CVHM.

Source
- Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO)[6]

Data Description
Compilation of extensive, detailed soil descriptions, which were generally to a maximum depth of 6 feet. 512 soil textural classes were organized according to their relative permeability and abundance in the vertical soil profile into 3 permeability categories.

Benefits
1. Data are widespread throughout the Central Valley (i.e., good coverage).
2. Soil survey data provide very detailed spatial information based on extensive field observations, sample collection, and laboratory analyses, and testing.

Limitation
1. Soil surveys are prepared on a county-by-county basis and may not use consistent textural descriptions across county boundaries.

[5] In hydrologic wet years, recharge of excess applied irrigation water is estimated to be approximately 2 times greater than stream losses. In hydrologic dry years, this ratio is amplified to approximately 6:1 (Faunt, 2009). The proportional magnitude of recharge from irrigation to groundwater demonstrates the enormous influence of irrigated agriculture on groundwater resources in the Central Valley.
[6] Data accessed March 2, 1010 at http://soildatamart.nrcs.usda.gov/

4.1.6 Shallow Groundwater Nitrate and Salt Concentrations

Rationale

Nitrogen and salts are recognized groundwater pollutants associated with confined animal facilities, including dairies. Information on shallow groundwater nitrate and salt concentrations gives an indication of existing groundwater conditions at a moment in time. The evaluation of existing conditions is a key component of the proposed methodology because it provides a relative measure of potential groundwater quality impacts associated with dairies.

Sources

- USGS National Water Information System (NWIS) including its Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basins Project (implemented by the California State Water Resources Control Board [SWRCB]).
- SWRCB GeoTracker, including the newly available GeoTracker GAMA (Beta version) groundwater quality download option to spreadsheet.
- CVRWQCB

Data Description

USGS groundwater quality data are provided on-line and can be searched, for example, by region, date, constituent (e.g., nitrate and total dissolved solids), and total well depth.

SWRCB GeoTracker GAMA (Beta version) contains groundwater monitoring records from SWRCB/RWQCB, the GAMA domestic well program, USGS GAMA, Lawrence Livermore National Laboratory (LLNL) GAMA, California Department of Pesticide Regulation (DPR), DWR, and Electronic Data File (EDF) submittals from regulated facilities. These data were recently made available on-line. Data can be searched, for example, by region, date, and constituent (e.g., nitrate and total dissolved solids).

CVRWQCB data are composed of maximum nitrate concentration analytical results reported for non-barn domestic wells and on-site production wells (2007 and 2008) that were submitted by individual dairies to the CVRWQCB (Fresno and Sacramento offices) in response to the General Order. Data from a limited number of monitoring well networks on individual dairies were also available.

Benefits

1. Most of the data are readily available from various sources.
2. Data are widespread throughout the Central Valley (i.e., good coverage for wells with well depth information).
3. Large data volume moderates the significance of individual values and facilitates statistical evaluation.
4. Historical data record supports historical assessment.
5. USGS database is searchable by total well depth (i.e., facilitates analysis of targeted shallow groundwater conditions).
6. Groundwater quality data submitted by individual dairies to the CVRWQCB in response to General Order requirements provide indication of near-dairy groundwater conditions.

Limitations

1. Possible bias due to varying data density and different/unknown well construction details (e.g., location of groundwater intake sections of the wells, extent of the gravel envelope, lack of sanitary seals especially in older non-domestic wells, and damaged well casings).
2. The vast majority of data was obtained from wells that were not specifically designed to examine groundwater quality impacts. Depending on construction details, the source areas for these wells may be several miles away from the sampling point and groundwater quality data will in most cases represent a mixture of contributing sources.

4.1.7 Whole Farm Nitrogen Balance

Rationale

The whole farm nitrogen balance (N-balance) evaluated herein relates the recent annual amount of nitrogen generated on the farm to the amount of nitrogen removed with the crop harvest(s). The N-balance is expressed as a ratio including nitrogen produced by the livestock via excretion, nitrogen exports and imports, nitrogen present in irrigation water, and processes such as atmospheric deposition and volatilization of nitrogen. The N-balance is a useful, albeit approximate, indicator of the overall balance between nitrogen application to crop land and nitrogen removal from crop land.

Source
- CVRWQCB

Data Description
The N-balance is a component of the Preliminary Dairy Assessment in the Existing Dairy Conditions Report, which was due at the CVRWQCB December 31, 2007 (i.e., a required submittal under the General Order). Due to leaching losses and gaseous nitrogen losses, the N application typically exceeds the amount of N removed with the harvest. Therefore, the N-balance is typically larger than 1. The Committee of Experts on Dairy Manure Management (2006) suggested that a field N-balance of 1.4 to 1.65 is feasible in a dairy farm setting in the Central Valley. The General Order uses the value of 1.65 as an important threshold value, an exceedance of which triggers applicability of certain regulatory requirements.

Benefits
1. Dairy-specific parameter that yields a reasonable overall proportional measure of the existing nitrogen balance in 2007 (i.e., existing conditions rather than desired future conditions to be accomplished via best management practices).
2. Data are widespread throughout the Central Valley (i.e., good coverage).
3. Large data volume moderates the significance of individual values and facilitates statistical evaluation.

Limitation
1. Individual values for the whole farm nitrogen balance do not provide conclusive evidence regarding groundwater impacts.

4.2 Selection Criteria

It is important that the area selected for the initiation and demonstration of the representative groundwater monitoring approach yield adequate data to evaluate sources of potential groundwater nitrate and salt loading on dairies (e.g., corrals, manure storage lagoons, and cropland) with sufficient confidence. The area would also have attributes that allow focused evaluation of the effect of changes in farming/operational practices on groundwater quality.

A region well suited for the initial demonstration of the representative groundwater monitoring approach should have a relatively high milk cow density in combination with minor presence of other livestock operations such as to correlate high nitrate and salinity concentrations in groundwater with more certainty to dairy operations compared to other land uses. For the same reason, a preponderance of high whole farm nitrogen balances (i.e., indicating a surplus of applied nitrogen) in the area is favorable. In terms of hydrogeologic conditions, the region should exhibit high groundwater nitrate and salinity concentrations to help identify an area of impact. Further, shallow groundwater occurrence, high recharge to groundwater, and permeable soils are desirable as they reduce the lag time between surface processes and the effects on underlying groundwater, and they enhance the confidence in the delineation of cause-and-effect relationships.

5 DATA EVALUATION

5.1 Geographic Distribution of Dairy Farms and Livestock

5.1.1 Clustering and Total Head Counts

92 percent of dairies for which coordinates were available from the CVRWQCB (n=1,554)[7] are located in the San Joaquin Valley, defined here as the area extending south of the county line between Sacramento and San Joaquin Counties (**Figure 1**). Two major clusters of dairies are apparent. One extends for approximately 90 miles from southern San Joaquin County to Madera County, with the highest density of dairies along the eastern side of the San Joaquin River throughout Stanislaus County and northern Merced County. The great majority of the dairies are located east of the San Joaquin River. The second cluster extends from Fresno County into Kings and Tulare Counties. Within this large cluster, the highest density of dairies is located along the western side of Highway 99 in Kings and Tulare Counties, and also east of Highway 99 in the area south of Visalia. The remaining 8 percent of dairies are located in the Sacramento Valley and, with the exception of a few dairies, most of them are located in Glenn and Sacramento Counties.

[7] Coordinates were made available in a .shp file dated July 2009.

Based on 2005 herd size information submitted to the CVRWQCB by 1,469 dairies, 1.843 million (97 percent) of the 1.903 million mature milk cows (milk cows) in the Central Valley reside in the San Joaquin Valley, and only 59,800 head (3 percent) reside in the Sacramento Valley[8] (**Table 1**). The three most populous counties are Tulare (574,146 head), Merced (315,090 head) and Stanislaus (236,919 head), and these account for 61 percent of the milk cows in the San Joaquin Valley (**Figure 2**). Mean herd sizes are substantially skewed toward high values due to several very large dairies in most counties. The above three counties account for 65 percent of dairies in the San Joaquin Valley and have median herd sizes of 1,380, 690, and 665, respectively. Kern County (50 dairies) has by far the largest median herd size (3,278 head) with its smallest herd (535 head) not much smaller than Stanislaus County's median herd size. The overall median herd size in the San Joaquin Valley is 863 head. The median herd size clearly increases from the northern to the southern San Joaquin Valley (**Figure 3**).

Data obtained from USDA NASS[9] show that milk cow herd sizes have grown in all San Joaquin Valley counties since 1975 and that the three counties identified above as the most populous in 2005 have also historically been the most populous (**Figure 4**). In Tulare County, the milk cow population increased by a factor of 5.6 from 86,800 head in 1975 to 483,500 head in 2009 (**Attachment 1**). Over the same period of record, the milk cow population in Merced and Stanislaus Counties increased by factors of 4.0 (64,600 – 260,300 head) and 2.2 (80,400 – 179,600 head), respectively. Kings County has historically had 30,000 to 50,000 milk cows less than Stanislaus County; however, this gap has closed in recent years. Kern County, historically having one of the lowest cow populations, has experienced the most rapid growth since 2005 and now has a cow population similar to that of Stanislaus and Kings Counties.

In the Sacramento Valley, the two most populous counties are Glenn (25,024 head) and Sacramento (21,541 head) with median herd sizes of 380 and 460, respectively (see **Table 1**). These two dairies account for 78 percent of the milk cows and 88 percent of the dairies in the Sacramento Valley (see **Figure 2**). Compared to the San Joaquin Valley, cow populations have remained fairly stable in the Sacramento Valley. The milk cow population has actually decreased in several counties (see **Figure 4**). In Sacramento County, the cow population in 2009 was similar to that in 1975 (approximately 15,000 head) after temporarily increasing to 27,000 in 1989.

5.1.2 Milk Cow Densities

Large portions of counties are not occupied by dairy farms. To estimate a realistic area for each county within which dairy cows reside, a buffer was set up around every dairy. Where buffers overlapped, the area was not double counted. Therefore, this approach does not merely attach an area to each dairy; it does not equate to the simple multiplication of the number of dairies and a certain acreage (unless there is no buffer overlap such as in Butte or Placer Counties). Instead, the computation yields a density index for each county for comparative purposes. The density index is not related to the amount of cropland supporting the cow population. However, under the assumptions that only a negligible amount of manure is applied to fields outside of the buffer and only a negligible amount of manure is exported out of the total buffer area for each county, the total buffer area can be understood as the area within which most of the manure-receiving cropland is located.

This approach breaks down when the buffer radius is too small and little overlap occurs, as is essentially the case in all of the Sacramento Valley. Even in the San Joaquin Valley, where dairies are densely clustered, for a buffer radius of r = 0.5 mile, the density index (ranging from 2.3 to 7.7 head acre^{-1}) precisely mirrors the mean herd sizes (i.e., from largest to smallest: Kern, Tulare, Madera, Fresno, Kings, Merced, San Joaquin, Stanislaus) (see **Table 1**). This occurs because buffer overlap is very small.

For a buffer radius of r = 2.0 miles, the range of the density index was much smaller (from 0.39 to 1.09 head acre^{-1}) (see **Table 1**). Ranked from highest to lowest, the order of counties is Tulare, Kern, Kings, Stanislaus, Merced, Madera, Fresno, and San Joaquin. Several observations can be made. Stanislaus and Merced Counties, i.e., counties with relatively small mean herd sizes and previously ranked the lowest and third lowest, moved up to the mid range. Kings County moved up to having the third highest density index. This phenomenon is particularly striking in the case of

[8] The dairies with available herd size information do not represent a perfect subset of the 1,554 dairies provided in the 2009 .shp file; both data sets contain a small number of mutually exclusive entries.
[9] The fact that 2005 milk cow population data from USDA NASS do not match data obtained from CVRWQCB does not limit the comparative assessments among data sets.

Stanislaus County and indicates the effect of increasing buffer overlay (due to high dairy farm density), which results in the computation of a proportionally higher density in comparison to the counties where dairies are spaced farther apart (i.e., San Joaquin, Fresno, and Madera Counties – all of which have a decreased density index). Tulare County, where the mean herd size is relatively large and clustering is significant, has the highest density index (i.e., it moved up from the second highest density index). The very large mean herd size in Kern County compensates the moderate clustering in this county and results in the second highest density index.

Overall, the buffer analysis indicates that the areas of highest dairy farm densities (i.e., Stanislaus and northern Merced Counties and Kings and Tulare Counties; see **Figure 1**) also roughly coincide with the areas of highest cow population densities.

5.1.3 Other Livestock

For comparative purposes, historical records were obtained from USDA NASS for beef cows (data for 1975-1992 and 2001-2009), hogs (data from 1974-1991), and sheep and lambs (data from 1975-1992). Whereas the population of milk cows increased in all San Joaquin Valley counties, other livestock populations remained relatively stable (**Figure 5**). In most counties, milk cows have always been more populous than other livestock. Exceptions are Madera County, where an approximately equal amount of milk cows, beef cows, and sheep and lambs have been reported; Fresno County, where sheep and lambs were historically approximately twice as abundant as milk cows; and Kern County, where 9 times more sheep and lambs and twice as many beef cows than milk cows have been reported in the past.

On the other end of the spectrum, milk cows recently outnumbered beef cows by 455,500 head in Tulare County. In the other two counties with the highest milk cow population, i.e., Merced and Stanislaus, milk cows outnumbered beef cows by 230,300 and 142,600 head, respectively. In Kings County, milk cows outnumbered the very small beef cow population (7,000 head) by 173,100 head. In Kern County, where the milk cow population has grown rapidly over the past 5 years, there are now 140,100 more milk cows than beef cows.

In contrast, in the Sacramento Valley, milk cows constitute only a small proportion of all livestock (**Figures 6** and **7**). Glenn and Sacramento Counties are the only counties where milk cow and beef cow populations have been relatively similar over the period of record.

5.1.4 Summary Discussion

The geographic distribution of dairy farms in the Central Valley is one of several key factors being used to recommend an area to initiate the representative groundwater monitoring approach. In the northern San Joaquin Valley, the area in Stanislaus County between the San Joaquin River and Highway 99, and extending south into Merced County, emerged as an area of very high dairy farm density and milk cow density. These two counties have consistently had the second and third largest overall herd size, while other livestock operations have been comparatively minor. These are favorable conditions for implementation of the representative monitoring program because elevated concentrations of nitrate and salts in groundwater in such an area are more likely attributable to dairy operations than other livestock or agricultural operations (see *Section 4.2*).

In the southern San Joaquin Valley, the area west and east of Highway 99 in Kings and Tulare Counties also emerged as an area of very high dairy farm density and milk cow density. Within the period of record, Tulare County has always had the largest herd size (1.8 times larger than Merced County's herd size in 2005), has experienced rapid growth over the last two decades, and other livestock operations have been very minor. Kings County has also experienced large increases in cow population, ranks fourth in terms of its herd size, and other livestock operations have been minor.

Only 3 percent of the Central Valley milk cow population resides in the Sacramento Valley, cow populations have remained fairly stable in the Sacramento Valley, and milk cows constitute a comparatively small proportion of the total livestock.

5.2 Depth to Groundwater

Spring 2000 contours of equal depth to groundwater in the unconfined aquifer of the San Joaquin Valley were compiled from several individually prepared DWR documents, georeferenced, and mapped (**Figure 8**)[10]. The individual documents are provided in **Attachment 2**. DWR's contouring effort is limited primarily to the east side of the San Joaquin Valley. Most generally, in Stanislaus, Merced, and Madera Counties, the depth to groundwater decreases in a southwesterly direction from more than 100 feet below ground surface (bgs) near the foothills to less than 10 feet (bgs) along the San Joaquin River. Although information west of the San Joaquin River is limited, it indicates that shallow depths to groundwater are present near the valley trough on the western side of the river.

In contrast, south of the San Joaquin River in Fresno County, the depth to groundwater generally increases from the area due east of Fresno, where the Kings River flows onto the alluvial sediments of the valley floor and very shallow groundwater is indicated (i.e., less than 20 feet, bgs) toward the center of the valley trough. However, patterns appear more complex with a cone of depression beneath the City of Fresno, which is separated by a ridge of shallower groundwater from another very large cone of depression southwest of Fresno (toward the center of the valley trough) where the depth to water increases to over 180 feet (bgs). A smaller cone of depression is located southeast of Fresno.

The depth to groundwater in Tulare County generally increases from 10 to 20 feet (bgs) in the east to over 90 feet (bgs) in western Tulare County and Kings County. Beneath the Kaweah River, the depth to groundwater tends to be shallower. Many small and larger cones of depression characterize this region, and the depth to groundwater steeply declines to over 180 feet (bgs) south of the Tule River and Lake Success.

In Kern County, similar to the northern San Joaquin Valley (i.e., Stanislaus, Merced, and Madera Counties), groundwater is deep near the foothills and becomes shallower toward the valley floor. Specifically, the depth to groundwater in northern Kern County decreases from approximately 600 feet (bgs) in the east to less than 200 feet (bgs) west of Highway 99. In the southernmost portion of the valley, groundwater is about 600 feet (bgs), and it is approximately 40 feet (bgs) west of Bakersfield beneath the Kern River. North of the Kern River, the depth to groundwater is over 200 feet (bgs).

The groundwater level trends observed during Spring 2000 are generally also reflected in the decadal average depth to groundwater computed for the 1990s based on CVHM output files (**Figure 9**). For example, a pattern of decreasing depth to groundwater from more than 100 feet (bgs) to less than 20 feet (bgs) is shown for much of the east side of the San Joaquin Valley, the groundwater ridge southwest of Fresno is clearly shown, and shallow groundwater is also indicated west of the San Joaquin River. Further, the decadal map agrees with shallower groundwater existing beneath the Kaweah River and the deepening of groundwater levels toward Kern County. In contrast, the relatively deep groundwater depicted east and south of Fresno does not coincide with DWR's Spring 2000 water levels in the unconfined aquifer.

In the area of the ancient Tulare lakebed in Kings County (for which DWR water level contours are not available), CVHM output indicates very shallow groundwater[11]. Historically, the CVHM output shows a contiguous area along the longitudinal axis of the Central Valley of very shallow groundwater (**Attachment 3**). The historical decadal average depth to groundwater has been relatively stable with a trend to deeper groundwater over time in some areas such as the Tulare lakebed area and Fresno County.

Contours of equal depth to groundwater in the unconfined aquifer of the Sacramento Valley were not available from DWR. Based on CVHM output only, dairies in Sacramento County and most other places in the Sacramento Valley are situated on very shallow groundwater. Overall, groundwater levels have been relatively stable in the Sacramento Valley.

5.2.1 Summary Discussion

[10] The DWR maps are of moderate resolution, and the moderate quality of the source is reflected in Figure 8. Contoured depth to groundwater is not available for the Sacramento Valley from DWR.

[11] These very shallow groundwater conditions appear reasonable (personal communication with Dr. Thomas Harter, UCCE, March 2010). In some areas, the CVHM output files incorrectly suggested flowing artesian conditions in the unconfined aquifer; and these areas were included in the "<20 foot (bgs)" category.

Based on the DWR contour maps and the CVHM output, the area, or dairy cluster, identified as having the highest density of dairies (i.e., in Stanislaus and northern Merced Counties, between the San Joaquin River and Highway 99; see *Section 5.1*) overlies an area of very shallow groundwater. Under the dairy farm cluster in Fresno, Tulare, and Kings Counties, the depth to groundwater is more heterogeneous and ranges mainly from 40 to 80 feet (bgs), with shallower groundwater beneath the dairies located near the Tulare lakebed and deeper groundwater beneath the dairies located south of the Tule River.

Contours of equal depth to groundwater in the unconfined aquifer of the Sacramento Valley were not available from DWR. Based on CVHM output only, dairies in Sacramento County and most other places in the Sacramento Valley are situated on very shallow groundwater. Overall, groundwater levels have been relatively stable in the Sacramento Valley.

5.3 Groundwater Recharge

Simulated annual groundwater recharge was computed for DWR Water Supply Planning Regions (WSPR) and averaged over 10-year periods. According to the CVHM simulation results, the highest average annual groundwater recharge (i.e., >1.0 ft y^{-1}) in the 1990s occurred in the northern Sacramento Valley in the northern parts of Glenn and Butte Counties, Tehama, and Shasta Counties (**Figure 10**). High recharge rates (i.e., 0.76 – 1.0 ft y^{-1}) occurred along the east side of the Sacramento Valley from Butte County into much of San Joaquin County, on the west side of the Sacramento Valley in parts of Yolo and Solano Counties, and in the southern San Joaquin Valley in Fresno, Kings, and Tulare Counties. Moderately high recharge rates (0.51 – 0.75 ft y^{-1}) prevailed in most of the remaining parts of the eastern San Joaquin Valley and the western Sacramento Valley from Glenn to Yolo County. The lowest recharge rates (<0.26 ft y^{-1}) occurred on the west side from Solano County south to the Mendota area (due west of Fresno) and in the center of the Sacramento Valley in the area of the Sutter Buttes. Moderate recharge rates (0.26 – 0.50 ft y^{-1}) occurred south of Mendota in Westlands Water District and further south to Bakersfield.

The simulated groundwater recharge estimates for the 1990s and also for earlier time periods (**Appendix 4**) provide a relatively rudimentary outline of recharge patterns. This may be partly due to the substantial spatial and temporal averaging involved in the data processing. For example, very high perennial streambed infiltration may substantially increase the average recharge in a given DWR subregion, thus, giving the misleading impression that relatively high groundwater recharge occurs over a large area. This is confounded by other variables beyond soil textural properties, such as precipitation patterns (both spatial distribution and temporal variation), variable land uses, and irrigation practices. Despite these limitations, several observations can be made. First, high to very high recharge rates occur consistently in the northern Sacramento Valley, namely in the northern parts of Glenn and Butte Counties, Tehama, and Shasta Counties. Second, as a whole, recharge rates on the east side of the San Joaquin Valley are consistently higher than on the west side. Third, moderately high to high recharge rates are more common in the area of high dairy farm density in Tulare and Kings Counties than in the area of high dairy farm density in Stanislaus and Merced Counties.

5.4 Soil Permeability

Soil texture classes are most commonly specified for the upper 6 feet of the soil profile and the relative soil permeability was estimated based on 512 soil texture classes (**Attachment 5**). The soil texture of the thickest identified soil horizon was categorized and mapped. As shown in **Figure 11**, there is a sharp transition from high permeability soils on the east side of the valley (not including the foothills) to low permeability soils on the west side. This correlates well with the earlier observation that recharge rates on the east side of the San Joaquin Valley are consistently higher than on the west side (see *Section 5.3*). On the east side, a sizable area of low permeability soils is located in San Joaquin County. A second area of low (and medium) permeability is located beneath a portion of the dairy farm cluster in Kings and Tulare Counties. Overall, most dairy farms in the San Joaquin Valley appear to be located on high permeability soils. In western Merced County, between I-5 and the San Joaquin River, a large number of dairies is situated on low permeability soils.

In the northern Sacramento Valley (north of Glenn County) high permeability soils prevail. This correlates well with the earlier observation that high to very high recharge rates occur consistently in the northern Sacramento Valley. South of Tehama County, medium to high permeability soils are prevalent east of Sacramento River, whereas low permeability soils dominate on the west side. This too, correlates well to recharge patterns simulated by CVHM.

5.5 Groundwater Quality

Nitrogen and salts are recognized groundwater pollutants associated with confined animal facilities including dairies. Of the various nitrogen components that can occur in groundwater, only nitrate was considered for the purposes of this report, as it is the most mobile and abundant nitrogen form in groundwater systems. Natural nitrate concentrations in groundwater are typically very low; and high nitrate concentrations are often the result of anthropogenic activities. In contrast, chloride concentrations fluctuate widely due to natural variability of the lithologic make up of the aquifer, so it can be more difficult to distinguish contributing sources.

As discussed in *Section 4.1.6*, groundwater nitrate and chloride concentrations were obtained from three sources: (i) USGS (NWIS) including its Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basins Project, (ii) SWRCB GeoTracker, and (iii) dairy-specific groundwater quality data directly from CVRWQCB. Only the USGS database is searchable by well depth, and concentrations were obtained for wells up to a total depth of 100 feet. The groundwater quality data were predominantly retrieved from wells that were not intended and constructed to yield information representative of potential dairy impacts (see *Section 4.1.6*). For example, groundwater quality data from the USGS database are collected from a variety of wells such as agricultural wells, domestic wells, municipal wells, and monitoring wells. In comparison, most of the wells in the DPH database are municipal water supply wells. These wells are typically constructed to draw water from deeper confined aquifers, and their source areas may be many miles upgradient of the wellhead where the sample is retrieved. Also, they are sited and designed to minimize potential adverse water quality impacts from anthropogenic surface processes. Finally, the data set from DPH is systematically biased toward nitrate-N concentrations below the maximum contaminant level (MCL) of 10 mg/L because sampling in wells exceeding this threshold is commonly discontinued when the well is no longer actively used as a source of supply. As a result, the data evaluated in *Sections 5.5.1* and *5.5.3* yield less focused information than data obtained from on-site dairy agricultural wells, domestic, and monitoring wells (*Section 5.5.2*).

5.5.1 Nitrate Monitoring

Nitrate-N concentrations discussed in this section are maximum concentrations summarized for 10-year increments starting in the 1960s. The well coverage of the Central Valley has changed significantly over the past 50 years. For the 1960s, nitrate concentration data were available only from the USGS and covered much of the Central Valley floor from Tehama to Kings Counties (**Figure 12**). At that time, maximum nitrate-N concentrations were below the regulatory threshold (i.e., the maximum contaminant level [MCL] for drinking water) of 10 mg/L (as N) in most wells, and most concentrations were less than half the MCL. This is also true for Stanislaus and Merced Counties. However, these two counties exhibit a proportionally higher number of concentrations between 5 and 10 mg/L compared to other counties in the Central Valley.

Nitrate data for the 1970s were also largely retrieved from the USGS database. The volume of data generated during this time had increased but monitoring efforts had clearly shifted to the Sacramento Valley where an abundance of very low (<5 mg/L) nitrate-N concentrations are documented (including the area in Glenn and Tehama Counties, where almost half of the Sacramento Valley dairy farms were located in 2005) as well as a few concentrations exceeding the MCL in areas were dairy farms are not located (**Figure 13**). Similarly low concentrations are documented in San Joaquin County, and little information is available south of San Joaquin County.

The well coverage across the valley floor increased substantially during the 1980s, as data were collected from many additional wells (**Figure 14**). Nearly all wells monitored by the USGS in the Sacramento Valley in the 1970s were subsequently discontinued. There was also very little overlap between USGS wells monitored in the 1960s and 1980s. Further, well data obtained from DPH largely covers areas in the Central Valley for which previous groundwater quality data do not exist. Nitrate-N concentrations in the 1980s were entirely below the MCL in the Sacramento Valley and this is most likely explained by the discontinued USGS effort in favor of DPH data (see *Section 5.5*). Similarly, the discrepancy between mostly low concentrations on the east side of the San Joaquin Valley (mostly DPH data) to mostly elevated concentrations in the Westlands Water District area in western Fresno County (mostly USGS data) and the Tulare Lake bed area in Kings County (mostly USGS data), is likely due, in part, to the different data sources (see *Section 5.5*). Lower recharge rates and well documented drainage challenges on the west side of the San Joaquin Valley, also contribute to comparatively elevated nitrate-N concentrations.

Data retrieved from the 1990s indicate continued reductions in the USGS monitoring program (**Figure 15**). At the same time, DPH's database experienced a moderate expansion. In general, in the areas where sufficient data overlap exists, groundwater quality conditions appear relatively similar to those during the 1980s. However, in Stanislaus County, a trend to higher concentrations is apparent.

The data collection effort substantially increased in the 2000s. Groundwater nitrate data were available from many different agencies, although the vast majority of the data were obtained from DPH (**Figure 16**). In the 2000s, the concentration of wells with reported maximum nitrate-N concentrations in excess of the MCL is apparent in the core area of the dairy farm cluster in Stanislaus and northern Merced Counties, and in the eastern area of the dairy cluster in the southern San Joaquin Valley (see *Section 5.1*).

5.5.2 Dairy-Specific Nitrate Monitoring

Nitrate-N concentrations discussed in this section constitute maximum concentrations observed in agricultural and domestic wells during 2007 and 2008, and some additional data for monitoring wells dating back to 2000. These data were submitted by dairy farms to the CVRWQCB in response to the General Order. Well construction information was not available. While monitoring wells were specifically constructed to monitor conditions in first encountered groundwater with relatively short well screen (presumably in locations where groundwater impacts were expected), domestic and agricultural wells are commonly constructed with longer intake sections, and represent a mix of shallow and deeper groundwater. Therefore, greater impacts are expected in the data obtained from monitoring wells.

5.5.2.1 Agricultural (Non-Domestic Wells)

Maximum nitrate-N concentrations in dairy agricultural wells in the Sacramento Valley were overwhelmingly below the MCL of 10 mg/L (**Figure 17**). In the dairy cluster located in the northern San Joaquin Valley, elevated concentrations were reported for a substantial amount of agricultural wells with many concentrations in excess of 20 mg/L (**Figure 18**). Elevated concentrations were especially common in the area of highest dairy farm density (in southern Stanislaus and northern Merced Counties between the San Joaquin River and Highway 99) where few values were reported below the MCL, many were reported to be 2 to 4 times greater than the MCL, and many of the very high values occurred (4 to 6 times the MCL or greater).

Nitrate-N concentrations in agricultural wells located in the dairy cluster in the southern San Joaquin Valley appear very similar (**Figure 19**). Concentrations between exceeding the MCL and up to 40 mg/L are most abundant, and a significant number of wells have concentrations above 40 and 60 mg/L. Nitrate-N concentrations tend to be lower (often below the MCL) in the southern portion of Tulare County (were the depth to groundwater increases, see *Section 5.2*) and in parts of Kings County, toward the Tulare Lake bed.

5.5.2.2 Domestic Wells

Similar to the results for agricultural wells, maximum nitrate-N concentrations in dairy domestic wells in the Sacramento Valley were overwhelmingly below the MCL of 10 mg/L (**Figure 20**). While concentrations of 2 to 4 times the MCL are common in San Joaquin, Stanislaus, and Merced Counties, such elevated concentrations are especially abundant in the area of highest dairy farm density in southern Stanislaus and northern Merced Counties (**Figure 21**). In this area, concentrations ranging from 4 to 6 times the MCL occur frequently, and concentrations in excess of 60 mg/L are common.

Although elevated nitrate-N concentrations (2 to 4 times the MCL) in dairy domestic wells located in the dairy cluster in the southern San Joaquin Valley are common, they are not nearly as prevalent as in the dairy farm area in southern Stanislaus and northern Merced Counties. A large number of concentrations below the MCL are reported in Fresno and Kings Counties (**Figure 22**). Also, similar to a trend observed in agricultural wells, Nitrate-N concentrations tend to be lower (often below the MCL) in the southern portion of Tulare County (were the depth to groundwater increases, see *Section 5.2*). In general, high concentrations (i.e., in excess of 40 mg/L) are less common in domestic wells than in agricultural wells.

5.5.2.3 Monitoring Wells

The data set for monitoring well nitrate-N results is much smaller than for agricultural and domestic wells and focuses on the southern San Joaquin Valley; only one data point is available north of Madera County (**Figure 23**). At nearly all dairies where monitoring well samples were retrieved, elevated nitrate-N concentrations were reported. This is not the case for several dairies in southern Kern County.

5.5.3 Chloride Monitoring

The dataset for chloride is similarly affected by changes in well coverage of the Central Valley as discussed in *Section 5.5.1* for nitrate. For the 1960s, chloride concentration data were available only from the USGS and covered much of the Central Valley floor from Tehama to Kings Counties (**Figure 24**). At that time, maximum chloride concentrations were very low (<50 mg/L) to low (50 **-** <150 mg/L) in the Sacramento Valley and most of the San Joaquin Valley east of the San Joaquin River. The abundance of high chloride concentrations is apparent on the west side of the San Joaquin River.

Chloride data for the 1970s were also largely retrieved from the USGS database. The volume of data generated during this time had increased but monitoring efforts had clearly shifted to the Sacramento Valley with an abundance of data indicating predominantly very low chloride concentrations (**Figure 25**). Some higher chloride concentrations are apparent in the Natomas area in Sutter County, an area where no dairies exist. As in the 1960s, some higher chloride concentrations are also documented in San Joaquin County, west of the San Joaquin River. Little information is available south of San Joaquin County.

The well coverage across the valley floor increased substantially during the 1980s, as data were collected from many additional wells (**Figure 26**). In the 1980s, most of the wells in the Sacramento Valley that had been monitored by the USGS in the 1970s were no longer monitored. However, the data volume increased in Yolo and Solano Counties (both counties historically had very little dairy farming activities, but they do have a proportionally bigger sheep and beef industries). There was also very little overlap between USGS wells monitored in the 1960s and 1980s. Further, data obtained from DPH largely covers areas in the Central Valley that were not previously covered. The discrepancy between mostly low concentrations on the east side of the San Joaquin Valley (mostly DPH data) to mostly elevated concentrations in the Westlands Water District area in western Fresno County (mostly USGS data) and the Tulare Lake Bed area in Kings County (mostly USGS data), is likely due, in part, to the different data sources (see *Section 5.5*). Lower recharge rates and well documented drainage challenges on the west side of the San Joaquin Valley, also contribute to comparatively elevated nitrate-N concentrations. Lastly, shallow groundwater in the Westlands Water District area and the vicinity of the Tulare lakebed has naturally high salinity. Higher chloride concentrations are also documented south of Bakersfield.

Data retrieved from the 1990s indicate continued reductions in the USGS monitoring program and an increase in DWR data (**Figure 27**). Chloride concentrations in the Sacramento Valley remained predominantly low in the 1990s. In general, in the areas where sufficient data overlap exists, groundwater quality conditions appear similar to those during the 1980s. Slight trends to higher chloride concentrations are apparent in Stanislaus and Tulare Counties along Highway 99.

The data collection effort substantially increased in the 2000s. Groundwater chloride data were available from many different agencies, although the vast majority of the data were obtained from DPH (**Figure 28**). Due to the increased data density, generally higher chloride concentrations are apparent on the west side of the San Joaquin Valley compared to the east side.

5.5.4 Summary Discussion

The most recent nitrate data (not specific to dairy farms), i.e., for the 2000s, are useful as they exhibit a correlation between elevated groundwater nitrate-N concentrations in the two areas with the highest milk cow populations (i.e., in Stanislaus and northern Merced Counties between the San Joaquin River and Highway 99 and in Kings and Tulare Counties west and east of Highway 99. In the area of the dairy farm cluster in Stanislaus and northern Merced Counties, a trend to higher nitrate-N concentrations is apparent since the 1980s. In the area of the dairy farm cluster in Kings and Tulare Counties, comparison of 1990s data to conditions in the 2000s shows a trend to higher nitrate-N concentrations. This increase occurred during a time when the herd size in Tulare County more than doubled.

The chloride data (not specific to dairy farms) identified historically higher salinities on the west side of the San Joaquin Valley than on its east side, and generally low concentrations in the Sacramento Valley. A slight trend to higher chloride concentrations in the area of the dairy farm cluster in Stanislaus and northern Merced Counties is apparent in the 1990s.

Overall, the chloride data do not significantly contribute to the identification of areas potentially impacted by dairy farm operations.

The results from the recent dairy-specific nitrate monitoring clearly identify the dairy farm area in Stanislaus and northern Merced Counties between the San Joaquin River and Highway 99 as being correlated with the greatest number of elevated groundwater nitrate concentrations.

5.6 Whole Farm Nitrogen Balance

The whole farm nitrogen balance (N-balance) evaluated herein relates the recent annual amount of nitrogen generated on the farm to the amount of nitrogen removed with the crop harvest(s) over the same time period. The N-balance is expressed as a ratio including nitrogen produced by the livestock via excretion, nitrogen exports and imports, nitrogen present in irrigation water, and processes such as atmospheric deposition and volatilization of nitrogen.

As stated in *Section 4.1.7*, the application of nitrogen to the crop fields typically exceeds the amount of nitrogen removed with the harvest to account for leaching losses and gaseous nitrogen losses. Consequently, the N-balance is typically larger than 1.00. An N-balance smaller than 1.00 indicates that less nitrogen (either from manure, commercial fertilizers, or both) was applied to the fields (on a whole farm scale) than removed by the crop harvest. This condition implies a depletion of soil nitrogen and is not sustainable. In most cases, these balances are believed to be the result of a systematic error in the computation of the N-balance (personal communication with Dr. Thomas Harter, UCCE, March 5, 2010). The General Order uses the value of 1.65 as an important threshold value, an exceedance of which triggers applicability of certain regulatory requirements.

While dairies in the San Joaquin Valley reported the greatest values for N-balances, these occurrences were few. With the exception of a few outliers, the N-balance distributions for the Sacramento and San Joaquin Valleys are very similar with first quartile values of 1.15 and 1.21, medians of 1.60 and 1.61, and third quartile values of 2.08 and 2.43, respectively (see **Table 1**). In the Sacramento Valley, 22 percent of dairies have an N-balance smaller than 1.00 (in the San Joaquin Valley, it is 17 percent). In both the Sacramento and San Joaquin Valleys, 54 percent of dairies have an N-balance smaller than 1.65. This means that the N-balance exceeds the threshold value of 1.65 at 46 percent of all dairies for which N-balances were submitted to the CVRWQCB.

A scatter plot of the whole farm N-balance in relation to dairy herd size shows that herd size is not a useful predictor for the N-balance and demonstrates the similarity between Sacramento and San Joaquin Valley dairies (**Figure 29**). Among larger dairies (i.e., dairies with more than approximately 2000 head), fewer dairies exist with high N-balances. Also, dairy farms in Stanislaus and Merced Counties exhibit proportionally more high N-balances than Kings and Tulare Counties.

