COMMENTS ON HYDROGEOLOGIC POINTS OF CONCERN FOR THE KERN RIVER WATERSHED COALITION AUTHORITY AREA

Regarding Monitoring and Reporting Program Tentative Order R5-2013-XXXX Waste Discharge Requirements General Order for Growers within the Tulare Lake Basin Area that are Members of Third-Party Group

01-KRW-001

Prepared For:

Ernest A. Conant of Young Wooldridge, LLP

Counsel for Kern River Watershed Coalition Authority

Prepared By:

SGI environmental THE SOURCE GROUP, INC.

3478 Buskirk Avenue, Suite 100
Pleasant Hill, CA 94523

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Robert M. Gailey, P.G., C.HG.
Principal Hydrogeologist

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1.0 INTRODUCTION

My name is Robert M. Gailey. I am licensed as a Professional Geologist and Certified Hydrogeologist in the state of California. Having practiced in the field of hydrogeology since 1985, my technical background includes both contaminant and water supply hydrogeology applied to urban, industrial and rural settings. I have technical degrees in Geology/Biology (Bachelor of Science) and Applied Hydrogeology (Master of Science), as well as a Master of Business Administration. My curriculum vitae is attached as Appendix A.

I have been retained on behalf of the Kern River Watershed Coalition Authority (KRWCA) to review and comment on the Monitoring and Reporting Program portion of *Tentative Order R5-2013-XXXX, Waste Discharge Requirements General Order for Growers within the Tulare Lake Basin Area that are Members of a Third-Party Group* dated March 2013. My area of focus is how hydrogeologic characteristics specific to the KRWCA area relate to the groundwater monitoring requirements, specifically the management practice evaluation and trend monitoring requirements for nitrate, stated in the tentative order.

The following information is a brief presentation of my review to date. My evaluation of the salient issues is ongoing and I may present additional comments in the future.

2.0 SUMMARY OF COMMENTS

From a hydrogeologic perspective, the KRWCA area is notably different from other parts of the Tulare Lake Hydrologic Region (TLHR) and also the East San Joaquin Watershed (ESJW) with respect to groundwater basin configuration, hydrologic stresses and depth to first-encountered groundwater. These hydrogeologic differences have the potential to greatly complicate groundwater monitoring as described in the tentative order. Among the issues that require additional consideration before the order is finalized are:

1. Time lags between agricultural activities at ground surface and changes in groundwater quality as a result of a thick unsaturated zone,
2. Nitrate residing in the unsaturated zone that acts as an ongoing source to groundwater years after nitrogen is applied at ground surface,
3. Processes acting on return flows during transit through the unsaturated zone,
4. Horizontal migration within the saturated zone and the resulting difficulty in attributing observed nitrate to specific source areas, and
5. The potential costs of an insufficiently planned groundwater quality monitoring program and the need for further study, or a pilot program as an interim regulatory step before any full-scale monitoring occurs.

The above-referenced points call into question the scientific basis, efficacy and cost effectiveness of groundwater monitoring as currently required in the tentative order and should be addressed in finalizing the tentative order.

3.0 PHYSICAL BACKGROUND

Figure 1 indicates the boundary of the KRWCA area. This area, a subsection of the South San Joaquin Valley Water Quality Coalition (SSJVWQC) and TLHR areas, contains a significant portion of Kern County and small portions of Tulare and Kings Counties, and is based upon water district boundaries. The primary groundwater subbasin in the KRWCA area as defined by the California Department of Water Resources (DWR) is the Kern County Subbasin (DWR Subbasin 5-22.14); however, small portions of the Tulare Lake and Tule subbasins (DWR Subbasins 5-22.12 and 5-22.13) are also included in the northern portion of the area. While Attachment A of the tentative order (Information Sheet) provides a brief summary of the geology, hydrogeology and groundwater quality for the TLHR area as a whole, the following sections present pertinent information on these topics specific to the KRWCA area.

3.1 Geology

The KRWCA area geology consists of sedimentary deposits located in the southernmost portion of the San Joaquin Valley that have been derived from the surrounding mountain ranges. The shallower deposits are continental in origin with a range of types that generally include alluvial fan, lacustrine and river (Page, 1986 and Gronberg et al, 1998). These deposits are as much as 15,000 feet thick resulting from structural deepening of the basin (Lofgren, 1975 and Page, 1986). The combination of deposits throughout the KRWCA area is a heterogeneous assemblage of alluvial fan deposits, both coarse- and fine-grained, interfingered with valley stream (coarser) and lake (finer) deposits (i.e., Wood and Dale, 1964; Dale et al, 1966; Croft, 1972) formed by processes that responded to changes in glacial activity in the Sierra Nevada as described by Weissmann et al (2002).

3.2 Groundwater Hydrology

The KRWCA area is part of a closed groundwater basin (Croft, 1972 and Bertoldi et al, 1991). Natural patterns and rates of groundwater flow, recharge and discharge have been significantly changed as a result of groundwater pumping, surface water importation, crop irrigation and artificial recharge (Bertoldi et al, 1991, Gronberg et al, 1998 and DWR, 2006)[1]. Groundwater pumping performed by, among others, agricultural, municipal and water banking operations extracts in excess of 2 million acre feet of groundwater per year (KCWA, 2008) from locations spread throughout the KRWCA area (Boyle et al, 2012). Recharge operations performed by many water storage districts and other entities (DWR, 2006; KCWA, 2008) introduce water to the subsurface through natural channels, irrigation canals, spreading basins. From 1971 through 2008, recharge operations introduced in excess of 27 million acre feet of water to the subsurface. In addition, some amount of groundwater recharge occurs as a result of irrigation return flows. Locally,

[1] See Figure 2 from Shelton et al (1998) for a graphical depiction of the extensive area within the KRWCA area that is involved in groundwater banking operations.

groundwater generally flows toward locations of groundwater pumping and away from locations of groundwater recharge.

First-encountered groundwater is relatively deep in the KRWCA area. Figures 2a and b display depth to water contours for first-encountered groundwater during the spring of 2010 as determined by the DWR and Kern County Water Agency (KCWA), respectively[2]. The depth to water ranges from as little as approximately 50 feet to as much as approximately 700 feet. Water in much of the area is between 150 and 300 feet deep. Figure 3 displays depth to water contours for first-encountered groundwater during the spring of 1988 as determined by the DWR. Comparison of Figures 2a and 3 indicates that first encountered groundwater is currently deeper than it was approximately two decades ago.

3.3 Groundwater Quality and Potential Sources of Nitrate

Nitrate in first-encountered groundwater is the primary focus of the tentative order. Boyle et al (2012) summarized information on nitrate concentrations in groundwater for the TLHR including the KRWCA area. Burton et al (2012) also investigated the occurrence of nitrate in groundwater in these areas. Several other studies have also investigated nitrate in groundwater in the San Joaquin Valley[3]; however, these studies focused on locations north of the KRWCA area (in other parts of the TLHR and in the ESJW) where, as discussed in later sections of this report, first-encountered groundwater is shallower and water quality impacts appear to be more pronounced.

Potential anthropogenic sources of nitrate to groundwater in the KRWCA area include: confined animal feeding operations, crop agriculture (past and current), dairies, municipal and industrial wastewater and sludge disposal, and septic systems[4]. Figure 4 indicates the current locations of various potential anthropogenic sources of nitrate throughout the KRWCA area, and Figure 5 (adapted from Harter et al, 2012) indicates the relative magnitudes of various sources at present[5]. While crop agriculture is a significant potential source, manure from dairies and other operations is also a significant potential source. Moreover, consideration of current potential sources is not sufficient to fully assess the potential sources of the observed nitrate in groundwater. Because the KRWCA is part of a closed groundwater basin, impacts accumulate over time (KCWA, 2008). Accordingly, Figure 6 builds upon Figure 5 by adding past potential sources starting in 1945 using

[2] The contours presented are for the geographically extensive first-encountered groundwater and do not include the limited areas of shallow groundwater outlined on Figure 2a.

[3] These studies include Botros et al (2012), Botros et al (2009), Burow et al (1998), Burton and Belits (2008), Domagalski et al (2008), Dubrovsky et al (1998), Dubrovsky et al (2010), Fischer and Healey (2008), Green et al (2008a), Green et al (2008b), Harter et al (2005), Landon et al (2010), Lindsey and Ruperet (2012), Onsoy et al (2005), Puckett et al (2008), Schmidt et al (2011), Singleton et al (2011) and Tesoriero (2007).

[4] Burton et al (2012) used available data sets from the KRWCA area to document statistical correlations between nitrate concentrations in groundwater and 1) dissolved oxygen content and 2) proximity to only certain types of crop agriculture (orchards and vineyards) and septic systems.

[5] The results of Harter et al (2012) are presented for discussion purposes. That work has not been reviewed in detail.

the information plotted on figures 7 through 10[6]. When accumulation over time is considered[7], past potential sources related to crop agriculture and manure are revealed as the most significant potential sources with approximately 79 percent of the total potential source contribution. Clearly, understanding the distribution of nitrate in groundwater in the KRWCA area must include consideration of historic activities. While the Central Valley Regional Water Quality Control Board has stated the order will not address the legacy issue in terms of regulating groundwater impacts from past land use practices, these impacts will affect groundwater quality monitoring conducted under the order.

3.4 Differences between KRWCA Area and Areas to the North

The KRWCA area differs from areas located farther north in the San Joaquin Valley: 1) the rest of the SSJVWQC/TLHR area and 2) the East San Joaquin Water Quality Coalition (ESJWQC)/ESJW area. The three points discussed below will be considered in the following sections of this report.

First, the depth to groundwater in the KRWCA area is significantly greater than in the areas located to the north. Table 1 compares the depths to first-encountered groundwater for the groundwater subbasins in the areas being discussed. Groundwater in the KRWCA area is by far the deepest based upon both the averages and maximum data. Boyle et al. (2012) graphically depict this condition (see Figure 2 of the cited document). As a result, it takes longer for agricultural return flows, where they exist, to reach first-encountered water in the KRWCA area.

Second, nitrate impact to first-encountered groundwater is less pronounced in the KRWCA area than it is to the north. Boyle et al. (2012) provide a graphical comparison of the areas (see Figures 41 through 44 of the cited document). Burton et al. (2012) provide statistics that support this conclusion. The aggregate conditions in the KRWCA area (i.e. hydrogeologic conditions and agricultural management practices) appear to be more protective of groundwater quality than is the case for areas located to the north.

Finally, there are significant hydrologic stresses imposed upon the groundwater system in the KRWCA area. With rainfall being approximately one-half to one-third of that for the above-referenced areas located to the north (Williamson et al, 1989; Gronberg et al., 1998), a substantial amount of groundwater pumping occurs in order to meet the water demand. Given the demand on the groundwater resource and decline in water levels over time mentioned in Section 3.2, a substantial amount of groundwater recharge has been performed to maintain the resource. These

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[6] Estimation of past potential nitrate sources (crop, manure and other) for Figure 6 involved scaling the values presented by Harter et al (2012). The scaling value for each category was calculated as the ratio of past (1945 to 2002) to current (2003 to 2007) for an indicator variable that was summed over the two time intervals. For the Crop category, the indicator variable was the product of acres in production (Figure 7) with synthetic nitrogen applied (Figure 8). For the Manure category, the indicator variable was the manure nitrogen applied (Figure 9). For the Other category, the indicator variable was the Kern County population (Figure 10).

[7] It is assumed that all nitrogen is converted to nitrate and there are no losses over time.

pumping and recharge operations have created the potential to induce lateral flow of groundwater and migration of dissolved constituents over significant distances.

Table 1

Summary of Depth to First-Encountered Groundwater within the ESJW and TLHR Areas

DWR Groundwater Subbasin or Group	Minimum	Average	Maximum
East San Joaquin Watershed (ESJWQC)	1	88	277
Kings Subbasin	0	87	254
Kaweah Subbasin	6	102	214
Tulare Lake Subbasin	1	77	309
Tule Subbasin	2	159	440
Kern County Subbasin (KRWCA)	100	265	634

Notes: 1) Results are in feet and rounded to the nearest foot.
2) Analysis performed on DWR monitoring data for spring 2010.
3) Averages were calculated on data declustered at the township-range level.
4) East San Joaquin Watershed water level data from the following DWR groundwater subbasins were used: Chowchilla, Madera, Merced, Modesto and Turlock
5) Consistent with Figures 2a, 2b and 3, the KRWCA entries do not address the limited areas of shallow groundwater outlined in Figure 2a.

4.0 SCIENTIFIC CHALLENGES FOR MONITORING GROUNDWATER QUALITY IN THE KRWCA AREA

The premise for groundwater quality monitoring in the tentative order is that collecting information will allow the effectiveness of irrigation and fertilizer management practices to be evaluated and improved where necessary in order to protect the quality of first-encountered groundwater. However, there are several aspects the hydrogeology in the KRWCA area that will complicate interpretation of the collected monitoring data. As observed in a United States Geological Survey (USGS) study conducted in both the TLHR and the ESJW areas by Burow et al. (2008), "Protection of groundwater for present and future use requires monitoring and understanding of the mechanisms controlling long-term quality of groundwater." The following sections identify some of the more important mechanisms that influence groundwater quality and discuss the implications for the Management Practice Evaluation and Groundwater Trend Monitoring programs required by the tentative order.

4.1 A Thick Unsaturated Zone Creates Time Lags Between Activities at Ground Surface and Changes in Groundwater Quality at Depth

As indicated on figures 2a and b, the depth to first-encountered groundwater in the KRWCA area varies greatly. Table 1, presented previously, summarizes the range in depth to water across the area and compares this condition to other areas within the TLHR and ESJW areas. Most of the studies conducted in the San Joaquin Valley and cited in the tentative order as a basis for regulating irrigated agriculture have been conducted in areas other than the KRWCA area, in areas where groundwater is much shallower. As indicated on Figure 11, the depth to first-encountered groundwater in the vast majority of the KRWCA area is much greater than that in the types of studies referenced in the tentative order[8]. The significant distance between ground surface and first encountered groundwater over much of the KRWCA area (hundreds of feet) increases transit times for return flows migrating down through the unsaturated zone to saturated groundwater. This condition creates a time lag between 1) irrigation and nitrogen management activities at ground surface and 2) changes in the quality of first-encountered groundwater[9].

Appendix B presents the results of nitrate travel time calculations for bulk flow through the unsaturated zone under the range of conditions that occur in the KRWCA area. Both agronomic factors (return flow and nitrogen lost below root zone) and hydrogeologic factors (unsaturated zone stratigraphy and depth to first encountered groundwater) were considered. The results indicate that nitrate may reach first-encountered groundwater in as little as 10 to 15 years in some areas, but requires many decades to several centuries for the migration path to be completed in other

[8] See references in Footnote #3.

[9] This condition may exist in other parts of the TLHR and in some parts of the ESJW as well. However, the greater depths to groundwater in the KRWCA area make the condition more significant to the interpretation of groundwater quality in the KRWCA area.

areas where first encountered groundwater is deeper. It is acknowledged that a variety of processes may lead to a range of travel times with migration occurring faster or slower than the estimates presented here[10]. However, it appears that the processes are very site-specific and those which might lead to faster migration are not likely to occur consistently over significant unsaturated zone thicknesses and across changes in lithology (i.e., interlayered sands and clays). This view is consistent with research conducted on relatively thick unsaturated zones[11]. Furthermore, these calculations are consistent with the observation that water quality is less impacted in the KRWCA area than in the northern portion of the TLHR and the ESJW where groundwater is generally shallower (see Section 3.4).

The implication of the presence of a thick unsaturated zone across much of the KRWCA area is that a significant portion of the nitrate from past fertilization practices currently remains in-transit in the unsaturated zone. As a result, current changes in groundwater quality are associated with return flows resulting from past farm practices as opposed to current practices. A trend monitoring program conducted under such conditions cannot meet the monitoring goals of the tentative order because there is a temporal disconnect between actions at ground surface and reactions in groundwater located at depth. Changing current irrigation and fertilization practices cannot affect what has occurred in the past.