The similarity of the N-balances from dairies in the Sacramento and San Joaquin Valleys is shown with box-and-whisker plots and supported by the low confidence in the Kruskal-Wallis H-statistic[12] (**Attachment 6**). In contrast, grouping by county yields significant differences (very high H-statistic supported by high confidence) although median values are relatively similar. Merced and Stanislaus Counties stand out as counties with relatively high median N-balances, and the most outliers and extreme values.

5.7 Summary of Key Findings and Identification of High Priority Region

In the northern San Joaquin Valley, the area in Stanislaus County between the San Joaquin River and Highway 99, and extending south into Merced County, emerged as an area of very high dairy farm density and milk cow density. These two counties have consistently had the second and third largest overall herd size while other livestock operations have been comparatively minor. Based on the DWR depth-to-groundwater contour maps and the CVHM groundwater level output, the above Stanislaus/Merced dairy farm area overlies very shallow groundwater (i.e., <20 feet, bgs). SSURGO soil data indicate a prevalence of high permeability soils in this area, and CVHM groundwater recharge estimates for this area indicate moderate to moderately high annual recharge. Greatly elevated groundwater nitrate-N concentrations occur in this area, and an overall increase of nitrate-N concentrations is apparent since the 1980s. The results from the recent

[12] The nonparametric Kruskal-Wallis group comparison indicates the rejection of the null hypothesis (the null hypothesis states that there is no difference between groups) by an H-statistic greater than 1.00. However, the confidence in this result is low, as indicated by a high p-value (0.1714).

(2007-2008) dairy-specific nitrate monitoring also show elevated groundwater nitrate concentrations in this area. Lastly, Stanislaus and Merced Counties are characterized by relatively high N-balances in comparison to other San Joaquin Valley dairy farms.

In the southern San Joaquin Valley, the area west and east of Highway 99 in Kings and Tulare Counties also emerged as an area of very high dairy farm density and milk cow density. Tulare County has always had the largest herd size (1.8 times larger than Merced County's herd size in 2005), has experienced substantial growth of the milk cow population over the last two decades while other livestock operations have been very minor. Kings County has also experienced large increases in cow population and ranks fourth in terms of its herd size; other livestock operations have been very minor. Based on the DWR depth-to-groundwater contour maps and the CVHM groundwater level output, the depth to groundwater beneath the Tulare/Kings dairy farm cluster is deeper and more heterogeneous (ranging mainly from 40 to 80 feet, bgs) than beneath the high density dairy farm area in Stanislaus and northern Merced Counties, with shallower groundwater beneath dairies near the Tulare lakebed and substantially deeper groundwater south of Tule River. CVHM recharge estimates for this area indicate predominantly high annual recharge. These model results are consistent with the prevalence of high permeability soils in this area. The area of low permeability soils west of Highway 99 in Tulare County also roughly corresponds to deeper water levels. Groundwater nitrate-N concentrations from the 1990s compared to those from the 2000s indicate an increasing trend. This increase occurred during a time when the herd size in Tulare County more than doubled. The results from the recent (2007-2008) dairy-specific nitrate monitoring also indicate elevated nitrate-N concentrations in this area. Lastly, N-balances in this area are similar to the rest of the San Joaquin Valley.

Only 3 percent of the Central Valley milk cow population resides in the Sacramento Valley, cow populations have remained fairly stable in the Sacramento Valley, and milk cows constitute a comparatively small proportion of all livestock. Contours of equal depth to groundwater in the unconfined aquifer of the Sacramento Valley were not available from DWR. Based on CVHM groundwater level output only, dairies in Sacramento County and most other places in the Sacramento Valley are situated on very shallow groundwater. However, the recent maximum nitrate-N concentrations in agricultural and domestic wells located on dairy farms in the Sacramento Valley are predominantly below the MCL.

The analyses and findings presented in this report indicate that elevated nitrogen-N concentrations in the area in Stanislaus and Merced Counties between the San Joaquin River and Highway 99 area are substantially attributable to dairy operations. Furthermore, the prevalence of high permeability soils in combination with very shallow depths to groundwater, high nitrate-N concentrations, and relatively high N-balances present favorable baseline conditions, as future changes in field and management practices are likely to positively affect groundwater quality more rapidly than in other regions. Therefore, this area is recommended as the region to initiate the representative groundwater monitoring program approach for a group of to-be-selected dairies (**Figure 30**).

6 LIMITATIONS OF THE ANALYSIS

Two data components used in the analysis were less useful than initially expected. First, the groundwater recharge estimates simulated with CVHM provided a relatively rudimentary outline of recharge patterns. This may have been partly due to the substantial spatial and temporal averaging involved in the data processing, and was likely confounded by other variables, such as precipitation patterns (both spatial distribution and temporal variation) and variability of land uses and irrigation practices, i.e., variables beyond soil textural properties. Second, the chloride data did not significantly contribute to the identification of areas potentially impacted by dairy farm operations due to the naturally high spatial variability of chloride in groundwater and its ubiquitous nature. Overall, the above data limitations did not affect the confidence in the recommendation summarized in *Section 5.7*.

7 PREPARATION OF REPRESENTATIVE MONITORING NETWORK DESIGN

In coordination with Dairy Cares, UCCE, and the CVRWQCB, a group of approximately 15 to 20 dairy farms would be selected for the design and initiation of the representative groundwater monitoring program in the Stanislaus/Merced County area between the San Joaquin River and Highway 99 (see **Figure 30**). The dairy farms would be selected based on the review of the dairies' Preliminary Dairy Facility Assessment, Waste Management Plan, Nutrient Management Plan, Salinity Report, Annual Reports, and other pertinent documents as appropriate. Considerations in the selection process would include (but not necessarily be limited to) facility layout, facility infrastructure and operation, existing groundwater monitoring facilities and data records, and adjacent land uses. The work effort would include the retrieval and processing of site maps from potentially several dozen dairy farms. Individual dairy site maps would be prepared to show all of the following (as available):

- existing groundwater wells (e.g., domestic, agricultural, and monitoring wells),
- corrals, freestalls, exercise areas, milking parlors, and other areas where cows reside,
- manure holding ponds and other manure drying and/or storage areas,
- storage and handling areas for commercial fertilizers,
- crop land with an indication of the slope of the ground and location of tile drains,
- above ground and underground conveyance facilities for manure, stormwater, and any other wastes,
- septic systems and leach lines,
- roads, buildings, property lines,
- existing and/or past dumping areas, and
- any other facilities or items that may be relevant to the design of the monitoring well network.

For the selected group of dairy farms, a comprehensive monitoring well network would be designed and proposed to the CVRWQCB in a Representative Groundwater Monitoring Network Well Installation and Sampling Plan, which would be prepared in compliance with General Order Attachment A, Item B – including (but not limited to) mapped well locations, specific monitoring objectives for each well and preliminary well design(s).

It is anticipated that a comprehensive data request can be placed 2 weeks after approval to proceed. Further, it is anticipated that the Representative Groundwater Monitoring Network Well Installation and Sampling Plan can be submitted in draft format to Dairy Cares within approximately 4-6 weeks following receipt of information summarized above.

8 REFERENCES

Central Valley Regional Water Quality Control Board. **2007**. *Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies*. May 3, 2007.

Central Valley Regional Water Quality Control Board. **2009**. *Evaluation of Alternative Groundwater Monitoring Options at Dairies Operating under Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies (Draft)*. June 4, 2009.

Dairy Cares. **2009**. *Proposal for collaborative plan development, to allow representative groundwater monitoring networks to satisfy the additional groundwater monitoring requirements of General Order R5-2007-0035*. Letter by J.P. Cativiela (Dairy Cares Program Coordinator) to Pamela Creedon (RWQCB Executive Officer, Region 5). October 5, 2009.

Faunt, Claudia C., ed. **2009**. *Groundwater Availability of the Central Valley Aquifer, California*. U.S. Geological Survey Professional Paper 1766, 225 p.

Harter, Thomas. **2008**. *Proposal for Groundwater Monitoring at Existing Dairies for Purposes of Meeting the Waste Discharge Requirements*. Post-Discussion Draft. University of California Cooperative Extension - Davis. September 5, 2008.

University of California Committee of Experts on Dairy Manure Management. **2006**. *Managing Dairy Manure in the Central Valley of California*. University of California Agricultural and Natural Resources Publication 9004. November 2006.

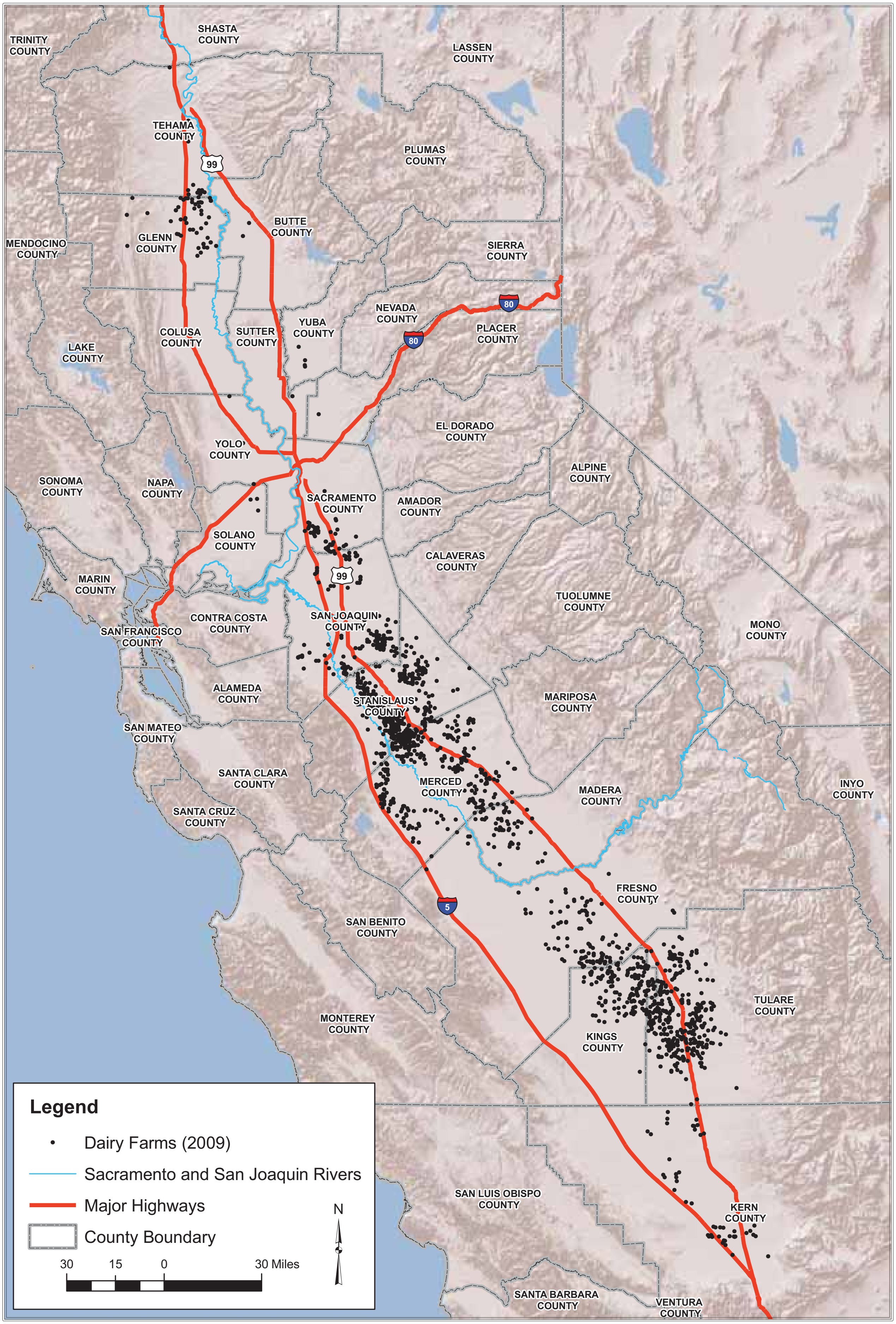
Tables

Table 1: Dairy Farm Statistical Information by County

		Sacramento Valley Counties								San Joaquin Valley Counties								
Statistic	All Dairies	Glenn	Placer	Sacramento	Solano	Sutter	Yolo	Yuba	***Total***	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare	***Total***
No. of dairies who submitted herd size	1,469	47	1	41	3	1	3	4	*100*	101	50	143	45	309	134	286	301	*1,369*
Total Head	1,903,035	25,024	1,093	21,541	4,161	633	3,773	3,619	*59,843*	151,142	177,546	188,330	77,673	315,090	122,347	236,919	574,146	*1,843,193*
Density Index ($r_{2.0}$ = 2 mi)	-	0.2	0.1	0.2	0.2	0.1	0.2	0.2	-	0.42	0.86	0.72	0.46	0.57	0.39	0.60	1.09	-
Density Index ($r_{0.5}$ = 0.5 mi)	-	1.2	1.7	1.3	2.2	1.0	2.9	1.9	-	3.3	7.7	3.3	3.5	2.7	2.5	2.3	4.6	-
Herd Size (mean)	1,295	532	na	525	1,387	na	1,258	905	*598*	1,496	3,551	1,317	1,726	1,020	913	828	1,907	*1,346*
Herd Size (median)	805	380	na	460	1,084	na	407	990	*405*	1,041	3,278	1,001	863	690	656	665	1,380	*863*
Herd Size (min)	58	58	na	130	288	na	146	351	*58*	161	535	117	265	92	127	115	92	*92*
Herd Size (max)	11,242	3,450	na	1,668	2,789	na	3,220	1,288	*3,450*	10,457	10,230	6,797	8,137	7,173	3,790	4,140	11,242	*11,242*
Herd Size (0.25 percentile)	495	170	na	276	686	na	277	700	*253*	500	1,806	678	575	403	403	403	863	*529*
Herd Size (0.75 percentile)	1,553	661	na	633	1,937	na	1,814	1,195	*770*	1,955	4,514	1,478	2,530	1,141	1,205	1,028	2,318	*1,610*
No. of dairies who submitted N-balance	1317	44	1	39	3	1	3	4	*95*	84	46	119	41	274	118	251	289	*1,222*
N-balance (mean)	3.55	1.80	2.11	1.73	2.91	1.13	1.94	1.61	*1.80*	18.7	1.62	5.57	2.03	2.84	1.93	2.66	1.54	*3.69*
N-balance (median)	1.61	1.58	na	1.60	2.23	na	1.95	1.74	*1.60*	1.52	1.47	1.51	1.67	2.06	1.56	1.98	1.48	*1.61*
N-balance (min)	-12.3	0.49	na	0.03	0.99	na	0.90	-0.66	*-0.66*	0.17	0.64	0.02	0.38	-12.3	-8.48	-6.17	0.01	*-12.30*
N-balance (max)	1,292	8.41	na	9.55	5.50	na	2.96	3.61	*9.55*	1,292	3.78	440	7.56	53.5	23.3	16.7	8.11	*1,292*
N-balance (0.25)	1.20	1.14	na	1.22	1.61	na	1.43	1.02	*1.15*	0.99	1.19	1.15	1.20	1.27	1.29	1.30	1.14	*1.21*
N-balance (0.75)	2.39	2.08	na	1.86	3.87	na	2.46	2.32	*2.08*	2.36	1.73	2.00	2.35	3.25	2.28	3.36	1.73	*2.43*
N-balance (N <= 1.00)	232	10	0	8	1	0	1	1	*21*	23	7	21	7	46	17	43	47	*211*
N-balance (1.00 < N <= 1.65)	481	13	0	15	0	1	0	1	*30*	30	25	56	13	58	47	61	161	*451*
N-balance (1.65 < N <= 3.00)	387	17	1	14	1	0	2	1	*36*	16	11	30	15	92	41	73	73	*351*
N-balance (N > 3.00)	217	4	0	2	1	0	0	1	*8*	15	3	12	6	78	13	74	8	*209*

Herd size (i.e., maximum number of mature cows) according to Report of Waste Discharge submitted in response to CVRWQCB 2005 Report of Waste Discharge letter.
Whole farm nitrogen balance according to Preliminary Dairy Assessment in the Existing Dairy Conditions Report due December 31, 2007.

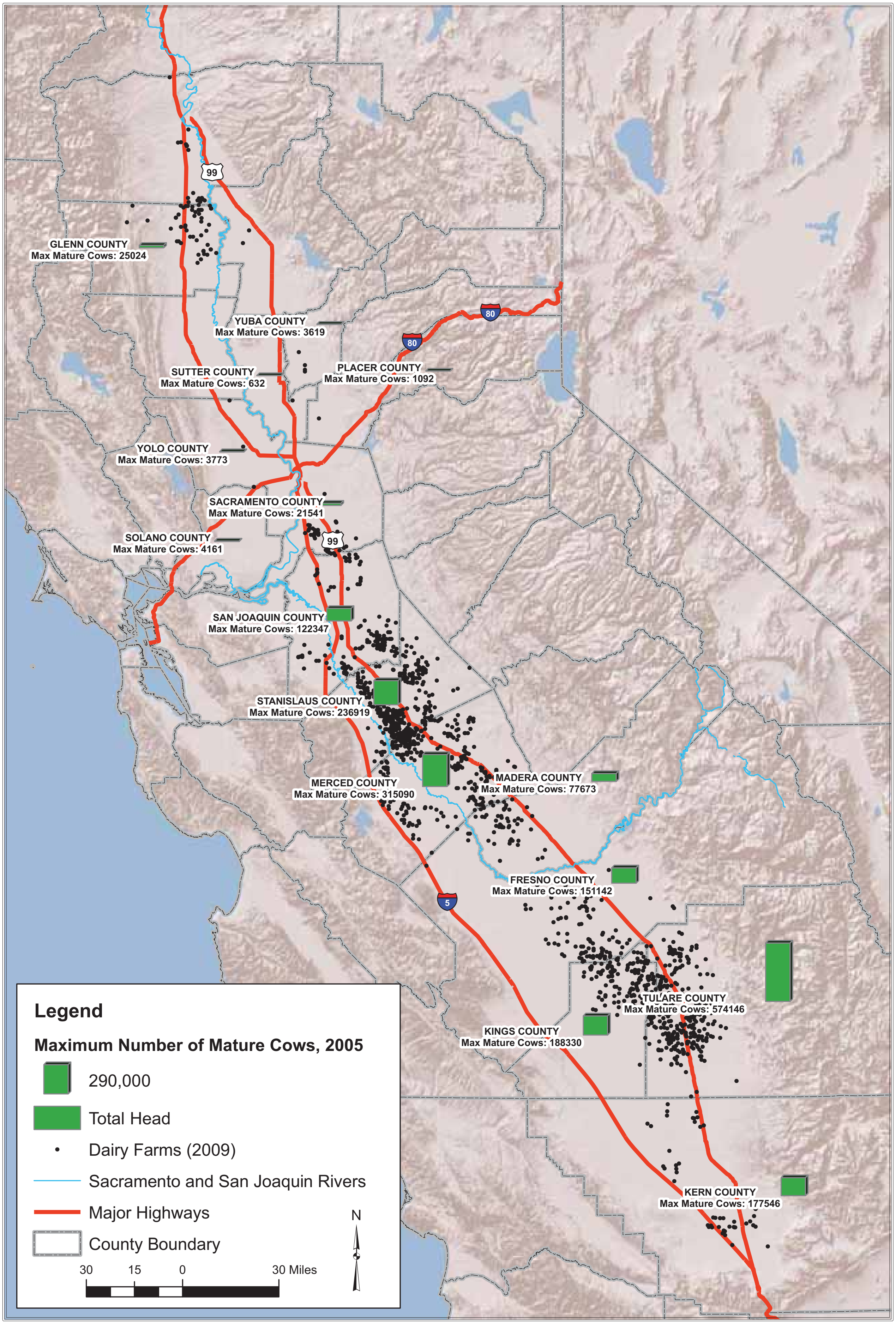
Figures



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\Basemap.mxd Date: 3/25/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

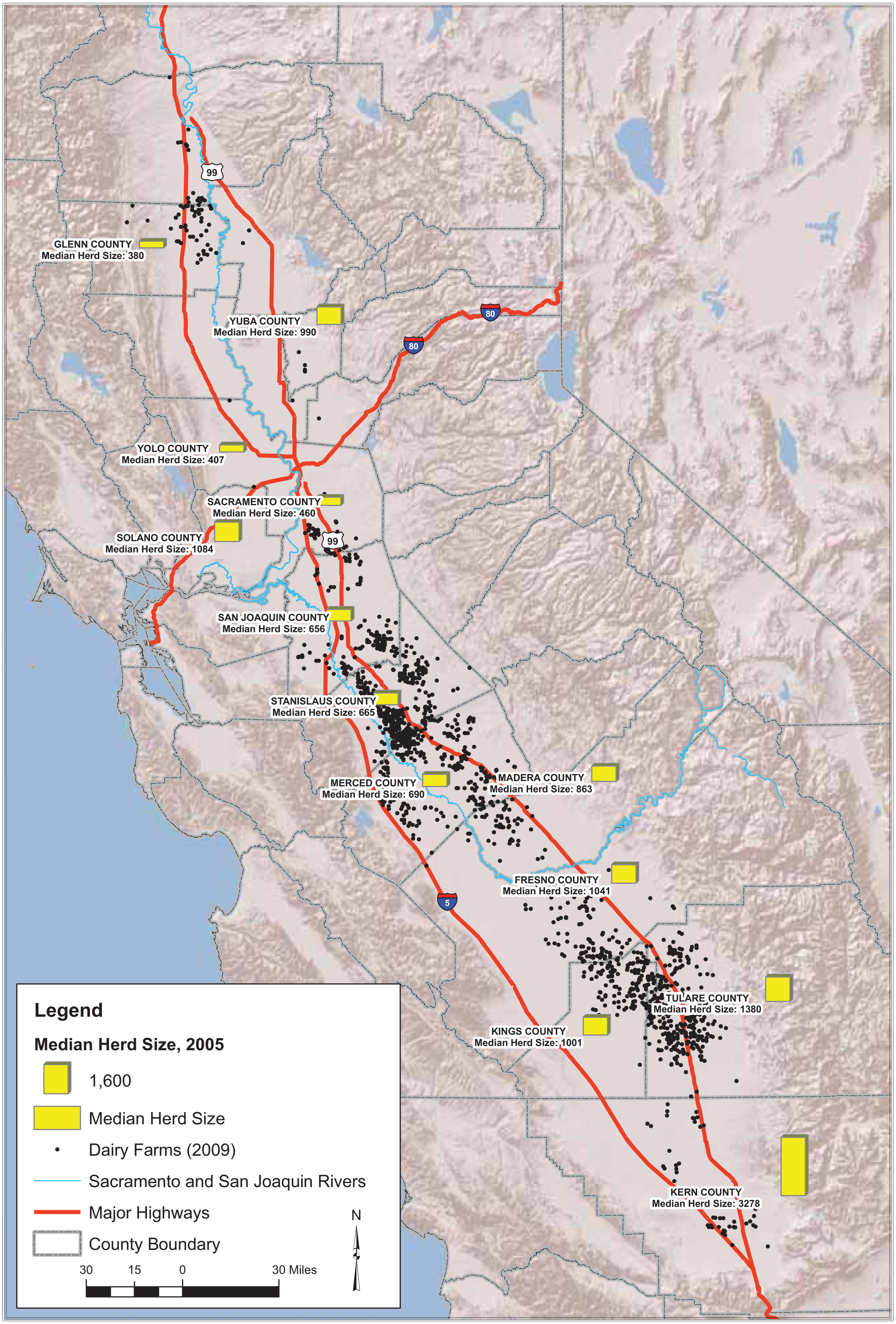
Figure 1
Dairy Locations in the Central Valley of California



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CowPop_Herd_2005.mxd Date: 3/25/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

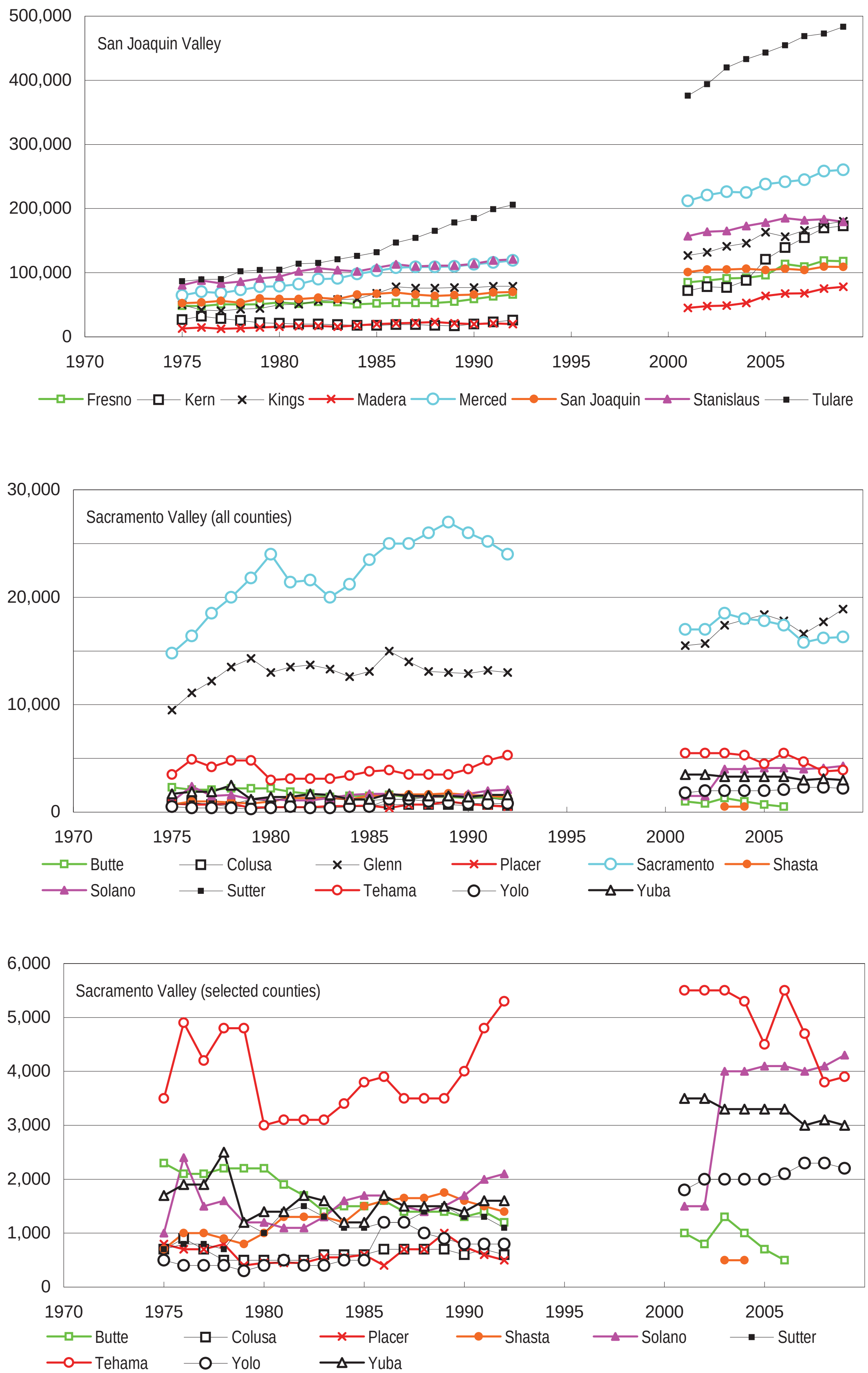
Figure 2
Mature Milk Cow Population by County in 2005



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CowPop_Herd_2005.mxd Date: 3/25/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 3
Median Herd Size by County in 2005



Abscissa: Year

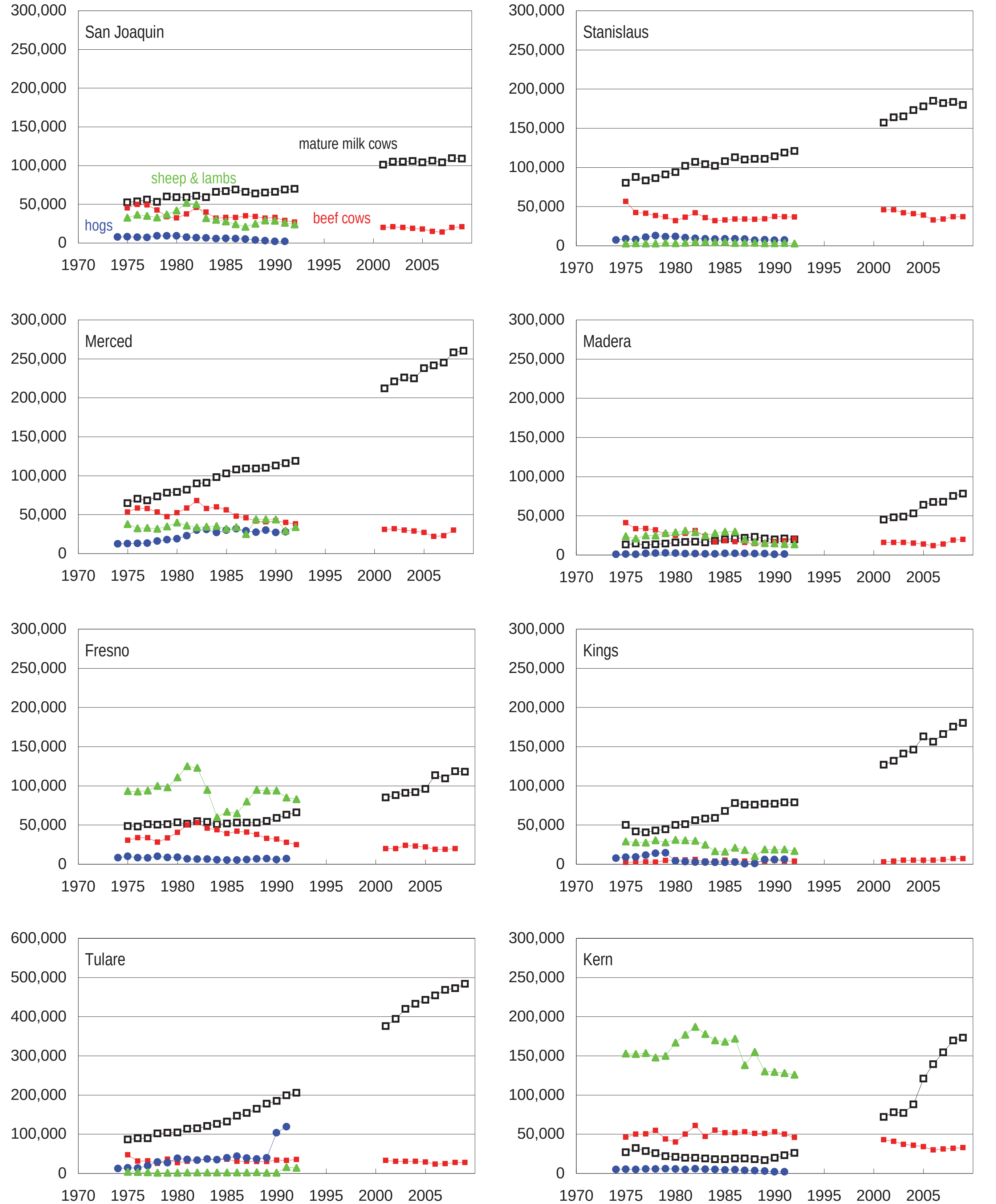
Ordinate: Milk Cows (head)

Data are tabulated in Attachment 1

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Figure 4

Historical Milk Cow Populations by County



Abscissa: Year

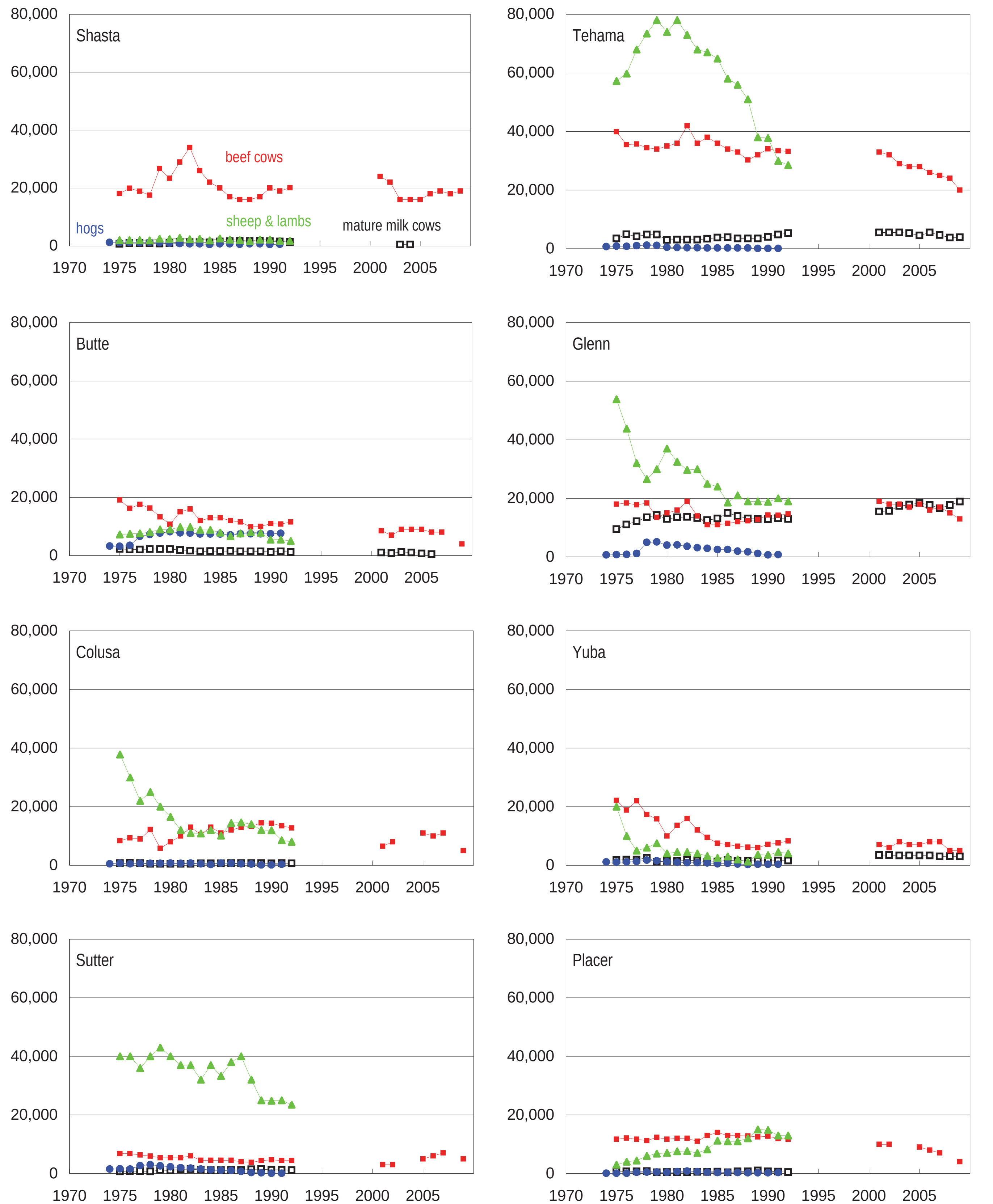
Ordinate: Livestock (head)

Notes: Order of Counties from north to south. Different scale for Tulare County.