4.2 Nitrate in the Unsaturated Zone Acts as an Ongoing Source to Groundwater

In situations where transit times from ground surface to first-encountered groundwater are significant (many years or more), the unsaturated zone effectively acts as a reservoir for nitrate to be released to groundwater at a later time. This condition complicates trend monitoring and makes effective regulation of current farm practices very difficult.

While some researchers have interpreted data for shallow groundwater sites to indicate that nitrate migrates through the unsaturated zone quickly and leaves little residual, this does not appear to be the case in much of the KRWCA area partly because first-encountered groundwater is deep and the unsaturated zone has a significant storage capacity. Figure 12 demonstrates that the unsaturated zone can, in fact, act as a long-term reservoir for nitrate. The monitored site was farmed until approximately the year 2000 and then converted into a spreading ground for groundwater recharge. The nitrate concentration in groundwater when the land was used for farming was slightly below the drinking water Maximum Contaminant Level of 45 milligrams per liter (mg/l). After groundwater recharge operations began, the concentration rose to a high of

[10] For faster migration, these processes may include anion exclusion, fingering, funneling and flow along high hydraulic conductivity pathways. For slower migration, these processes may include physical interaction with soil, diffusion into slow velocity or immobile zones and denitrification under some conditions (Kung, 1990a and 1990b; Green and Bekins, 2010).

[11] McMahon et al. (2006) evaluated the transit times for chemicals through thick unsaturated zones in the High Plains region of the United States. For irrigated croplands with unsaturated zone thicknesses ranging from approximately 55 to 160 feet, they found that travel times to groundwater varied between approximately 50 and 370 years.

slightly more than 80 mg/l, and the elevated concentrations persisted for more than a decade as the newly established recharge operation continued. A reasonable interpretation of this information is that 1) the downward migration rate through the unsaturated zone increased as a result of the recharge operation, 2) groundwater concentrations increased as a result of the large amount of nitrate from past farming migrating downward at an increased rate and 3) the increased nitrate concentrations persisted because the reservoir of nitrate in the unsaturated zone was large[12]. Most recently, the nitrate concentrations in groundwater have begun to decrease. This development may be the result of the nitrate reservoir in the unsaturated zone being depleted over time by the flushing associated with the recharge operation.

Figure 13 presents data from an area not used as a spreading ground. Here, there is clearly a positive correlation between water level and nitrate concentration. Although the monitoring data early in the period of record are sparse, a reasonable interpretation of this information is that the unsaturated zone acts as a reservoir for nitrate which is released to groundwater during periods of high water levels when saturated groundwater conditions rise up into previously unsaturated sediments. As a result, in order for groundwater quality trend monitoring to be effective, the legacy issue discussed above must be considered and incorporated into the approach before the tentative order is finalized.

4.3 Processes Acting on Return Flows During Transit Through the Unsaturated Zone Can Affect Trends Observed in First-Encountered Groundwater

As noted above, several processes can lead to a range of travel times through the unsaturated zone beneath a single parcel. When thick unsaturated zones and long travel times to groundwater are also involved, there is the potential to mix older and younger return flows at the point where faster and slower migration paths terminate (first-encountered groundwater). To the extent that these flows are significantly different in age, they may have originated during times of different nitrogen management practices. Mixing of such flows could blur differences in water quality trends associated with past and current management practices that might otherwise be apparent.

The processes involved in creating the different flows may include 1) for faster migration, anion exclusion, fingering, funneling and flow along high hydraulic conductivity pathways and 2) for slower migration, physical interaction with soil, diffusion into slow velocity or immobile zones (Green et al., 2005) and denitrification under some conditions[13] (Dubrovsky et al., 2010; Landon et al., 2010; Schmidt et al. 2011). However, a USGS study conducted in the SSJVWQC area (Burow et al., 2008) noted that “few wells have been sampled over time spans long enough to assess the

[12] This example should not be interpreted as an indication that all recharge operations flush nitrate into the saturated zone. Land use history is a very important factor that must be considered. The purpose of this discussion is to provide evidence that past farming practices, as opposed to current farming practices, have added large amounts of nitrate to the unsaturated zone.

[13] For instance, above clay strata where the moisture content may increase and contact with air in the pore space may decrease. The decrease in dissolved oxygen and long travel times could create conditions conducive to nitrate loss by denitrification.

relation between regional management practices and potential long-term degradation of water quality in the eastern San Joaquin Valley aquifer system." So, it isn't clear what unresolved scientific questions may be encountered as the monitoring data are collected. Successful water quality trend analysis requires a favorable signal to noise ratio, and concentration data effectively contain noise when they are affected by processes that are not understood. Therefore, travel through a thick unsaturated zone is expected to increase the noise and complicate interpretation of actual trends unless the processes acting on the return flows are understood. The complexities that may be encountered during monitoring should be considered before the large-scale monitoring program in the tentative order is finalized. One approach for acquiring the necessary experience with monitoring deep groundwater would be to conduct a pilot monitoring program in a small portion of the KRWCA area.

4.4 Horizontal Flows in Subbasin Can Complicate the Attribution of Observed Nitrate to Specific Source Areas

As noted in Section 3 above, the KRWCA area is located within a closed groundwater basin that experiences relatively large artificial hydrologic stresses in the forms of water supply well pumping and recharge operations. In addition, many potential sources of nitrate are located close together (Figure 4). Under these conditions, nitrate from different sources likely mixes. In fact, a study of domestic well water quality in the SSJVWQC area (Singleton et al., 2011) found that many wells contained mixtures of nitrate from many sources (manure, fertilizer and septic/community wastewater). This finding is consistent with a USGS study conducted in the SSJVWQC area (Burow et al., 2008) that noted "Predicting the long-term fate of nitrate and pesticides in ground water in this region is difficult owing to intensive ground water pumping, mixed sources of recharge water, and complex flow paths through heterogeneous alluvial fan sediments." This situation can make the Management Practice Evaluation Program quite difficult to implement as existing water quality impacts may not be attributable to the monitored, or even specific, locations.

In addition, horizontal migration can induce changes in concentrations over time and complicate Trend Monitoring. Figure 14 provides an example. Two fairly similar periods of high water are contained in the plotted record; however, the concentration responses during those periods are quite different. The history of extraction and recharge in this part of the subbasin is indicated along the top of the figure.` While changes in the locations of extraction and recharge are not indicated, it is clear that there are differences in timing, duration and the cumulative magnitude of the hydrologic stresses. A reasonable interpretation of this information is that nitrate in the saturated zone migrates horizontally under the influence pumping and recharge.

In another USGS study that included locations in the San Joaquin Valley, Rupert (2008) noted the complexities associated with evaluating trends in groundwater quality data. Two of the points made were that 1) it is difficult to evaluate trends unless the recharge age is known so that correlation with changes in land use can be made and 2) changes in oxidation-reduction conditions can significantly affect trends. These are just some of the complexities that should be considered and evaluated before the large-scale monitoring program in the tentative order is finalized.

4.5 The Potential Costs of Insufficiently Planned Groundwater Quality Monitoring are Significant

Evaluations of potential costs associated with the monitoring programs required in the tentative order have been made on behalf of the State and continue to be revised. While a final assessment of the costs has not yet been prepared, it is clear that the program will be costly. Moreover, costs in the KRWCA area are likely to be higher than the average for the SSJVWQC area because the depth to first-encountered groundwater is greater than in other parts of the SSJVWQC area. Given the costs, details of the monitoring program should be carefully planned to increase the likelihood of successful implementation. Consideration of the issues raised above should be incorporated into that planning. The primary implication of these issues is that the monitoring program goals (evaluating the effectiveness of irrigation and fertilizer management practices and improving them where necessary in order to protect the quality of first-encountered groundwater) may not be achievable through the monitoring programs required in the tentative order. That possibility stems from problems with data interpretation that may be encountered, for the reasons stated above, when trying to attribute water quality conditions to farming activities at specific locations and times.

Potentially more costly than implementation of a flawed monitoring program would be regulatory required changes in farm management practices based upon incorrect conclusions from an insufficiently planned monitoring program (i.e., possibly contained in Groundwater Quality Management Plans). Acting on false positives would not achieve the goals of the monitoring program and would create additional costs (both direct costs associated with compliance activities and opportunity costs associated with any decreases in yield) for farmers. Further study or, possibly, a pilot program as an interim regulatory step should be considered before creating a comprehensive set of monitoring regulations given the, as yet, rudimentary understanding of how nitrate moves through subsurface in the KRWCA area.

5.0 COMMENTS ON SPECIFIC ASPECTS OF THE ORDER

The following sections highlight some of the more obvious shortcomings of the tentative order if it were applied to the KRWCA area. These comments are not intended to be presented as a comprehensive evaluation of the tentative order.

5.1 General Order

The details set forth in Section VIII (Required Reports and Notifications – Third Party) D (Groundwater Quality Assessment Report and Evaluation/Monitoring Workplans) involve 1) evaluation of groundwater quality vulnerability to impacts from irrigated agriculture (Management Practice Evaluation) and 2) observation of current and future groundwater quality trends attributable to irrigated agriculture (Trend Monitoring). It is important to note that complications associated with identifying sources, or potential sources, of groundwater contamination - both in space (i.e., impacts that migrate away from source locations) and time (i.e., the legacy issue) as noted in Section 4 of this report - will likely be encountered during the performance of the required work. Furthermore, it is likely that more questions than answers will be encountered in many instances. Some recognition of and allowance for these potential technical complications should be included in the tentative order. For example, the development of a Groundwater Quality Management Plan (Section VIII.H.2) should not be required of a current irrigated agricultural operation if there is evidence that an exceedance may have resulted from past (legacy) activities.

5.2 Attachment B – Monitoring and Reporting Program

The reasoning upon which the groundwater portion of this section of the tentative order is based follows from previous sections where there appears to be an implicit assumption that groundwater quality responds to activities occurring at ground surface over a relatively short time period[14]. As an example, Section IV (Groundwater Quality Monitoring and Management Practice Assessment, and Evaluation Requirements) requires that "The third party must collect sufficient data to describe irrigated agricultural impacts on groundwater quality and to determine whether existing or newly implemented management practices comply with the groundwater receiving water limitations of the Order." This task may require decades or more for areas where first-encountered groundwater is located deep beneath the ground surface and transit times are long. (See Section 4.1 of this report for supporting discussion.) Therefore, allowance for potentially long monitoring periods must be reflected in compliance schedules.

As stated above in these comments, there are several complex processes occurring in the KRWCA area that must be interpreted before attempting to link current changes in the quality of first encountered groundwater with current irrigation and fertilizer management practices. As a result, difficulties associated with identifying sources of groundwater contamination – both in space

[14] For the purposes of developing the tentative order, a very simple conceptual model of cause and effect has been applied to a situation where the aggregate effect of active transport processes could be significantly more complicated.

and time – will likely be encountered during the performance of the required work in many instances. Some recognition of and allowance for these potential technical complications should be noted.

Large-scale implementation of the monitoring concept is not appropriate for much of the KRWCA area without further consideration of the issues presented in these comments. Rather, a phased approach should be implemented with initial work being performed on a limited group of areas where technical interpretation of the water quality data is anticipated to be the least complicated. Areas of shallowest first-encountered groundwater may be appropriate candidates for the initial phase of work.

5.3 Appendix MRP-1, Management Plan Requirements, Surface Water and Groundwater

The details presented in Section I (Management Plan Development and Required Components) D (Monitoring Methods) 3 (Groundwater – Additional Requirements) involve evaluation of groundwater quality trend monitoring data in order to draw conclusions regarding additional monitoring requirements. As discussed above, there may be difficulties interpreting the data as a result of unique technical challenges that exist for the KRWCA area. Some recognition of and allowance for these potential technical complications should be noted.

Section I (Management Plan Development and Required Components) G (Source Identification Study Requirements) allows for the identification of sources other than irrigated agriculture that are responsible for groundwater quality impacts. The text should state that past irrigated agriculture is a potential source that is distinct from current irrigated agriculture. It is appropriate to include past irrigated agriculture as a distinct potential source because regulation of current agricultural practices will have no effect on impacts resulting from past practices.

5.4 Appendix MRP-2, Monitoring Well Installation and Sampling Plan and Monitoring Well Installation Completion Report

The reasoning upon which this section of the tentative order is based follows from previous sections where there appears to be an implicit assumption that groundwater quality responds to activities occurring at ground surface over a relatively short time period. As an example, Section II (Monitoring Well Installation and Sampling Plan), A (Stipulations), 4 states that “Groundwater monitoring shall…be of sufficient frequency to allow for evaluation of any seasonal variations.” This assumption is flawed. Please refer to the discussion of complexities associated with the KRWCA area presented above.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the information and analysis presented in the preceding sections of this report, it is clear that hydrogeologic characteristics specific to much of the KRWCA area will greatly complicate and impede implementation of the groundwater monitoring requirements stated in the tentative order. Moreover, the information presented in this report calls into question the scientific basis, efficacy and cost effectiveness of groundwater monitoring as currently required in the tentative order. These points should be addressed in finalizing the tentative order.

It should be noted, however, that there are some relatively small areas within the KRWCA area where the hydrogeology may not impede implementation of monitoring requirements as presented in the tentative order. In areas of shallow first-encountered groundwater (identified approximately with red dashed lines on figures 2a and 3), the depth to groundwater ranges between approximately 0 and 20 feet deep. Given the shallow depth to groundwater in these areas, any water quality responses to current irrigation practices may occur with little delay and trend monitoring may reflect the effects of current irrigation activities. However, impacts to groundwater quality in these areas may have accumulated over time, and current water quality conditions may reflect a combination of effects from past and current irrigation practices. Therefore, it is important that the language in the Tentative Order regarding source identification be modified to categorize past irrigation practices as sources separate from current irrigation operations (see second paragraph of Section 5.3 above).

7.0 REFERENCES

Bertoldi, G.L.., R.H. Johnson and K.D. Evenson. 1991. Ground Water in the Central Valley, California – A Summary Report. U.S. Geological Survey Professional Paper 1401-A. 44 p.

Botros, F.E., T. Harter, Y.S. Onsoy, A. Tuli and J.W. Hopmans. 2009. Spatial Variability of Hydraulic Properties and Sediment Characteristics in a Deep Alluvial Unsaturated Zone. Vadose Zone Journal, 8, 276-289.

Botros, F.E., Y.S. Onsoy, T.R. Ginn and T. Harter. 2012. Richards Equation-Based-Modeling to Estimate Flow and Nitrate Transport in a Deep Alluvial Vadose Zone. Vadose Zone Journal, 11(4), doi: 10.2136/vzj2011.0145.

Boyle, D., A. King, G. Kourakos, K. Lockhart, M. Mayzelle, G.E. Fogg and T. Harter. 2012. Groundwater Nitrate Occurrence, Technical Report 4 in: Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater, Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Science, University of California, Davis. July 2012. 277 p.

Burow, K.R., J.L. Shelton and N.M. Dubrovsky. 1998. Occurrence of Nitrate and Pesticides in Ground Water beneath Three Agricultural Land-Use Settings in the Eastern San Joaquin Valley, California, 1993-1995. U.S. Geological Survey Water-Resources Investigation Report 97-4284. 51 p.

Burow, K.R., J.L. Shelton and N.M. Dubrovsky. 2008. Regional Nitrate and Pesticide Trends in Ground Water in the Eastern San Joaquin Valley, California. Journal of Environmental Quality, 37, S249-S263.

Burton, C.A., J.L. Shelton and K. Belitz. 2008. Ground Water Quality Data in the Southeast San Joaquin Valley, 2005-2006 – Results from the California GAMA Program. U.S. Geological Survey Data Series 351, 103 p.

Burton, C.A., J.L. Shelton and K. Belitz. 2012. Status and Understanding of Groundwater Quality in the Two Southern San Joaquin Valley Study Units, 2005-2006 – California GAMA Priority Basin Project. U.S. Geological Survey Scientific Investigations Report 2011-5218, 150 p.

Croft, M.G. 1972. Subsurface Geology of the Late Tertiary and Quaternary Water-Bearing Deposits of the Southern Part of the San Joaquin Valley, California. U.S. Geological Survey Water-Supply Paper 1999-H. 29 p.

Dale, R.H., J.J. French and G.V. Gordon. 1966. Ground-Water Geology and Hydrology of the Kern River Alluvial-Fan Area, California. U.S. Geological Survey Open-File Report 66-0620. 92 p.

Domagalski, J.L., S.P. Phillips, E.R. Bayless, C. Zamora, C. Kendall, R.A. Wildman Jr. and J.G. Hering. 2008. Influences of the Unsaturated, Saturated, and Riparian Zones on the Transport of Nitrate near the Merced River, California, USA. Hydrogeology Journal, 16, 675-690.

Dubrovsky, N.M., C.R. Kratzer, L.R. Brown, J.M. Gronberg and K.R. Burow. 1998. Water Quality in the San Joaquin – Tulare Basins, California, 1992-1995. U.S. Geological Survey Circular 1159. 38p.

Dubrovsky, N.M., K.R. Burow, G.M. Clark, J.M. Gronberg, P.A. Hamilton, K.J. Hitt, D.K. Mueller, M.D. Munn, B.T. Nolan, L.J. Puckett, M.G. Rupert, T.M. Short, N.E. Spahr, L.A. Sprague and W.G. Wilber. 2010. The Quality of Our Nation's Waters – Nutrients in the Nation's Streams and Groundwater, 1992-2004. U.S. Geological Survey Circular 1350. 174p.

DWR. 2006. California's Groundwater (section on San Joaquin Valley Groundwater Basin, Kern County Subbasin). California Department of Water Resources Bulletin 118, updated January 20, 2006. (http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/5-22.14.pdf, last accessed 1/10/13).

Fisher, L.H. and R.W. Healey. 2008. Water Movement within the Unsaturated Zone in Four Agricultural Areas of the United States. Journal of Environmental Quality, 37, 1051-1063.

Green, C.T., D.A. Stonestrom, B.A. Bekins, K.C. Akstin and M.S. Schultz. 2005. Percolation and Transport in a Sandy Soil under a Natural Hydraulic Gradient. Water Resources Research, 41, W10414, doi:10.1029/2005WR004061.

Green, C.T., L.J. Puckett, J.K. Bohlke, B.A. Bekins, S.P. Phillips, L.J. Kauffman, J.M. Denver and H.M. Johnson. 2008a. Limited Occurrence of Denitrification in Four Shallow aquifers in Agricultural Areas of the Unites States. Journal of Environmental Quality, 37, 994-1009.

Green, C.T., L.H. Fisher and B.A. Bekins. 2008b. Nitrogen Fluxes through Unsaturated Zones in Five Agricultural Settings across the United States. Journal of Environmental Quality, 37, 1073-1085.

Green, C.T. and B.A. Bekins. 2010. Sustainability of Natural Attenuation on Nitrate in Agricultural Aquifers. U.S. Geological Survey Fact Sheet 2010-3077. 4 p.

Gronberg, J.M., N.M. Dubrovsky, C.R. Kratzer, J.L. Domagalski, L.R. Brown and K.R. Burow. 1998. Environmental Setting of the San Joaquin – Tulare Basins, California. U.S. Geological Survey Water-Resources Investigations Report 97-4205. 45 p.

Harter, T., Y.S. Onsoy, K. Heeren, M. Denton, G. Weissmann, J.W. Hopmans and W.R. Horwath. 2005. Deep Vadose Zone Hydrology Demonstrates Fate of Nitrate in Eastern San Joaquin Valley. California Agriculture, 59(2), 124-132.

Harter, T., J.R. Lund, J. Darby, G.E. Fogg, R. Howitt, K.K. Jessoe, G.S. Pettygrove, J.F. Quinn and J.H. Viers (Investigators). 2012. Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater, Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Science, University of California, Davis. January 2012. 78 p.

KCWA. 2008. Water Supply Report: 2008. Kern County Water Agency. 79 p.

Kung, K-J.S. 1990a. Preferential Flow in a Sandy Vadose Zone:1. Field Observation. Geoderma, 46, 51-58.

Kung, K-J.S. 1990b. Preferential Flow in a Sandy Vadose Zone: 2. Mechanism and Implication. Geoderma, 46, 59-71.

Landon, M.K., K. Belitz, B.C. Jurgens, J.T. Kulongoski and T.D. Johnson. 2010. Status and Understanding of Groundwater Quality in the Central-Eastside San Joaquin Basin, 2006: California GAMA Priority Basin Project. U.S. Geological Survey Scientific Investigations Report 2009-5266. 97 p.

Lindsey, B.D. and M.G. Rupert. 2012. Methods for Evaluating Temporal Groundwater Quality Data and Results of Decadal-Scale Changes in Chloride, Dissolved Solids and Nitrate Concentrations in Groundwater in the United States, 1988-2010. U.S. Geological Survey Scientific Investigations Report 2012-5049. 46 p.

Lofgren, B.E. 1975. Land Subsidence Due to Ground-Water Withdrawal, Arvin-Maricopa Area, California. U.S. Geological Survey Professional Paper 437-D. 55 p.

McMahon, P.B., K.F. Dennehy, B.W. Bruce, J.K. Bohlke, R.L. Michel, J.J. Gurdak and D.B. Hurlbut. 2006. Storage and Transit Time of Chemicals in Thick Unsaturated Zones under Rangeland and Irrigated Cropland, High Plains, United States. Water Resources Research, 42, W03413, doi:10.1029/2005WR004417.

Onsoy, Y.S., T. Harter, T.R. Ginn and W.R. Horwath. 2005. Spatial Variability and Transport of Nitrate in a Deep Alluvial Vadose Zone. Vadose Zone Journal, 4, 41-54.

Page, R.W. 1986. Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections. U.S. Geological Survey Professional Paper 1401-C. 54 p.

Puckett, L.J., C. Zamora, H. Essaid, J.T. Wilson, H.M. Johnson, M.J. Brayton and J.R. Vogel. 2008. Transport and Fate of Nitrate at the Ground-Water/Surface-Water Interface. Journal of Environmental Quality, 37, 1034-1050.

Rupert, M.G. 2008. Decadal-Scale Changes of Nitrate in Ground Water of the United States, 1988-2004. Journal of Environmental Quality, 37, S240-S248

Schmidt, C.M., A.T. Fisher, A. Racz, C.G. Wheat, M. Los Huertos and B. Lockwood. 2011. Rapid Nutrient Load Reduction During Infiltration of Managed Aquifer Recharge in an Agricultural Groundwater Basin: Pajaro Valley, California. Hydrological Processes, wileyonlinelibrary.com, doi: 10.1002/hyp.8320.

Shelton, J.L., I. Pimentel, M.S. Fram and K. Belitz. 2008. Ground-Water Quality Data in the Kern County Subbasin Study Unit, 2006 – Results from the California GAMA Program. U.S. Geological Survey Data Series 337. 75 p.

Singleton, M.J., S.K. Roberts, J.E. Moran and B.K. Esser. 2001. California GAMA Domestic Wells: Nitrate and Water Isotopic Data for Tulare County. Final Report for GAMA Special Studies Task 7.2, Specialized Analyses for GAMA Domestic Wells, LLNL-TR-450497. Lawrence Livermore National Laboratory. January 2001.

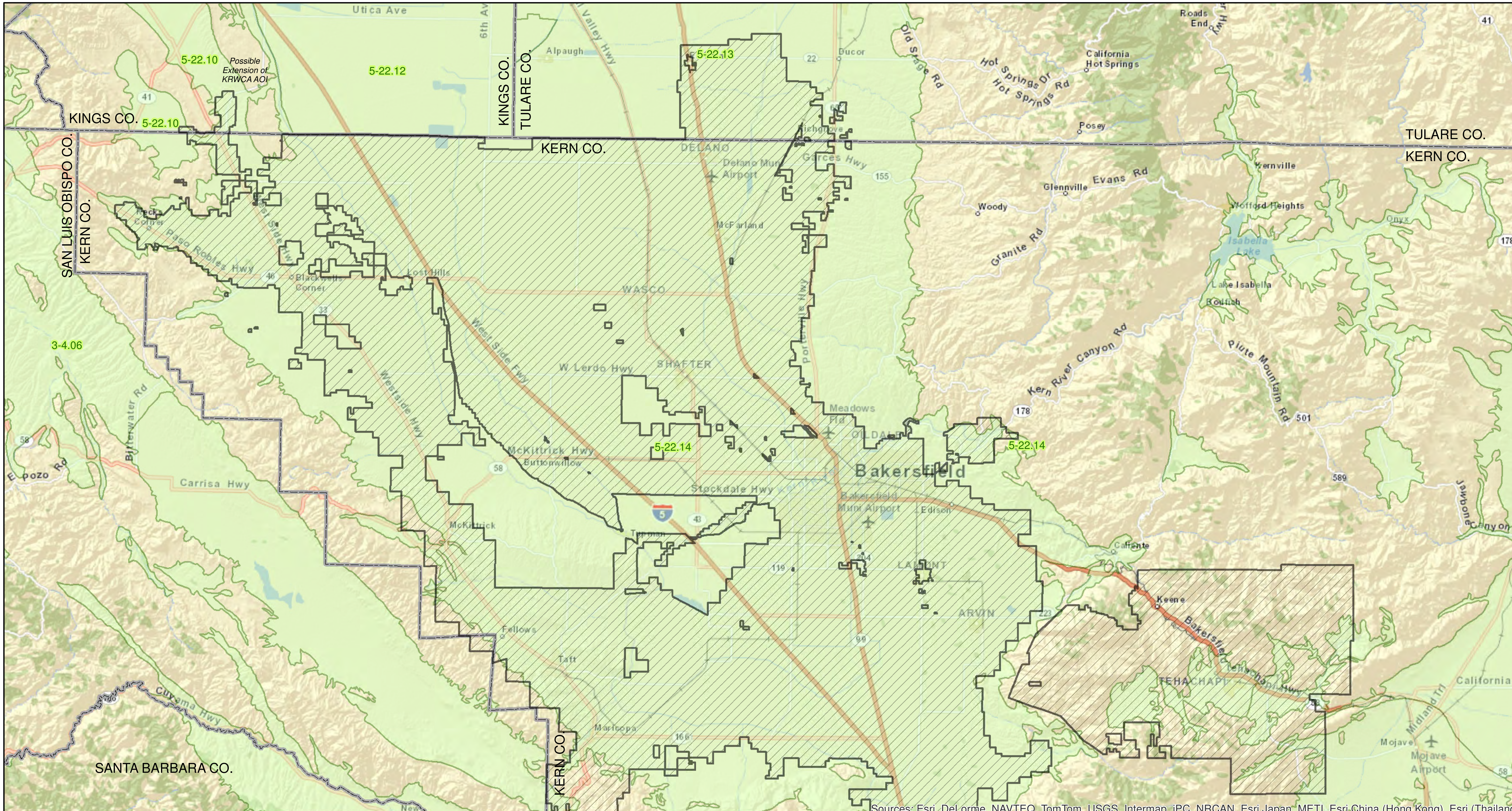
Tesoriero, A.J., D.A. Saad, K.R. Burow, E.A. Frick, L.J. Puckett and J.E. Barbash. 2007. Linking Ground-Water Age and Chemistry Data Along Flow Paths: Implications for Trends and Transformations of Nitrate and Pesticides. Journal of Contaminant Hydrology, 94, 139-155.

Weissmann, G.S., J.F. Mount and G.E. Fogg. 2002. Glacially Driven Cycles in Accumulation Space and Sequence Stratigraphy of a Stream-Dominated Alluvial Fan, San Joaquin Valley, California, U.S.A. Journal of Sedimentary Research, 72(2), 240-251.

Williamson, A.K., D.E. Prudic and L.A. Swain. 1989. Ground-Water Flow in the Central Valley, California. U.S. Geological Survey Professional Paper 1401-D. 127 p.

Wood, P.R. and R.H. Dale. 1966. Geology and Ground-Water Features of the Edison-Maricopa Area Kern County, California. U.S. Geological Survey Water-Supply Paper 1656. 108 p.

FIGURES



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(559) 636-1166

DWR Groundwater Basin/Subbasin (ID Label)
County
KRWCA Boundary

Kern County Irrigated Lands Program
Kern Sub-Watershed

KRWCA Area

FIGURE 1

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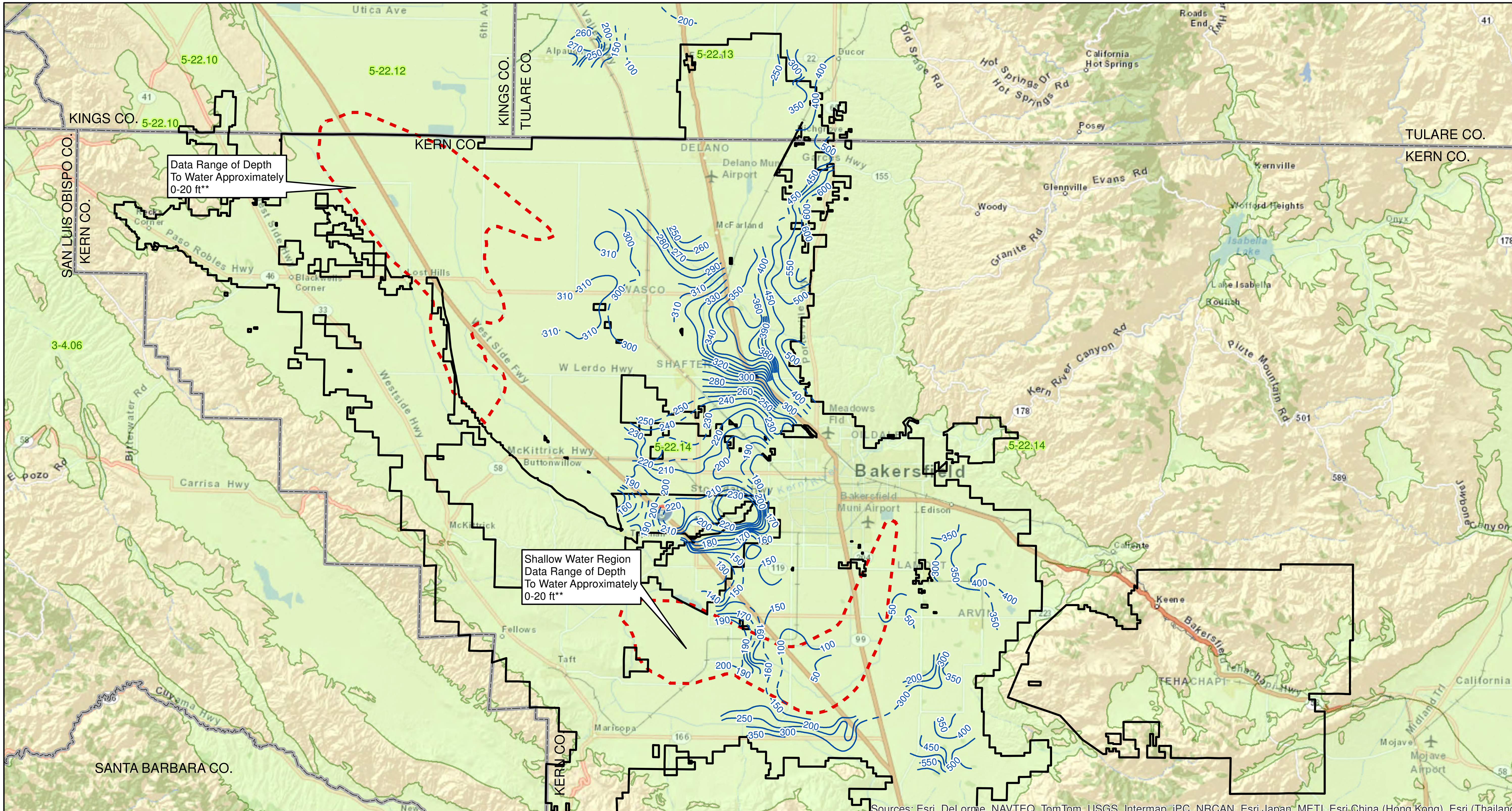

0 5 10 Miles

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DWR Groundwater Basin/Subbasin (ID Label)
County
KRWCA Boundary
Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

High Degree of Confidence
Inferred

Data References:

**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, 2010
http://www.water.ca.gov/pubs/drainage/2010_shallow_groundwater_map__san_joaquin_valley/sgw10.pdf