Data are tabulated in Attachment 1

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 5
Historical Livestock Populations by County
San Joaquin Valley

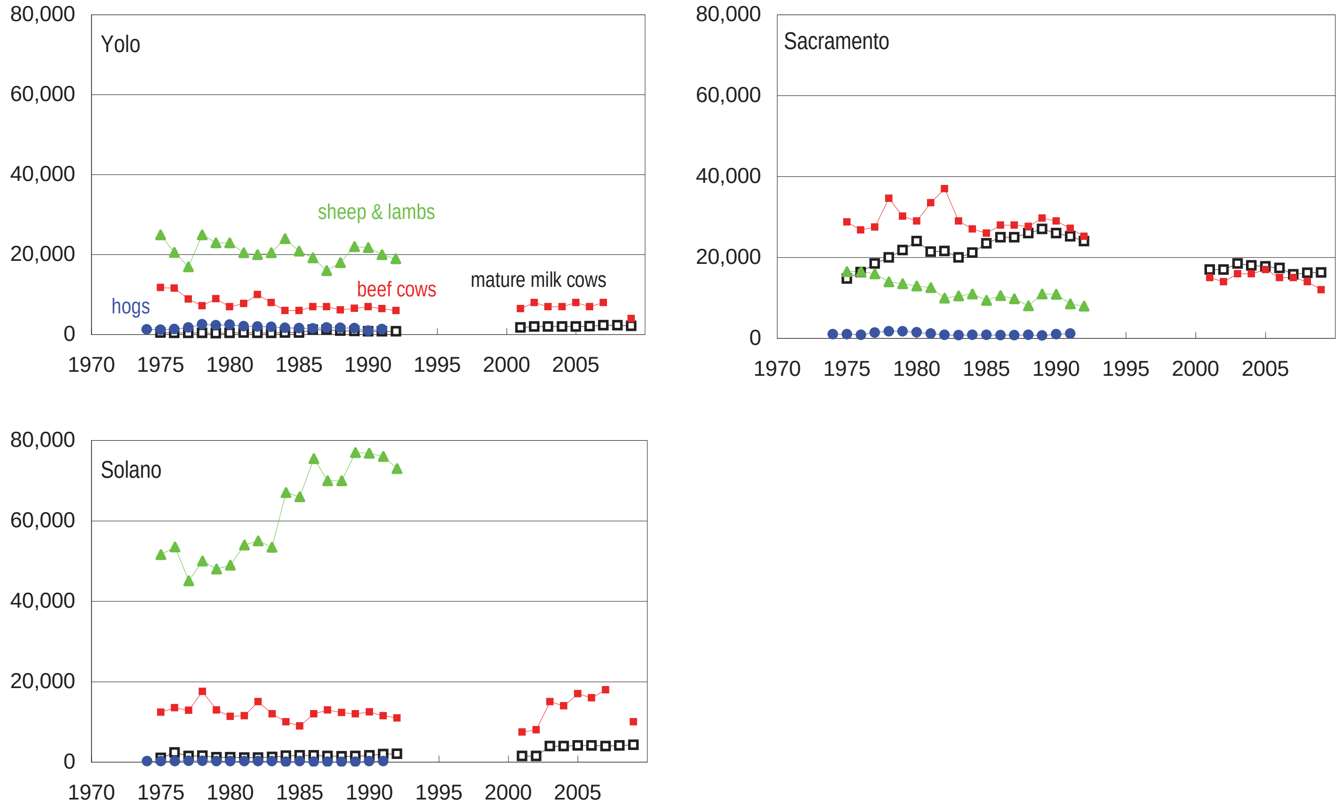


Abscissa: Year
Ordinate: Livestock (head)

Notes: Order of Counties from north to south.
Data are tabulated in Attachment 1

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

Figure 6
Historical Livestock Populations by County
Northern Sacramento Valley

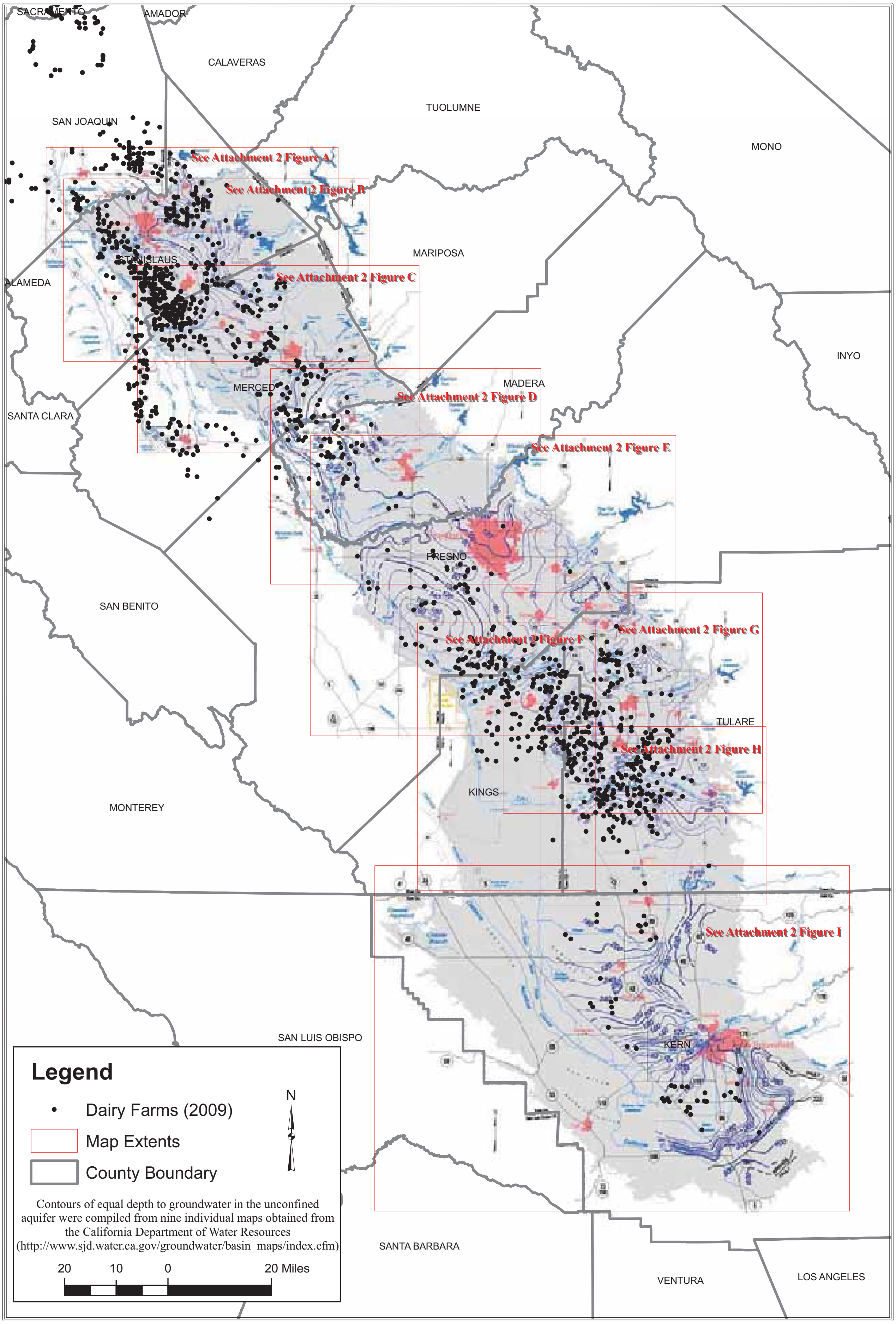


Abscissa: Year
Ordinate: Livestock (head)

Notes: Order of Counties from north to south.
Data are tabulated in Attachment 1

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

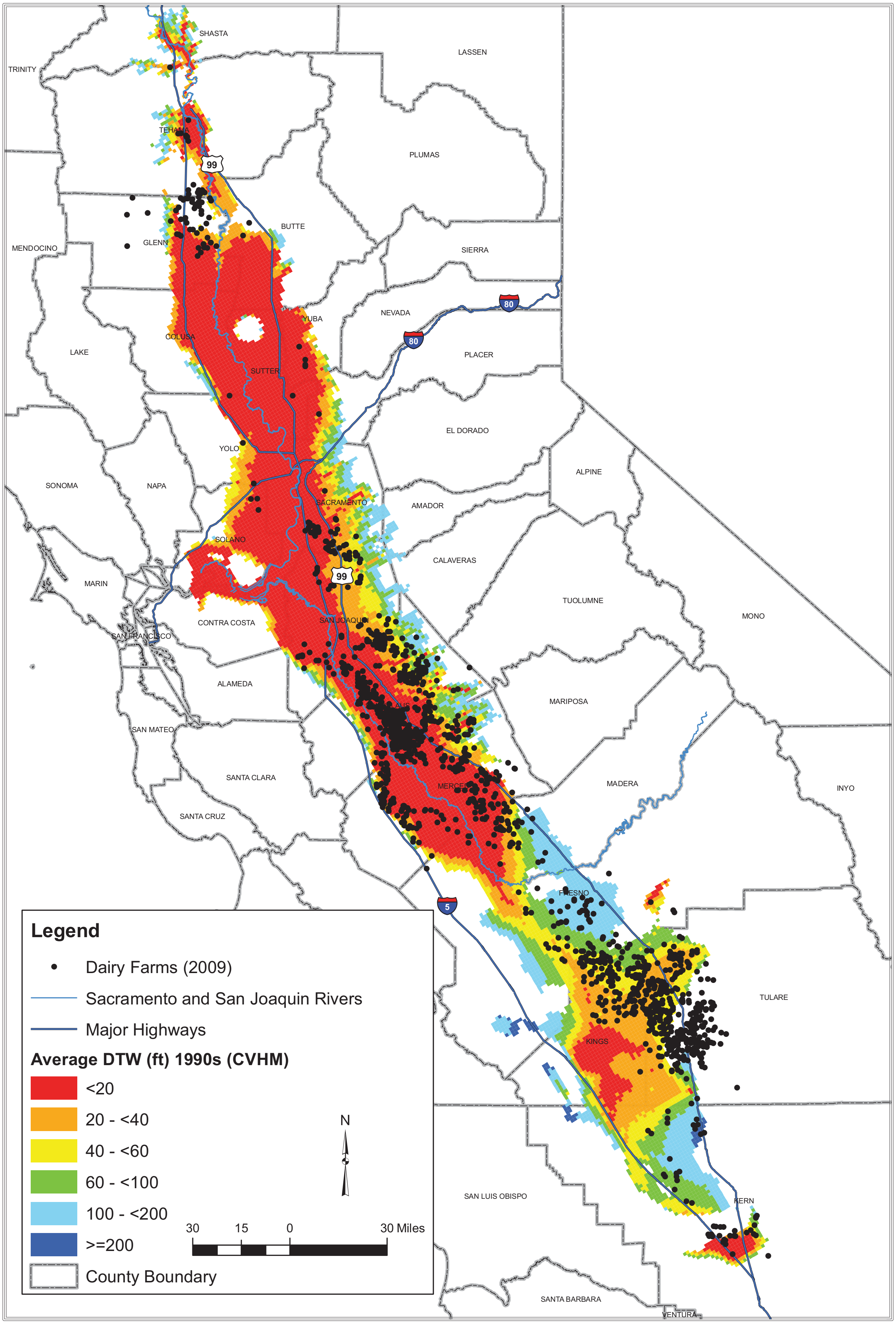
Figure 7
Historical Livestock Populations by County
Southern Sacramento Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DWR_WLContourMaps.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

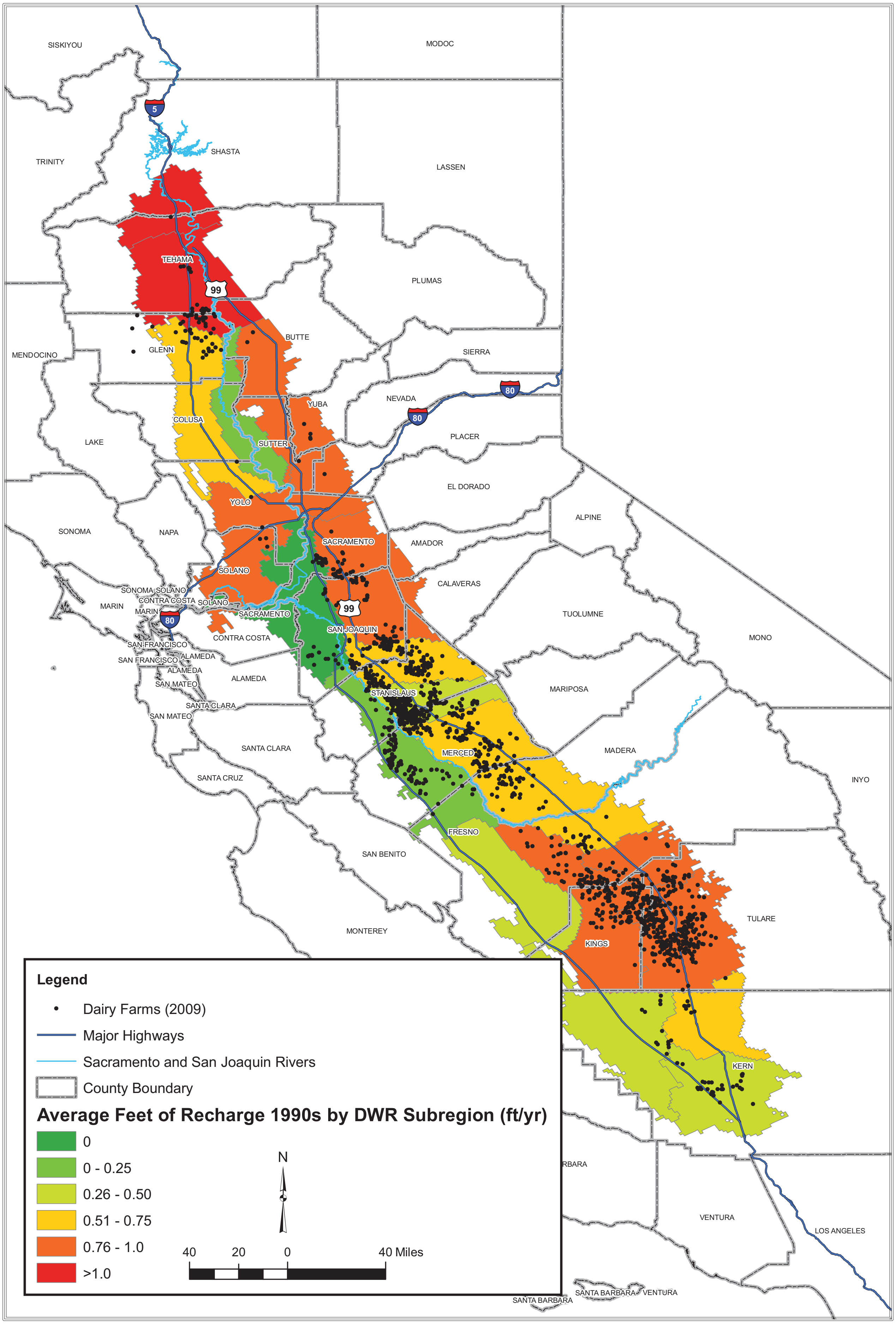
Figure 8
Index Map - Spring 2000 Contours of Equal Depth to Water
Unconfined Aquifer
San Joaquin Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_avgDTWs.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

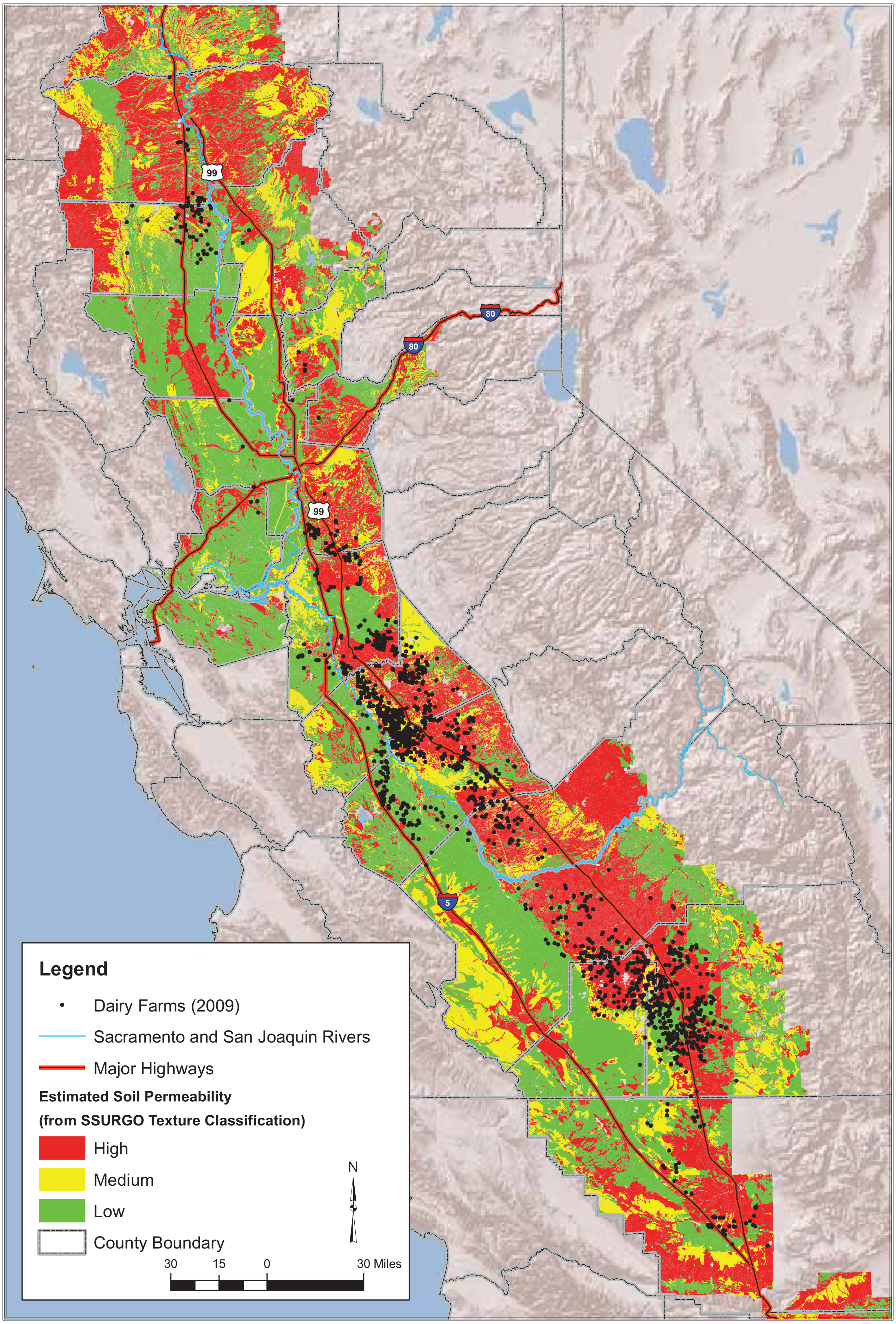
Figure 9
Average Depth to Water (1990s), Unconfined Aquifer
CVHM Results



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_RechargeData.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

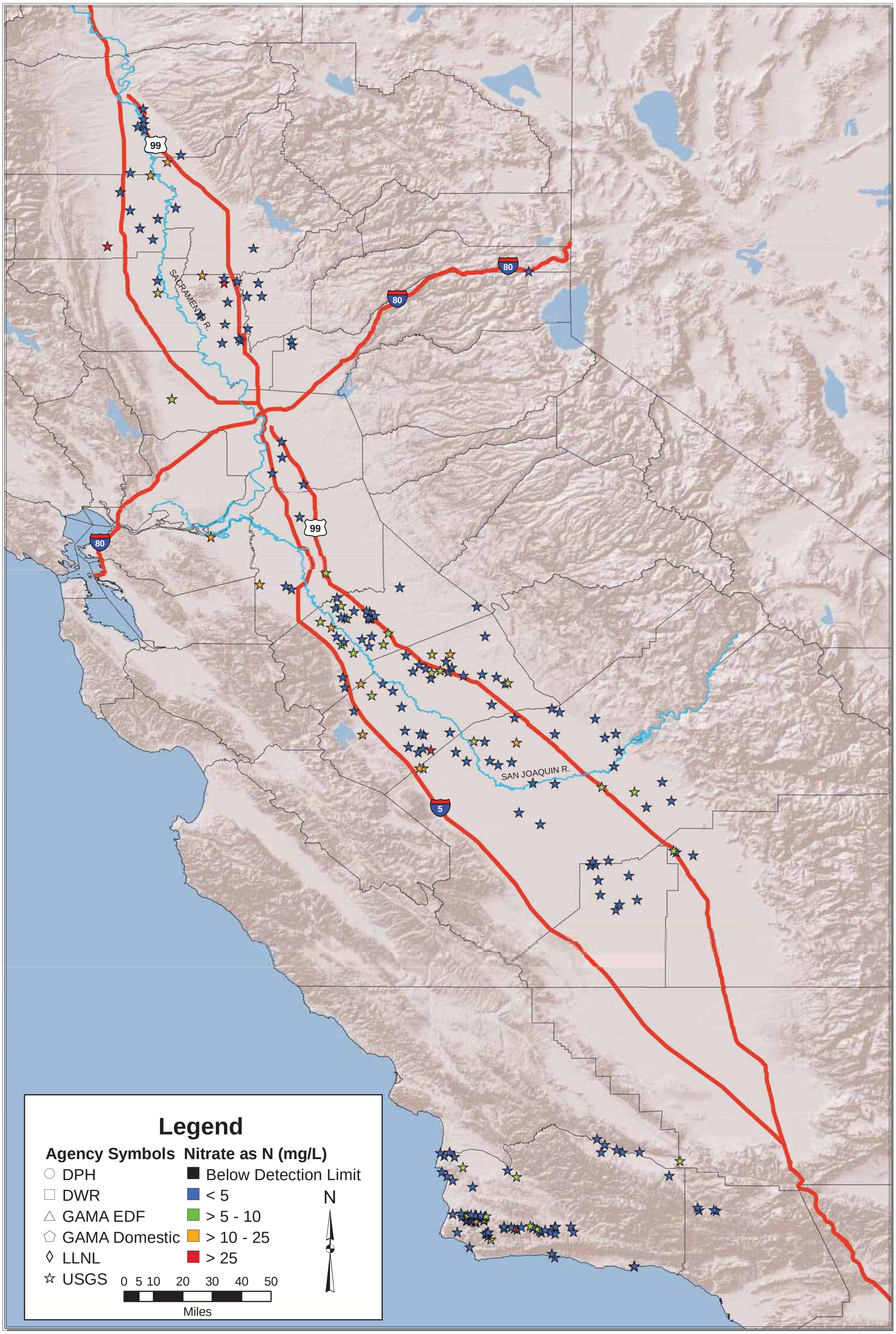
Figure 10
Average Annual Groundwater Recharge (1990s) by DWR Subregion CVHM Results



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\SSURGO_work.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

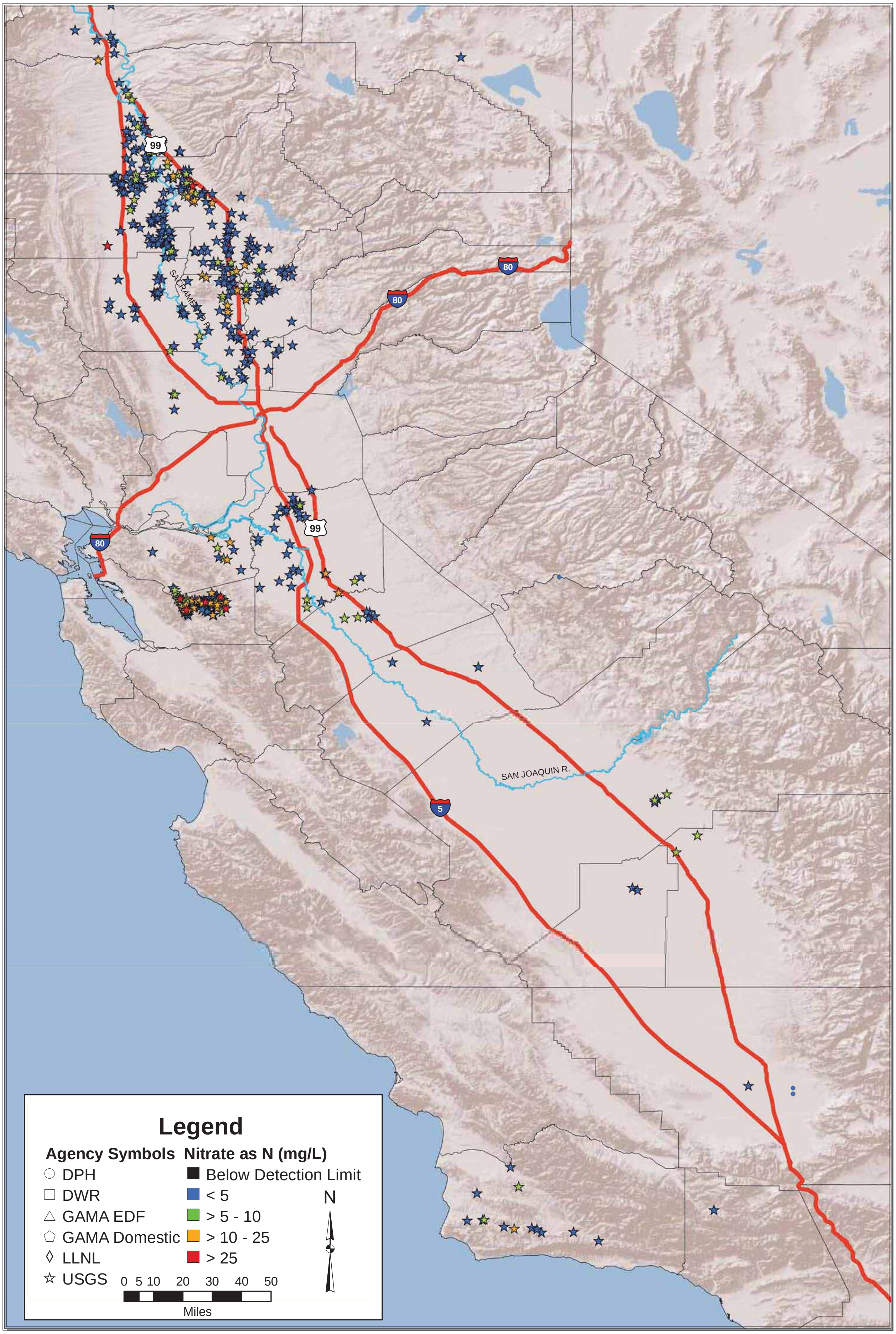
Figure 11
Soil Permeability Based on Texture Data



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

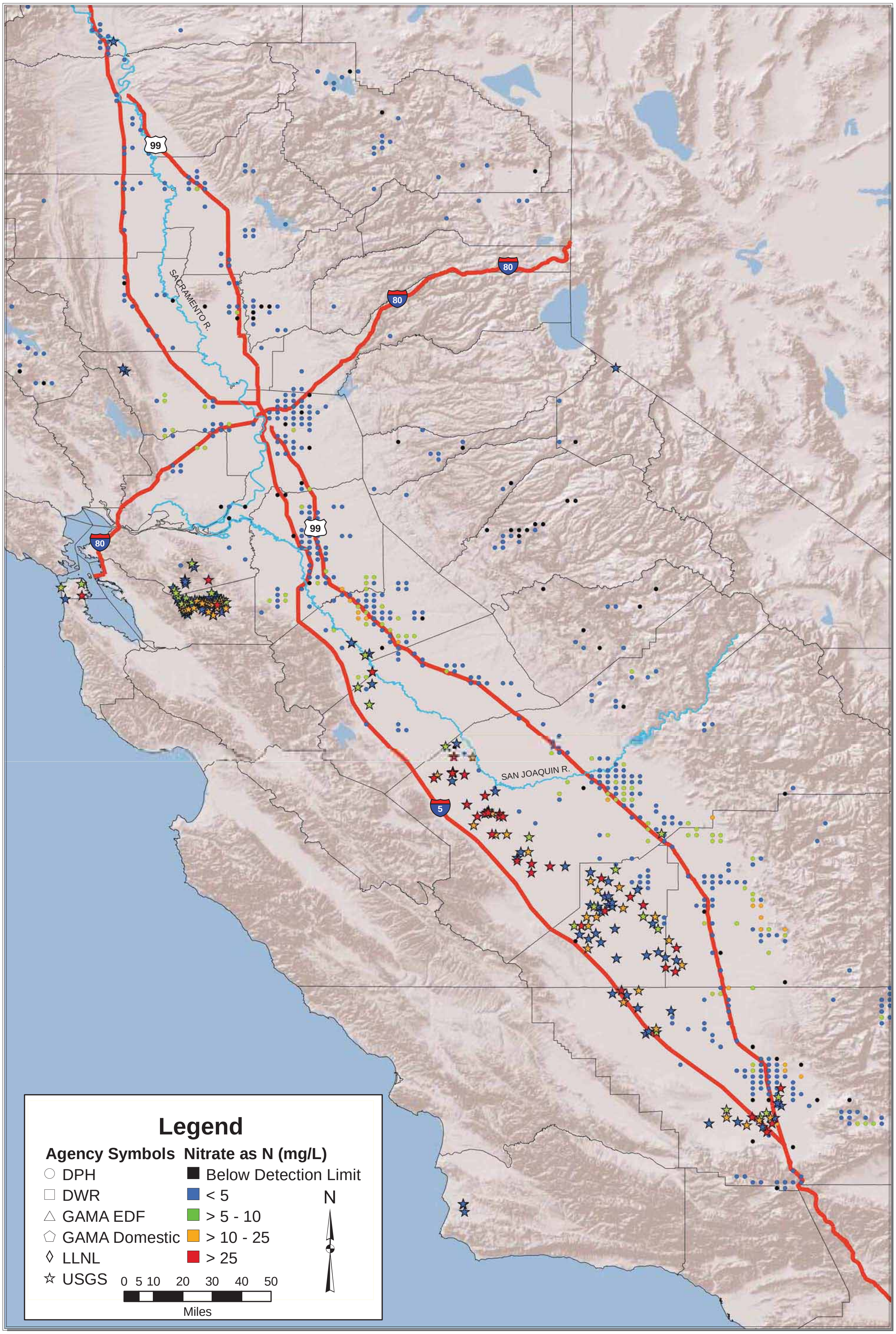
Figure 12
Nitrate Concentrations in Groundwater (1960s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

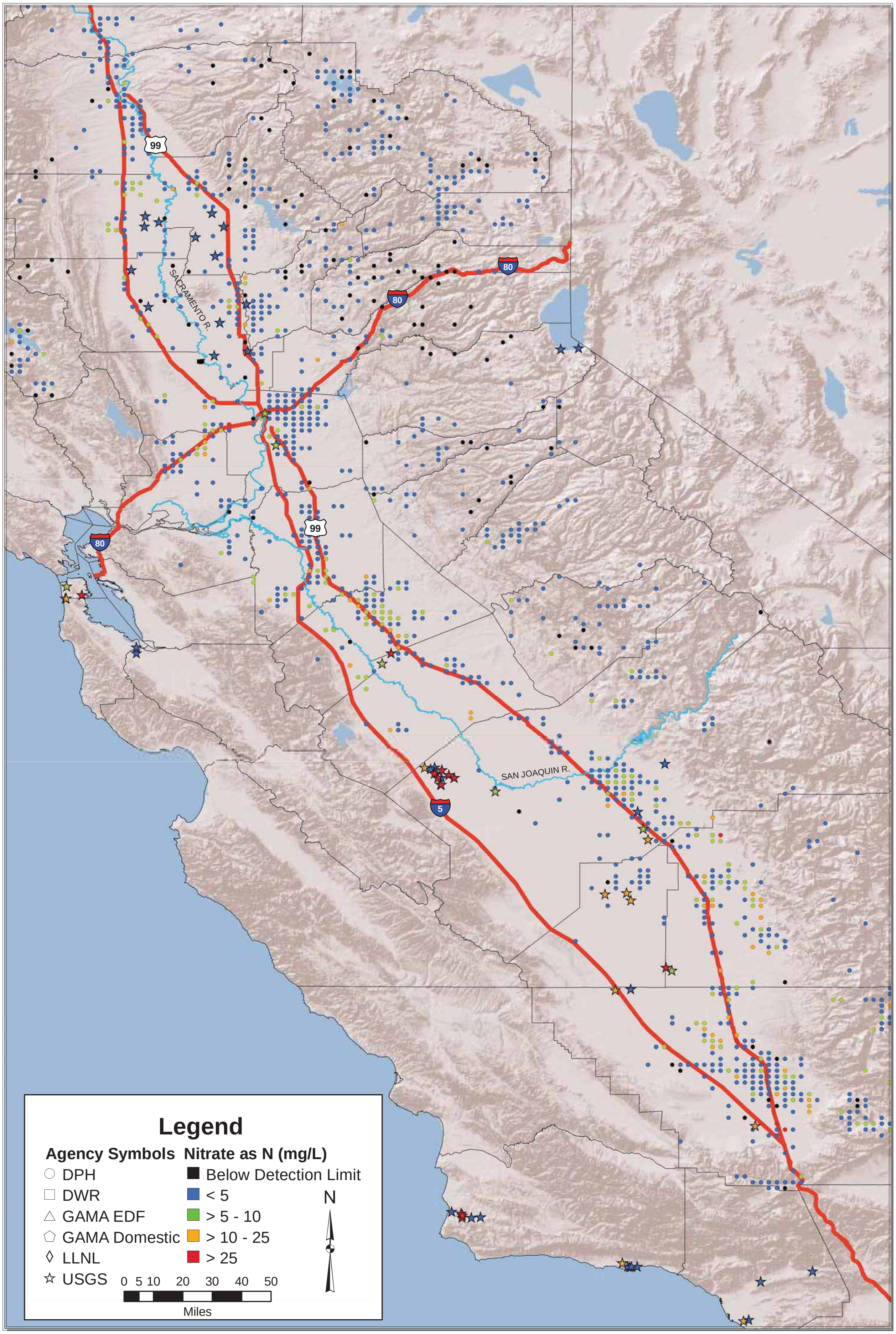
Figure 13
Nitrate Concentrations in Groundwater (1970s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

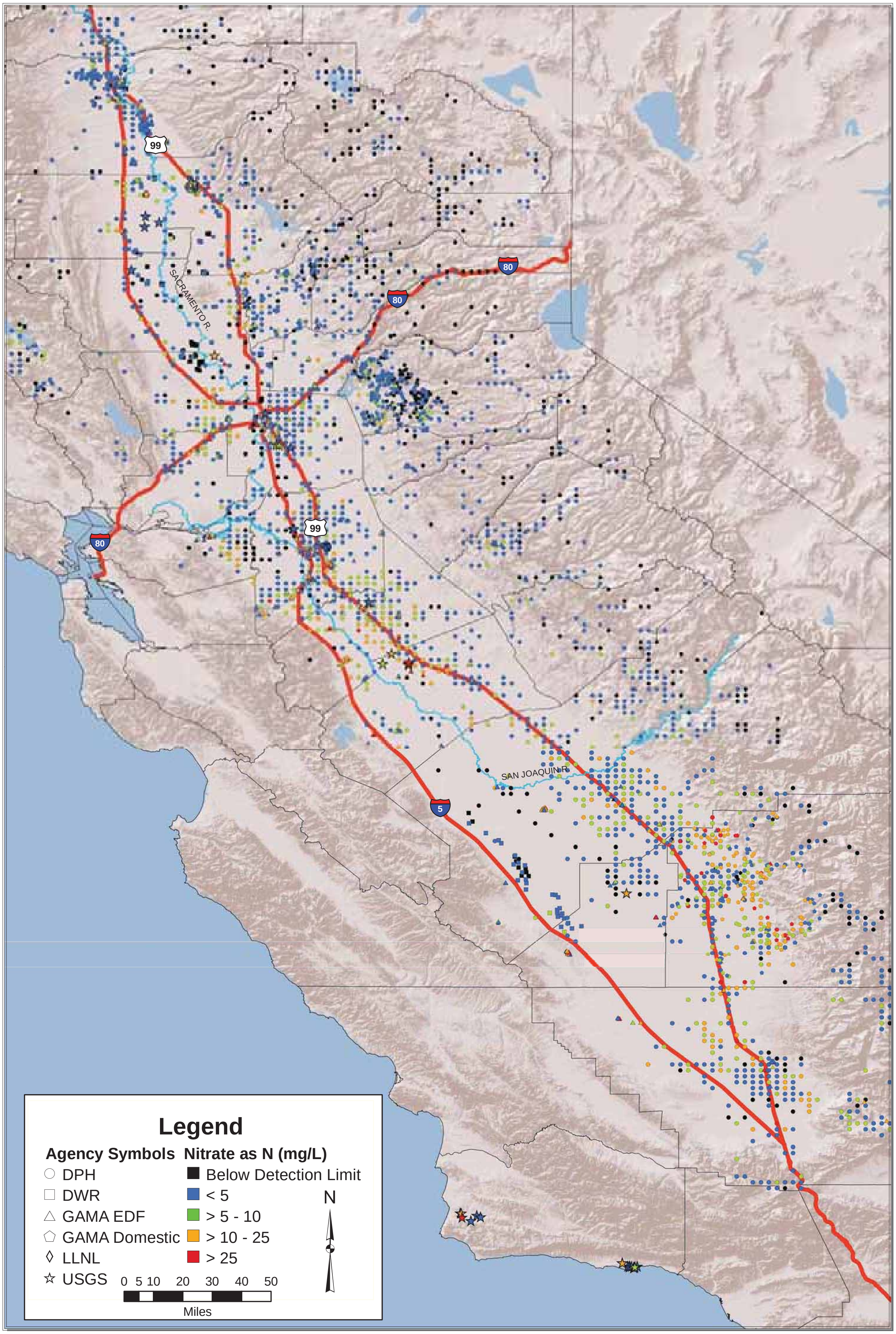
Figure 14
Nitrate Concentrations in Groundwater (1980s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

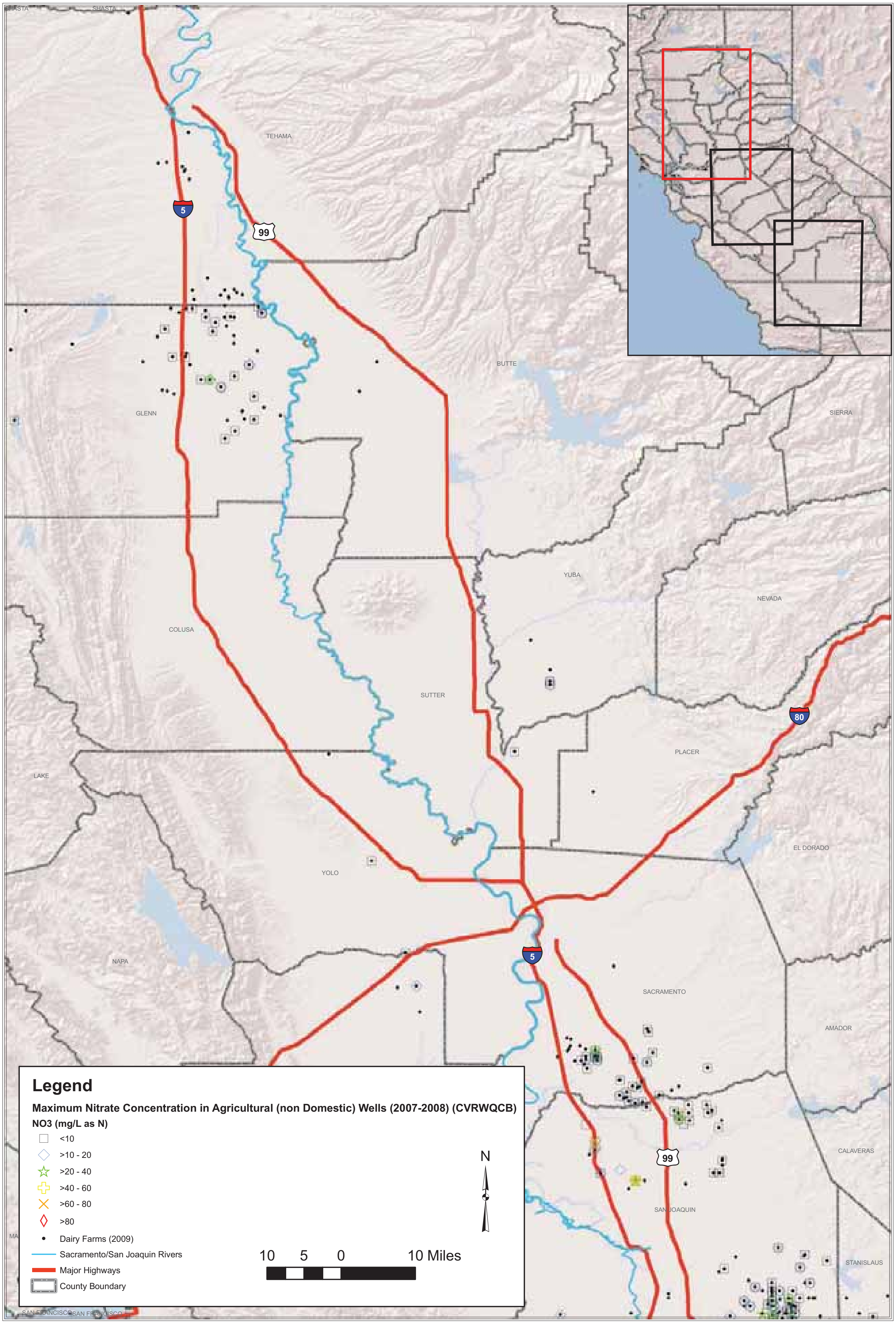
Figure 15
Nitrate Concentrations in Groundwater (1990s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

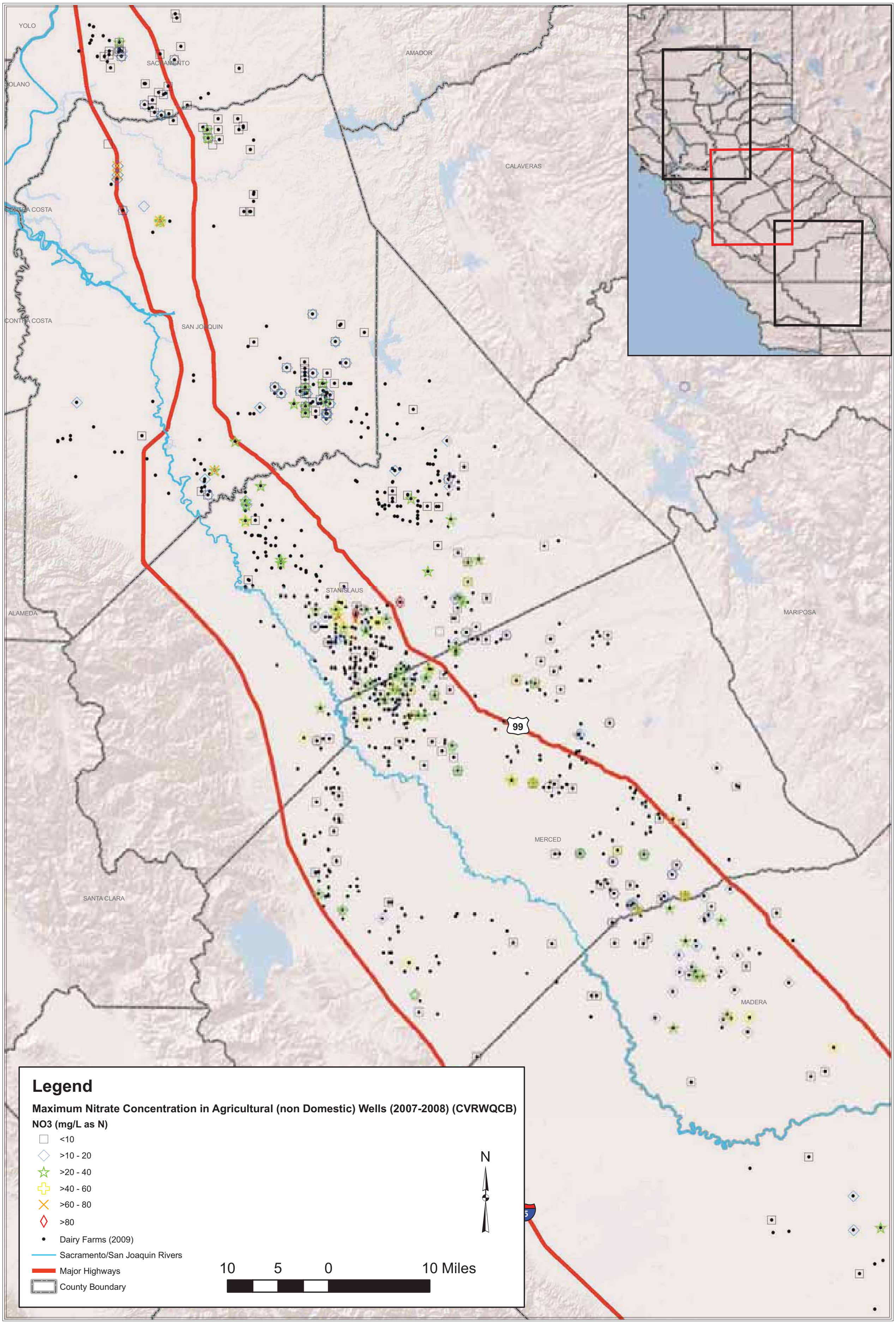
Figure 16
Nitrate Concentrations in Groundwater (2000s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

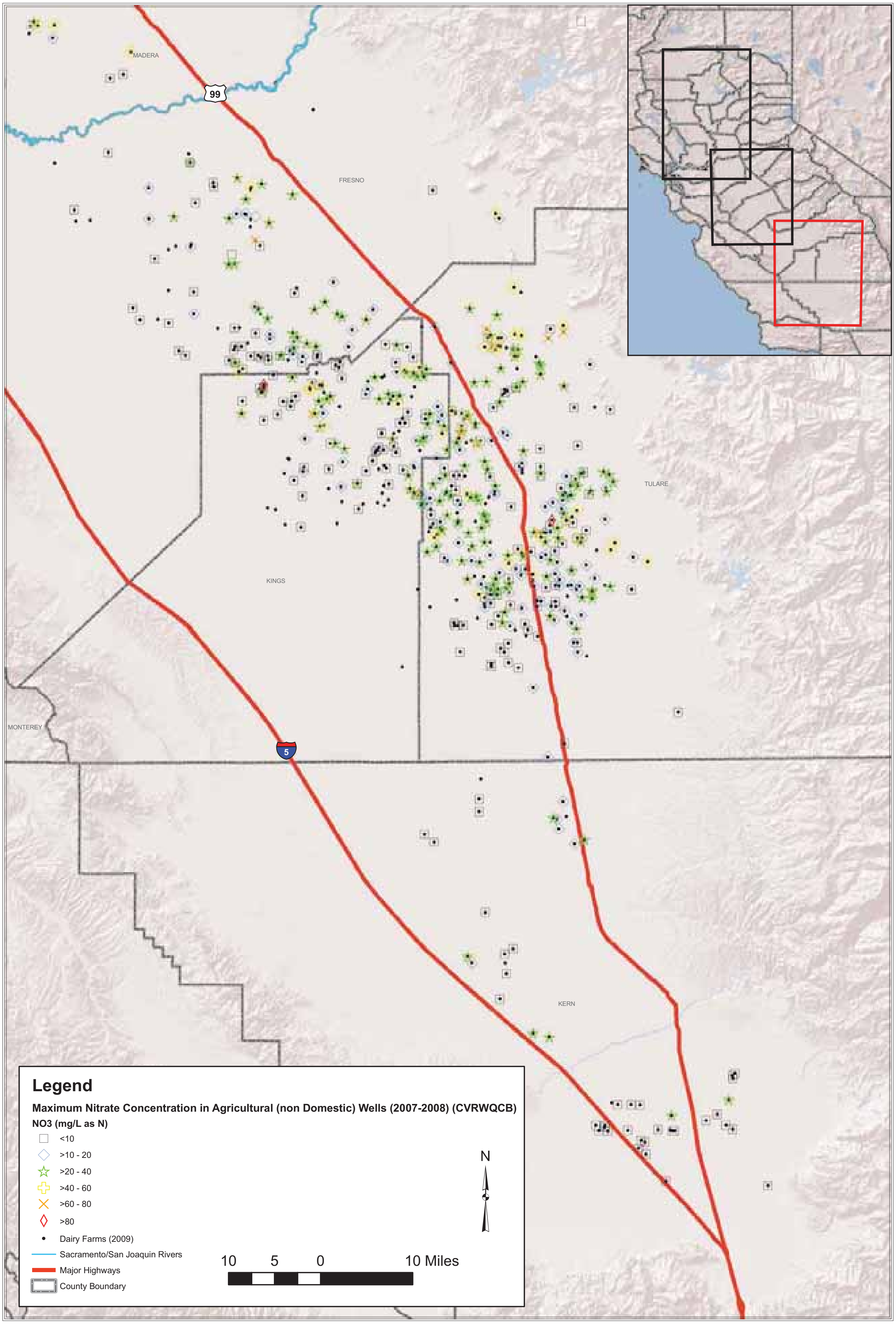
Figure 17
Maximum Nitrate Concentrations in Dairy Agricultural (Non-Domestic) Wells (2007-2008)
Sacramento Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

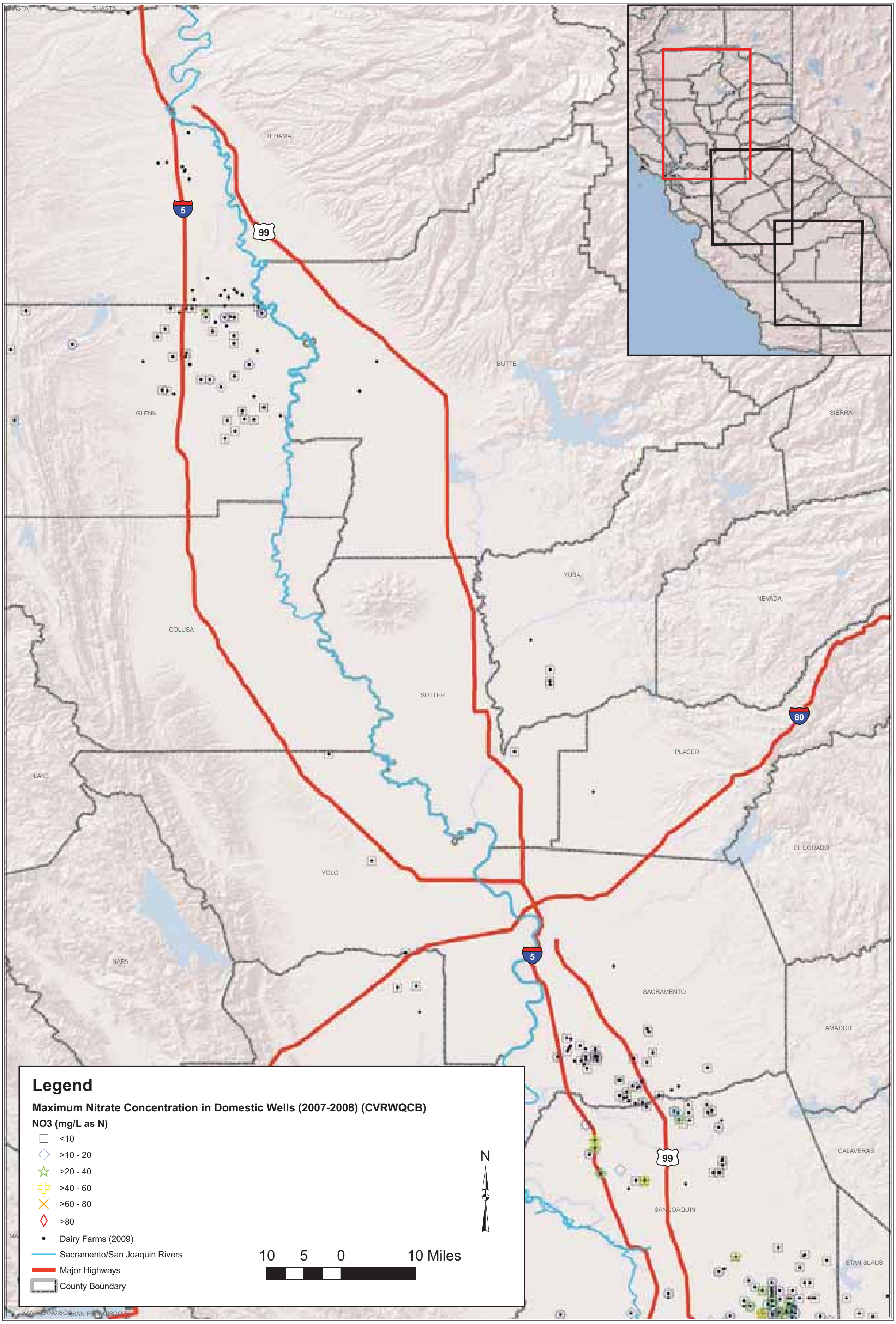
Figure 18
Maximum Nitrate Concentrations in Dairy Agricultural (Non-Domestic) Wells (2007-2008)
Northern San Joaquin Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

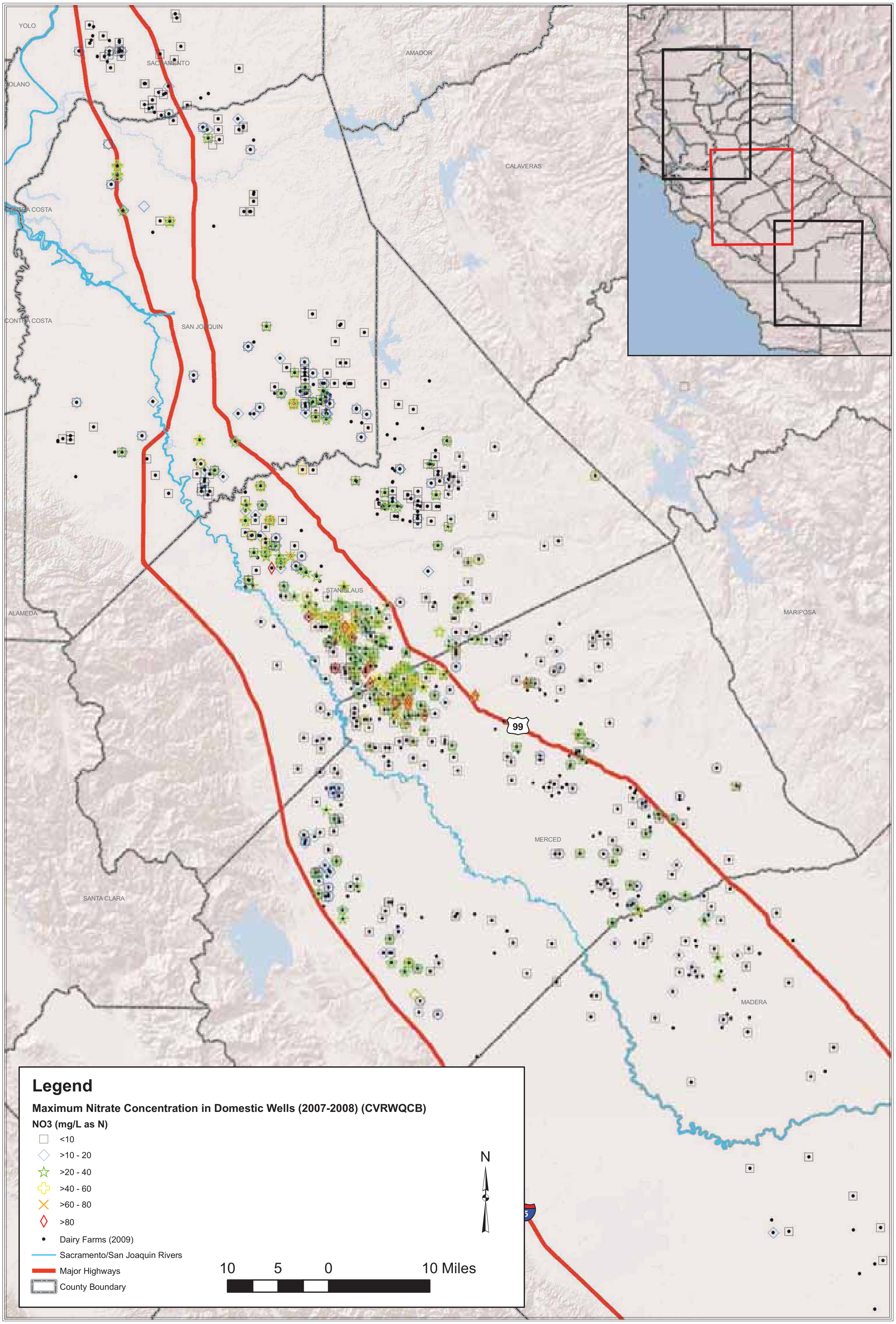
Figure 19
Maximum Nitrate Concentrations in Dairy Agricultural (Non-Domestic) Wells (2007-2008)
Southern San Joaquin Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS

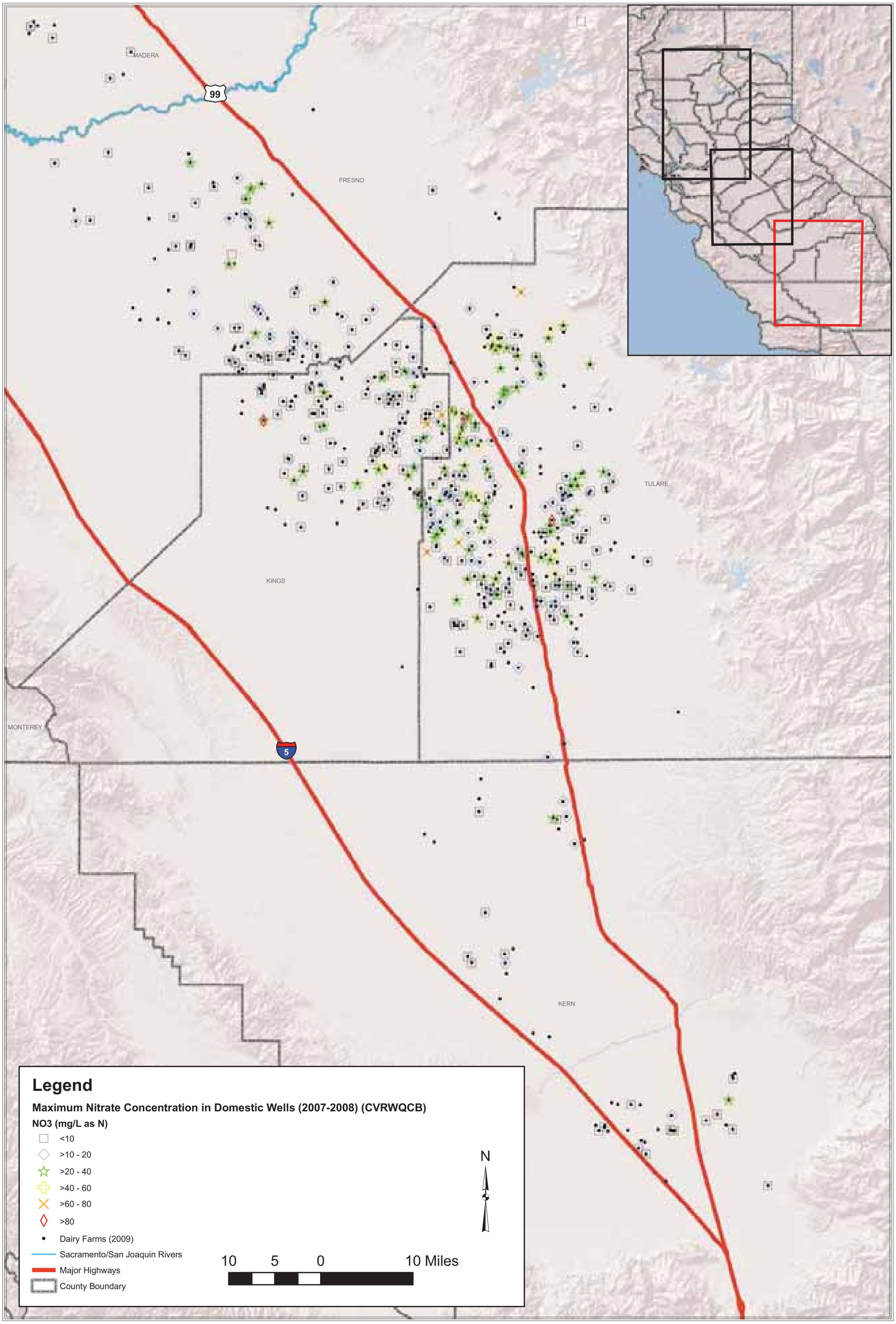
Figure 20
Maximum Nitrate Concentrations in Dairy Domestic Wells (2007-2008)
Sacramento Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

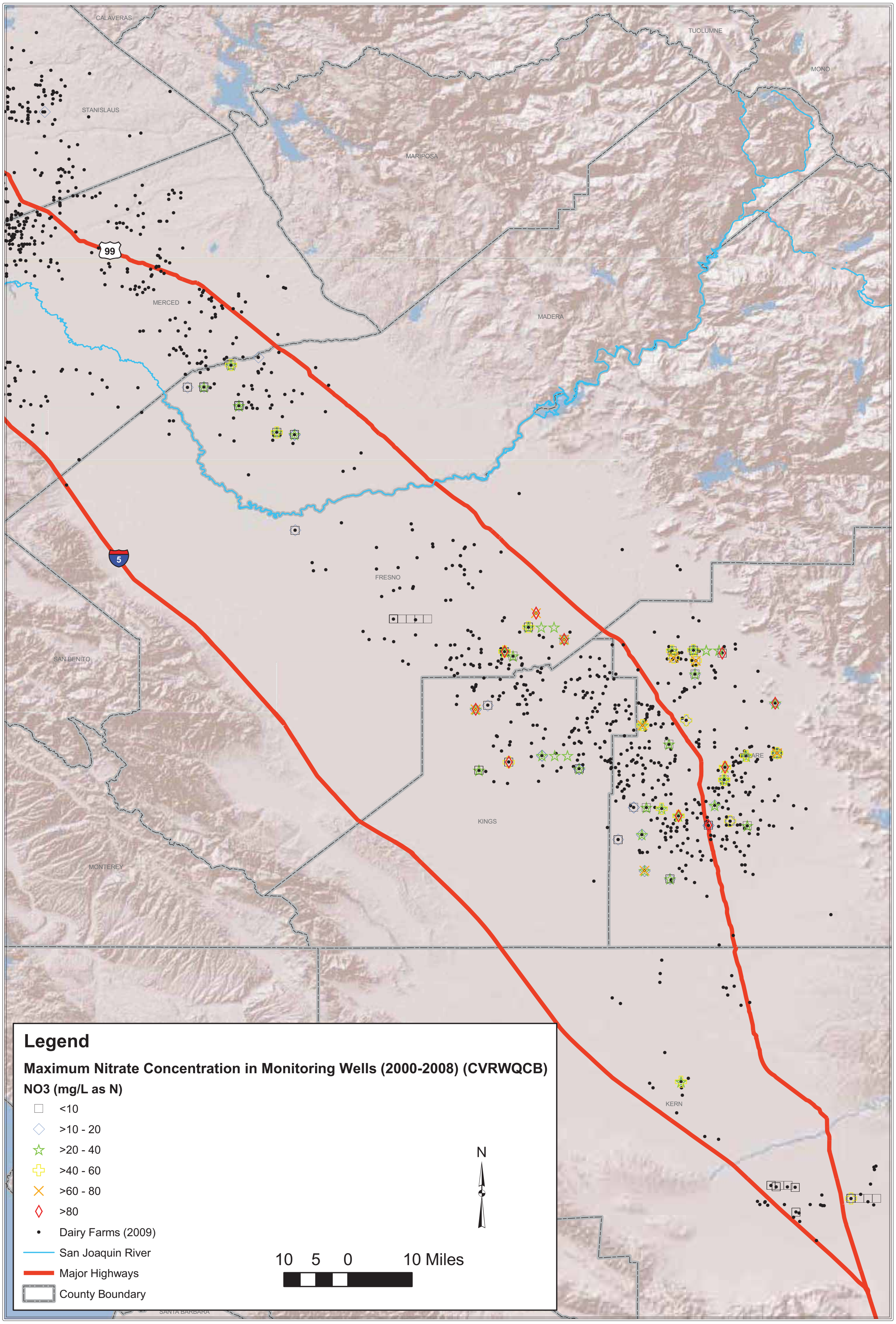
Figure 21
Maximum Nitrate Concentrations in Dairy Domestic Wells (2007-2008)
Northern San Joaquin Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_Data.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 22
Maximum Nitrate Concentrations in Dairy Domestic Wells (2007-2008) Southern San Joaquin Valley



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\DairyNitrate_MWData(RWQCB).mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 23
Maximum Nitrate Concentrations in Dairy Monitoring Wells (2000-2008)

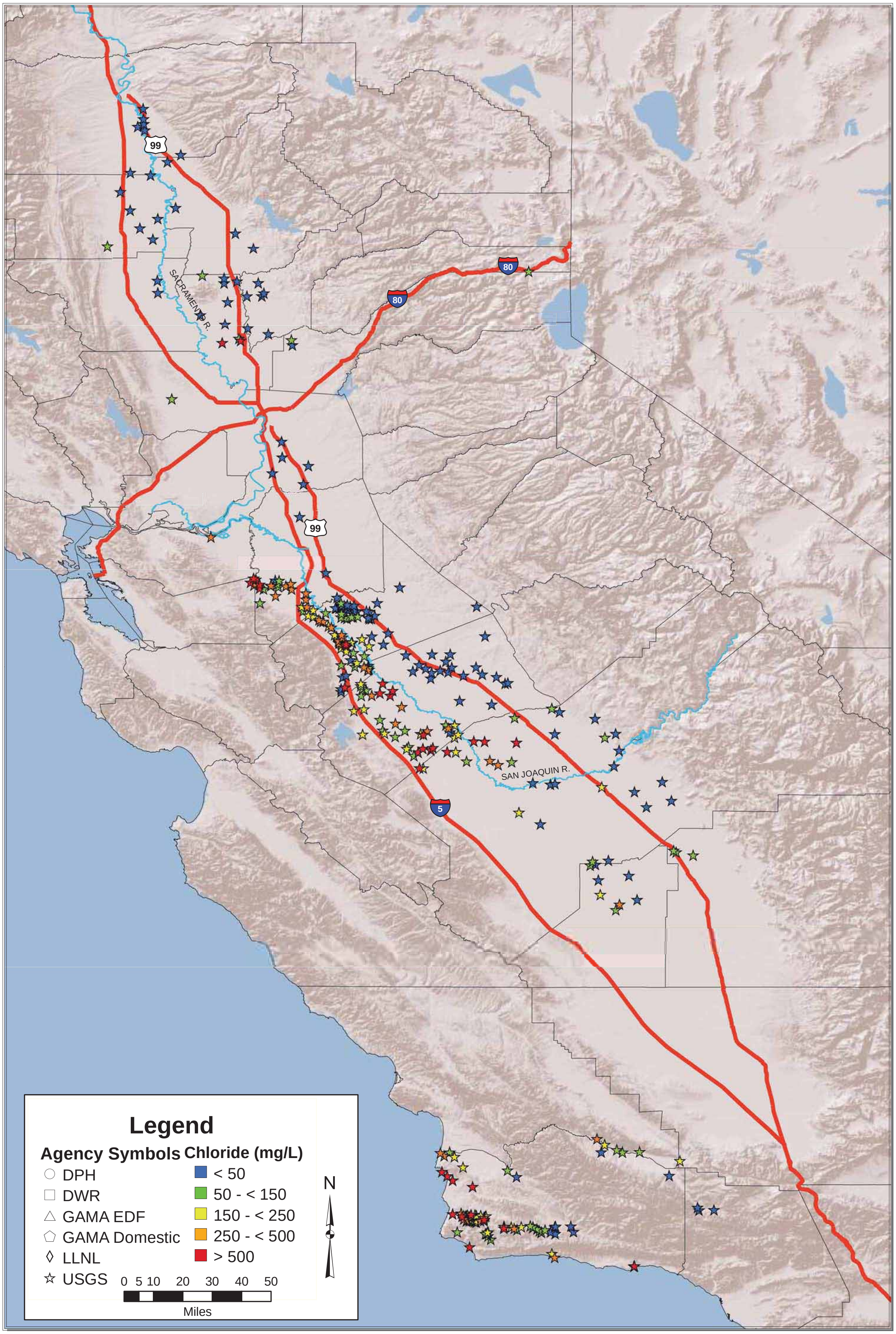
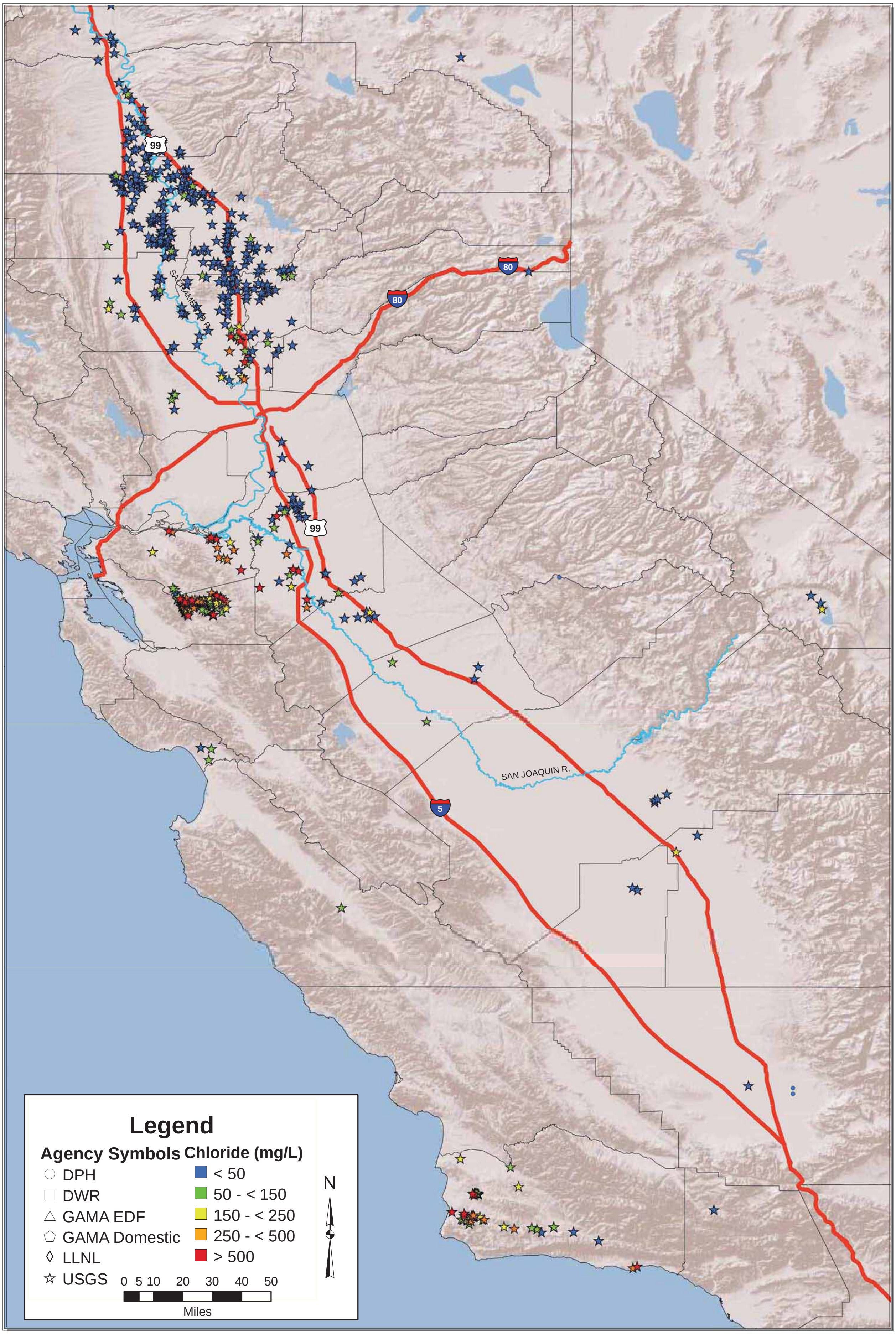


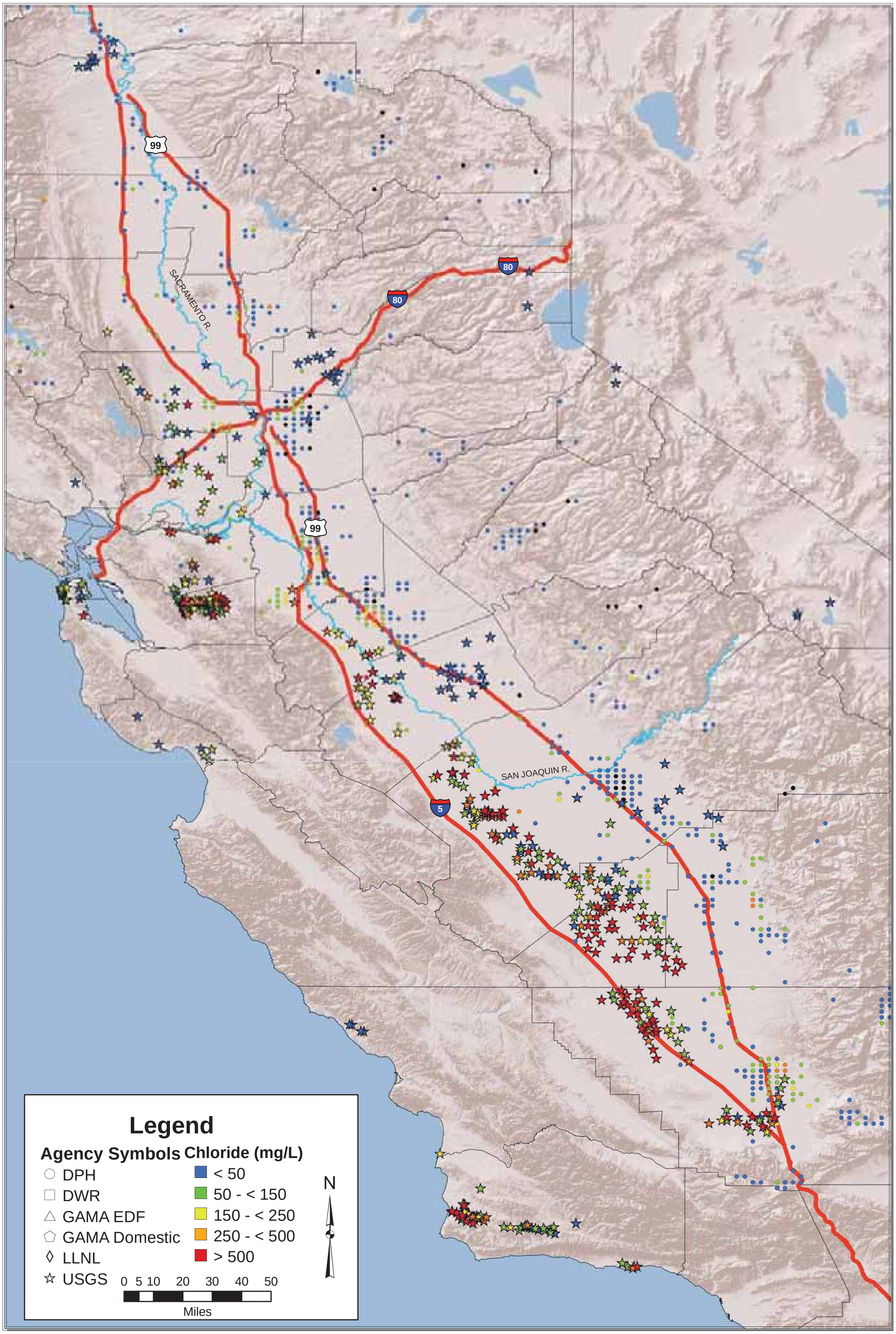
Figure 24
Chloride Concentrations in Groundwater (1960s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

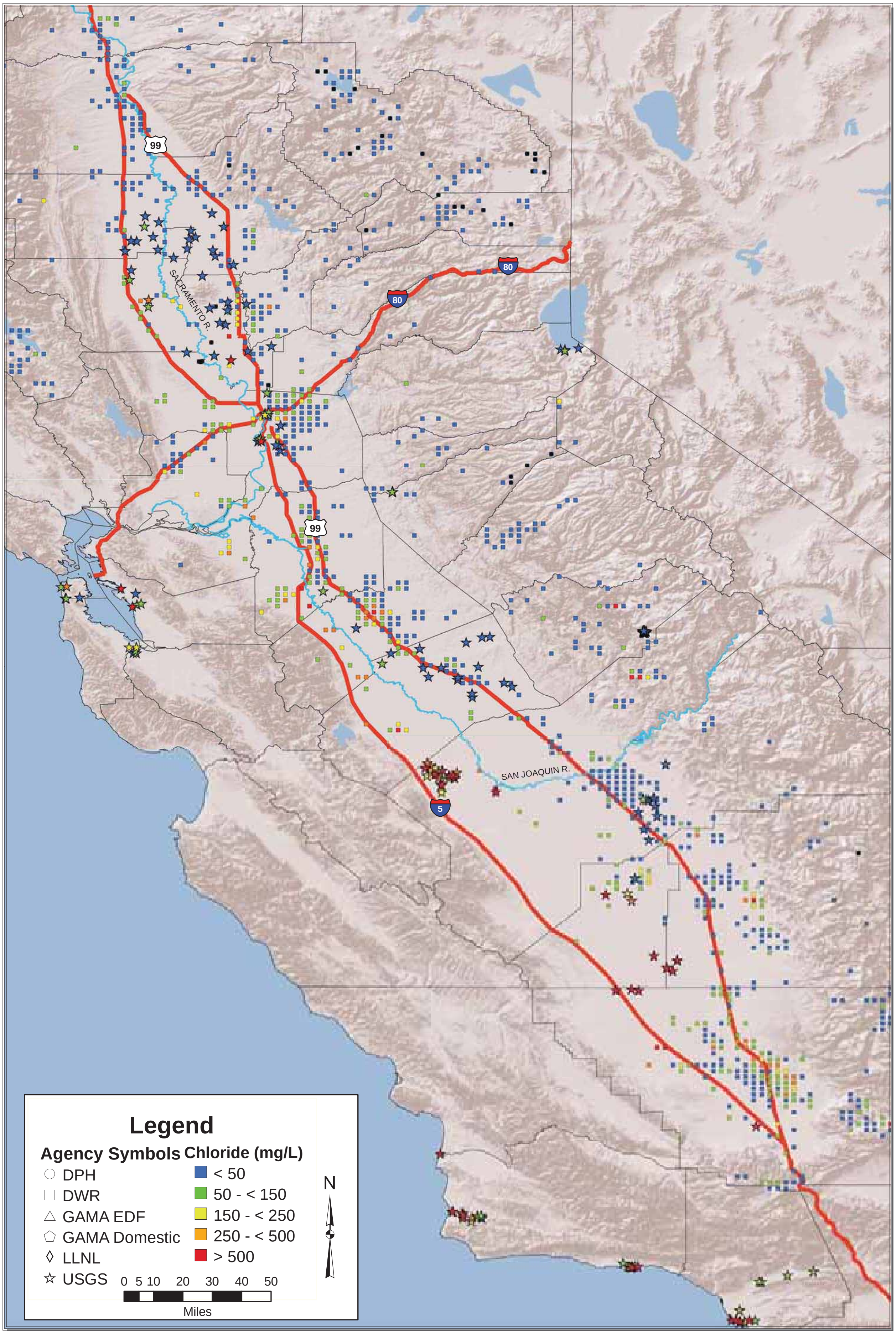
Figure 25
Chloride Concentrations in Groundwater (1970s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