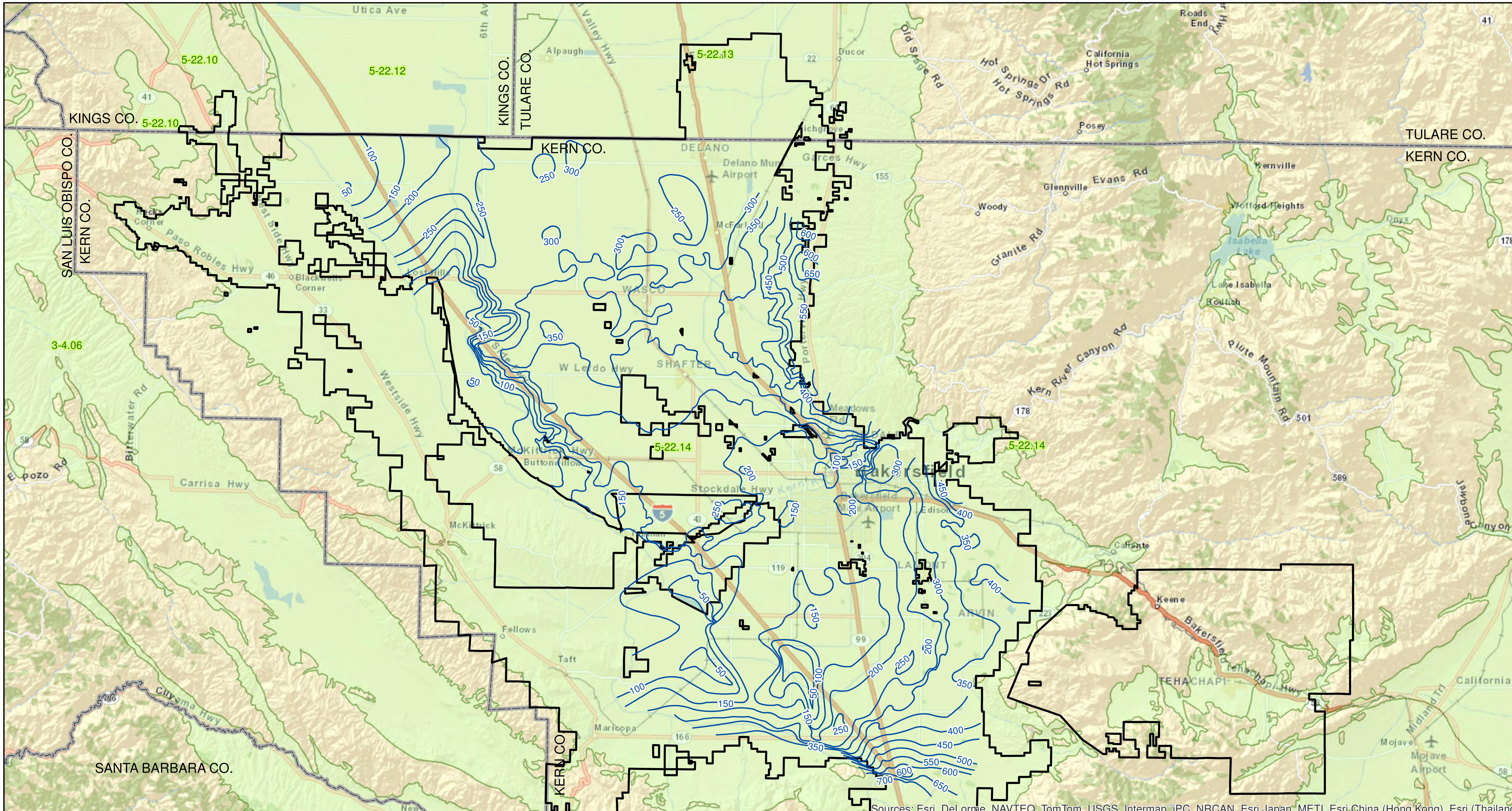
***Isopleth lines from CA DWR "Lines of Equal Depth to Water in Wells, Unconfined Aquifer, San Joaquin Valley, Spring 2010"
http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv2010spr_unc_depth.pdf

Kern County Irrigated Lands Program
Kern Sub-Watershed

Spring 2010
Depth To Water In Wells
DWR Representation

FIGURE 2A

4/5/2013: V:\Clients\Kern River Watershed Coalition Authority-3484\348412V1-ILRP 2012\GIS\Map\DataProcessingForRobGailey\ReportFigs\figure2.mxd



0 5 10 Miles

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- DWR Groundwater Basin/Subbasin (ID Label)
- County
- KRWCA Boundary
- Depth to Water - KCWA Spring 2010, 50 ft interval**

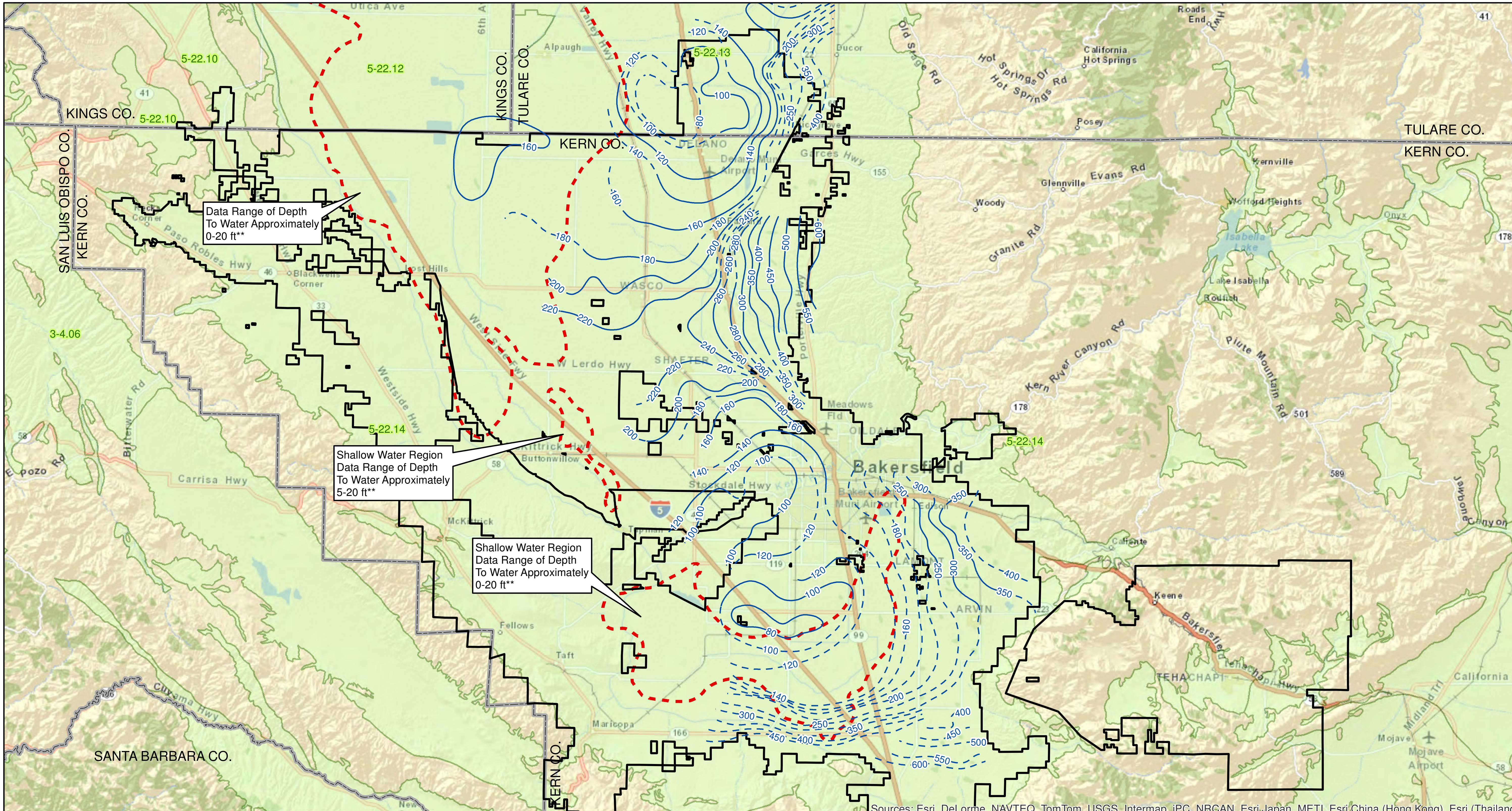
Data References:

**Isopleth lines digitized from Kern County Water Agency, published map of Depth to Groundwater, Unconfined Aquifer, Spring 2010. Published 07/2010.

Kern County Irrigated Lands Program
Kern Sub-Watershed

Spring 2010
Depth To Water In Wells
KCWA Representation

FIGURE 2B



0 5 10 Miles

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DWR Groundwater Basin/Subbasin (ID Label)

County

KRWCA Boundary

Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

High Degree of Confidence

Inferred

Data References:

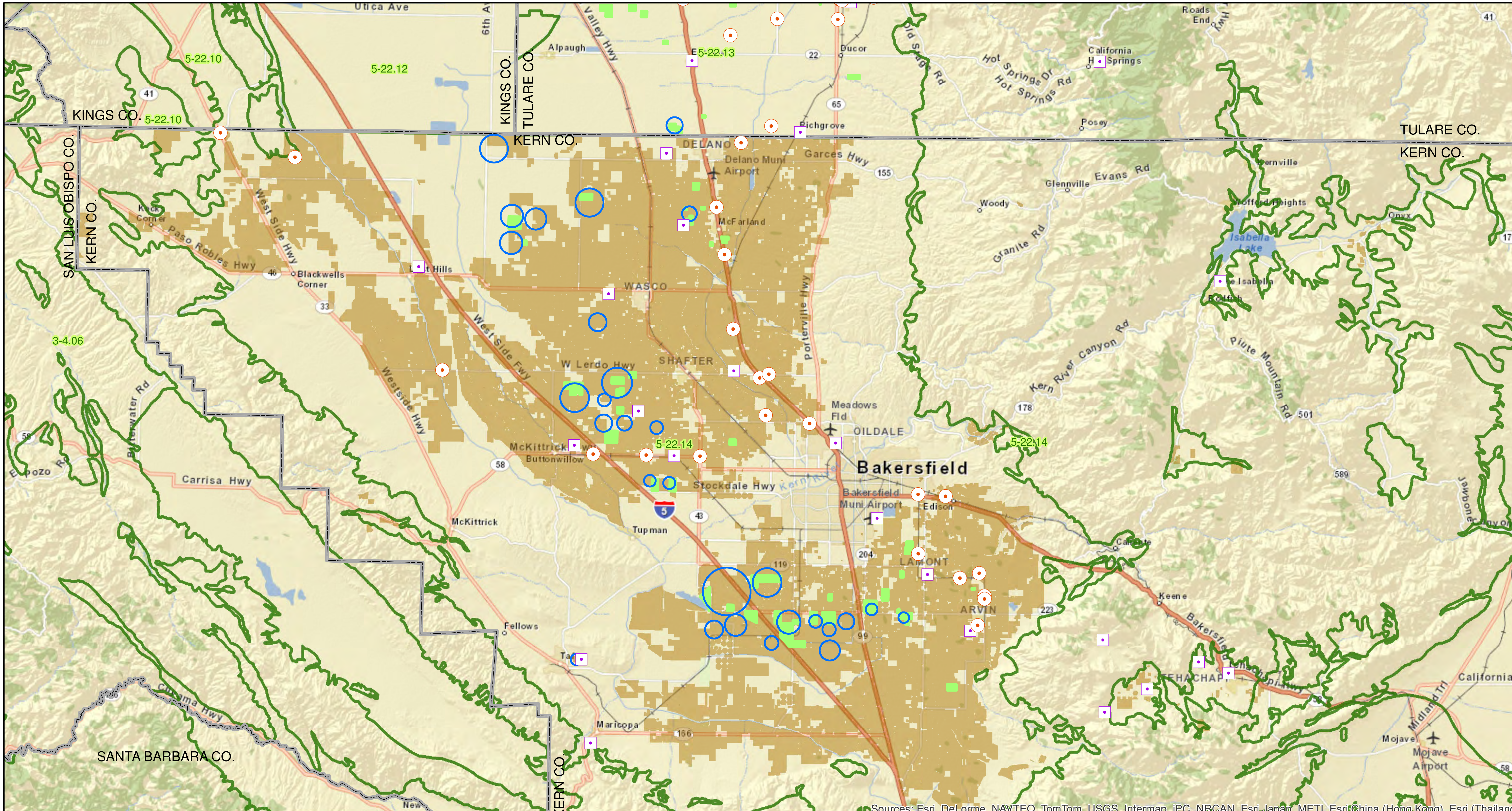
**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, Figure 4, data from 1986. Map dated April 1987. Report dated April 1988.
http://www.water.ca.gov/pubs/drainage/1986_drainage_monitoring_report__san_joaquin_valley/86dmr.pdf

***Isopleth lines from CA DWR "Lines of Equal Depth to Water in Wells, Unconfined Aquifer, San Joaquin Valley, Spring 1988"
http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv1988spr_unc_depth.pdf

Kern County Irrigated Lands Program
Kern Sub-Watershed

Later 1980's
Depth To Water In Wells
DWR Representation

FIGURE 3



0 5 10 Miles

Food Processor (Approx. Location)*

Waste Water Facility (Approx. Location)**

Effluent, Biosolids, and On-Dairy Manure N for Cropland Application***

Dairy Facility****

Irrigated Lands - Kern County Crop Survey 2011

DWR Groundwater Basin/Subbasin (ID Label)

County

Data References:

* Approximate locations. UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Appendix Fig. 1.

**Approximate locations. UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Appendix Fig. 2.

***Generalized areas of modeled Nitrate applied to croplands, kg N/ha/yr >500 . UC Davis Report for the SWRCB SBX2 1 Report to the Legislature, Addressing Nitrate in California's Drinking Water. Technical Report 2. Hater et al. July 2012. Fig. 11.

****SWRCB draft dairy facilities parcels.

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Kern County Irrigated Lands Program
Kern Sub-Watershed

Potential Nitrate Sources

FIGURE 4

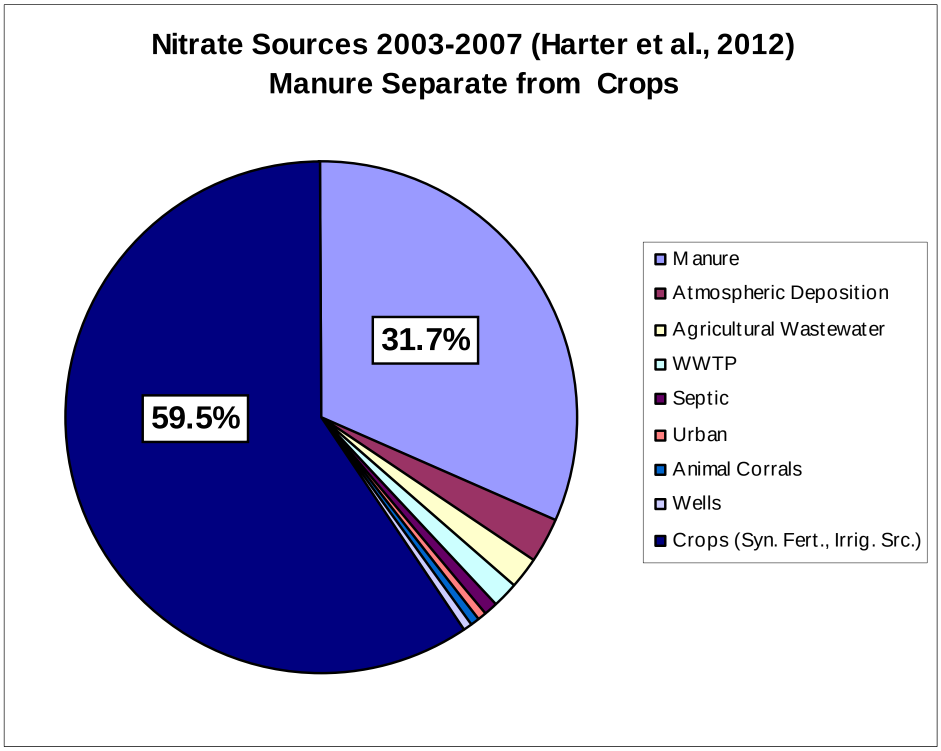


Figure 5: Current Nitrate Sources 2003 – 2007

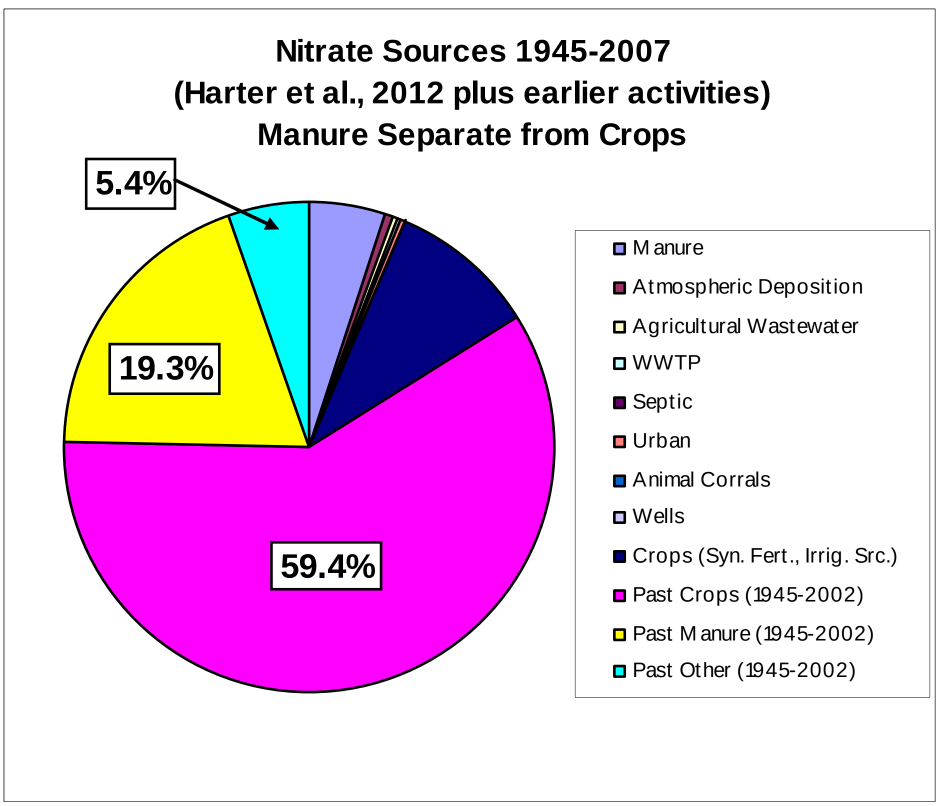


Figure 6: Current and Past Nitrate Sources 1945 – 2007

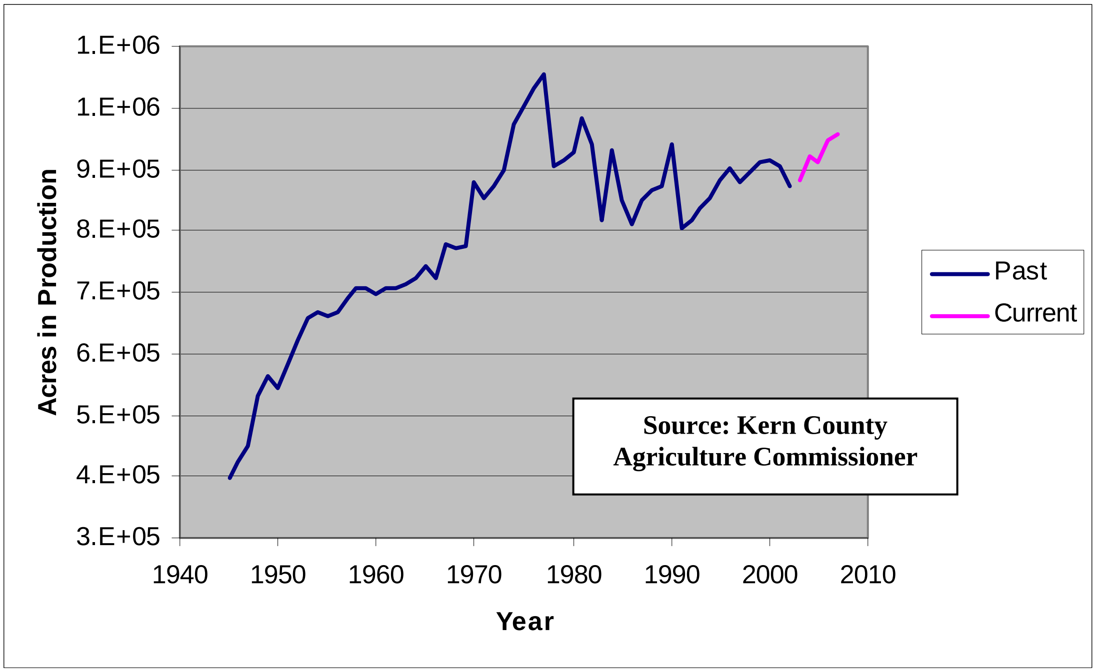


Figure 7: Historical Record of Kern County Acres in Crop Production

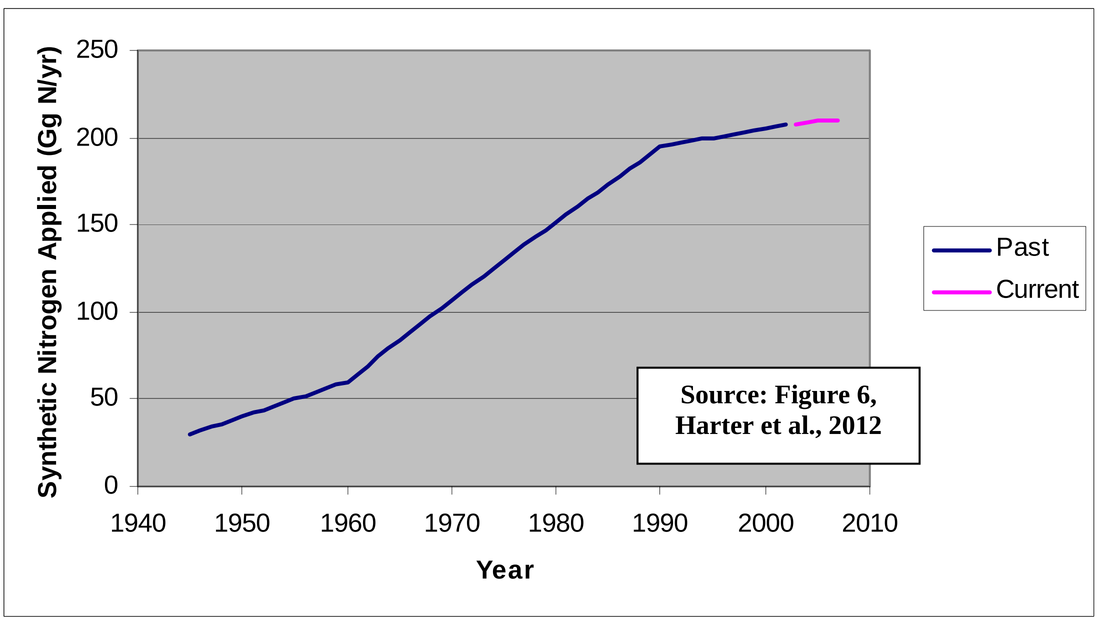


Figure 8: Historical Record of Fertilizer Nitrogen Applied to Crops in the United States

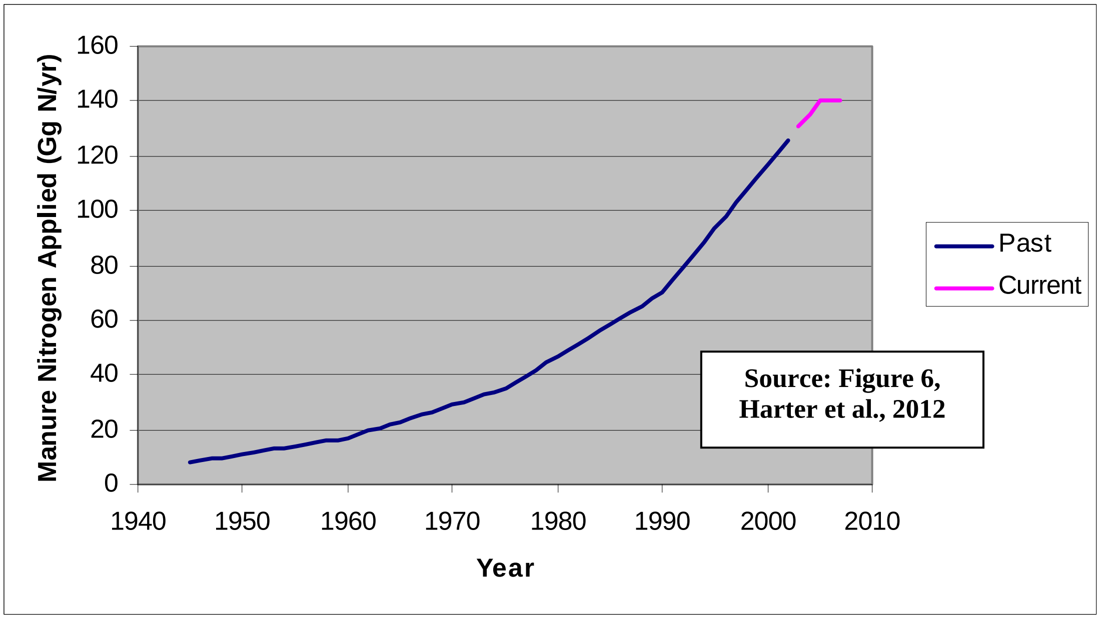


Figure 9: Historical Record of Manure Nitrogen Applied to Crops in the United States

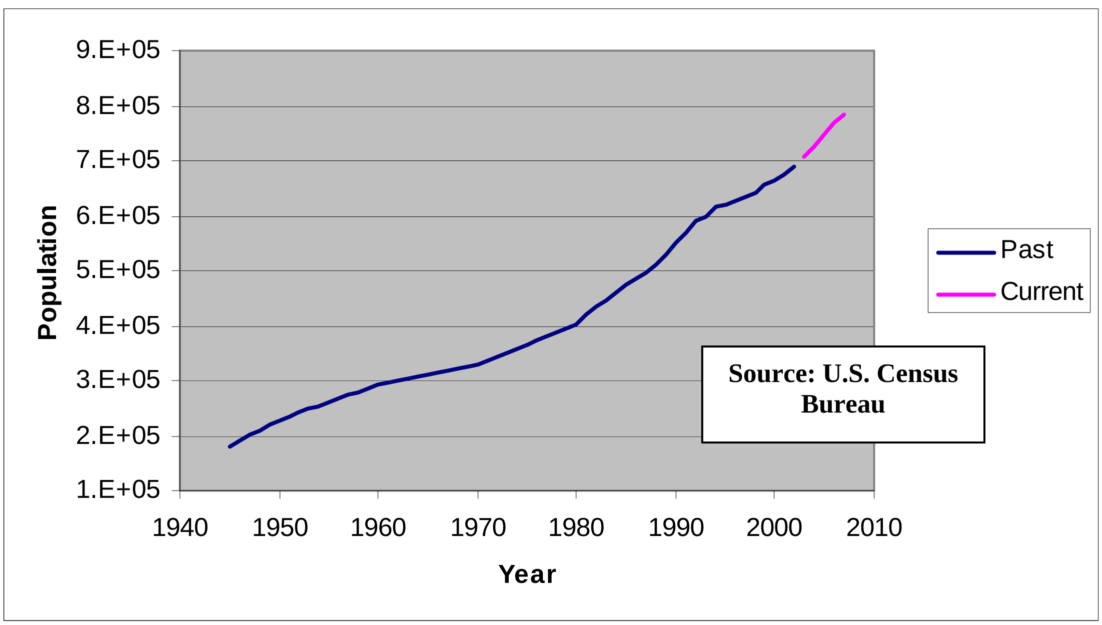


Figure 10: Historical Record of Kern County Population

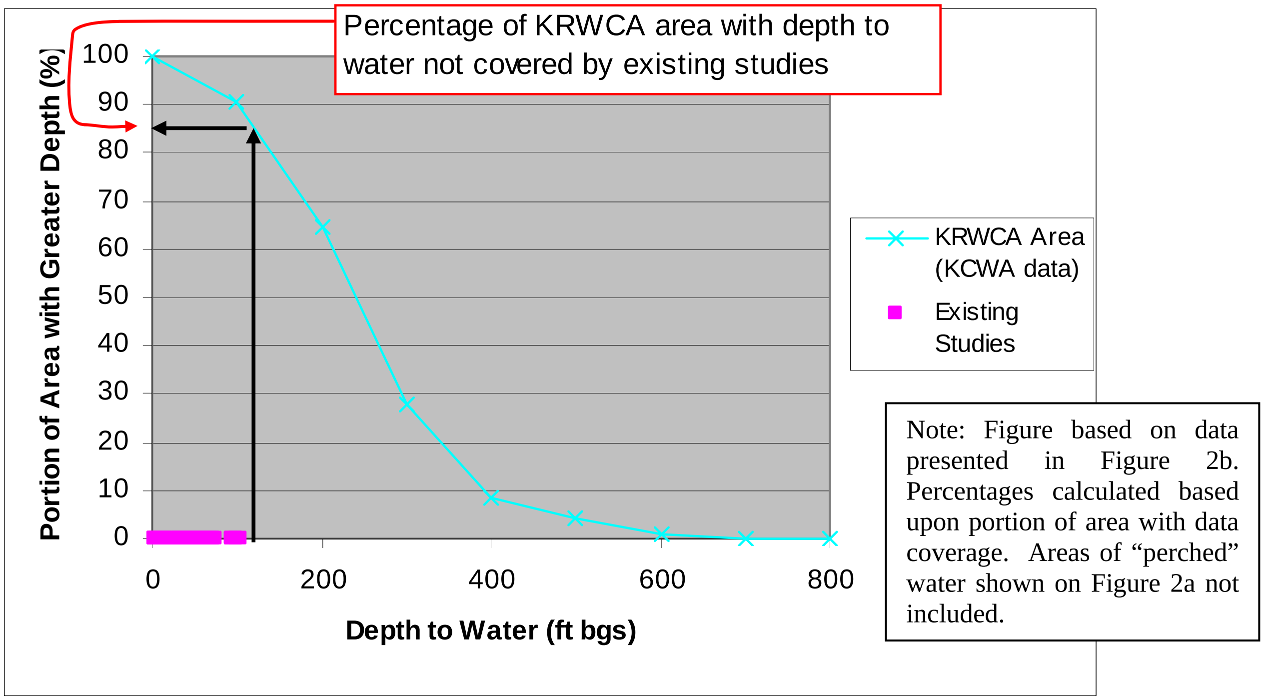
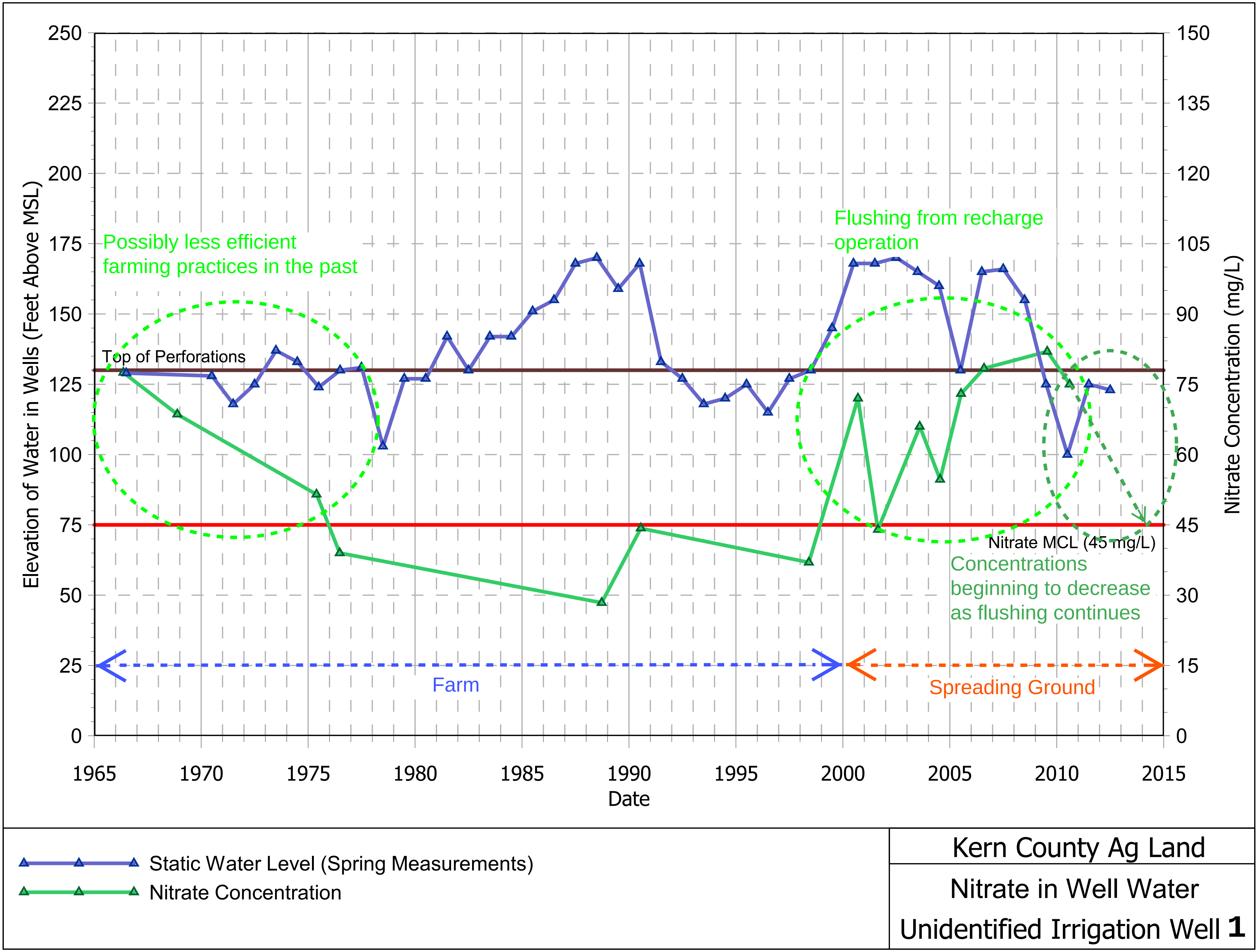