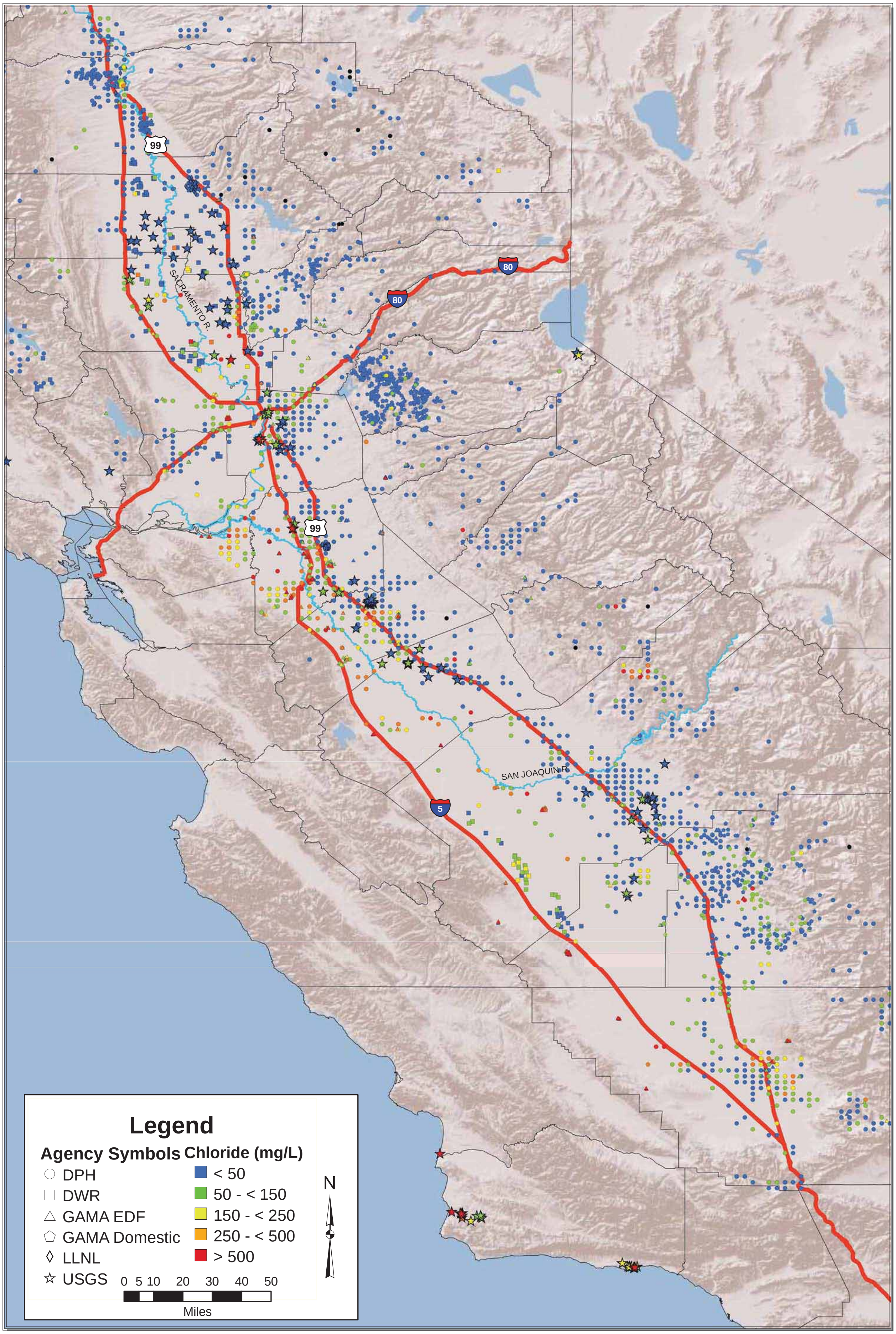
Figure 26
Chloride Concentrations in Groundwater (1980s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

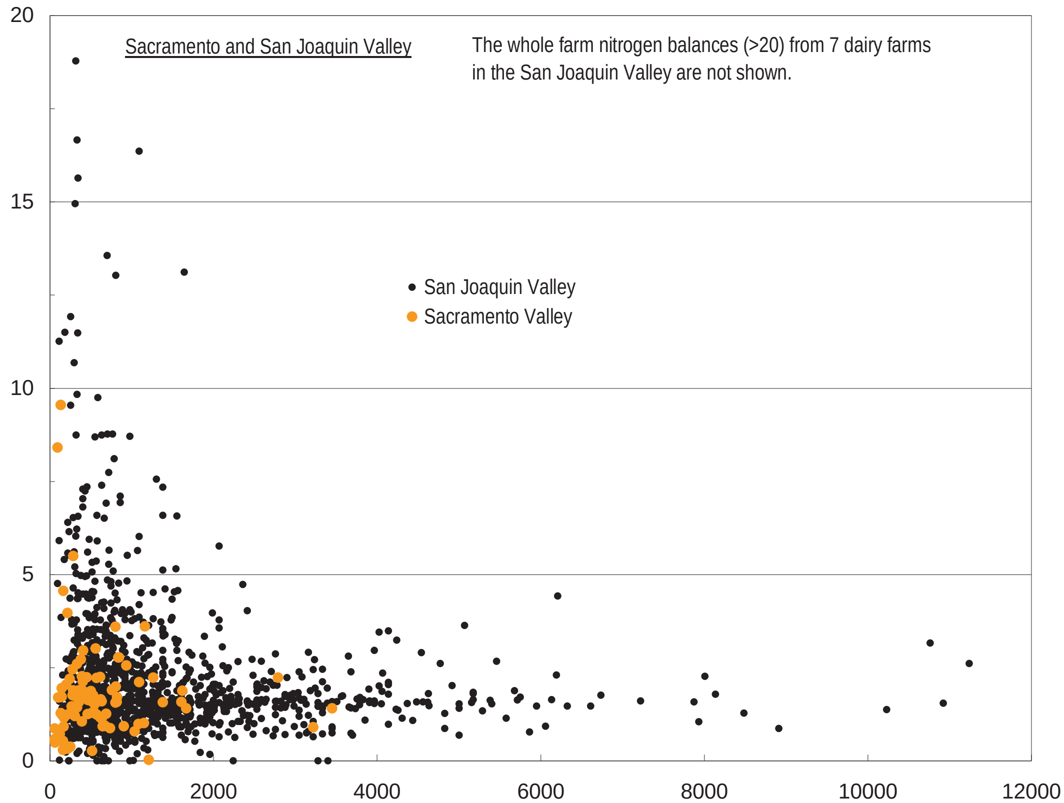
Figure 27
Chloride Concentrations in Groundwater (1990s)

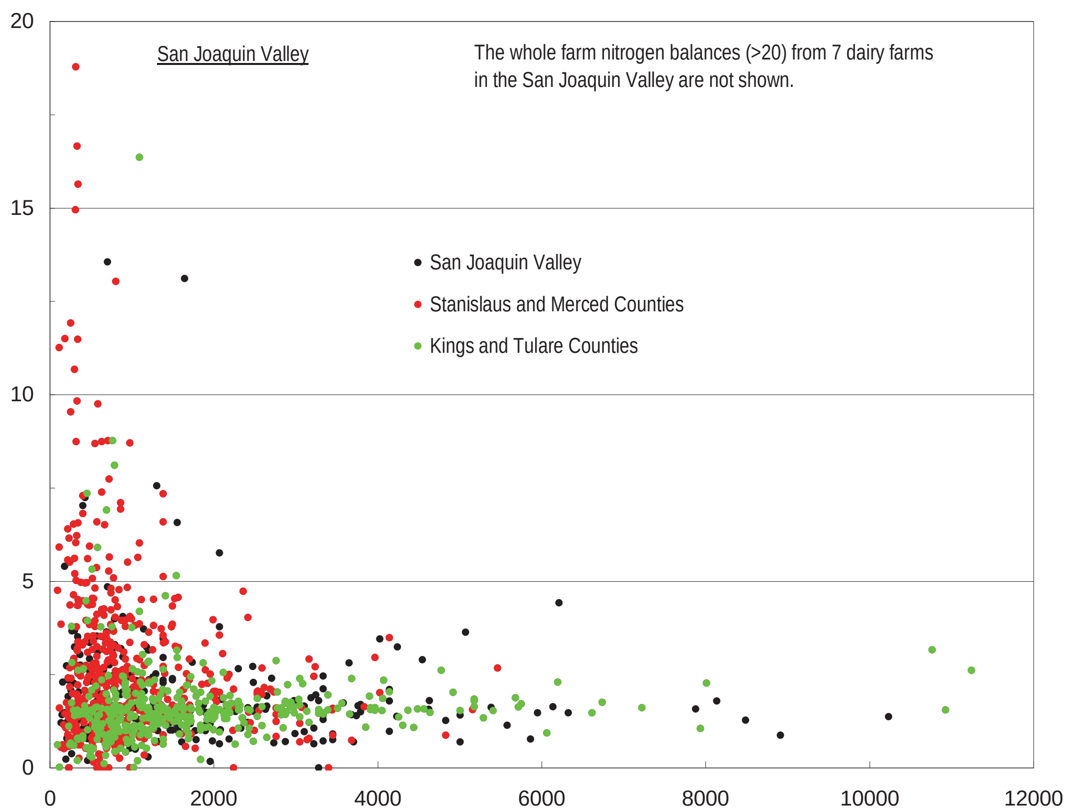


FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\USGS_WQ_DATA.mxd Date: 3/29/2010

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

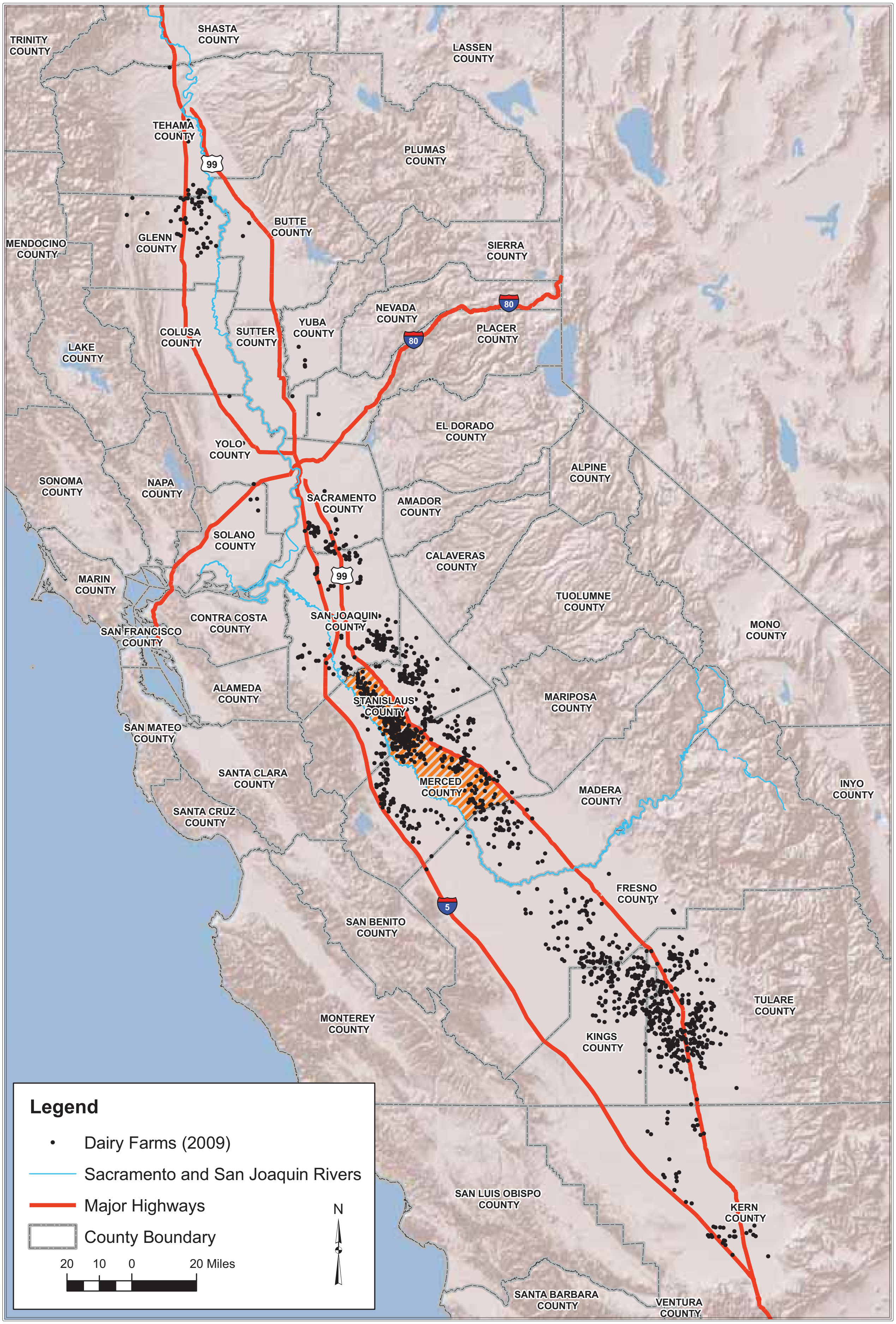
Figure 28
Chloride Concentrations in Groundwater (2000s)





Abscissa: Herd Size (Maximum Number of Mature Cows on Dairy Farm in 2005) (see Table 1)
Ordinate: Whole Farm Nitrogen Balance (see Table 1)

Figure 29
Whole Farm Nitrogen Balance and Herd Size



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\Basemap.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure 30
Identification of High Priority Area for the Initiation of the Representative Groundwater Monitoring Network
Central Valley, California

Attachments

Attachment 1

Tablulated Livestock Information by County

Attachment 1, Table A: Milk Cows (Head) by County

	County																		
Year	Butte	Colusa	Fresno	Glenn	Kern	Kings	Madera	Merced	Placer	Sacramento	San Joaquin	Shasta	Solano	Stanislaus	Sutter	Tehama	Tulare	Yolo	Yuba
1975	2,300	700	48,600	9,500	26,900	50,000	13,200	64,600	800	14,800	52,400	700	1,000	80,400	700	3,500	86,800	500	1,700
1976	2,100	900	48,000	11,100	32,200	41,800	14,500	70,300	700	16,400	53,600	1,000	2,400	87,700	800	4,900	89,600	400	1,900
1977	2,100	700	51,000	12,200	28,600	40,600	12,800	68,200	700	18,500	56,200	1,000	1,500	83,400	800	4,200	89,800	400	1,900
1978	2,200	500	50,500	13,500	25,800	43,000	13,600	73,400	800	20,000	53,200	900	1,600	86,300	700	4,800	102,200	400	2,500
1979	2,200	500	51,000	14,300	22,000	44,500	14,500	78,000	400	21,800	60,000	800	1,200	91,000	1,200	4,800	104,000	300	1,200
1980	2,200	500	53,500	13,000	21,000	50,000	16,000	79,000	450	24,000	59,000	1,000	1,200	94,000	1,000	3,000	104,500	400	1,400
1981	1,900	500	51,500	13,500	20,000	51,000	16,500	82,000	450	21,400	59,000	1,300	1,100	102,000	1,400	3,100	114,000	500	1,400
1982	1,700	500	54,700	13,700	20,000	56,000	17,000	90,000	450	21,600	61,000	1,300	1,100	107,000	1,500	3,100	115,000	400	1,700
1983	1,400	600	54,000	13,300	19,000	58,000	16,000	91,000	550	20,000	59,000	1,300	1,300	104,000	1,300	3,100	121,000	400	1,600
1984	1,500	600	51,000	12,600	18,000	59,000	18,000	98,000	550	21,200	66,000	1,200	1,600	102,000	1,100	3,400	126,000	500	1,200
1985	1,500	600	52,000	13,100	18,000	68,000	20,000	103,000	600	23,500	67,000	1,500	1,700	108,000	1,100	3,800	132,000	500	1,200
1986	1,600	700	53,000	15,000	19,000	78,000	21,000	108,000	400	25,000	69,000	1,600	1,700	113,000	1,200	3,900	147,000	1,200	1,700
1987	1,400	700	53,000	14,000	19,000	76,000	22,000	109,000	700	25,000	66,000	1,650	1,500	110,000	1,200	3,500	154,000	1,200	1,500
1988	1,400	700	53,000	13,100	18,000	76,000	23,000	109,000	700	26,000	64,000	1,650	1,400	111,000	1,400	3,500	165,000	1,000	1,500
1989	1,400	700	55,000	13,000	17,000	77,000	21,000	110,000	1,000	27,000	65,000	1,750	1,500	111,000	1,500	3,500	178,000	900	1,500
1990	1,300	600	59,000	12,900	20,000	77,000	20,000	113,000	750	26,000	66,000	1,600	1,700	114,000	1,300	4,000	185,000	800	1,400
1991	1,400	700	63,000	13,200	23,000	79,000	21,000	116,000	600	25,200	69,000	1,500	2,000	119,000	1,300	4,800	199,000	800	1,600
1992	1,200	600	66,000	13,000	26,000	79,000	20,000	119,000	500	24,000	70,000	1,400	2,100	121,000	1,100	5,300	206,000	800	1,600
2001	1,000		85,000	15,500	72,000	127,000	45,000	212,000		17,000	101,000		1,500	157,000		5,500	376,000	1,800	3,500
2002	800		88,000	15,700	78,000	132,000	48,000	221,000		17,000	105,000		1,500	164,000		5,500	394,000	2,000	3,500
2003	1,300		91,000	17,400	77,000	141,000	49,000	226,000		18,500	105,000	500	4,000	165,000		5,500	420,000	2,000	3,300
2004	1,000		92,000	17,900	88,000	146,000	53,000	225,000		18,000	106,000	500	4,000	173,000		5,300	433,000	2,000	3,300
2005	700		96,000	18,400	121,000	163,000	64,000	238,000		17,800	104,000		4,100	178,000		4,500	443,000	2,000	3,300
2006	500		113,400	17,800	139,200	156,300	67,600	241,500		17,400	106,100		4,100	185,100		5,500	454,400	2,100	3,300
2007			109,500	16,600	154,500	166,000	68,000	245,000		15,800	104,000		4,000	182,000		4,700	468,500	2,300	3,000
2008			118,600	17,700	169,500	175,500	75,300	258,200		16,200	109,500		4,100	183,400		3,800	472,700	2,300	3,100
2009			117,900	18,900	173,100	180,100	78,200	260,300		16,300	109,000		4,300	179,600		3,900	483,500	2,200	3,000

Attachment 1, Table B: Beef Cows (Head) by County

	County																		
Year	Butte	Colusa	Fresno	Glenn	Kern	Kings	Madera	Merced	Placer	Sacramento	San Joaquin	Shasta	Solano	Stanislaus	Sutter	Tehama	Tulare	Yolo	Yuba
1975	19,100	8,400	30,600	18,000	46,200	2,500	41,200	53,400	11,700	28,800	45,400	18,100	12,400	56,600	6,800	39,900	47,200	11,800	22,100
1976	16,200	9,300	33,700	18,400	50,000	2,900	33,500	58,500	12,100	26,800	49,800	19,900	13,500	42,400	6,800	35,500	31,700	11,600	18,800
1977	17,600	8,900	33,700	17,800	50,400	3,100	33,700	58,000	11,700	27,500	49,300	18,900	12,900	41,600	6,300	35,700	31,800	8,900	22,000
1978	16,300	12,200	28,300	18,400	54,900	2,800	32,000	53,400	11,200	34,600	42,500	17,500	17,600	38,500	5,900	34,500	25,400	7,200	17,300
1979	13,300	5,800	33,500	13,500	44,000	4,800	26,000	47,500	12,300	30,200	34,000	26,700	13,000	37,000	5,400	34,000	36,200	9,000	15,800
1980	10,700	8,000	40,500	15,000	40,000	5,500	25,000	52,500	11,700	29,000	32,500	23,400	11,400	32,000	5,400	35,000	27,000	7,000	10,000
1981	15,000	10,000	50,000	16,000	50,000	5,200	27,500	58,500	12,000	33,500	37,500	29,000	11,500	36,500	5,400	36,000	31,000	7,800	13,600
1982	16,000	13,000	53,000	19,000	61,000	6,000	31,000	68,000	12,000	37,000	46,000	34,000	15,000	42,000	6,000	42,000	34,000	10,000	16,000
1983	12,000	10,500	46,000	14,000	47,000	4,000	24,000	58,000	11,000	29,000	40,000	26,000	12,000	36,000	4,500	36,000	36,000	8,000	12,000
1984	13,000	13,000	44,000	11,000	55,000	4,000	17,000	60,000	13,000	27,000	32,000	22,000	10,000	32,000	4,500	38,000	35,000	6,000	9,500
1985	13,000	11,000	39,000	11,000	52,000	5,000	18,000	56,000	14,000	26,000	33,000	20,000	9,000	33,000	4,500	36,000	36,000	6,000	7,500
1986	12,000	12,000	42,000	11,500	52,000	4,000	17,000	48,000	13,000	28,000	33,000	17,000	12,000	34,000	4,500	34,000	31,000	7,000	7,000
1987	11,500	13,000	41,000	12,000	53,000	4,000	16,000	46,000	13,000	28,000	35,000	16,000	13,000	34,000	4,000	33,000	31,000	7,000	6,500
1988	9,900	13,300	37,800	12,300	51,000	3,000	14,500	41,700	12,800	27,700	34,200	16,000	12,300	33,700	3,800	30,300	30,100	6,200	6,200
1989	10,000	14,500	33,000	12,800	51,000	4,000	14,000	41,000	12,500	29,700	32,000	17,000	12,000	34,500	4,400	32,000	30,500	6,600	6,000
1990	11,000	14,300	32,000	14,300	53,000	4,800	17,200	42,000	12,700	29,000	33,000	20,000	12,500	37,500	4,700	34,100	33,500	7,000	7,100
1991	10,800	13,400	28,000	14,200	50,000	4,000	18,000	40,000	11,900	27,200	29,000	19,000	11,500	37,000	4,400	33,400	33,000	6,500	7,600
1992	11,500	12,700	25,000	14,700	46,000	4,000	20,500	38,200	11,700	25,200	27,000	20,100	11,000	36,800	4,400	33,200	35,500	6,000	8,300
2001	8,500	6,500	20,000	19,000	43,000	3,000	16,000	31,000	10,000	15,000	20,000	24,000	7,500	46,000	3,000	33,000	33,000	6,500	7,000
2002	7,000	8,000	20,000	18,000	41,000	4,000	16,000	32,000	10,000	14,000	21,000	22,000	8,000	46,000	3,000	32,000	31,000	8,000	6,000
2003	9,000		24,000	18,000	37,000	5,000	16,000	30,000		16,000	20,000	16,000	15,000	42,000		29,000	31,000	7,000	8,000
2004	9,000		23,000	17,000	36,000	5,000	15,000	29,000		16,000	19,000	16,000	14,000	41,000		28,000	31,000	7,000	7,000
2005	9,000	11,000	22,000	18,000	34,000	5,000	14,000	27,000	9,000	17,000	18,000	16,000	17,000	39,000	5,000	28,000	29,000	8,000	7,000
2006	8,000	10,000	19,000	16,000	30,000	5,000	12,000	22,000	8,000	15,000	15,000	18,000	16,000	33,000	6,000	26,000	24,000	7,000	8,000
2007	8,000	11,000	19,000	17,000	31,000	6,000	14,000	23,000	7,000	15,000	14,000	19,000	18,000	34,000	7,000	25,000	25,000	8,000	8,000
2008			20,000	15,000	32,000	7,000	19,000	30,000		14,000	20,000	18,000		37,000		24,000	28,000		5,000
2009	4,000	5,000		13,000	33,000	7,000	20,000		4,000	12,000	21,000	19,000	10,000	37,000	5,000	20,000	28,000	4,000	5,000

Attachment 1, Table C: Breeding Sheep and Lambs (Head) by County

	County																		
Year	Butte	Colusa	Fresno	Glenn	Kern	Kings	Madera	Merced	Placer	Sacramento	San Joaquin	Shasta	Solano	Stanislaus	Sutter	Tehama	Tulare	Yolo	Yuba
1975	7,200	37,800	93,400	53,800	153,100	29,100	24,000	38,000	3,000	16,500	32,800	2,000	51,600	3,000	40,000	57,200	4,000	25,000	20,000
1976	7,500	30,000	92,900	43,800	152,500	28,000	21,000	32,500	4,000	16,500	36,600	2,000	53,500	3,300	40,000	59,800	3,600	20,600	10,000
1977	7,600	22,000	93,900	32,000	153,600	27,700	25,000	33,000	4,400	16,000	35,000	2,000	45,100	3,000	36,000	68,000	3,000	17,000	5,000
1978	8,000	25,000	100,000	26,600	148,000	30,500	25,000	32,000	6,000	14,000	33,000	1,900	50,000	3,000	40,000	73,400	2,000	25,000	6,000
1979	9,000	20,000	98,000	30,000	150,000	28,000	28,000	35,000	6,800	13,500	37,000	2,500	48,000	4,000	43,000	78,000	2,000	23,000	7,500
1980	9,000	16,500	111,000	37,000	167,000	31,000	29,000	40,000	7,000	13,000	42,000	2,400	49,000	3,400	40,000	74,000	1,900	23,000	4,000
1981	9,800	12,000	125,000	32,500	177,000	30,500	31,000	36,000	7,600	12,600	52,000	2,800	54,000	3,800	37,000	78,000	2,200	20,500	4,500
1982	9,800	11,000	123,000	29,700	187,000	30,000	29,000	33,700	7,700	10,000	50,000	2,300	55,000	5,000	37,000	73,000	2,500	20,000	4,500
1983	8,800	10,800	95,000	30,000	178,000	25,000	25,000	34,700	7,000	10,500	32,000	2,500	53,400	5,000	32,000	68,000	2,300	20,500	4,000
1984	8,800	12,000	60,000	25,000	170,000	16,700	28,000	35,500	8,200	11,000	30,000	1,900	67,000	4,500	37,000	67,000	2,300	24,000	3,200
1985	7,900	10,100	67,000	24,000	168,000	16,000	29,900	32,000	11,200	9,400	27,900	2,600	66,000	5,000	33,300	64,900	2,200	20,900	2,500
1986	6,700	14,400	65,000	18,600	172,000	21,000	30,000	34,000	11,000	10,600	24,200	2,200	75,500	3,500	38,000	58,000	2,300	19,200	3,000
1987	7,600	14,600	80,000	21,000	138,000	18,000	20,000	25,000	11,000	9,800	21,000	2,000	70,000	3,800	40,000	56,000	2,200	16,000	2,000
1988	8,000	14,000	95,000	19,000	155,000	10,000	17,000	44,000	12,000	8,100	25,000	1,700	70,000	3,800	32,000	51,000	3,100	18,000	1,300
1989	7,800	12,000	94,000	19,000	130,000	19,000	15,000	44,000	15,000	11,000	29,000	2,200	77,000	3,400	25,000	38,000	1,800	22,000	3,600
1990	5,500	11,900	94,000	18,800	129,400	18,800	14,900	43,800	14,900	10,900	28,700	2,200	76,800	3,400	24,800	37,800	1,800	21,800	3,500
1991	5,500	8,500	85,000	20,000	128,000	19,000	14,000	29,500	13,000	8,500	26,000	1,800	76,000	3,500	25,000	30,000	16,000	20,000	4,500
1992	5,000	8,000	83,000	19,000	126,000	17,000	13,500	34,000	13,000	8,000	24,000	1,800	73,000	3,000	23,500	28,500	14,500	19,000	4,000

Attachment 1, Table D: Hogs (Head) by County

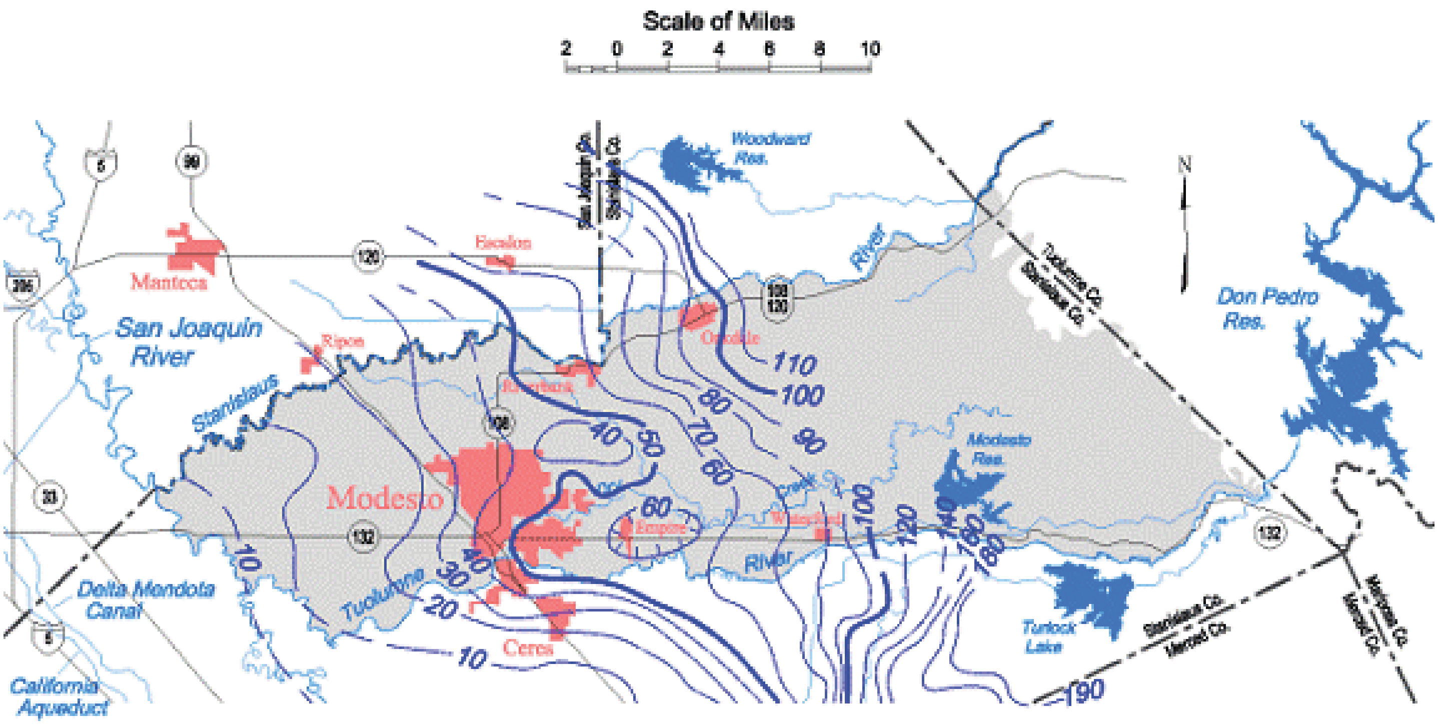
	County																		
Year	Butte	Colusa	Fresno	Glenn	Kern	Kings	Madera	Merced	Placer	Sacramento	San Joaquin	Shasta	Solano	Stanislaus	Sutter	Tehama	Tulare	Yolo	Yuba
1974	3,300	500	8,300	700	5,000	7,800	900	12,600	100	1,000	7,900	1,200	200	7,400	1,500	700	12,700	1,300	1,100
1975	3,200	600	10,100	800	5,400	9,000	1,100	12,900	100	1,000	8,200	1,200	200	8,900	1,600	900	14,300	1,200	1,000
1976	3,500	500	8,300	900	5,000	9,100	900	13,100	100	900	7,600	1,200	200	8,000	1,500	800	13,400	1,400	1,100
1977	6,600	600	8,000	1,200	5,500	11,500	2,000	13,300	400	1,400	7,300	1,100	300	10,900	2,700	1,000	19,500	1,800	1,300
1978	7,200	600	10,000	5,000	5,700	14,000	2,500	16,000	500	1,700	9,200	1,200	300	13,000	3,000	1,200	29,000	2,600	1,700
1979	7,700	600	8,500	5,100	6,000	14,400	2,600	18,000	500	1,700	9,400	1,100	200	11,500	2,600	1,100	27,000	2,300	1,500
1980	8,200	700	8,900	4,000	5,600	4,100	2,400	19,000	400	1,500	9,400	1,000	200	12,000	2,300	500	38,500	2,500	1,200
1981	7,800	600	6,800	4,100	5,000	3,300	1,900	23,000	600	1,200	7,500	800	200	10,500	2,000	400	35,500	2,100	1,000
1982	7,700	700	6,500	3,600	6,000	2,700	1,800	30,000	800	900	7,000	700	200	9,500	1,800	300	34,000	2,000	900
1983	7,400	500	6,400	3,200	5,400	2,600	1,500	31,000	600	800	6,500	700	200	9,000	1,500	300	37,000	1,900	900
1984	7,400	200	5,700	2,900	5,000	2,300	1,500	27,000	400	900	5,800	500	100	8,500	1,300	200	35,000	1,700	800
1985	7,400	700	5,400	2,500	4,300	2,500	2,000	30,000	300	900	6,000	700	200	9,000	1,100	200	40,000	1,600	500
1986	7,100	600	5,200	2,500	4,800	2,600	2,200	32,000	300	800	5,800	700	100	9,000	1,000	200	44,000	1,500	600
1987	7,500	500	5,900	2,000	4,000	500	2,000	29,100	300	800	5,000	600	100	8,500	700	200	39,000	1,800	400
1988	7,500	400	6,700	1,700	3,700	800	1,800	27,500	250	900	4,000	700	100	7,000	300	200	36,500	1,700	200
1989	7,500	100	7,000	1,200	2,900	5,800	1,700	30,000	200	700	3,000	700	100	7,600	200	100	40,000	1,600	300
1990	7,500	100	6,000	700	2,000	5,900	1,000	27,000	200	1,000	2,100	500	200	7,000	100	100	104,000	1,000	300
1991	7,600	300	7,000	800	2,000	6,100	1,300	28,000	300	1,200	2,100	600	200	7,500	100	100	119,000	1,400	300

Attachment 2

Depth to Groundwater Maps
from California Department of Water Resources

Modesto Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



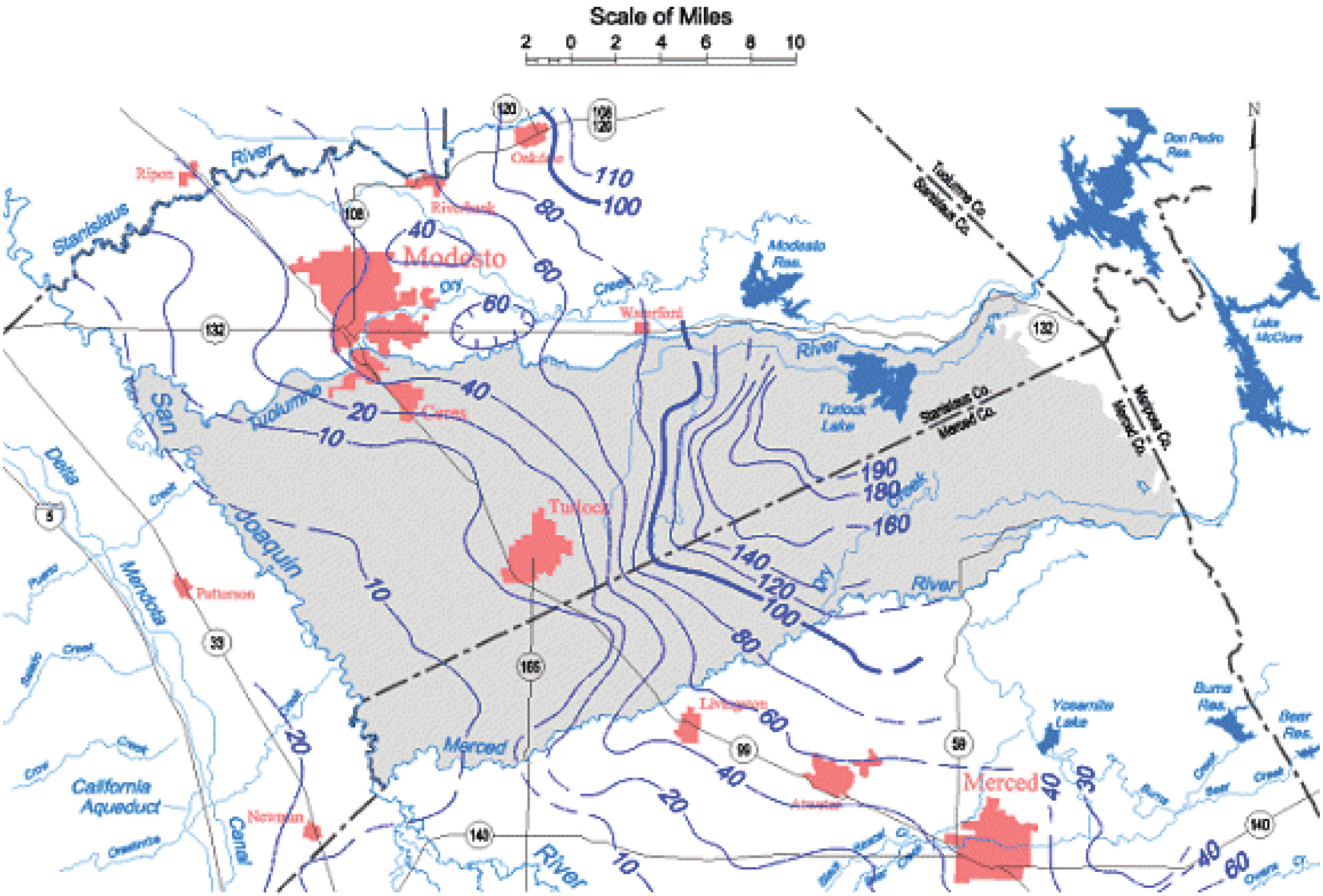
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Turlock Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