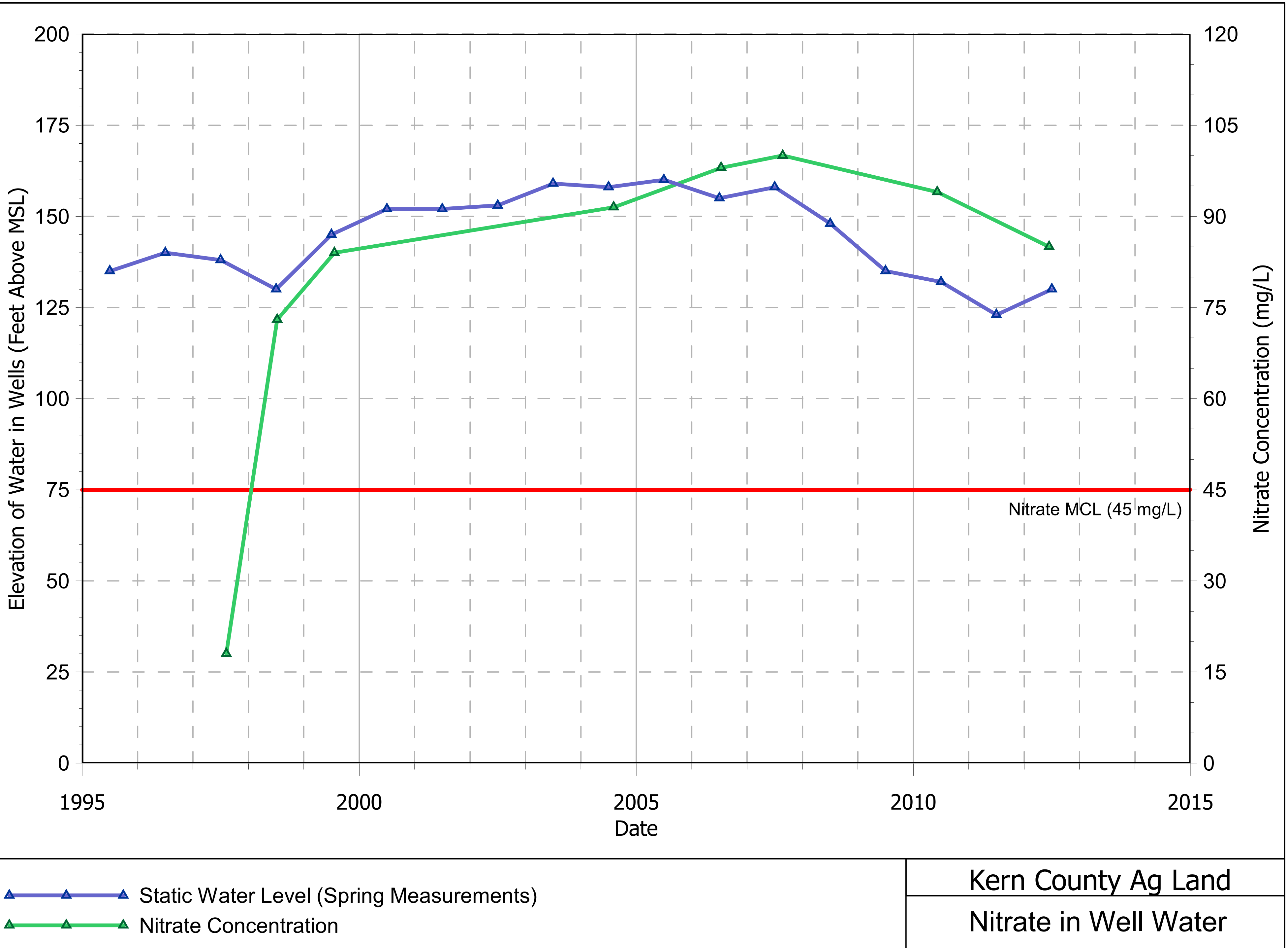
Figure 11: Portion of KRWCA Area with First-Encountered Saturated Zone Water Deeper than a Specified Value

Figure 12



Elevation of Water in Wells (Feet Above MSL)
250
225
200
175
150
125
100
75
50
25
0
Nitrate Concentration (mg/L)
150
135
120
105
90
75
60
45
30
15
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Date
Possibly less efficient farming practices in the past
Flushing from recharge operation
Top of Perforations
Nitrate MCL (45 mg/L)
Concentrations beginning to decrease as flushing continues
Farm
Spreading Ground
Static Water Level (Spring Measurements)
Nitrate Concentration
Kern County Ag Land
Nitrate in Well Water
Unidentified Irrigation Well 1

Figure 13

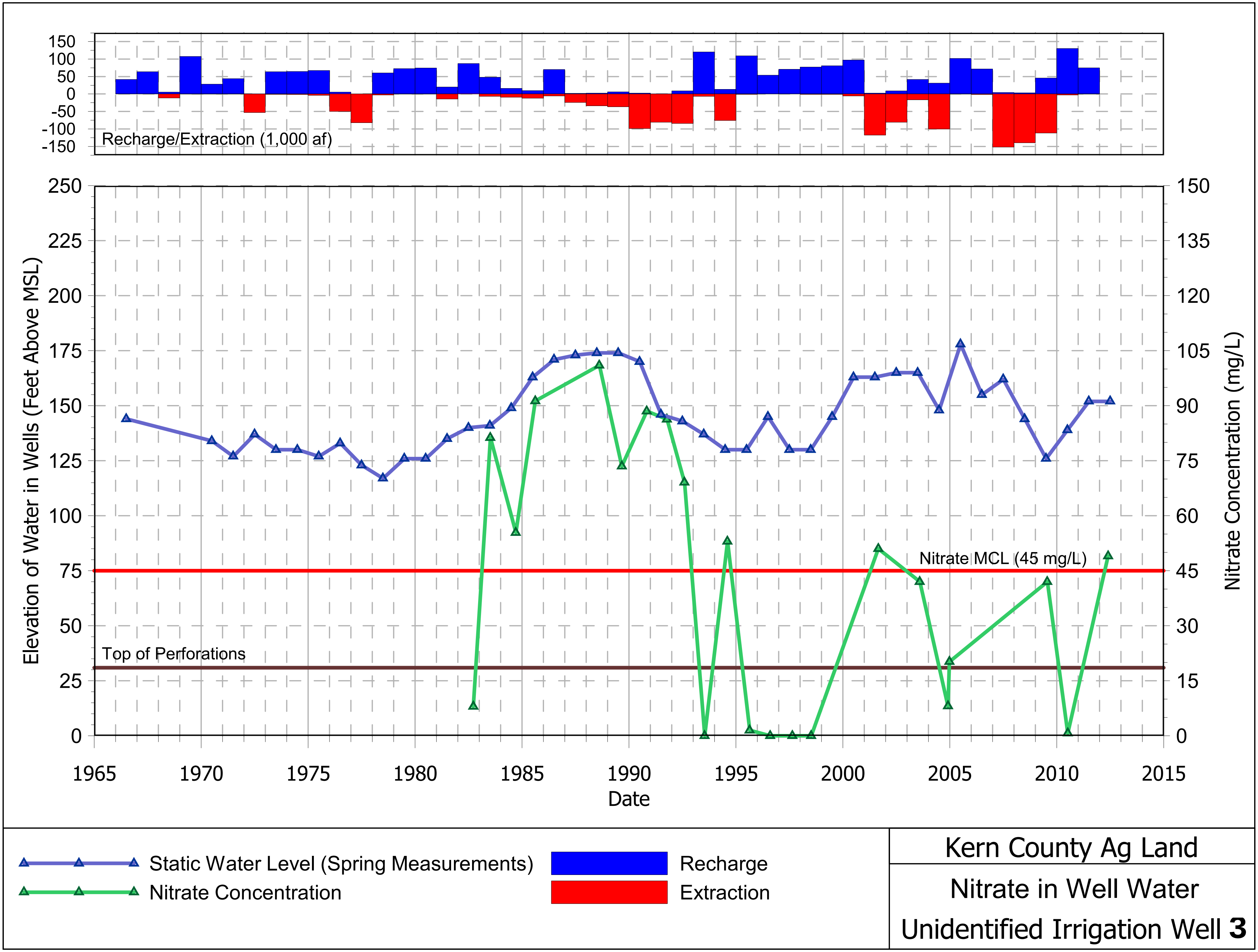


Kern County Ag Land

Nitrate in Well Water

Unidentified Irrigation Well 2

Figure 14



Kern County Ag Land

Nitrate in Well Water

Unidentified Irrigation Well **3**

APPENDIX A

CURRICULUM VITAE FOR ROBERT M. GAILEY

Robert M. Gailey, P.G., C.HG.

Principal Hydrogeologist

Summary

Mr. Gailey has 28 years of experience on a wide range of projects in the field of hydrogeology. In the process of conducting projects throughout much of the United States, he has conducted site investigations ranging from preliminary site assessments to remedial investigations, negotiated with regulatory agencies for closure of contaminated sites as well as operation of municipal supply wells, provided critical review of technical documents, prepared written and verbal arguments for litigation and cost allocation, evaluated strategies for capture of groundwater solute plumes, designed and implemented remedial actions, assessed the effectiveness of ongoing groundwater remediation programs, mapped aquifers and assessed conditions for water supply development, performed water supply well siting evaluations, assessed water supply well conditions and performance, evaluated potential effects of well-field operations on water rights for adjacent parcels, and evaluated potential impacts on groundwater supplies related to groundwater contamination and proposed land development. This work has been conducted in accordance with local and state requirements, and federal requirements (CERCLA, RCRA, and SDWA) as administered by both state and federal agencies. Many of the hydrogeologic evaluations have been performed at scales that range up to basin-wide analysis.

For remediation and wastewater projects, Mr. Gailey has worked on both active and inactive industrial and commercial facilities where both organic constituents (petroleum, semi-volatile organic compounds [SVOCs], and volatile organic compounds [VOCs]) and inorganic constituents (heavy metals, nitrate, perchlorate, total dissolved solids [TDS], and tritium) have been present. The types of industries involved include agriculture (dairy and crop), airline, banking, barrel processing, chemical, defense, dry cleaning, electronics, food processing, flare manufacturing, insurance, machining, mining, petroleum (retail, storage, and refining), real estate, steel, trucking, waste disposal, and wood treatment. In addition, he has performed review and analysis for law firms and government agencies (Army Corps of Engineers [ACE], Department of Energy [DOE], Environmental Protection Agency [EPA], and Washington Department of Ecology). This work has involved hydrogeologic evaluation, modeling, statistical and other data analysis, and database management. The purposes of this work have included characterizing site conditions, predicting exposure point concentrations, developing remedial designs, evaluating ongoing remedial effectiveness, and performing comparative data analyses to meet various project needs.

For water supply projects, Mr. Gailey has worked on both municipal and rural facilities. The industries served include private and municipal water supply, agriculture, food processing, hospital, hotel, and mining. This work has involved hydrogeologic evaluation, well siting and performance evaluation (step discharge, pumping and wire-to-water tests), flow and concentration profiling (under pumping and static conditions using both spinner logs and the U.S. Geological Survey [USGS] dye tracer approach) water quality impact assessment (arsenic, bacteria, nitrate, pesticides, TDS, uranium and VOCs), feasibility testing for well modification, modeling, database management, economic and optimization analysis, and preparing construction and equipment specifications. The purposes of this work have been included developing and rehabilitating municipal and other water supplies, enhancing well field operations, and managing groundwater resources.

Project Experience

- Provides technical analysis related to hydrogeologic aspects of projects. Issues for analysis include hydraulic analysis for water supply and construction projects, water supply assessment, the distribution and migration of constituents of concern in groundwater, benefits of naturally occurring biodegradation, remediation system performance, and environmental impact assessment under the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA).
- Provides testimony, technical counsel, and support for regulatory negotiations and litigation involving 1) groundwater/soil cleanup and cost allocation related to serial and adjacent tenancy of commercial, industrial, and retail parcels and 2) conflicts over water resources. Has prepared expert reports and material for interrogatories and declarations, participated in the meet-and-confer process and settlement discussion, developed case strategy under the client-attorney confidentiality umbrella, briefed expert witnesses on technical aspects of cases, and provided deposition testimony.

Water Supply Assessment and Service

- Serving as Technical Lead evaluating the source of PCE in a municipal water supply well located in the Central Valley of California. Vertical flow and concentration profiling (USGS dye tracer approach) under ambient (non-pumping) conditions has been performed and profiling under dynamic (pumping) conditions is planned. The goal of the project is to modify the well and improve water quality at the wellhead.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Serving as Technical Lead for ongoing supply well water quality evaluations at various locations throughout California. At issue is whether pumping operations and the well screens can be modified to reduce constituent concentrations (i.e., arsenic, manganese, nitrate, TDS, uranium and VOCs) to below drinking water standards. Vertical flow and concentration profile data are often collected from the wells using miniaturized tools so that the pumps do not have to be removed (USGS dye tracer approach). Data collection plans are developed to, among other things, account for uncertainty in pump intake depths, maximize information value and minimize the impact of any data collection uncertainties. For projects where evaluation results indicate that modifications may improve water quality, feasibility testing is performed and, as appropriate, recommendations for final modification of operations and facilities are provided. Management, or support as appropriate, of fieldwork is provided throughout the projects.
- Serving as Technical Lead performing analysis and construction tasks related to rehabilitating and modifying a water supply well for a disadvantaged community located in the Central Valley of California. The goal of the project is to reduce nitrate concentrations at the wellhead. Project work includes preparing technical specifications as well as conducting construction inspection, vertical flow and concentration profiling (USGS dye tracer approach), feasibility testing data analysis.
- Providing technical support to a public utility district regarding data collection and analysis for establishing baseline hydrologic conditions in a small groundwater basin located on the Central Coast of California. The work is being performed to support interest in developing the water resource. Project work has included installing water level and barometric transducers, training district staff regarding transducer maintenance and data retrieval, and data analysis related to evaluating safe yield for the basin
- Serving as Technical Lead to provide technical specifications and construction inspection support for the rehabilitation of four municipal water supply wells located in the Central Valley of California. The work is being performed subsequent to an initial evaluation of ten wells (specific capacity testing, progressive-volume water quality sampling, and video inspection without removing the vertical turbine pumps). The wells have not been rehabilitated within the past 40 to 60 years, and the removal of significant amounts of calcium carbonate scaling is necessary to increase the specific capacities of the wells. Space and wastewater discharge limitations are particular challenges being addressed to successfully complete the project. Particular attention has been given to balancing the benefits of improving hydraulic performance of the wells against the potential costs of damaging the aged wells. Thus far, spinner log and specific capacity testing conducted before and after the rehabilitation work have quantified performance increases in specific capacity of as much as 30 percent.
- Serving as Technical Lead to provide technical specifications and construction inspection support for the rehabilitation of four municipal water supply wells and pumps located in the Central Valley of California. The wells have not been rehabilitated within the past 20 years, and the removal of calcium carbonate and iron oxide scaling as well as bacterial mass is necessary to increase the specific capacities of the wells. Because the municipality relies heavily on the groundwater portion of its water supply, the project is being phased so that the construction activity does not impede the municipality's ability to meet demand. Thus far, spinner log, specific capacity and wire to water testing conducted before and after the rehabilitation work have quantified performance increases in specific capacity of 16 percent and plant efficiency of 32 percent.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Serving as Technical Lead for evaluating potential hydraulic manipulation evaluation of a municipal water supply well located in the Central Valley of California. The focus of the work is to reduce nitrate concentration at the wellhead by changing how the well draws from strata that contain varying concentrations of nitrate. Vertical flow and concentration profiling data from the well (USGS dye tracer approach) were considered in order to identify a design strategy that would allow the well to be brought back on-line without the use of expensive wellhead treatment. The design strategy entailed well screen modification. Field testing of the design concept entailed step-discharge testing, sequential discharge sampling and packer testing in order to evaluate the potential improvement to water quality and decrease in production capacity associated with the chosen well screen modification design. The testing results proved that well modification will be sufficient to address the water quality issue and no treatment system will be required. Current project activities involve finalizing the well modification.
- Provided technical consultation related to bringing a new municipal water supply well online in the Central Valley of California. At issue were bacterial concentrations (total coliform and heterotrophic place counts). Extended purging, chlorination and cycle testing resulted in approval from the Department of Public Health for bringing the well online.
- Served as Technical Lead to perform an analysis for a county water management agency in northeastern California that determined the applicability of alternative monitoring approaches for compliance with the California Statewide Groundwater Elevation Monitoring (CASGEM) program. Six basins were evaluated and a report consistent with California Water Code requirements was prepared within five weeks to meet a client deadline. The report, first in the state to be accepted by the California Department of Water Resources (DWR), was finalized with only minor revisions after review by the DWR.
- Provided technical review of a draft Environmental Impact Statement prepared in accordance with NEPA for a proposed shale gas hydraulic fracturing project to be performed in a western state. At issue were a variety of concerns related to impacts upon water quantity and quality.
- Served as Technical Lead for an expedited review of well and pumping system conditions for four municipal supply wells located in the Central Valley of California. Issues of interest were 1) reduced production rates over time and 2) potential improvements in water quality through well modification in order to avoid the use of treatment systems. Miniaturized equipment was used to video log the wells in order to perform an initial assessment of well and pumping system condition. The pumps in all four wells were further evaluated by performing wire-to-water testing. Three of the wells were further evaluated by performing flow and concentration profiling (USGS dye tracer approach). The constituents of potential concern were arsenic, uranium, manganese and TDS. The findings were that 1) reduced production rates had resulted from both pump wear and well screen fouling and 2) well modification likely would not significantly improve water quality. The field work and reporting was completed in just under four weeks to meet this client's schedule requirements.
- Provided consultation related to increasing the water supply for a medical facility in northern California. The initial task was to review water development efforts in a limited-access area that had been unsuccessful and to recommend additional efforts in the same area. After reviewing the available information and performing field reconnaissance of the subject area, an alternative course of action was identified. The alternative approach to water development was based upon making a connection, previously missed by others, between pieces of information related to the groundwater availability and pumping system capacity. Once limited pumping capacity was identified as the primary issue, additional work in the remote access area was avoided and a significant water supply was readily developed.
- Served as Technical Lead for evaluating potential hydraulic manipulation of a municipal water supply well located in southern California east of Los Angeles. The focus of the work was to reduce arsenic concentrations at the wellhead by changing how the well draws from strata that contain varying concentrations of arsenic. Vertical flow and concentration profiling data (USGS dye tracer approach) from the well were considered along with other water supply system information in order to identify a design strategy that would allow the well to be brought back on-line without the use of expensive wellhead treatment. The design strategy included a combination of well screen modification and blending of the well discharge with that from two other wells. Field testing of the design concept entailed step-discharge testing, sequential discharge sampling and packer testing in order to evaluate the potential improvement to water quality and decrease in production capacity associated with the chosen well screen modification design. In this case, it was established that the site hydrogeology did not support successful well modification.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Served as Technical Lead for evaluating the potential to hydraulically manipulate a municipal water supply well located in the Central Valley of California. The constituent of concern was arsenic. Vertical flow and concentration profiling data (USGS dye tracer approach) were collected. No additional work related to well modification was performed since it was determined that the distribution of arsenic concentrations in strata located along the well screen was not conducive to well modification.
- Served as Technical Lead for a groundwater supply management analysis for a city in the Central Valley of California. The purpose of the project was to evaluate current production operations and suggest operational guidelines and facility modifications to both maintain required production and protect water quality from a variety of constituents (nitrate, uranium and VOCs).
- Served as Technical Lead for developing an irrigation supply well for an athletic park in a coastal area of northern California. Issues considered included well siting, design and yield, and potential water quality impacts from a nearby municipal wastewater treatment facility. An opinion on the potential affects on the groundwater system with respect to production potential and water quality was also prepared for use in a CEQA analysis.
- Served as Technical Lead for a water supply well source area contamination assessment in the Central Valley of California. The sources and migration pathways related to nitrate and other potential contaminants were evaluated through 1) property and well records review, 2) focused well sampling and 3) isotopic analysis to evaluate the age of water pumped from different screened intervals (USGS dye tracer approach) in the municipal well and fingerprint the source of contamination. The purposes of the assessment were to provide information for 1) designing a wellhead treatment system, 2) addressing groundwater cleanup needs and 3) negotiating with the responsible party (RP) and the Central Valley Regional Water Quality Control Board (RWQCB).
- Served as Technical Lead for a hydrogeologic evaluation of water supply development potential in a basin located near the Central Coast of California. Factors considered included geologic formation and structure of water-bearing strata, groundwater flow patterns, existing well yields, water quality distribution patterns and trends, and hydrogeologic conditions specific to the parcel considered for development. Because the basin was not in a state of overdraft, recommendations were made for site-specific investigation of the parcel.
- Served as Technical Lead for a water quality impact analysis in support of regulatory negotiations regarding plans for increased groundwater pumping by a growing community in the Central Valley of California. At issue was whether additional deep pumping would degrade water quality by causing shallow nitrate contamination to migrate downward in significant quantities. The available data were reviewed and historic conditions under which downward migration of nitrate had occurred were identified. This information suggested that the increased pumping would not cause water quality degradation. Technical negotiations with the State Water Board were conducted and a limited amount of additional hydrogeologic data was collected. The collected data corroborated the original findings and the plans for increased pumping were approved.
- Provided technical review for a hydrogeologic impact assessment of dewatering related to expansion of gravel mining operations in the Central Valley of California. The review entailed comparing the results of two different groundwater modeling studies, explaining differences in results of the two studies, and evaluating these differences within the context of potential impacts to the local groundwater system.
- Served as Senior Hydrogeologist for the preparation of a State loan application/workplan to conduct a feasibility study for supplementing a municipal groundwater-based drinking water supply in the Central Valley of California. The workplan included tasks related to modeling groundwater recharge and wellfield operations, and groundwater management planning under the Groundwater Management Act.
- Served as Senior Hydrogeologist and Project Manager on a water well rehabilitation and maintenance project for a water purveyor in northern California. The initial focus of the project was to develop and implement a course of action to rehabilitate under-performing wells. The second focus of the project was to develop and implement a long-term plan for preserving efficiency and extending the lives of satisfactorily-performing wells by considering the economic life expectancy of each well and specifying data collection requirements for tracking performance. This information was managed using database and economic analysis software.

Project Experience – *Water Supply Assessment and Service (cont.)*

- Served as Senior Hydrogeologist Project Manager for the rehabilitation of a municipal water supply well in northern California. Services included developing specifications for both chemical/mechanical rehabilitation of the well screen and installation of a new pumping system that was compatible with an existing variable-frequency drive.
- Served as Project Manager and Senior Hydrogeologist for a new well and reservoir siting study conducted for a municipality in northern California. The goal of the project was to identify viable sites for the new facilities from the list of surplus city-owned lands. Issues considered included aquifer characteristics, proximity to groundwater contamination, proximity to existing facilities, potential for well interference, site suitability for aboveground facilities, aesthetics, and other criteria.
- Served as Project Manager on the design of pumping and transmission facilities for two new municipal water supply wells on the Central Coast of California. Services included developing equipment and construction specifications, and providing construction and system startup inspection. Timely completion of the project allowed the client to apply for project cost reimbursement from Federal funds.
- Provided consultation regarding the rehabilitation needs of a municipal water supply well located in the Central Valley of California. Services provided included consulting with the client on issues that arose during field implementation of the rehabilitation measures.
- Served as Senior Hydrogeologist for an electronics manufacturing facility siting assessment in western Mexico. Issues related to the quality and reliability of the water supply for the proposed site were considered as part of the assessment.
- Served as Senior Hydrogeologist for assessing conditions for developing a groundwater supply for a fruit processing facility located in the northern Central Valley of California. The local groundwater quality was poor, and a well was designed to maintain efficiency and integrity under anticipated use scenarios. Requirements for the well installation and related water treatment system construction were specified in accordance with the California Department of Health Services Office of Drinking Water.
- Developed and installed groundwater and surface water level measurement instruments for a watershed monitoring project in southwestern Mexico. The work was part of a larger malaria control research project.
- Evaluated potential impacts on groundwater supplies related to a proposed land development project on the Central Coast of California. Available hydrogeologic data were reviewed within the context of plans for groundwater withdrawal related to the development. Potential reductions in water availability were identified, and recommendations were made to further assess the degree of impact.
- Performed data collection and interpretation for groundwater resource evaluations in eastern South Dakota. Glacially derived aquifers were delineated and characterized in support of agricultural water supply development.

Wastewater

- Serving as Technical Lead related to renegotiation of WDRs for a cheese plant in southern California east of San Diego. The project is driven by changes in the wastewater stream. Tasks performed include 1) characterization of the wastewater quantity and quality, 2) preparation of a Report of Waste Discharge and a Nutrient/Salt Management Plan, and 3) contribution of various types of information and insights to support infrastructure modifications at the facility. Negotiation with the Colorado River Basin RWQCB on the WDR modification is in-process.
- Serving as Technical Expert reviewing and commenting on draft language for a General Order and WDRs regarding the Irrigated Lands Regulatory Program that has been prepared by the Central Valley RWQCB.
- Served as Project Manager for an environmental site assessment conducted on a 150-acre mixed-use/agricultural parcel located in the Central Valley of California. The purpose of the assessment was to facilitate acquisition of the parcel for expansion of wastewater land application operations at a food processing facility. Accordingly, the list of details for the assessment was expanded to address the intended use of the parcel.

Project Experience – *Wastewater (cont.)*

- Served as Technical Lead for planning and analysis related to technical and regulatory aspects of performing surface and groundwater drainage in a coastal area of northern California. Issues considered include potential rates of drainage, surface water quality, septic discharges and permissible ocean discharges.
- Served as Technical Lead related to renegotiation of WDRs for a dairy in southern California east of San Diego. The project was driven by changes in both the wastewater stream and the lands to which the water would be discharged. Tasks performed include 1) completion of a water use audit that resulted in a 40% reduction in wastewater production, 2) preparation of a Nutrient Management Plan and an Engineered Wastewater Management Plan that were accepted by the RWQCB in initial form, 3) contribution of various types of information and insights that supported infrastructure modifications at the facility, and 4) expedited negotiation with the RWQCB on the WDR modification.

Groundwater Modeling and Optimization Analysis

- Served as Technical Lead for a prospective performance evaluation of a new wastewater storage pond liner technology proposed at a dairy in the Central Valley of California. Information on site conditions and planned pond design were used to construct a groundwater flow and transport model. A range of estimated seepage rates through the liner were simulated with the model in order to evaluate potential impacts to shallow groundwater quality. The evaluation was used to finalize construction requirements and permitting details for the new wastewater pond.
- Served as Technical Lead for a probabilistic cost analysis regarding the remediation of a commercial property in the Central Valley of California that was impacted by chlorinated volatile organic compounds. Site conditions were somewhat uncertainty because only preliminary characterization of soil, soil gas and groundwater had been performed. The set of tasks required to perform the cleanup were identified and cost ranges were estimated based upon the existing uncertainties. A Monte Carlo analysis was performed to evaluate the range in total project cost and the probabilities of occurrence for costs within the range. The results provided a cost-benefit basis for the potential purchaser of the property to make decisions regarding site management.
- Served as Technical Lead for sea water intrusion and groundwater/surface water interaction modeling studies. The work considered past and potential future effects of groundwater extraction for irrigation upon flow and water quality in a river and estuary on the Central Coast of California. Technical aspects of this work were assessing buried channel geometry and hydraulic properties from the wide range of available data, and evaluating the simultaneous effects of groundwater pumping and spring tide occurrence. Detailed transient models that included several river reaches and hourly tidal variations were created based upon previously available information and data collected for this project. The work was used to support negotiations with the California Department of Fish and Game and, ultimately, hearings at the State Water Resources Control Board.
- Served as Technical Lead for flow and transport modeling conducted to evaluate the source of nitrate contamination to a municipal water supply well located in the Central Valley of California. The model was calibrated using the results of 1) a 30-day pumping test and 2) flow and concentration profiling performed on the impacted municipal supply well. Important aspects of the modeling were 1) simulating the contaminant plume response to different historical pumping periods and 2) including the effects of a nearby improperly constructed water supply well that acted as a vertical conduit.
- Served as Technical Lead for hydrogeologic analysis and development of software for the prediction of groundwater quality impacts resulting from operations at a northern California facility. The software used historic and projected facility operations to predict sourcing and migration of tritium in groundwater. A flow and transport code was developed to simulate advection, dispersion, decay and other processes particular to the site that are not included in standard modeling packages (in-place constituent mass creation and rate-limited mass transfer at multiple spatial scales). Once calibrated, the model was used to evaluate the impacts of various future operations scenarios within the context of making facilities management and regulatory negotiation decisions.