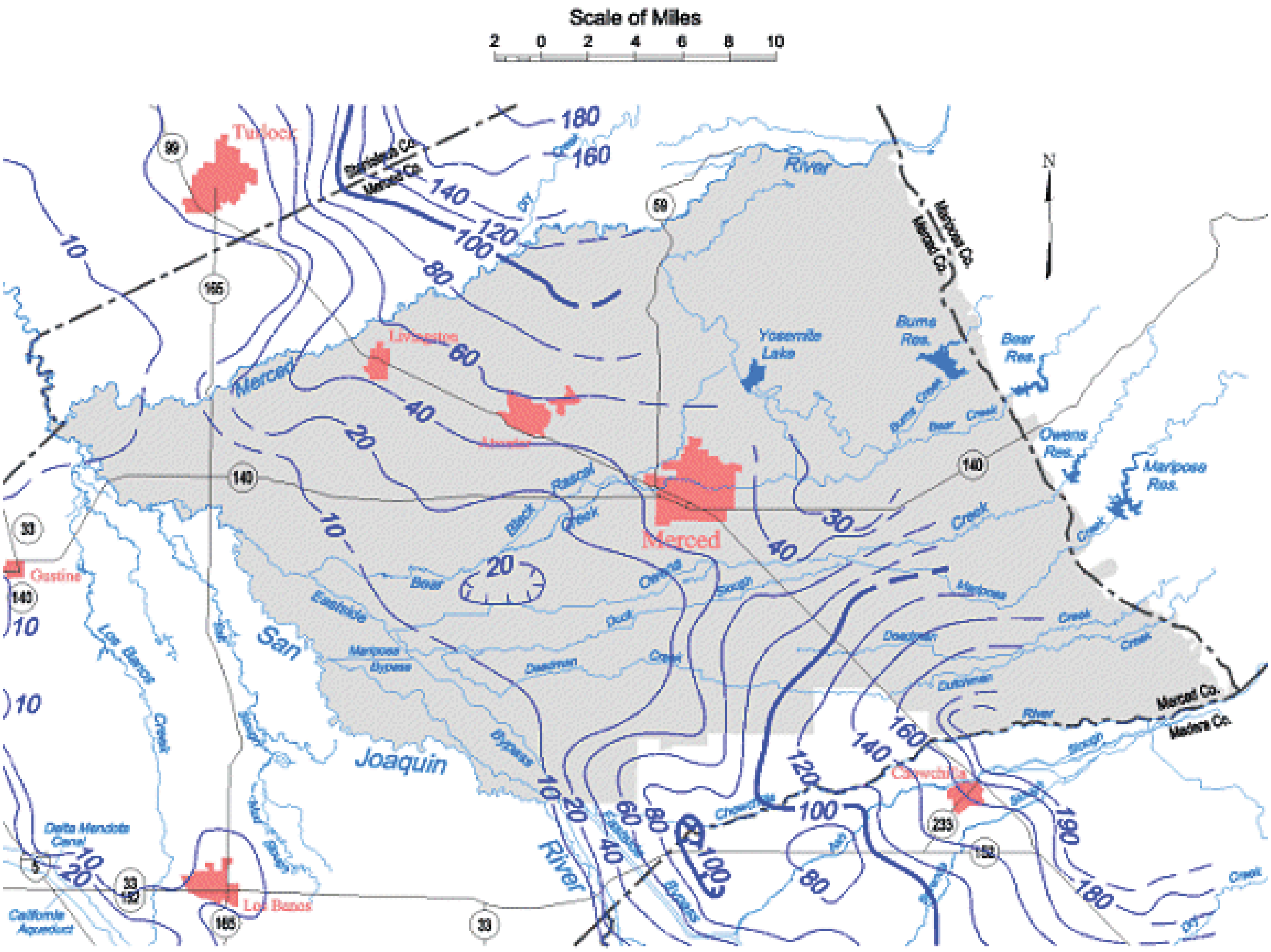
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Merced Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



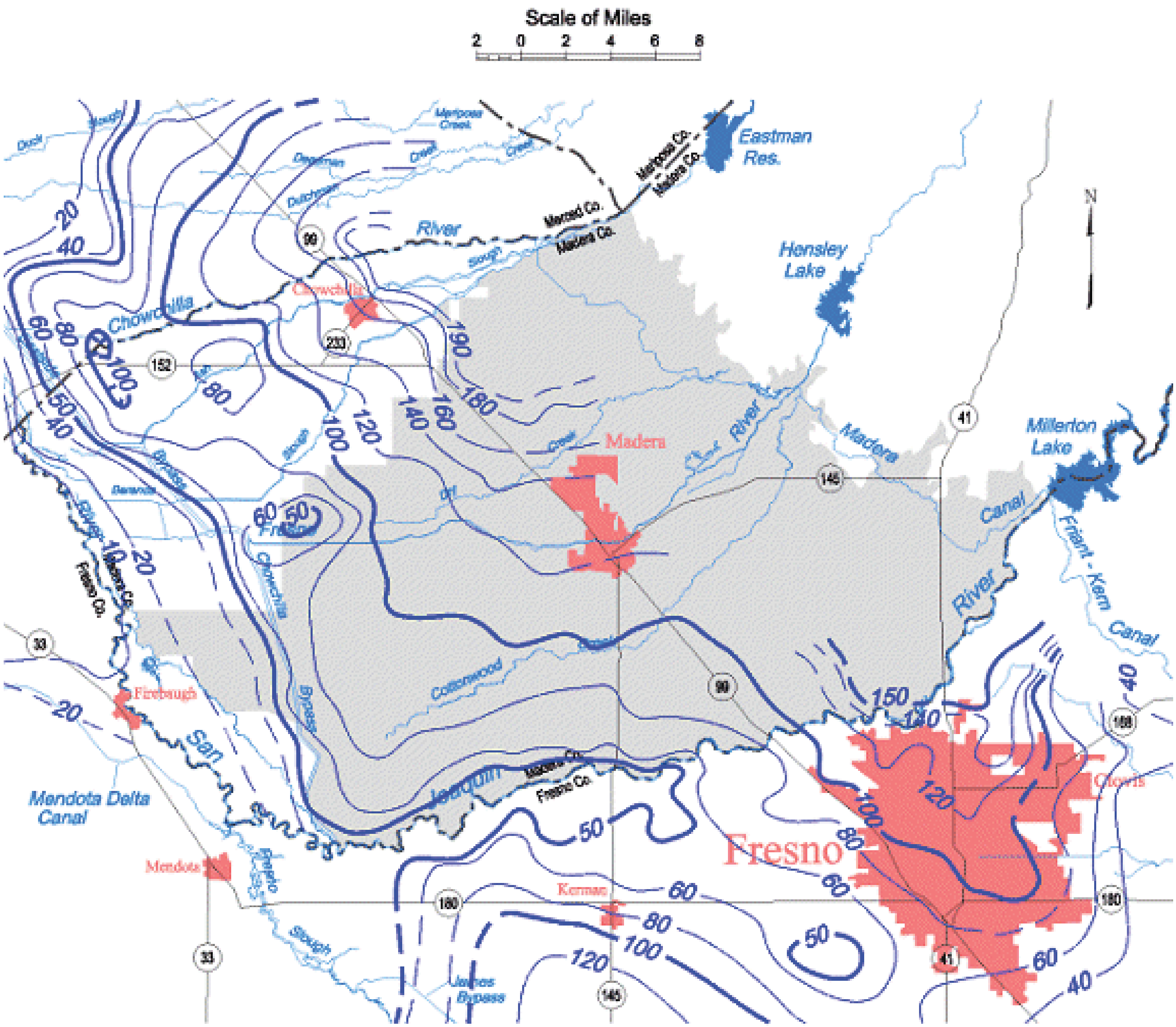
Contours are dashed where inferred. Contour interval is 10 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Madera Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



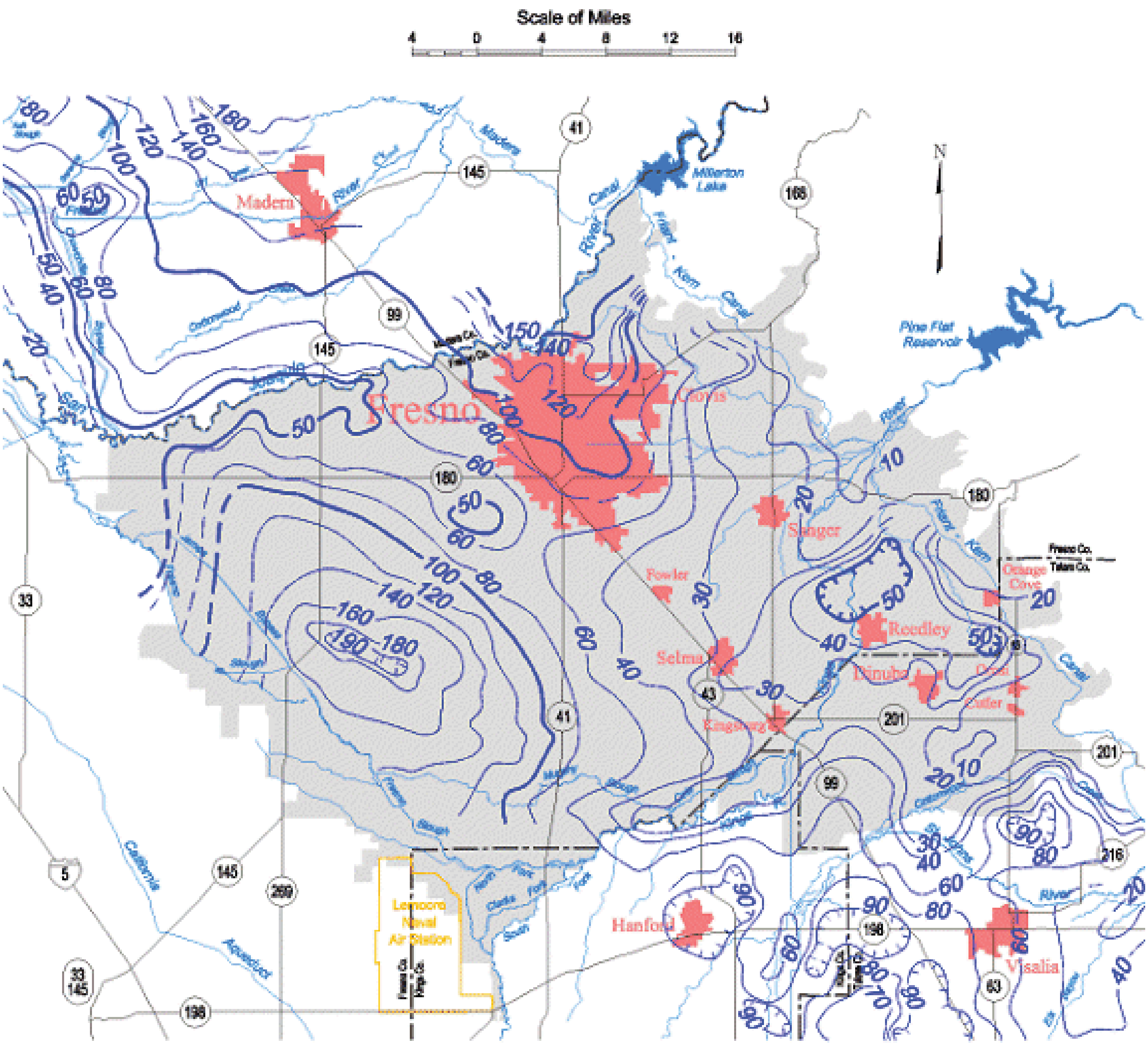
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Kings Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



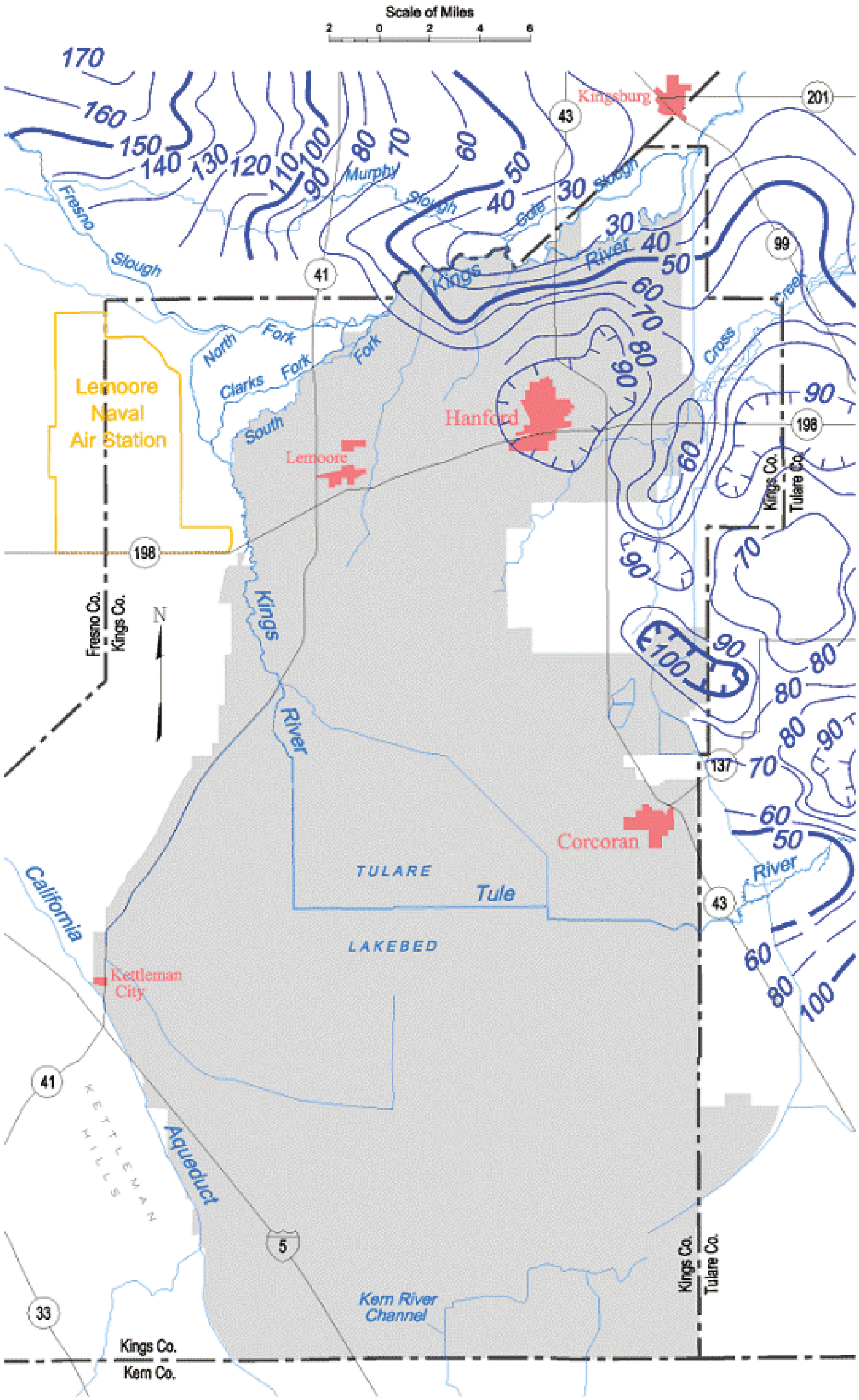
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Tulare Lake Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



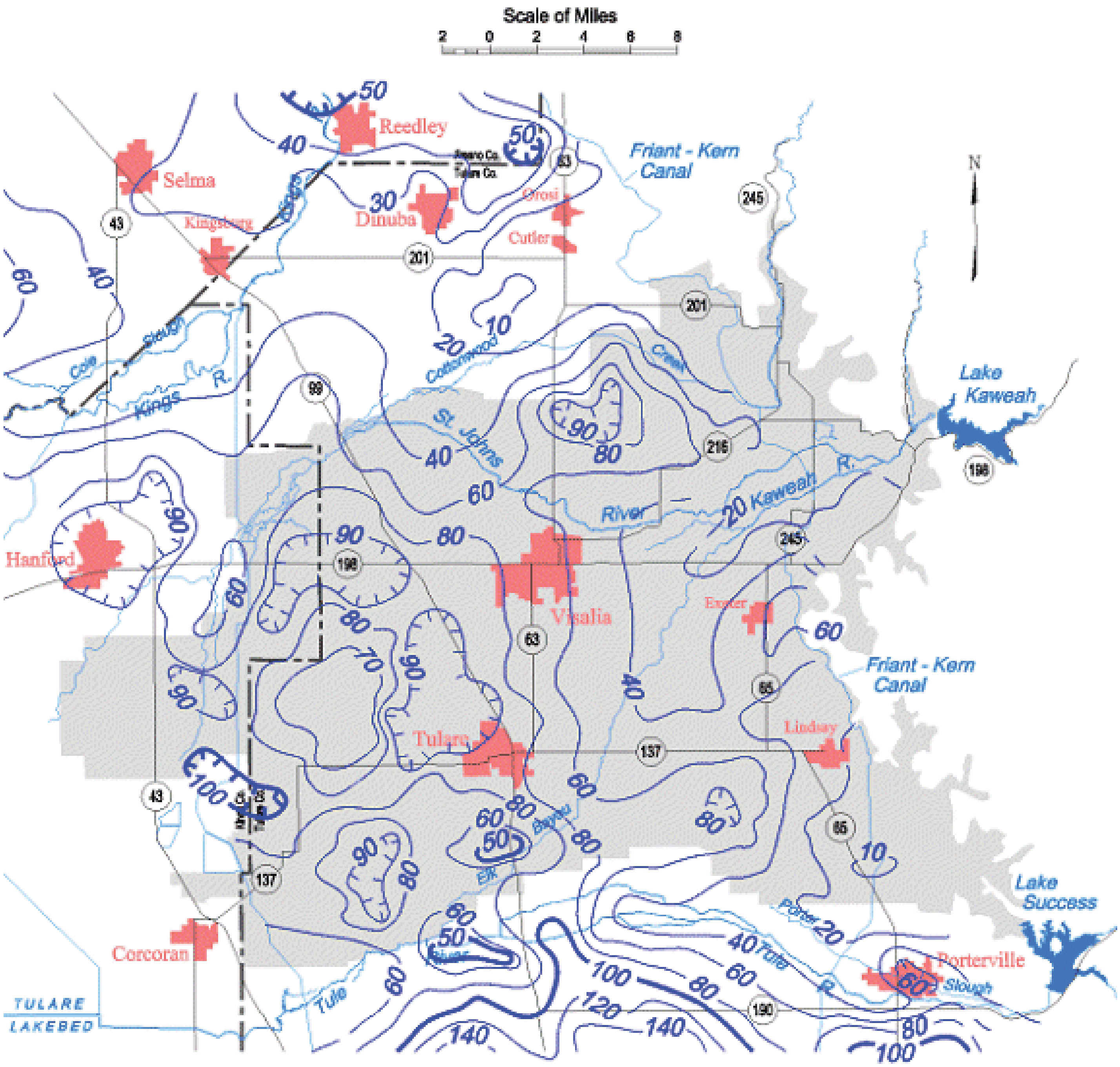
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Kaweah Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



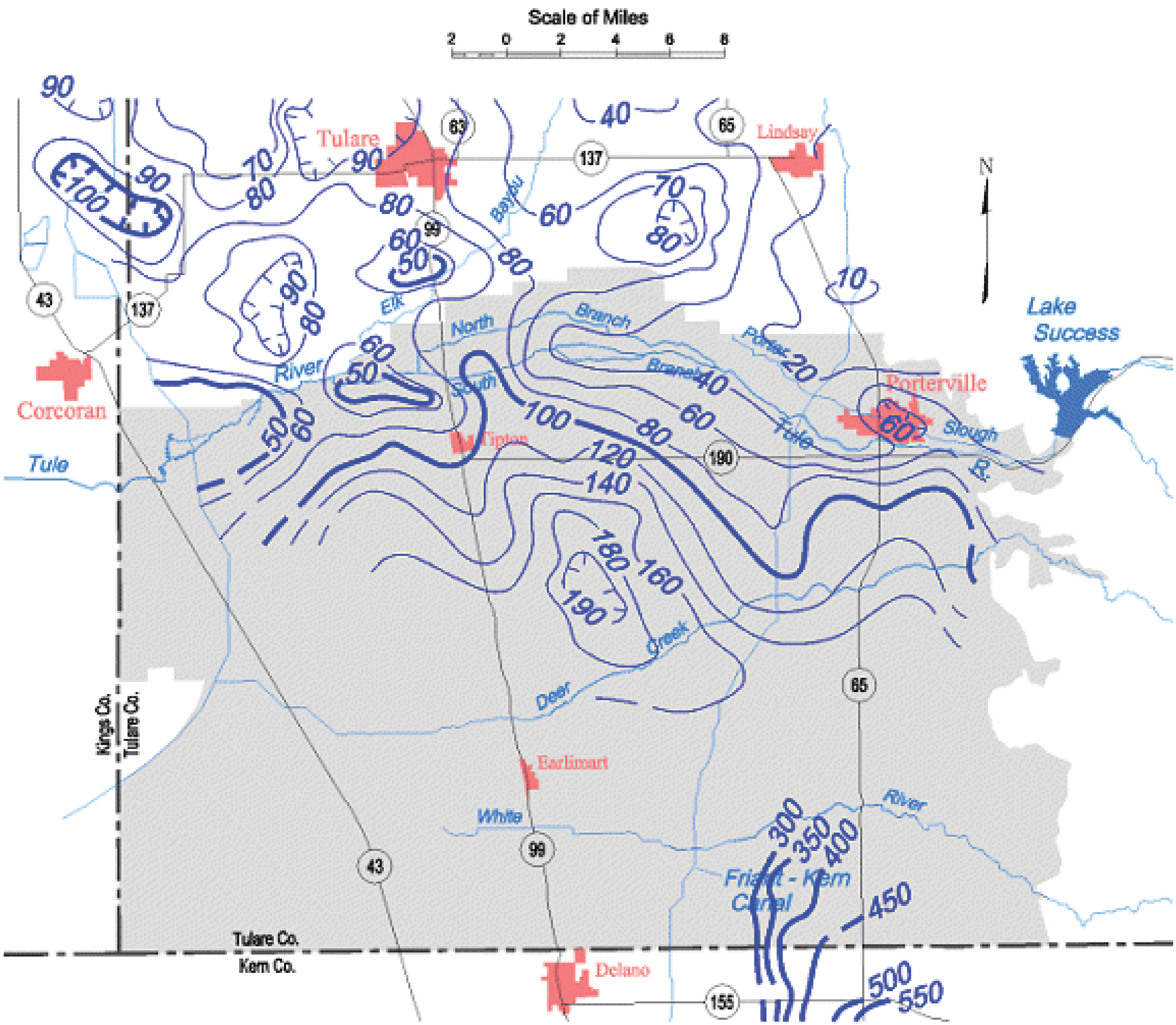
Contours are dashed where inferred. Contour interval is 10 and 20 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Tule Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



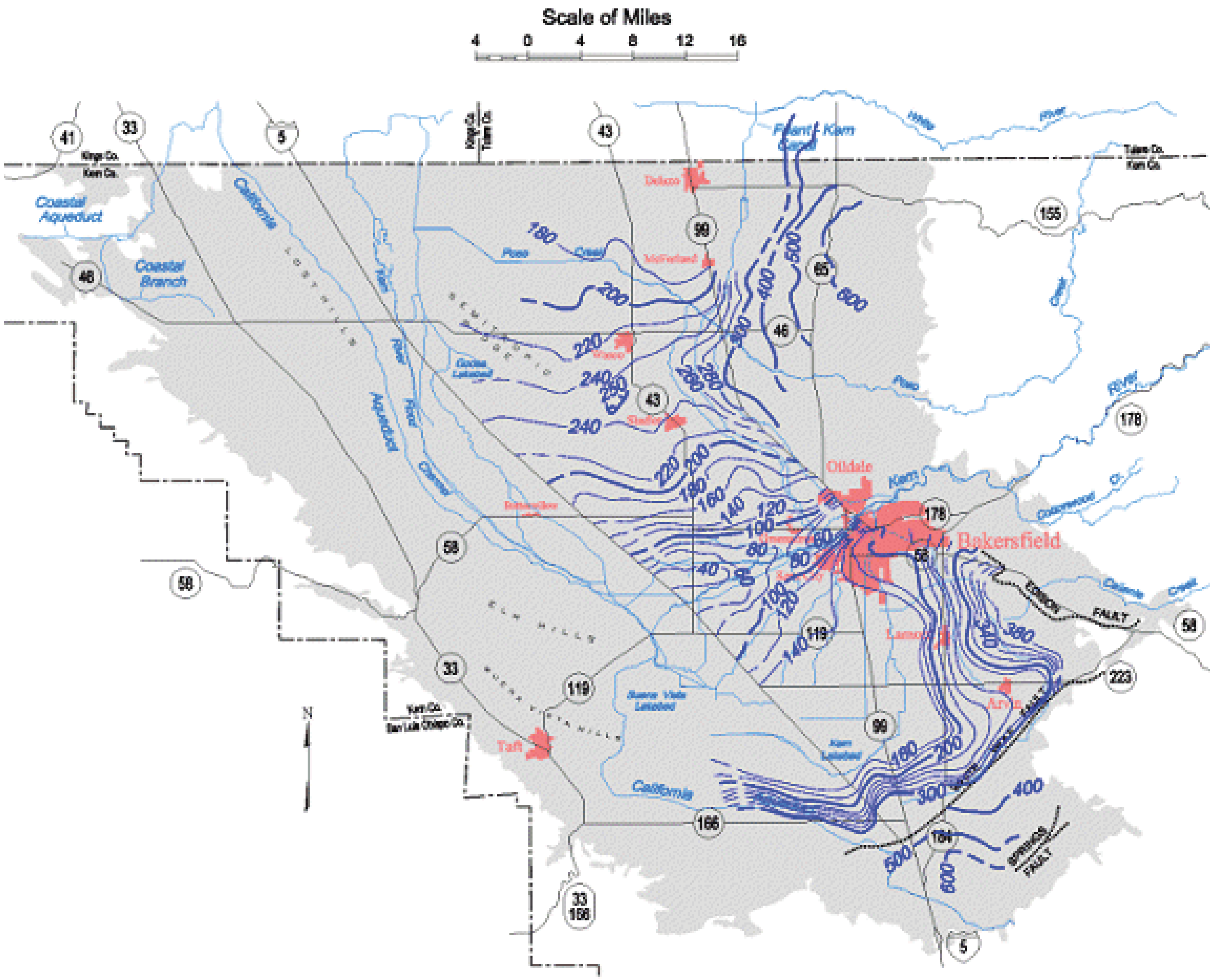
Contours are dashed where inferred. Contour interval is 10, 20 and 50 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Kern Groundwater Basin

Spring 2000, Lines of Equal Depth to Water in Wells, Unconfined Aquifer



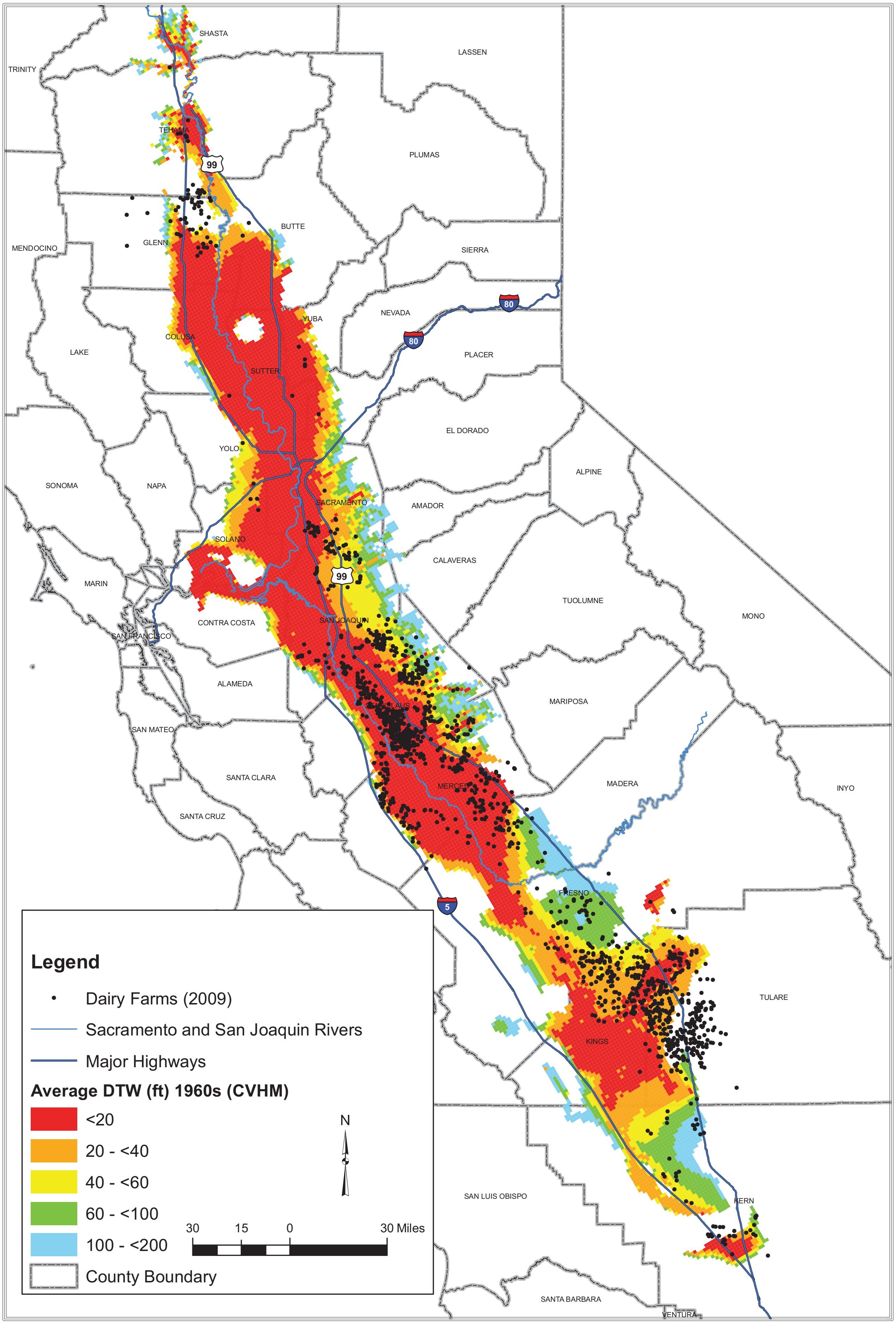
Contours are dashed where inferred. Contour interval is 10, 20 and 100 feet.

Source: http://www.sjd.water.ca.gov/groundwater/basin_maps/index.cfm

(accessed 3/1/2010)

Attachment 3

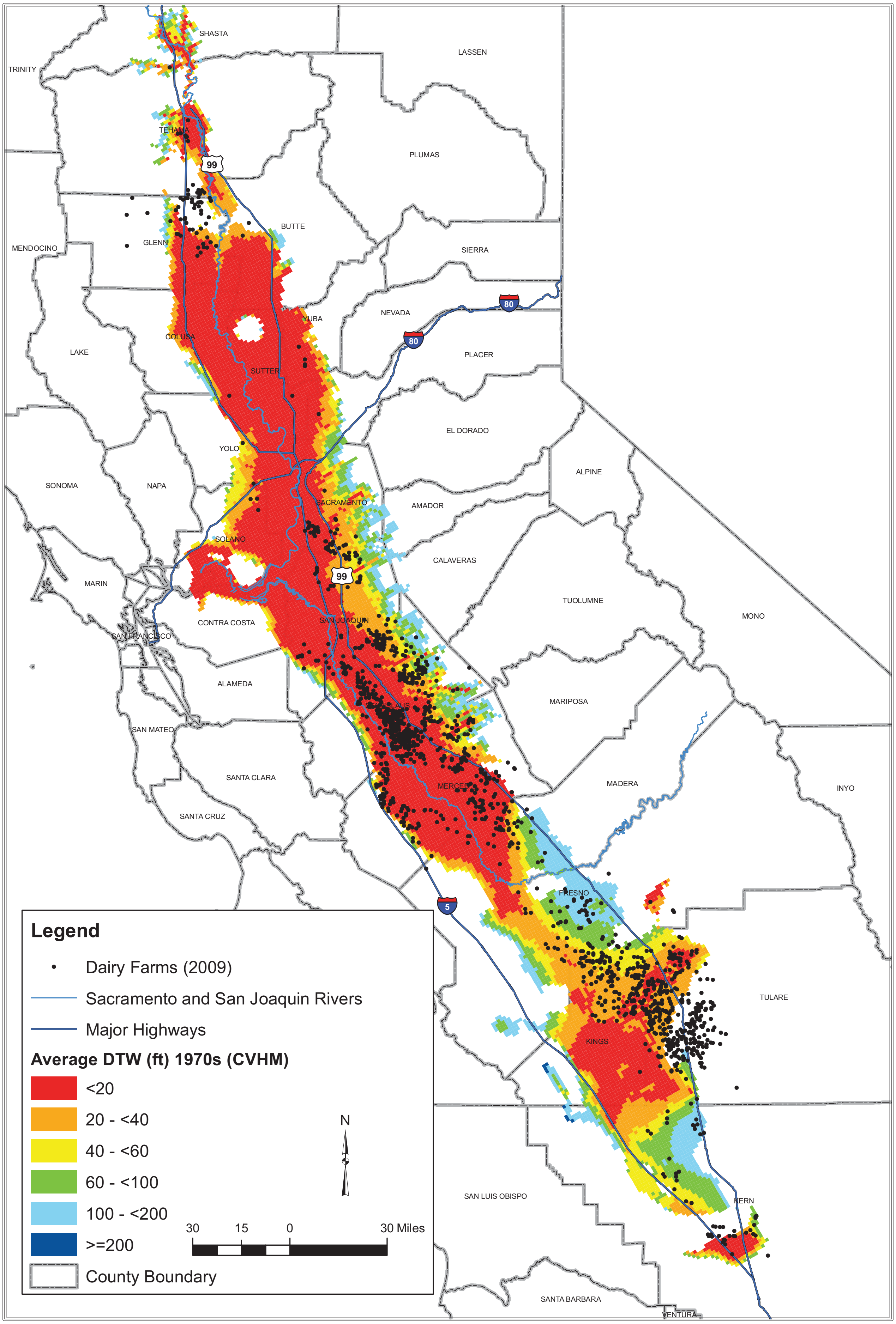
Decadal Average Depth to Groundwater
Computed from CVHM Output
(1960s, 1970s, and 1980s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_avgDTWs.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

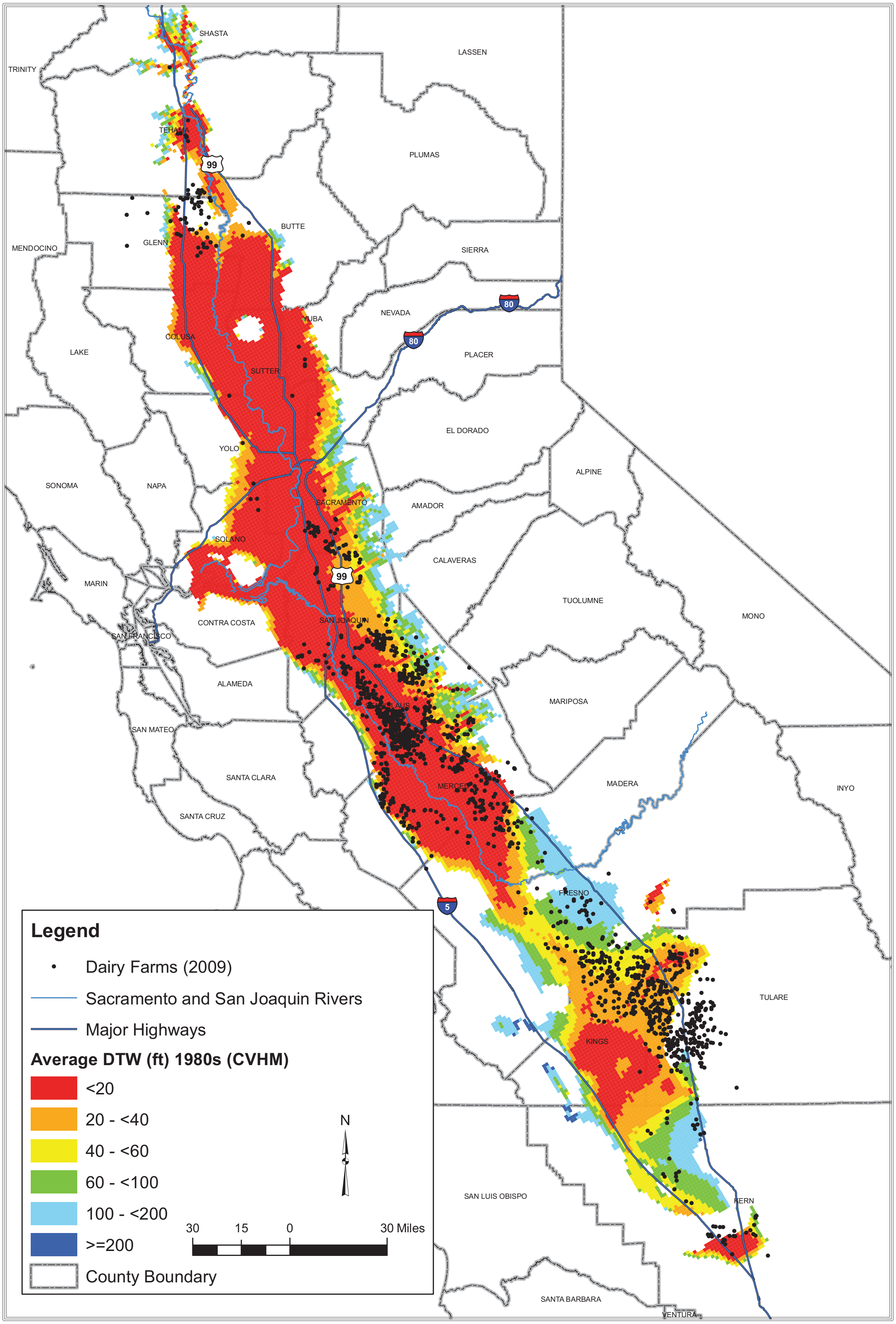
Attachment 3 Figure A
Average Depth to Water (1960s), Unconfined Aquifer
CVHM Results



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_avgDTWs.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Attachment 3 Figure B
Average Depth to Water (1970s), Unconfined Aquifer
CVHM Results



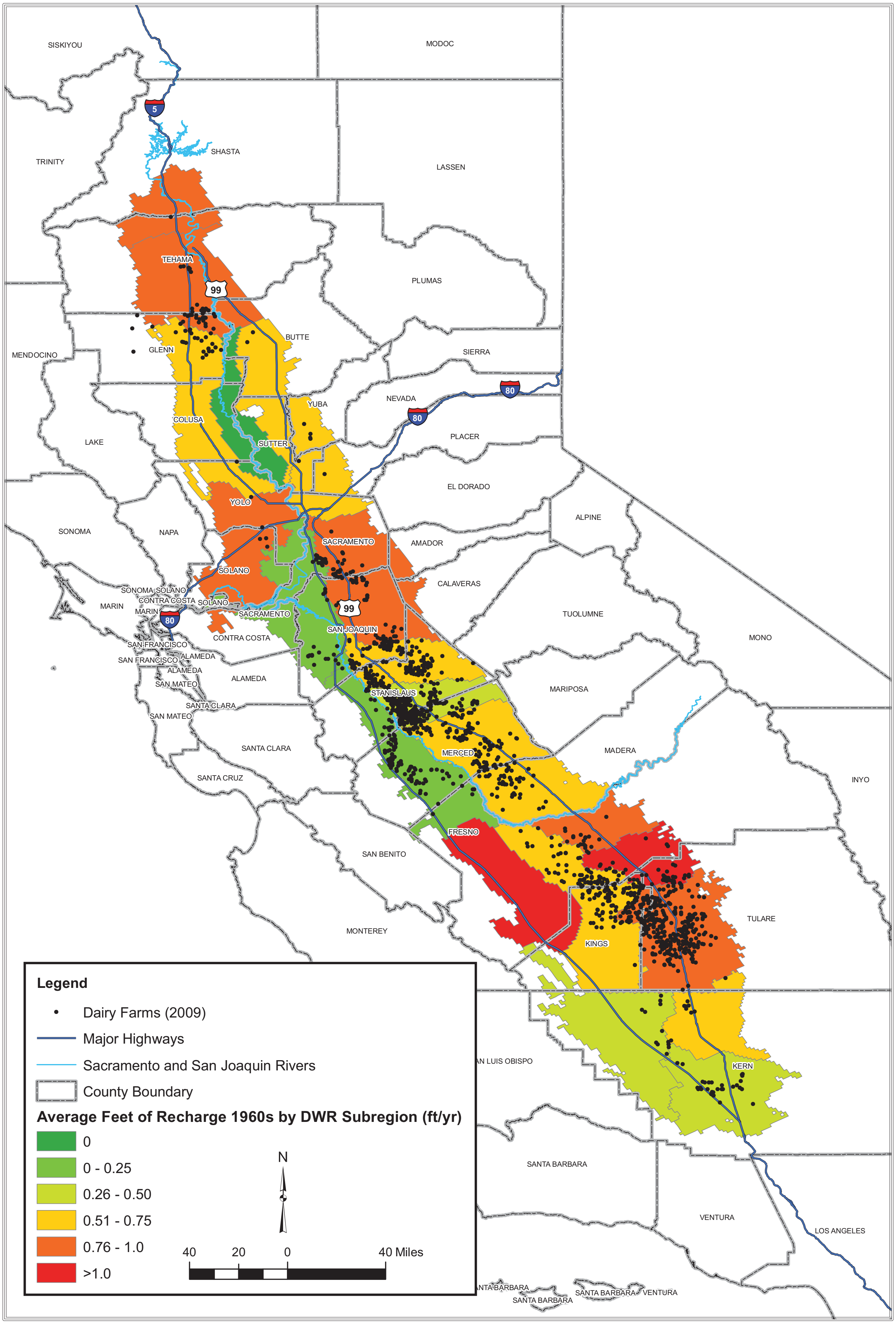
FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_avgDTWs.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Attachment 3 Figure C
Average Depth to Water (1980s), Unconfined Aquifer
CVHM Results

Attachment 4

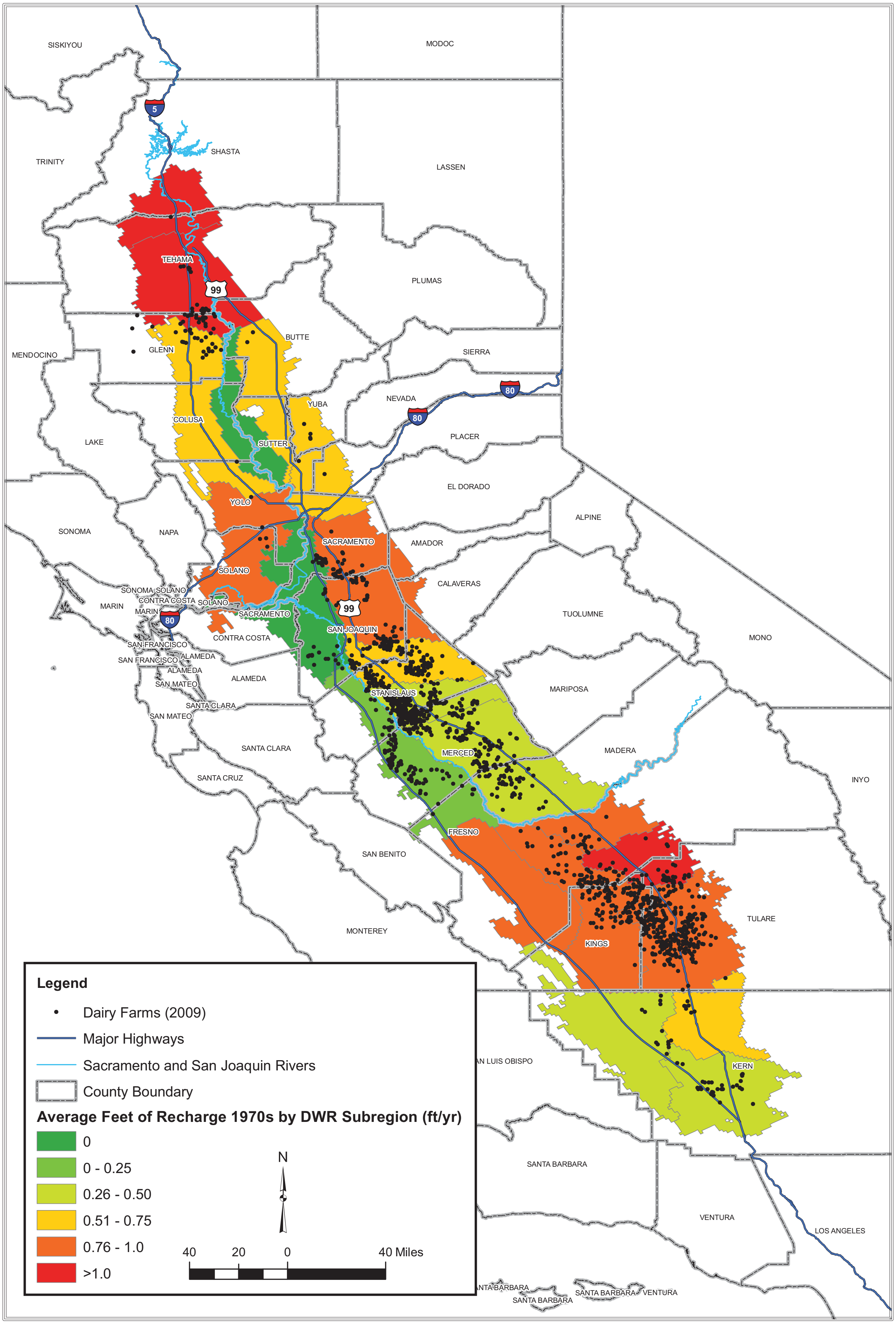
Decadal Annual Groundwater Recharge
by DWR Subregion - Computed from CVHM Output
(1960s, 1970s, and 1980s)



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_RechargeData.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

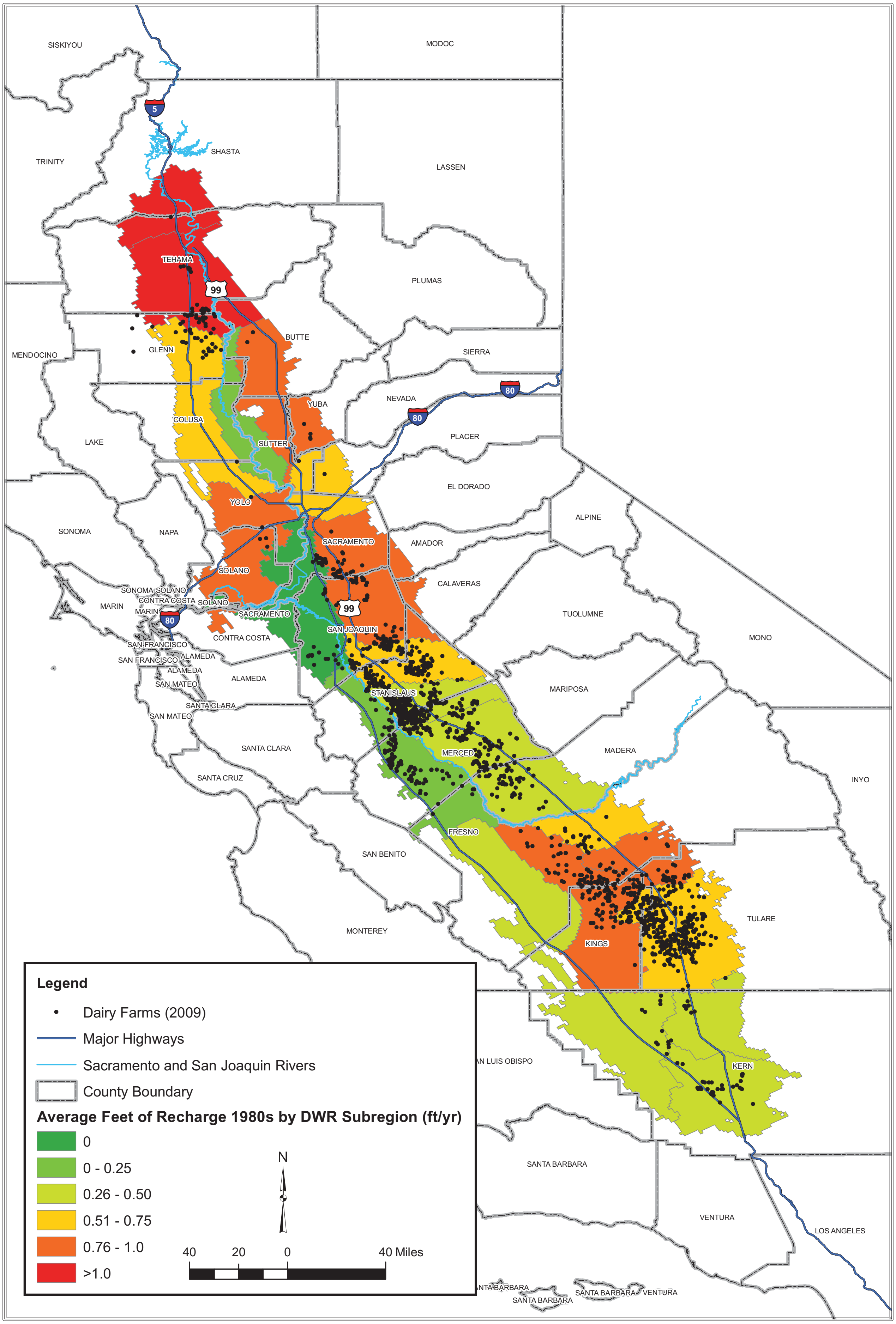
Attachment 4 Figure A
Average Annual Groundwater Recharge (1960s)
by DWR Subregion
CVHM Results



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_RechargeData.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Attachment 4 Figure B
Average Annual Groundwater Recharge (1970s)
by DWR Subregion
CVHM Results



FILE: \\server_pe2900\Clerical\2009 Job Files\09-075\GIS\CVHM_RechargeData.mxd Date: 3/29/2010 DATE: 2/17/2006 1:18:55 PM

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Attachment 4 Figure C
Average Annual Groundwater Recharge (1980s)
by DWR Subregion
CVHM Results

Attachment 5

Soil Texture Classes and Relative Permeability

Attachment 5
Soil Texture Classes and Relative Permeability

Texture	Relative Permeability
Bedrock	Low
Cemented	Low
Cemented coarse sandy loam, loam, loamy coarse sand	High
Cemented extremely gravelly material	High
Cemented gravelly loamy sand	High
Cemented indurated	Medium
Cemented material	Medium
Cemented sandy loam	High
Cemented, Indurated	Medium
Channery clay	Low
Channery clay loam	Medium
Channery loam	Medium
Cinders	Medium
Clay	Low
Clay loam	Low
Clay loam, fine sandy loam, gravelly clay loam, gravelly fine sandy loam, gravelly loam, gravelly sandy clay loam, loam, sandy clay loam	Low
Clay loam, fine sandy loam, loam, sandy loam	Low
Clay loam, fine sandy loam, loam, silty clay loam, silt loam, sandy loam	Low
Clay loam, gravelly clay loam	Low
Clay loam, gravelly clay loam, gravelly loam	Low
Clay loam, gravelly clay loam, gravelly loam, gravelly sandy clay loam, gravelly silty clay, gravelly sandy loam, loam, sandy clay loam, silty clay, sandy loam	Low
Clay loam, gravelly clay loam, gravelly loam, gravelly sandy clay loam, loam, sandy clay loam	Low
Clay loam, gravelly clay loam, gravelly loam, gravelly silty clay loam, gravelly silt loam, loam, silty clay loam, silt loam	Low
Clay loam, gravelly clay loam, gravelly loam, gravelly silty clay loam, loam, silty clay loam	Low
Clay loam, gravelly clay loam, gravelly loam, loam	Low
Clay loam, gravelly clay loam, gravelly loam, loam, silt loam	Low

Texture	Relative Permeability
Clay loam, gravelly clay loam, gravelly loam, very gravelly clay loam, very gravelly loam, loam	Low
Clay loam, Gravelly clay loam, Gravelly sandy clay loam	Low
Clay loam, gravelly clay loam, silty clay loam, silt loam	Low
Clay loam, Gravelly clay, Gravelly clay loam	Low
Clay loam, gravelly loam	Low
Clay loam, gravelly loam, loam	Low
Clay loam, gravelly sandy clay loam, loam, sandy clay loam	Low
Clay loam, loam	Low
Clay loam, loam, sandy clay loam	Low
Clay loam, loam, sandy clay loam, silty clay	Low
Clay loam, loam, sandy clay loam, silty clay loam	Low
Clay loam, loam, sandy loam	Low
Clay loam, loam, silt loam	Low
Clay loam, loam, silty clay loam	Low
Clay loam, loam, silty clay loam, silt loam	Low
Clay loam, loam, silty clay, silty clay loam, silt loam	Low
Clay loam, Sandy clay	Low
Clay loam, sandy clay loam	Low
Clay loam, silt loam	Low
Clay loam, silty clay	Low
Clay loam, silty clay loam	Low
Clay loam, silty clay loam, silt loam	Low
Clay loam, silty clay loam, very fine sandy loam	Low
Clay loam, silty clay, silty clay loam	Low
Clay, bedrock	Low
Clay, bedrock, clay loam, bedrock, silty clay, bedrock	Low
Clay, clay loam	Low
Clay, clay loam, coarse sand, gravelly clay, gravelly clay loam, gravelly coarse sand, gravelly loam, gravelly sand, gravelly sand, gravelly sandy clay loam, gravelly sandy lo:	Low
Clay, clay loam, coarse sand, gravelly clay, gravelly clay loam, gravelly coarse sand, gravelly loam, gravelly sand, gravelly sandy clay loam, gravelly sandy loam, loam, sanc	Low

Texture	Relative Permeability
Clay, clay loam, fine sandy loam, loamy coarse sand, silty clay, sandy loam	Low
Clay, Clay loam, Gravelly clay	Low
Clay, clay loam, gravelly clay loam, gravelly silty clay loam, silty clay, silty clay loam	Low
Clay, clay loam, gravelly sandy clay loam, sandy clay, sandy clay loam	Low
Clay, clay loam, loam, silt loam	Low
Clay, clay loam, sandy clay	Low
Clay, Clay loam, Sandy clay loam	Low
Clay, clay loam, silty clay	Low
Clay, clay loam, silty clay loam	Low
Clay, clay loam, silty clay, silty clay loam	Low
Clay, clay, clay loam	Low
Clay, cobbly clay loam, clay loam, gravelly clay, gravelly clay loam, very gravelly clay, sandy clay, sandy clay loam	Low
Clay, cobbly clay loam, cobbly sandy clay, very cobbly clay, very cobbly clay loam, clay loam, gravelly clay loam, gravelly sandy clay, gravelly sandy clay loam, very gravelly	Low
Clay, cobbly clay, cobbly clay loam, very cobbly clay loam, very cobbly silty clay loam, clay loam, gravelly clay, gravelly clay loam, gravelly silty clay, very gravelly silty clay	Low
Clay, cobbly clay, gravelly clay	Low
Clay, cobbly clay, gravelly clay, silty clay	Low
Clay, cobbly clay, very cobbly clay, extremely cobbly clay, gravelly clay	Low
Clay, cobbly clay, very cobbly clay, extremely cobbly clay, gravelly clay, gravelly clay loam, gravelly silty clay, very gravelly clay loam, very gravelly silty clay loam, extremel	Low
Clay, cobbly clay, very cobbly clay, gravelly clay	Low
Clay, cobbly loam, clay loam, gravelly clay, gravelly clay loam, loam	Low
Clay, gravelly clay	Low
Clay, gravelly clay, gravelly clay loam, gravelly loam, gravelly sandy clay loam, loam, loam, sandy clay loam	Low
Clay, gravelly clay, silty clay	Low
Clay, gravelly silty clay, silty clay	Low
Clay, Sandy clay	Low
Clay, silty clay	Low
Clay, silty clay loam	Low
Clay, silty clay, silty clay loam	Low
Coarse sand, fine sandy loam, loam, loamy coarse sand, loamy sand, sandy loam	High

Texture	Relative Permeability
Coarse sand, gravelly coarse sand, sand	High
Coarse sand, Loamy coarse sand, Loamy sand	High
Coarse sand, Loamy sand	High
Coarse sandy loam	High
Coarse sandy loam, fine sandy loam, gravelly coarse sandy loam, gravelly fine sandy loam, gravelly fine sandy loam, gravelly loam, gravelly loamy sand, gravelly sandy loa	High
Coarse sandy loam, fine sandy loam, gravelly fine sandy loam, gravelly sandy loam, sandy loam	High
Coarse sandy loam, fine sandy loam, loam, loamy fine sand, loamy sand, sand, silt loam, sandy loam, very fine sandy loam	High
Coarse sandy loam, fine sandy loam, loam, sandy loam	High
Coarse sandy loam, fine sandy loam, loamy sand, sandy loam	High
Coarse sandy loam, fine sandy loam, sandy loam	High
Coarse sandy loam, gravelly coarse sandy loam, gravelly loamy coarse sand, gravelly sandy loam, loamy coarse sand, sandy loam	High
Coarse sandy loam, gravelly coarse sandy loam, gravelly loamy coarse sand, gravelly sandy loam, sandy loam	High
Coarse sandy loam, gravelly coarse sandy loam, gravelly loamy sand, loamy sand	High
Coarse sandy loam, gravelly coarse sandy loam, gravelly sandy loam, sandy loam	High
Coarse sandy loam, gravelly sandy loam	High
Coarse sandy loam, gravelly sandy loam, extremely gravelly loam, loam, sandy clay loam, silty clay loam	High
Coarse sandy loam, Loam, Loamy coarse sand	High
Coarse sandy loam, loam, sandy loam	High
Coarse sandy loam, Loamy coarse sand	High
Coarse sandy loam, loamy sand, sandy loam	High
Coarse sandy loam, sandy clay loam	High
Coarse sandy loam, sandy loam	High
Coarse sandy loam, sandy loam, very fine sandy loam	High
Cobbly clay	Medium
Cobbly clay loam	Medium
Cobbly clay loam, clay loam, gravelly clay loam	Medium
Cobbly clay loam, cobbly loam	Medium
Cobbly clay loam, cobbly loam, very cobbly clay loam, clay loam, gravelly clay loam, gravelly loam, very gravelly clay loam, loam, very stony clay loam	Medium
Cobbly clay loam, cobbly loam, very cobbly clay loam, very cobbly loam, clay loam, gravelly clay loam, gravelly loam, gravelly sandy clay loam, very gravelly clay loam, ver	Medium

Texture	Relative Permeability
Cobbly clay loam, Gravelly clay loam, Gravelly loam	Medium
Cobbly clay loam, gravelly clay loam, gravelly sandy clay loam, very gravelly clay loam, very gravelly loam, very gravelly sandy clay loam, extremely gravelly clay loam	Medium
Cobbly clay loam, stony clay loam	Medium
Cobbly clay loam, very cobbly clay	Medium
Cobbly clay loam, very cobbly clay, very cobbly clay loam, very cobbly silty clay, very gravelly clay loam, extremely gravelly clay	Medium
Cobbly clay, cobbly clay loam	Medium
Cobbly clay, cobbly clay loam, very cobbly clay, very cobbly clay loam, clay loam, gravelly clay loam, very gravelly clay loam	Medium
Cobbly clay, cobbly clay loam, very cobbly clay, very cobbly clay loam, extremely cobbly clay, extremely cobbly clay loam, gravelly clay, gravelly clay loam, very gravelly cl	Medium
Cobbly clay, extremely cobbly clay loam, gravelly clay, gravelly clay loam, very gravelly clay loam, extremely gravelly sandy clay loam, very stony clay loam, extremely sto	Medium
Cobbly clay, Stony clay	Medium
Cobbly clay, very cobbly clay, extremely cobbly clay, gravelly clay, very gravelly clay, very gravelly clay loam, very gravelly sandy clay loam	Medium
Cobbly coarse sand, cobbly loamy sand, cobbly sand, cobbly sandy loam, very cobbly coarse sand, very cobbly loamy sand, very cobbly sand, very cobbly sandy loam, ex	High
Cobbly loam	High
Cobbly loam, gravelly clay loam, gravelly loam, very gravelly clay loam, loam	High
Cobbly loam, very cobbly clay loam, very cobbly loam, extremely cobbly clay loam, gravelly loam, very gravelly loam, extremely gravelly loam	High
Cobbly loam, very cobbly loam, gravelly loam, very gravelly loam	High
Cobbly loam, very cobbly loam, gravelly loam, very gravelly loam, loam	High
Cobbly loamy coarse sand, extremely cobbly coarse sandy loam, extremely cobbly sandy loam, gravelly loamy sand, very gravelly loamy sand, extremely stony sandy loa	High
Cobbly medial loam, cobbly medial sandy loam, very cobbly medial loam, very cobbly medial sandy loam, extremely cobbly medial sandy loam, gravelly medial loam, gra	High
Cobbly sandy clay loam	High
Cobbly sandy loam	High
Cobbly sandy loam, gravelly sandy loam, very gravelly sandy loam, sandy loam	High
Cobbly sandy loam, very cobbly sandy loam, extremely cobbly sandy loam, gravelly sandy loam, very gravelly sandy loam, extremely gravelly sandy loam, very stony sanc	High
Cobbly sandy loam, very cobbly sandy loam, extremely cobbly sandy loam, gravelly sandy loam, very gravelly sandy loam, sandy loam, stony sandy loam, very stony sanc	High
Cobbly silty clay loam, very cobbly silty clay loam, very gravelly silty clay, very gravelly silty clay loam	Medium
Duripan	Low
Extremely bouldery clay, very cobbly clay, very cobbly clay loam, very gravelly clay loam, extremely stony clay loam	Medium
Extremely bouldery sandy clay loam, Extremely stony loam, Extremely stony sandy clay loam	High
Extremely cobbly clay loam, extremely cobbly loam	High

Texture	Relative Permeability
Extremely cobbly clay loam, extremely cobbly loam, cemented extremely gravelly sand, extremely gravelly clay loam, extremely gravelly sandy clay	Medium
Extremely cobbly coarse sandy loam, extremely gravelly coarse sandy loam, extremely gravelly loamy sand	High
Extremely cobbly fine sandy loam, very gravelly sandy loam, extremely gravelly sandy loam	High
Extremely cobbly fragmental material	High
Extremely cobbly loam, extremely cobbly sandy clay loam, extremely cobbly sandy loam, extremely gravelly loam, extremely gravelly sandy clay loam, extremely gravelly	High
Extremely cobbly loam, extremely gravelly loam, extremely gravelly sandy clay loam, extremely gravelly silt loam	High
Extremely cobbly loamy sand, Extremely gravelly loamy sand	High
Extremely cobbly medial fine sandy loam, extremely cobbly medial sandy loam, very gravelly medial sandy loam, extremely gravelly medial sandy loam	High
Extremely cobbly medial sandy loam, very gravelly medial sandy loam, extremely gravelly medial coarse sandy loam, extremely gravelly medial sandy loam, extremely sto	High
Extremely cobbly medial sandy loam, very gravelly medial sandy loam, extremely gravelly medial sandy loam, extremely stony medial fine sandy loam	High
Extremely gravelly clay, extremely gravelly clay loam	High
Extremely gravelly coarse sandy loam, extremely gravelly loamy coarse sand	High
Extremely gravelly coarse sandy loam, Extremely gravelly sandy loam	High
Extremely gravelly loam	High
Extremely gravelly loam, extremely gravelly sandy loam	High
Extremely gravelly loamy coarse sand	High
Extremely gravelly sand	High
Extremely gravelly sandy clay loam	High
Extremely gravelly sandy clay, extremely gravelly sandy clay loam	High
Extremely gravelly sandy clay, sandy clay loam, sandy loam	High
Extremely gravelly sandy loam	High
Extremely paragravelly loam	High
Extremely paragravelly loam, extremely paragravelly silt loam	High
Fine sand	High
Fine sand, loamy fine sand	High
Fine sand, loamy sand	High
Fine sand, loamy sand, sand	High
Fine sand, Sand	High
Fine sandy loam	High

Texture	Relative Permeability
Fine sandy loam, extremely gravelly loamy coarse sand, extremely gravelly loamy sand, loamy coarse sand, loamy sand, sandy loam	High
Fine sandy loam, gravelly coarse sandy loam, gravelly sandy loam, sandy loam	High
Fine sandy loam, gravelly fine sandy loam, gravelly loam, gravelly sandy loam, very gravelly loam, very gravelly sandy loam, loam, sandy loam	High
Fine sandy loam, gravelly fine sandy loam, gravelly sandy loam, very gravelly fine sandy loam, very gravelly sandy loam, sandy loam	High
Fine sandy loam, gravelly sandy loam	High
Fine sandy loam, loam	High
Fine sandy loam, loam, loamy fine sand, sand, silt loam	High
Fine sandy loam, loam, sandy clay loam, sandy loam	High
Fine sandy loam, loam, sandy loam	High
Fine sandy loam, loam, sandy loam, very fine sandy loam	High
Fine sandy loam, loam, silt loam	High
Fine sandy loam, sandy loam	High
Fine sandy loam, Silty clay loam, Silt loam	High
Fine sandy loam, Very fine sandy loam	High
Fragmental material	High
Gravelly clay	Medium
Gravelly clay loam	Medium
Gravelly clay loam, gravelly coarse sandy loam, gravelly sandy clay loam, very gravelly loamy sand, very gravelly sandy clay loam, extremely gravelly coarse sand, extrem	Medium
Gravelly clay loam, gravelly loam	Medium
Gravelly clay loam, gravelly loam, gravelly sandy clay loam	Medium
Gravelly clay loam, gravelly loam, gravelly sandy clay loam, gravelly sandy loam, very gravelly clay loam, very gravelly loam, very gravelly sandy clay loam, very gravelly s	Medium
Gravelly clay loam, gravelly loam, gravelly sandy clay loam, very gravelly clay loam	Medium
Gravelly clay loam, gravelly loam, gravelly silt loam	Medium
Gravelly clay loam, gravelly loam, gravelly silty clay loam	Medium
Gravelly clay loam, gravelly loam, very gravelly clay loam, very gravelly loam	Medium
Gravelly clay loam, gravelly sandy clay loam	Medium
Gravelly clay loam, gravelly sandy clay loam, gravelly silty clay loam	Medium
Gravelly clay loam, gravelly sandy loam, very gravelly clay loam, very gravelly sandy loam	Medium
Gravelly clay loam, gravelly silty clay loam	Medium

Texture	Relative Permeability
Gravelly clay loam, very gravelly clay loam	Medium
Gravelly clay loam, very gravelly clay loam, very gravelly loam, very gravelly silty clay loam	Medium
Gravelly clay loam, Very gravelly clay, Very gravelly clay loam	Medium
Gravelly clay, gravelly clay loam	Medium
Gravelly clay, Gravelly clay loam, Gravelly sandy clay	Medium
Gravelly clay, gravelly clay loam, very gravelly clay loam	Medium
Gravelly clay, Gravelly sandy clay	Medium
Gravelly clay, very gravelly clay, very gravelly clay loam, very gravelly sandy clay, very gravelly sandy clay loam, extremely gravelly clay loam	Medium
Gravelly coarse sandy loam	High
Gravelly coarse sandy loam, gravelly fine sandy loam, gravelly loam, gravelly sandy loam, very gravelly coarse sandy loam, very gravelly fine sandy loam, very gravelly loa	High
Gravelly coarse sandy loam, gravelly fine sandy loam, gravelly sandy loam	High
Gravelly coarse sandy loam, gravelly loam, gravelly sandy loam	High
Gravelly coarse sandy loam, Gravelly loamy coarse sand	High
Gravelly coarse sandy loam, gravelly loamy coarse sand, gravelly loamy sand, gravelly sandy loam, very gravelly sandy loam, loamy sand, sandy loam	High
Gravelly coarse sandy loam, Gravelly sandy loam	High
Gravelly coarse sandy loam, gravelly sandy loam, very gravelly coarse sandy loam, very gravelly sandy loam, loam, sandy loam	High
Gravelly fine sand, gravelly loamy sand, gravelly sand	High
Gravelly fine sandy loam	High
Gravelly fine sandy loam, gravelly loam	High
Gravelly fine sandy loam, gravelly loam, gravelly sandy loam	High
Gravelly fine sandy loam, gravelly sandy loam	High
Gravelly fine sandy loam, loam	High
Gravelly fine sandy loam, very gravelly fine sandy loam, very gravelly sandy clay loam, very gravelly sandy loam, very stony sandy clay loam, extremely stony sandy clay l	High
Gravelly loam	High
Gravelly loam, gravelly sandy clay loam	High
Gravelly loam, gravelly sandy clay loam, loam, sandy clay loam	High
Gravelly loam, gravelly sandy clay loam, very gravelly loam, very gravelly sandy loam, loam, sandy loam	High
Gravelly loam, Gravelly sandy loam	High
Gravelly loam, Gravelly sandy loam, Sandy loam	High

Texture	Relative Permeability
Gravelly loam, gravelly silt loam, silt loam	High
Gravelly loam, loam	High
Gravelly loam, very gravelly loam	High
Gravelly loamy coarse sand	High
Gravelly loamy coarse sand, gravelly sandy loam, loamy coarse sand, loamy sand, sandy loam	High
Gravelly loamy sand	High
Gravelly loamy sand, gravelly sandy loam	High
Gravelly loamy sand, gravelly sandy loam, sandy loam	High
Gravelly material	High
Gravelly sand and gravel	High
Gravelly sand, very gravelly coarse sand, very gravelly coarse sandy loam, very gravelly loamy coarse sand, very gravelly sand, extremely gravelly coarse sand	High
Gravelly sandy clay	Medium
Gravelly sandy clay loam	Medium
Gravelly sandy clay loam, gravelly sandy loam, sandy clay loam, sandy loam	Medium
Gravelly sandy clay loam, sandy clay loam	Medium
Gravelly sandy clay loam, sandy clay loam, sandy loam	Medium
Gravelly sandy loam	High
Gravelly sandy loam, extremely gravelly coarse sandy loam, extremely gravelly sandy clay loam, loamy sand, sandy clay loam	High
Gravelly sandy loam, sandy loam	High
Gravelly sandy loam, very gravelly loam, very gravelly sandy loam	High
Gravelly sandy loam, Very gravelly sandy loam	High
Gravelly sandy loam, very gravelly sandy loam, extremely gravelly sandy loam, sandy loam	High
Gravelly silt loam, loam, silt loam	Medium
Gravelly silty clay loam, very gravelly silty clay loam	Medium
Indurated	High
Loam	High
Loam, sandy clay loam	High
Loam, sandy clay loam, sandy loam	High
Loam, sandy clay loam, silt loam, sandy loam	High

Texture	Relative Permeability
Loam, sandy loam	High
Loam, sandy loam, stony loam, stony sandy loam	High
Loam, silt loam	High
Loam, Silt loam, Sandy loam	High
Loam, silty clay loam, silt loam	Medium
Loam, Stony loam	High
Loam, stratified very fine sandy loam to silt loam	High
Loam, very fine sandy loam	High
Loamy coarse sand	High
Loamy coarse sand, loamy fine sand, loamy sand	High
Loamy coarse sand, loamy sand	High
Loamy coarse sand, Loamy sand, Sand	High
Loamy fine sand	High
Loamy fine sand, loamy sand	High
Loamy fine sand, loamy sand, sand	High
Loamy sand	High
Loamy sand, sand	High
Loamy sand, sandy loam	High
Loamy sand, silt loam, sandy loam	High
Material	Medium
Muck	Medium
Mucky clay	Low
Mucky clay loam	Medium
Mucky clay loam, Mucky silty clay loam, Mucky silt loam	Low
Mucky clay, mucky silty clay	Low
Mucky peat	Medium
Mucky peat, Muck, Peat	Medium
Mucky peat, Peat	Medium
Paracobbly sandy clay loam, sandy clay, sandy clay loam	High

Texture	Relative Permeability
Peat	Medium
Sand	High
Sand and gravel	High
Sand, g	High
Sandy clay	Medium
Sandy clay loam	Medium
Sandy clay loam, sandy loam	Medium
Sandy loam	High
Sandy loam, material	High
Shaly loam	Low
Silt loam	Low
Silt loam, very fine sandy loam	Low
Silt, silty clay loam, silt loam	Low
Silty clay	Low
Silty clay loam	Low
Silty clay loam, silt loam	Low
Silty clay loam, silt loam, very fine sandy loam	Low
Silty clay, silty clay loam	Low
Sr to gravelly sand to extremely gravelly coarse sand	High
Sr to sand to g	High
Sr to sandy loam to loam	High
Sr to sandy loam to silt loam	High
Sr to very gravelly sandy loam to gravelly sandy loam	High
Stony clay	Low
Stony clay loam, stony loam	Low
Stony clay loam, stony loam, stony silt loam	Low
Stony clay loam, stony sandy clay loam	Low
Stony clay loam, very stony loam	Low
Stony loam	Medium

Texture	Relative Permeability
Stony sandy clay loam	Medium
Stony sandy clay loam, very stony sandy clay loam, extremely stony sandy clay loam	Medium
Stony sandy loam	High
Stratified clay loam to clay	Low
Stratified clay loam to silty clay loam	Low
Stratified clay loam, stratified loamy sand, stratified silty clay, stratified silt loam	Low
Stratified clay, stratified loam, stratified sand, stratified silt loam	Low
Stratified coarse sand to loamy sand	High
Stratified coarse sand to sandy loam	High
Stratified coarse sandy loam to clay loam	High
Stratified coarse sandy loam to fine sandy loam	High
Stratified cobbly sandy loam to cobbly sandy clay loam	High
Stratified extremely cobbly loamy sand to extremely gravelly loamy sand	High
Stratified extremely gravelly coarse sand to gravelly sand	High
Stratified extremely gravelly loamy coarse sand to very gravelly clay loam	High
Stratified extremely gravelly loamy sand to loam	High
Stratified extremely gravelly sand to loamy sand	High
Stratified fine sand to loam	High
Stratified fine sand to sandy loam	High
Stratified fine sandy loam to clay	Medium
Stratified fine sandy loam to sandy clay loam	Medium
Stratified fine sandy loam to silt loam to silty clay loam	Medium
Stratified fine sandy loam to silty clay loam	Medium
Stratified fine sandy loam to very fine sandy loam	High
Stratified fine sandy loam, stratified loam, stratified sandy loam	High
Stratified g to sand	High
Stratified gravelly coarse sand to gravelly sandy loam	High
Stratified gravelly coarse sand to loam	High
Stratified gravelly coarse sand to sand	High

Texture	Relative Permeability
Stratified gravelly coarse sand to sandy loam	High
Stratified gravelly coarse sandy loam to fine sandy loam	High
Stratified gravelly coarse sandy loam to gravelly sandy clay loam	High
Stratified gravelly fine sandy loam to gravelly loam	High
Stratified gravelly loam to clay loam	Medium
Stratified gravelly loam to extremely gravelly sandy clay loam	High
Stratified gravelly loamy sand to gravelly sandy loam	High
Stratified gravelly sand to extremely gravelly sand	High
Stratified gravelly sand to gravelly loam	High
Stratified gravelly sand to gravelly loamy sand	High
Stratified gravelly sandy clay loam to very gravelly clay	Medium
Stratified gravelly sandy loam to cobbly sandy loam	High
Stratified gravelly sandy loam to gravelly clay loam	Medium
Stratified gravelly sandy loam to gravelly loam	High
Stratified gravelly sandy loam to loam	High
Stratified loam to clay	Low
Stratified loam to clay loam	Low
Stratified loam to silt loam	Low
Stratified loam to silty clay loam	Low
Stratified loamy coarse sand to loam	High
Stratified loamy fine sand to fine sandy loam	High
Stratified loamy fine sand to loam	High
Stratified loamy fine sand to silt loam	Medium
Stratified loamy fine sand to silty clay	Medium
Stratified loamy sand to clay loam	High
Stratified loamy sand to fine sandy loam	High
Stratified loamy sand to fine sandy loam to silt loam	High
Stratified loamy sand to loam	High
Stratified loamy sand to sandy clay loam to clay loam	Medium

Texture	Relative Permeability
Stratified loamy sand to sandy loam	High
Stratified loamy sand to silt loam	High
Stratified loamy sand to very fine sandy loam	High
Stratified muck to silty clay loam	Medium
Stratified mucky peat to fine sandy loam to loam to silt loam to silty clay loam	Medium
Stratified mucky silty clay loam to mucky clay	Low
Stratified sand to clay	Medium
Stratified sand to clay loam	Medium
Stratified sand to fine sandy loam	High
Stratified sand to loam	High
Stratified sand to loamy fine sand	High
Stratified sand to loamy sand	High
Stratified sand to silt loam	Medium
Stratified sand to silty clay loam	Medium
Stratified sandy clay loam to clay	Low
Stratified sandy clay loam to clay loam	Low
Stratified sandy clay loam to silty clay loam	Low
Stratified sandy loam to clay	Medium
Stratified sandy loam to clay loam	Medium
Stratified sandy loam to fine sandy loam	High
Stratified sandy loam to gravelly loam	High
Stratified sandy loam to gravelly sand	High
Stratified sandy loam to loam	High
Stratified sandy loam to sandy clay loam	Medium
Stratified sandy loam to silt loam	High
Stratified sandy loam to silty clay loam	Medium
Stratified sandy loam to very gravelly clay loam	Medium
Stratified silt loam	Low
Stratified silt loam to clay	Low

Texture	Relative Permeability
Stratified silt loam to clay loam	Low
Stratified silt loam to silty clay loam	Low
Stratified silt to silt loam	Low
Stratified silty clay loam to clay	Low
Stratified silty clay loam to loam	Low
Stratified silty clay loam to silty clay	Low
Stratified silty clay to clay	Low
Stratified very cobbly sand to very gravelly loamy sand	High
Stratified very cobbly sandy loam to very gravelly sandy loam	High
Stratified very fine sand to silt loam	Medium
Stratified very fine sandy loam to silt loam	Medium
Stratified very fine sandy loam to silty clay loam	Medium
Stratified very gravelly coarse sand to gravelly sand	High
Stratified very gravelly coarse sand to gravelly sandy loam	High
Stratified very gravelly coarse sand to gravelly silt loam	High
Stratified very gravelly coarse sand to very gravelly loamy coarse sand	High
Stratified very gravelly loam to extremely gravelly sandy clay loam	High
Stratified very gravelly loamy coarse sand to gravelly loam	High
Stratified very gravelly loamy coarse sand to gravelly sandy loam	High
Stratified very gravelly loamy sand to clay loam	High
Stratified very gravelly loamy sand to very gravelly loam	High
Stratified very gravelly sand to loam	High
Stratified very gravelly sand to very cobbly loamy sand	High
Stratified very gravelly sand to very gravelly loamy sand	High
Stratified very gravelly sand to very gravelly sandy clay loam	High
Stratified very gravelly sandy clay loam to gravelly clay loam	High
Stratified very gravelly sandy loam to gravelly sandy loam	High
Stratified very gravelly sandy loam to very gravelly clay loam	High
Stratified very gravelly sandy loam to very gravelly sandy clay loam	High

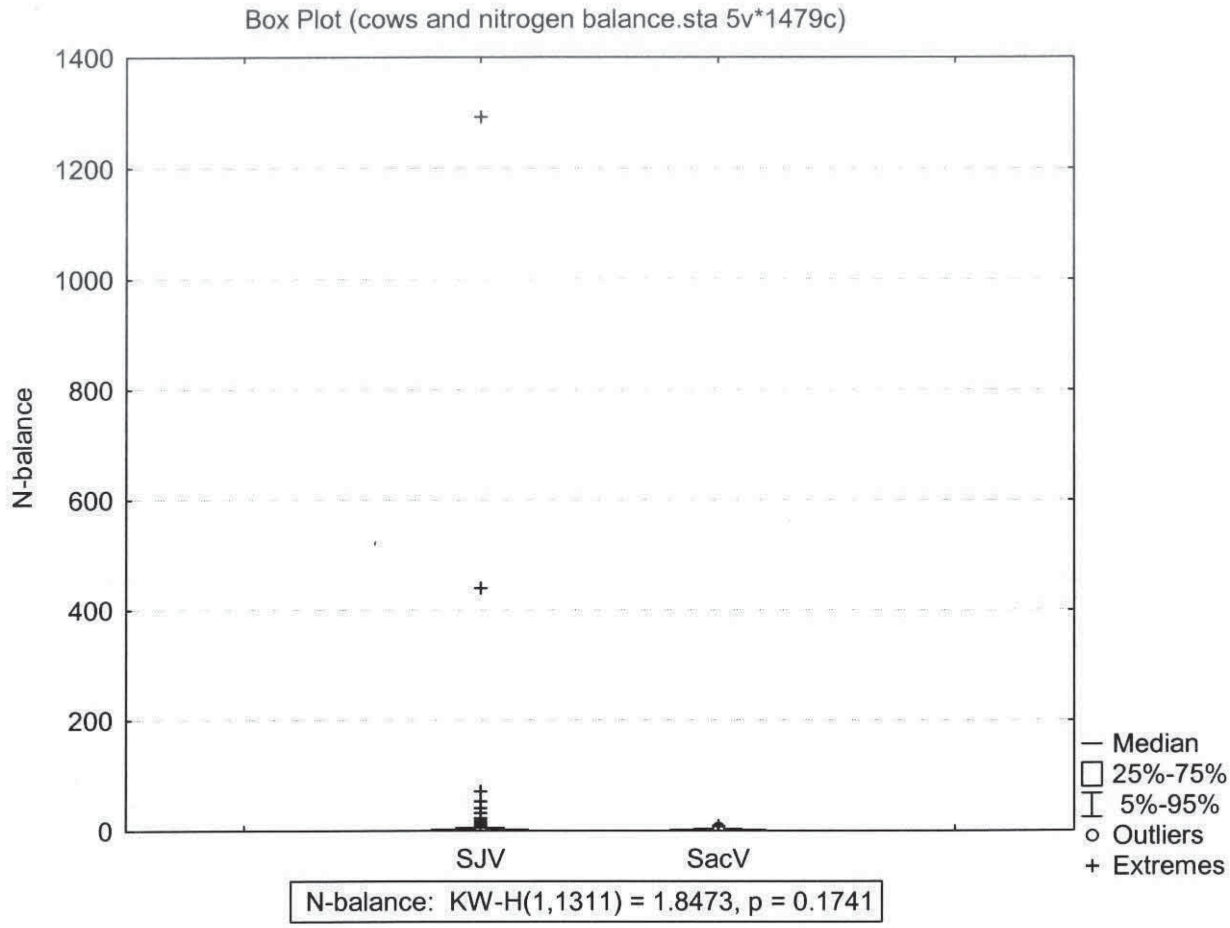
Texture	Relative Permeability
Unweathered bedrock	Low
Variable	Medium
Very bouldery sandy loam, extremely bouldery coarse sandy loam, extremely bouldery loamy coarse sand, cobbly sandy loam, very cobbly sandy loam, extremely cobbly	High
Very bouldery sandy loam, extremely bouldery sandy loam, sandy loam	High
Very channery clay loam, very channery sandy clay loam	Medium
Very cobbly clay	Medium
Very cobbly clay loam	Medium
Very cobbly clay loam, extremely cobbly clay loam	Medium
Very cobbly clay loam, extremely cobbly clay loam, extremely cobbly loam, very gravelly clay loam, very gravelly loam, extremely gravelly clay loam, very stony clay loam,	Medium
Very cobbly clay loam, extremely cobbly clay loam, extremely cobbly sandy clay loam, clay loam, gravelly loam, very gravelly loam, extremely gravelly sandy clay loam, lo	Medium
Very cobbly clay loam, extremely cobbly clay loam, gravelly clay loam, very gravelly clay, very gravelly clay loam, very gravelly sandy clay, very gravelly sandy clay loam, e	Medium
Very cobbly clay loam, very cobbly loam	Medium
Very cobbly clay loam, very cobbly loam, extremely cobbly clay loam, extremely cobbly loam, extremely gravelly clay loam, extremely gravelly loam	Medium
Very cobbly clay loam, very cobbly loam, extremely cobbly clay loam, extremely cobbly loam, very gravelly clay loam, very gravelly loam, extremely gravelly clay loam	Medium
Very cobbly clay loam, very cobbly loam, very cobbly sandy clay loam, very cobbly sandy loam, gravelly clay loam, gravelly loam, gravelly sandy clay loam, gravelly sandy	Medium
Very cobbly clay, very cobbly sandy clay	Medium
Very cobbly fragmental material	High
Very cobbly loam	High
Very cobbly loam, extremely cobbly loam	High
Very cobbly loam, gravelly clay loam, gravelly loam, very gravelly clay loam, very gravelly loam, extremely gravelly clay loam	High
Very cobbly loam, very cobbly sandy loam	High
Very cobbly loam, very cobbly sandy loam, extremely cobbly sandy loam, gravelly sandy clay loam, gravelly sandy loam, very gravelly loam, very gravelly sandy loam, ext	High
Very cobbly loam, very cobbly sandy loam, gravelly sandy clay loam, gravelly sandy loam, very gravelly loam, very gravelly sandy clay loam, very gravelly sandy loam, san	High
Very cobbly loam, very gravelly clay loam, very gravelly loam	High
Very cobbly loam, very gravelly clay loam, very gravelly loam, extremely gravelly clay loam, extremely gravelly loam	High
Very cobbly loam, very gravelly sandy loam	High
Very cobbly loamy sand	High
Very cobbly loamy sand, stratified cobbly sand to gravelly loamy sand	High
Very cobbly loamy sand, very cobbly sand, very cobbly sandy loam, extremely cobbly loamy sand, extremely cobbly sand, extremely cobbly sandy loam	High

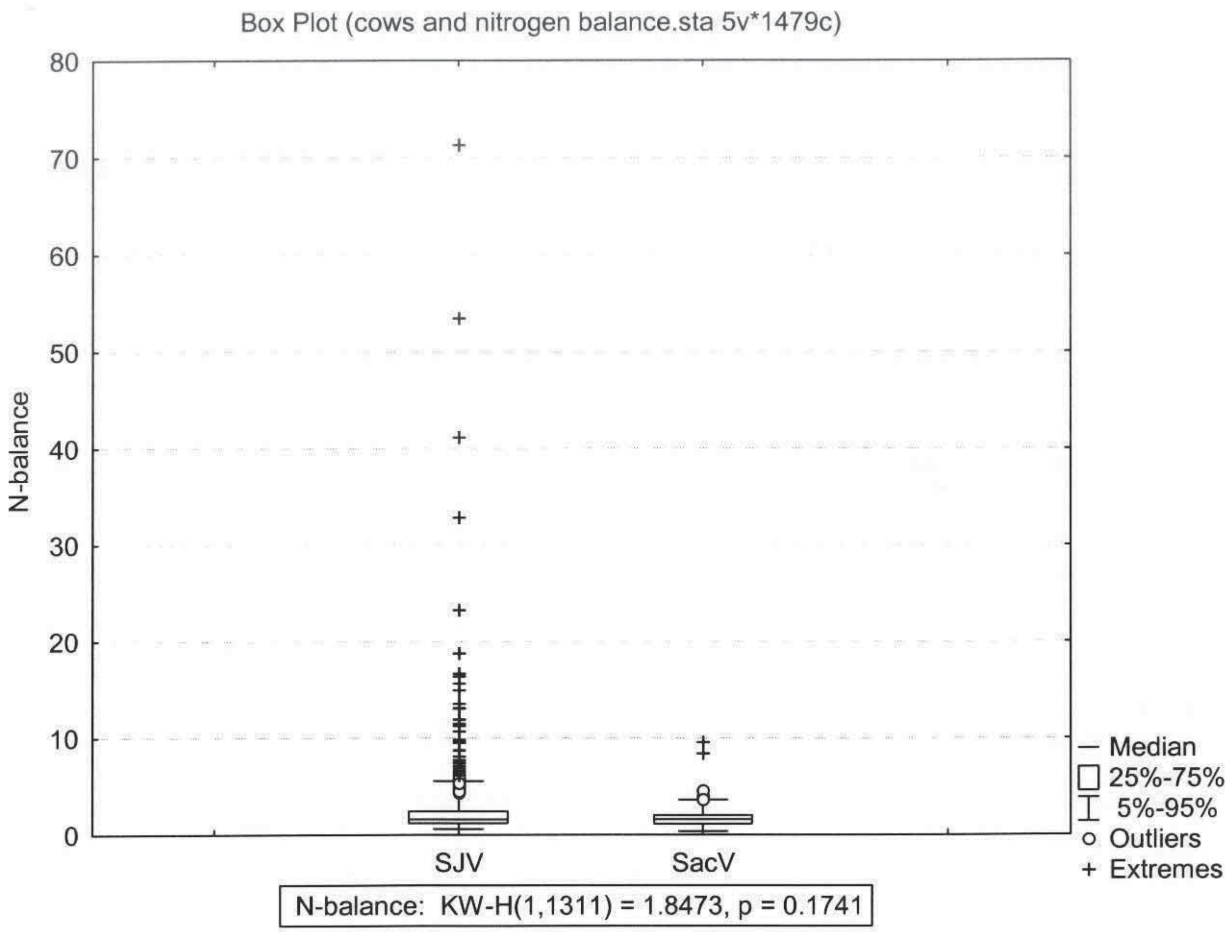
Texture	Relative Permeability
Very cobbly loamy sand, very gravelly loamy sand	High
Very cobbly sandy clay loam, extremely cobbly sandy clay loam, extremely gravelly sandy clay, extremely gravelly sandy clay loam	High
Very cobbly sandy loam	High
Very cobbly sandy loam, extremely stony sandy loam	High
Very cobbly sandy loam, Very gravelly sandy loam	High
Very fine sandy loam	High
Very gravelly clay	Medium
Very gravelly clay loam	Medium
Very gravelly clay loam, Extremely gravelly clay loam	Medium
Very gravelly clay loam, very gravelly loam	Medium
Very gravelly clay loam, very gravelly loam, extremely gravelly clay loam	Medium
Very gravelly clay loam, very gravelly loam, very gravelly sandy clay loam	Medium
Very gravelly clay loam, very gravelly sandy clay loam	Medium
Very gravelly clay loam, very gravelly sandy clay loam, extremely gravelly clay loam	Medium
Very gravelly clay, very gravelly clay loam	Medium
Very gravelly coarse sand, extremely gravelly coarse sand, extremely gravelly sand	High
Very gravelly coarse sand, Very gravelly sand, Extremely gravelly coarse sand	High
Very gravelly coarse sandy loam	High
Very gravelly coarse sandy loam, very gravelly fine sandy loam, very gravelly sandy clay loam, very gravelly sandy loam, extremely gravelly sandy loam	High
Very gravelly fine sandy loam, extremely gravelly coarse sandy loam, extremely gravelly sandy loam, very stony loam	High
Very gravelly fine sandy loam, very gravelly sandy clay loam, very gravelly sandy loam, extremely gravelly fine sandy loam, extremely gravelly sandy clay loam, extremely	High
Very gravelly loam	High
Very gravelly loam, very gravelly sandy clay loam, very gravelly sandy loam, very stony loam	High
Very gravelly loam, very gravelly sandy loam	High
Very gravelly loam, Very gravelly sandy loam, Extremely gravelly sandy loam	High
Very gravelly loam, very gravelly silt loam	High
Very gravelly loamy coarse sand	High
Very gravelly loamy coarse sand, very gravelly loamy sand, very gravelly sand, very gravelly sandy loam, extremely gravelly loamy coarse sand, extremely gravelly loamy	High
Very gravelly loamy sand, very gravelly sandy loam	High

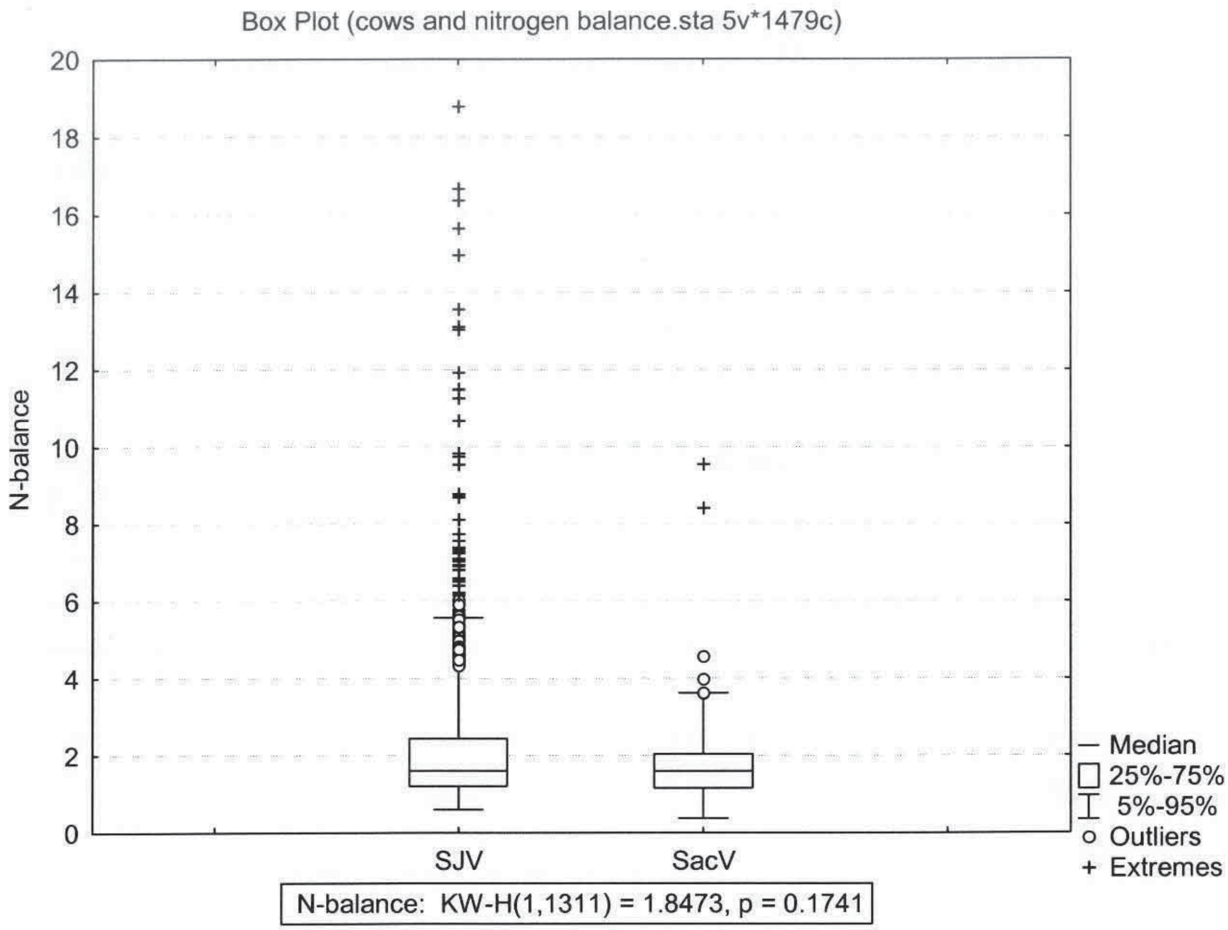
Texture	Relative Permeability
Very gravelly loamy sand, very gravelly sandy loam, extremely gravelly loamy sand, extremely gravelly sandy loam	High
Very gravelly loamy sand, very gravelly sandy loam, extremely gravelly sandy loam, extremely gravelly sandy loam	High
Very gravelly medial sandy loam, extremely gravelly medial coarse sandy loam, extremely gravelly medial loamy coarse sand	High
Very gravelly sand	High
Very gravelly sand, extremely gravelly loamy sand	High
Very gravelly sand, extremely gravelly sand	High
Very gravelly sandy clay	High
Very gravelly sandy clay loam	High
Very gravelly sandy clay loam, extremely gravelly clay loam, extremely gravelly sandy clay loam	High
Very gravelly sandy clay loam, extremely gravelly sandy clay loam	High
Very gravelly sandy clay loam, very gravelly sandy loam	High
Very gravelly sandy clay loam, very gravelly sandy loam, extremely gravelly sandy clay loam, extremely gravelly sandy loam	High
Very gravelly sandy loam	High
Very gravelly sandy loam, extremely gravelly sandy loam	High
Very gravelly sandy loam, stratified sandy loam to clay loam	High
Very gravelly silt loam	Medium
Very stony clay loam	Low
Very stony clay loam, very stony loam	Medium
Very stony coarse sandy loam, Very stony sandy loam	High
Very stony loam	High
Very stony silt loam	Medium
Weathered bedrock	Medium

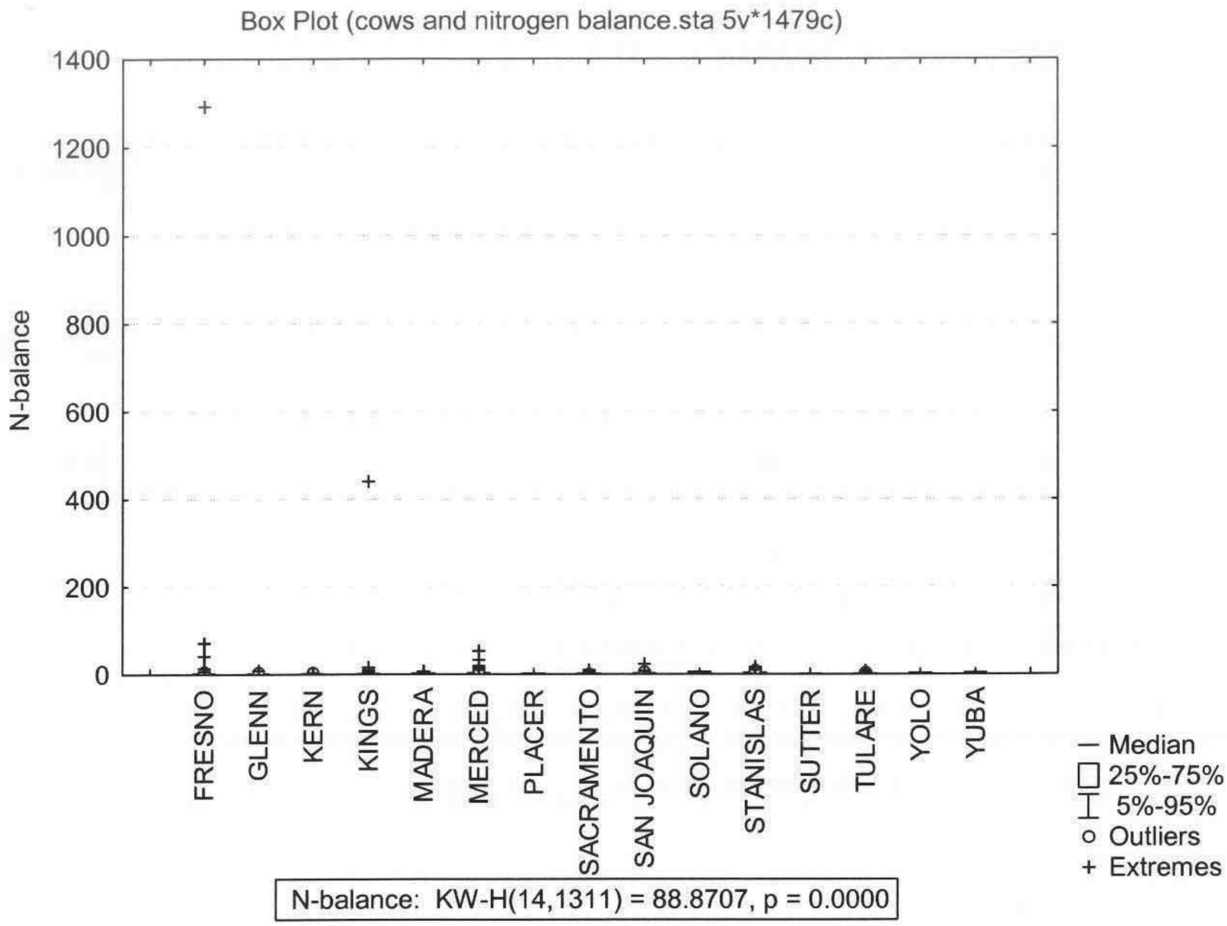
Attachment 6

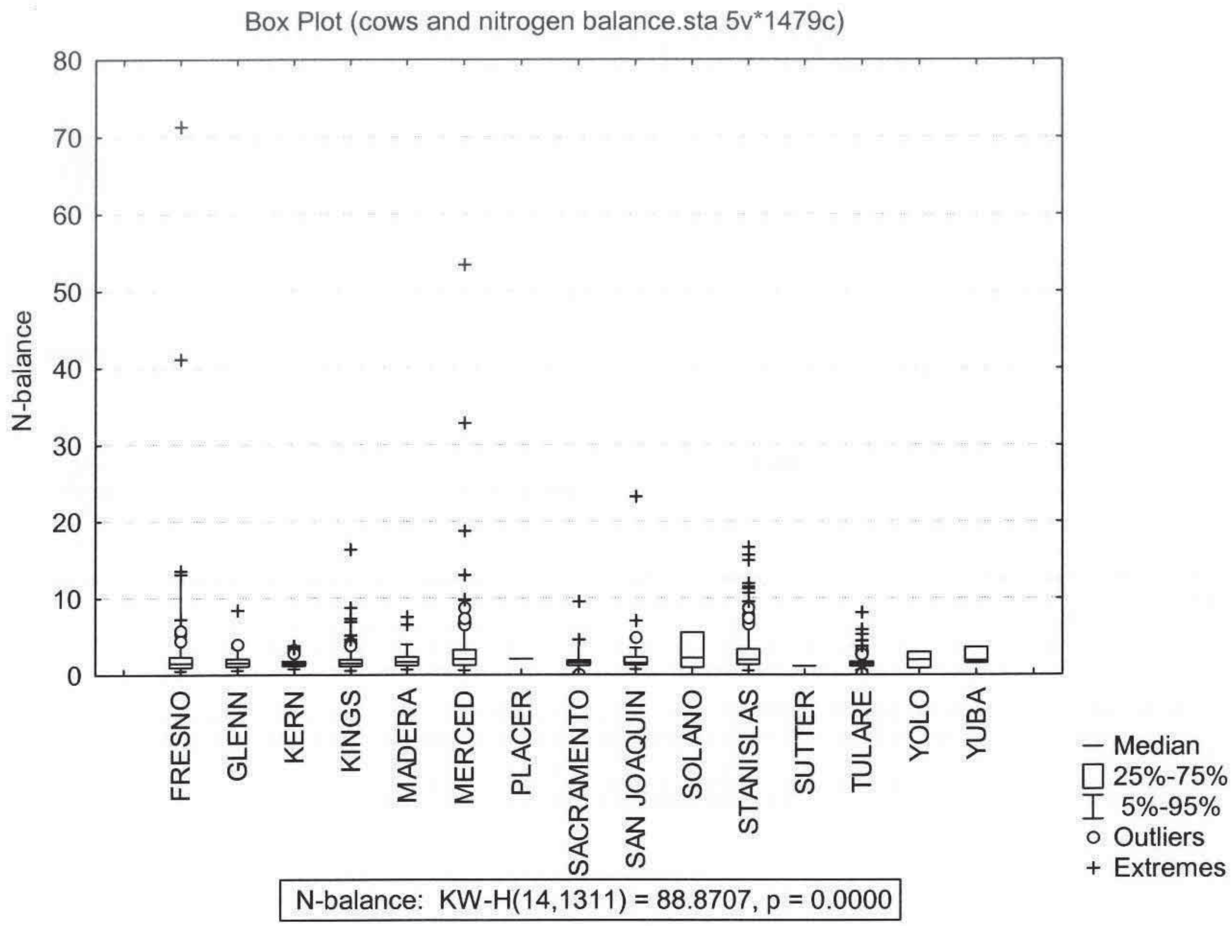
Comparison of Whole Farm Nitrogen Balances

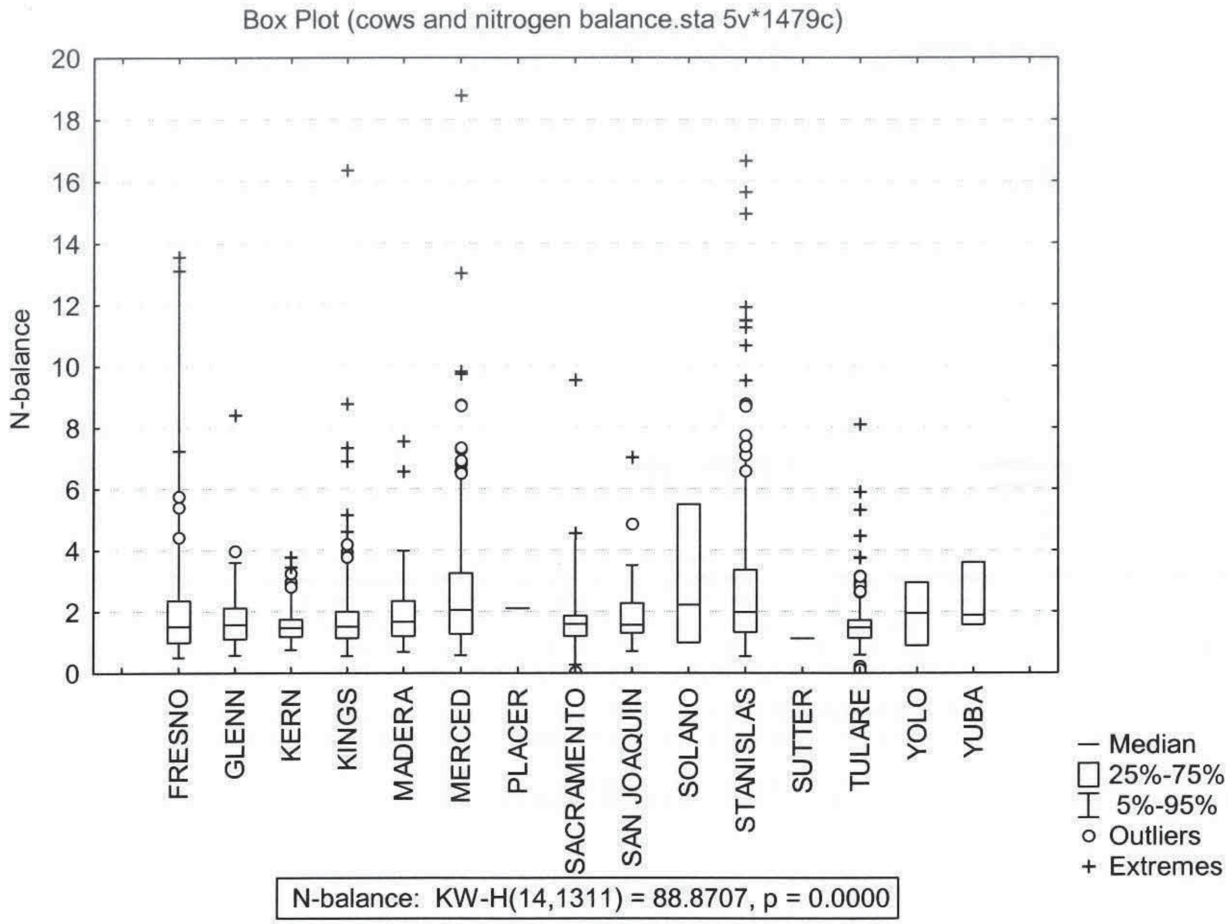

Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
1400
1200
1000
800
600
400
200
0
SJV
SacV
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(1,1311) = 1.8473, p = 0.1741


Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
80
70
60
50
40
30
20
10
0
SJV
SacV
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(1,1311) = 1.8473, p = 0.1741


Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
0
2
4
6
8
10
12
14
16
18
20
SJV
SacV
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(1,1311) = 1.8473, p = 0.1741


Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
1400
1200
1000
800
600
400
200
0
FRESNO
GLENN
KERN
KINGS
MADERA
MERCED
PLACER
SACRAMENTO
SAN JOAQUIN
SOLANO
STANISLAS
SUTTER
TULARE
YOLO
YUBA
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(14,1311) = 88.8707, p = 0.0000


Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
80
70
60
50
40
30
20
10
0
FRESNO
GLENN
KERN
KINGS
MADERA
MERCED
PLACER
SACRAMENTO
SAN JOAQUIN
SOLANO
STANISLAS
SUTTER
TULARE
YOLO
YUBA
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(14,1311) = 88.8707, p = 0.0000



Box Plot (cows and nitrogen balance.sta 5v*1479c)
N-balance
20
18
16
14
12
10
8
6
4
2
0
FRESNO
GLENN
KERN
KINGS
MADERA
MERCED
PLACER
SACRAMENTO
SAN JOAQUIN
SOLANO
STANISLAS
SUTTER
TULARE
YOLO
YUBA
Median
25%-75%
5%-95%
Outliers
Extremes
N-balance: KW-H(14,1311) = 88.8707, p = 0.0000

Attachment 2

Construction Details of Existing Monitoring Wells

Attachment 2
Construction Details of Existing Monitoring Wells
Phase 1 Representative Groundwater Monitoring Workplan

Well Identification	Total Well Depth (feet below ground surface)	Screened Interval (feet below ground surface)	Casing Diameter (inch)	Casing Material	Reference Point Elevation (feet, above mean sea level)
East Side					
ANC-MW1	24	tbd	2	PVC	tbd
ANC-MW2	35	tbd	2	PVC	tbd
ANC-MW3	25	tbd	2	PVC	tbd
ANC-MW4	33	tbd	2	PVC	tbd
COT-MW-1	30	15-30	2	PVC	113.99
COT-MW-2	35	20-35	2	PVC	115.37
COT-MW-3	30	15-30	2	PVC	112.78
COT-MW-4	25	10-25	2	PVC	112.48
COT-MW-5	23	8-23	2	PVC	109.67
COT-MW-6	23	8-23	2	PVC	109.22
COT-MW-7	25	10-25	2	PVC	108.36
COT-MW-8	22	12-22	2	PVC	107.47
COT-MW-9	25	10-25	2	PVC	107.88
COT-MW-10	10	10-20	2	PVC	103.17
West Side					
MOO-MW1	25	5-25	4	PVC	75.58
MOO-MW2	29	9-29	4	PVC	73.01
MOO-MW3	25	5-25	4	PVC	72.05
MOO-MW4	25	5-25	4	PVC	74.28

tbd = to be determined

Attachment 3

Example field sheet for groundwater sampling

Field Purge Data (Monitoring Wells)

Client	Date	Project No.
Project	Measured/Collected by (Initial)	

Well ID	Total Well Depth (ft)	Casing Diameter (in) PVC / Steel
Static DTW (ft)	Standing Water Column (ft)	
Standing Water Column (ft) x 0.16 (for 2" casing); 0.37 (for 3" casing); 0.65 (for 4" casing); 1.0 (for 5" casing); 1.5 (for 6" casing); 2.6 (for 8" casing) = Wet Casing Volume, Vc (gal)		3 Vc (gal)

Clock Time	Pumping Time (min)	Flow Rate (gpm)	Cumulative Flow (gal)	DTW (ft)	Temp (°F / °C)	pH	Spec. Cond. temp. comp. to 25 °C (µS/cm)	Turbidity (NTU)	DO (mg/L)	ORP (milliVolt)	Observations (e.g., color, odor)

Notes / Water Sample Collection (number of bottles and sample I.D.)

Form last updated December 2006

LUHDORFF & SCALMANINI
CONSULTING ENGINEERS
500 FIRST STREET. WOODLAND, CA 95695