Project Experience – *Groundwater Modeling and Optimization Analysis (cont.)*

- Served as Technical Advisor for modeling performed in support of a feasibility study regarding groundwater cleanup in the Central Valley of California. Flow and transport modeling were performed to evaluate contaminant plume movement under different remedial pumping scenarios. Of particular importance in this work were the effects of many water supply wells located near the plume and flows between vertically adjacent water-bearing zones.
- Served as Technical Lead for a study that developed conjunctive use strategies and wellfield operational rules related to meeting future municipal water supply requirements of a growing community in the Central Valley of California. The project entailed developing a groundwater flow model that included 1) the operations of wellfields run by two adjacent communities and 2) groundwater-surface water interactions. Once calibrated, the model was linked to optimization tools in order to cost effectively evaluate a range of operational scenarios. At issue was how to meet projected higher demands without mobilizing contaminants (naturally occurring total dissolved solids and two plumes containing VOCs and pesticides) that would result in increased future treatment costs. Results of the study included wellfield operations guidelines, suggested maximum extraction schedules, and proposed coordination of wellfield operations by the two adjacent communities. The model was extended in time and recalibrated four years later. Future plans are to use the model as part of water supply planning for city expansion.
- Served as Technical Lead on a groundwater management study performed to support remedial design for a landfill site in Arizona. Remedial designs necessary to accommodate Groundwater flows resulting from present and future water supply management practices were evaluated with a groundwater model developed for the project. The goal of the work was to develop designs that were both economically viable and able to contain the leachate plume as water supply pumping and basin recharge practices changed.
- Served as Senior Hydrogeologist for a feasibility study and remedial action at an industrial site in the Central Valley of California. The project was reviewed by the California Department of Toxic Substances Control (DTSC) and entailed hydrogeologic analysis and groundwater modeling to mitigate impacts to a water supply wellfield by VOCs. Evaluating and implementing wellhead treatment as the remedial approach entailed accounting for both seasonal variations in wellfield pumping demand and economic constraints on performance of the project. Use of automated/optimization techniques for assessment of design options streamlined the modeling process and reduced project expenditures. The work also included developing a cost-effective monitoring program for the remedial action.
- Served as Senior Hydrogeologist for a remedial action at a decommissioned research facility located in northern California. The project was reviewed by the EPA, DTSC, and the Central Valley RWQCB. It included hydrogeologic analysis and modeling to mitigate impacts to groundwater and nearby irrigation supply wells by VOCs, and litigation support. This work supported preparation of an Engineering Evaluation/Cost Analysis and an Interim Remedial Action, and favorable settlement of the litigation matter. The work also included an assessment of rehabilitation needs for injection wells used in the remedial action.
- Served as Technical Lead for an assessment of potential VOC, SVOC and metals concentrations in groundwater at an industrial facility located in northern California. The project, reviewed by the EPA, DTSC, and National Oceanic and Atmospheric Administration, entailed modeling groundwater transport of constituents of potential concern and mixing of the constituents with surface waters. The concentration predictions were used to support performance of ecological and human health risk assessments.
- Served as Technical Lead on a groundwater supply management study for a mining operation located in the western United States. The focus of the project was exploring options for both meeting water production requirements and capturing impacted water while accounting for restrictions related to water rights and well/transmission line capacity limits. Use of automated/optimization techniques for assessing options streamlined the process and allowed a more detailed study to be conducted with a limited budget.
- Served as Technical Lead for an evaluation of groundwater drainage rates and volumes resulting from a planned tunnel construction project in the Sierra Nevada of California. A spreadsheet model was constructed to simulate transient drainage from fractured host rock surrounding the planned tunnel construction. Best- and worst-case estimates of the drainage rates and volumes were prepared to support plans for removal of suspended solids from the water prior to discharge.

Project Experience – *Groundwater Modeling and Optimization Analysis (cont.)*

- Provided consultation regarding the feasibility of modeling groundwater flow and solute transport in an alluvial valley located in the western United States. Flow in the valley has been increasingly influenced by water supply pumping. Key elements for conducting the assessment were development of a complete conceptual model of how groundwater flow patterns have changed over time, and identifying a viable approach for model calibration.
- Served as Senior Hydrogeologist to develop a remedial approach for an industrial site in Nevada impacted by chlorinated VOCs. Groundwater modeling was used as a planning tool for phased implementation of a pumping system to address remediation requirements for the 7,000-foot-long plume. The plume was present throughout the saturated alluvium in a small valley, and viable remedial pumping designs are highly sensitive to available drawdowns and potential dewatering. Use of automated/optimization techniques for model calibration and design development streamlined the modeling process and reduced project expenditures.
- Supported development of technical strategy and provided senior review for groundwater modeling performed for remedial investigation/feasibility study and litigation tasks related to a site in Oregon impacted by chlorinated VOCs. Hydrogeologic analysis involved accounting for the effects of nearby water supply well pumping on VOC transport in the vicinity of the site. Automated/optimization techniques were developed and demonstrated to streamline the modeling process.
- Evaluated an optimization model for cost-effective disposal of dredging wastes for potential application to San Francisco Bay. The evaluation was performed for the ACE. Methods were developed for applying the model to problems that included constraints imposed by environmental regulations. A result of the evaluation was the determination that increased permitting fees might not change disposal patterns within the Bay.
- Analyzed transient hydraulic head data collected during soil boring to estimate the hydraulic conductivity and potential solute migration rates for a petroleum site in Oregon. The analysis entailed developing a mathematical model for assessing slug test data in a three-dimensional flow field. Performance of the analysis reduced project costs by providing migration rate information without installation of monitoring wells.
- Conducted a modeling study for the DOE to determine the effect of spatially variable solute adsorption on groundwater solute concentration predictions. This included use of statistical techniques to increase the reliability of the transport predictions. These techniques have recently been used on other projects to defend conclusions that are based upon model predictions.
- Developed pump-and-treat designs for capturing organic and heavy metal compounds at an impacted groundwater site in Canada. The design involved development of a site-specific model of groundwater flow and solute transport for prediction of exposure point concentrations and application of optimization techniques for developing designs. The designs involved minimum capital and recurring remediation costs. Reliability of concentration predictions upon which the designs were based was demonstrated through application of statistical techniques.

Modeling, statistical analysis, and database management tasks performed by Mr. Gailey on many of the above-referenced projects have entailed use of software including Groundwater Vistas, MODFLOW, MODPATH, MT3D, SEAWAT, RT3D, MOC, Bioscreen, Bioplume II/III, SUTRA, PEST, LINDO, STARPAC, GEOEAS, NPSOL, AQMAN, Visual MODFLOW, GMS, ModelCad and GIS/Key.

Groundwater Remediation

- Provided technical support on subsurface characterization, modeling and reporting for a solvent contamination site in southern California. Much of the work focused on addressing technical challenges posed by the hydrogeologic setting (structurally deformed, fractured sedimentary rock). The project included significant scientific contributions in the areas of field characterization and groundwater flow modeling.

Project Experience – *Groundwater Remediation (cont.)*

- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activities (groundwater and soil vapor extraction) and monitoring progress toward cleanup for a multiparty, subregional plume of chlorinated VOCs. Reporting and interaction with the San Francisco Bay RWQCB involved completing semi-annual Self Monitoring Reports. Recent activity also included conducting a Five-Year Remedial Effectiveness Evaluation. Documenting and emphasizing the effects of impediments to pump-and-treat and naturally occurring biodegradation were important aspects of this project with respect to limiting future remedial requirements.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activity (groundwater extraction) and monitoring progress toward cleanup for a plume of chlorinated VOCs. Reporting and interaction with the North Coast RWQCB involved completing semi-annual Self Monitoring Reports. Other project work also included reassessment of the hydrogeology and the approach to groundwater extraction with the goal of increasing project efficiency.
- Served as Principal Hydrogeologist for evaluating the results of shutting down a groundwater extraction system at an industrial site located in northern California. The San Francisco RWQCB approved remedial system shutdown on a temporary basis because (1) on-going pump-and-treat efforts had resulted in only limited progress toward attaining remedial goals and (2) there was evidence that naturally occurring biodegradation may have prevented plume migration. The project entailed evaluating the groundwater data (elevations as well as VOC and inorganic water chemistry) for pre- and post-shutdown periods. A convincing case for VOC degradation was made based on spatial data trends. A case for plume stabilization was also been made based on temporal data trends. Accounting for the effects of concentration rebound after pumping and plume migration from the source area was an important consideration for future site monitoring in order to assess whether the plume front was stable.
- Served as Principal Hydrogeologist for proposing monitored remedial system shutdown at an industrial site in northern California. The proposal to the North Coast RWQCB included a workplan for collecting the necessary groundwater data to demonstrate the effects of naturally occurring biodegradation of VOCs in groundwater.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed enhancing remedial activities (groundwater and soil vapor extraction) for a plume of chlorinated VOCs. Reporting and interaction with the DTSC involved conducting expedited conceptual and engineering design for expansion of a remedial system. Plans were also been developed for collecting data to document the potential effects of naturally occurring biodegradation in order to limit future remedial requirements. This work was conducted within the context of negotiating a Prospective Purchaser Agreement for an adjacent parcel that was impacted by the plume.
- Served as Principal Hydrogeologist for ongoing remedial action at an industrial site located in northern California. The project entailed conducting remedial activity (groundwater extraction) and monitoring progress toward cleanup for a specific site within a multiparty, subregional plume of chlorinated VOCs. Reporting and interaction with the EPA involved semi-annual Self Monitoring Reports. Recent activity also included reevaluating measures for maintaining a site-specific capture zone given that remedial activities were also occurring on adjacent sites.
- Served as Lead Hydrogeologist for remedial action design related to petroleum-impacted groundwater near residential water supply wells in central California. The constituents of concern included MTBE, and the Central Valley RWQCB conducted a detailed review of the Remedial Action Plan. The potential effects of residential well pumping were factored into the remedial pumping design so that containment of the constituents of concern was achieved and the water supplies were protected.
- Served as Senior Hydrogeologist for a fate and transport analysis related to petroleum-impacted groundwater near residential water supply wells in Alaska. The effects of naturally occurring biodegradation were incorporated into the analysis and supported the conclusion that risk to the water supplies was low.
- Served as Senior Hydrogeologist for a remedial investigation and action at an industrial facility in central California. The project was reviewed by the Central Valley RWQCB. It included hydrogeologic analysis, historical review, and negotiation to define remedial action requirements and allocate responsibility among responsible parties.

Project Experience – *Groundwater Remediation (cont.)*

- Served as Project Manager and Senior Hydrogeologist for a subsurface investigation of an air cargo facility at the San Francisco International Airport. The project was reviewed by the RWQCB and parties involved in cost allocation for cleanup of petroleum-impacted groundwater and soil. Evaluation of subsurface impacts and recommendation of future actions was conducted within the context of maintaining current business activities at the site and deferring any intrusive remedial activities until an appropriate time in the future.
- Served as Senior Hydrogeologist for a landfill closure in Mexico City, Mexico. Tasks performed included acquiring data on potential leachate production rates and recommending design parameters for a leachate collection system. Collection of the leachate was required to facilitate the next step of the closure, extraction of accumulated landfill gas.
- Served as Senior Hydrogeologist for a five-year review and remedial effectiveness evaluation of a groundwater cleanup operation in northern California. The project entailed evaluation of remedial performance data for six groundwater extraction systems installed in alluvial sediments and was reviewed by the San Francisco RWQCB. Key points considered during the evaluation were hydraulic containment of the chlorinated VOC groundwater plume, cumulative removal of groundwater and VOCs, VOC removal efficiency, offsite sources of VOCs, and the potential for attaining cleanup goals set by the RWQCB. Presentation of the project findings positioned the client well for negotiation on further remedial actions.
- Provided technical/economic analysis and technical review for remedial investigations/ feasibility studies involving three industrial sites owned by a single client in southern California. The work was performed under the review of the DTSC. Project findings were used to develop estimates of cleanup cost and facilitate completion of real estate transactions for the benzene-impacted properties. Detailed evidence of naturally occurring biodegradation was developed and used to limit the extent of cleanup measures that were considered.
- Served as Senior Hydrogeologist for a remedial investigation conducted at a commercial site in northern California. The investigation was performed under review of the San Francisco Bay RWQCB. Communication with the RWQCB on technical aspects of the investigation prior to commencing work positioned the client well for negotiations on further investigative requirements. The option for cost recovery was developed by maintaining consistency with the National Contingency Plan during the remedial investigation and interim remedial action, and by presenting arguments for the presence of off-site sources of chlorinated VOCs. Potential off-site source areas were identified, and arguments for requiring subsurface investigation by neighboring parties were supported through an analysis of site hydrogeology and migration potential. The arguments were presented and defended to the RWQCB. The ultimate goal of this effort is to identify other parties also responsible for the cleanup so that costs may be shared.
- Served as Project Manager and Senior Hydrogeologist for a soil and groundwater remedial investigation/feasibility study and an ecological river assessment conducted at a decommissioned wood treatment facility in Michigan. Creosote was present at the facility as a dense nonaqueous phase liquid. Negotiations with state regulatory agencies were key to successfully limiting the scopes of the investigations. Early data review allowed expeditious performance of the site characterization and development of a risk assessment strategy that both met regulatory requirements and was protective of client cleanup liability. The quality of the site characterization work contributed to the cooperative relationship between the client and regulatory agency, which reduced the potential for natural resource damage claims by the state.
- Performed remedial investigations and developed site closure arguments for petroleum sites in California, Florida, Massachusetts, and Rhode Island. The work in California was performed under the review of the Kern County Department of Environmental Health. Site closure arguments were accepted in all four states.
- Performed an emergency investigation, and designed, installed, and maintained a petroleum recovery system in response to a high-volume spill of diesel fuel into the subsurface at a commercial site in Massachusetts. Implementation of interim petroleum recovery measures minimized petroleum migration away from the source area. During the first year of recovery system operation, 25,000 gallons of fuel were recovered. System enhancements were then made to maintain recovery rates. Project costs were defrayed by reuse of the recovered fuel.

Project Experience – *Groundwater Remediation (cont.)*

- Designed, installed and maintained numerous petroleum and groundwater recovery systems in several states. This work also included evaluation of overall remedial effectiveness and the benefits of using groundwater infiltration systems to enhance petroleum recovery. Work in California was performed under review of the Central Valley RWQCB.
- Performed site assessments for real estate transactions involving retail petroleum, commercial, and industrial sites throughout California and Massachusetts. The assessment findings were used to facilitate completion of the transactions.

Litigation Support

- Recent cases in which Mr. Gailey has been declared as an expert:
  - RF Land Inc. v. City of Ripon (California) 2010
  - Raymond Coldani v. Jack Hamm and Patricia Hamm (Federal 2009)
  - NCH Corporation v. Hartford Accident and Indemnity Company, et al. (New Jersey) Deposition testimony in 2007
  - Union Bank of California v. Rheem Corp. (California), 2006
  - Pinal Creek Group v. Newmont Mining Corp., et al. (Federal – Arizona) Deposition testimony in 2003 and 2006
- Serving as a Technical Consultant regarding responsibility for VOC contamination of a municipal water supply well. The case is being heard in the California courts.
- Served as an expert witness regarding financial responsibility for nitrate contamination of a municipal supply well from an industrial facility in northern California. Contributions included planning both data collection from the impacted well and inspection of the industrial facility, as well as presenting findings during mediation. The case, filed in the California state court system, ultimately settled.

Project Experience – *Litigation Support (cont.)*

- Served as an expert witness regarding responsibility for nitrate contamination of groundwater in the vicinity of a dairy in northern California. Work on the case, filed under the Clean Water Act in the California state court system, involved field investigation and analysis, mediation support and presentations, and preparing a technical declaration in support of a motion for recovery of attorney/expert fees and costs. The case was ultimately rescinded.
- Served as an expert witness regarding cost recovery and future apportionment among RPs for cleanup of a large acid mine drainage site in Arizona. The case involved several RPs active over almost a century and located throughout a mining complex, had been filed under CERCLA, and was heard in the federal court system. Expert analysis included a comprehensive consideration of the site hydrogeology and historic mining activities, and flow calculations (water budgets and mass balance assessments on surface water and groundwater flows, and three-dimensional groundwater flow modeling) to assess the relative contributions to the acid plume by various RPs. Video taped deposition testimony was given twice.
- Served as an expert witness regarding insurance coverage claims related to cleanup of a Superfund site. The case was filed under CERCLA and heard in the New Jersey state court system. Analysis and opinion development focused on hydrogeologic and regulatory factors that would influence the ultimate cost of the cleanup. Methods for incorporating uncertainty into the cost estimates was also addressed. Deposition testimony was given. Issues related to the above-referenced opinions were subsequently dropped from the case.
- Served as an expert witness regarding cost recovery for a former electronics manufacturing facility. The case was filed under CERCLA and heard in the California state court system. Analysis and opinion development focused on hydrogeologic factors that controlled both the duration of release to groundwater and the extent of subsequent off-site migration. The case settled before any testimony was given.

Project Experience – *Litigation Support (cont.)*

- Served as a consultant regarding a CERCLA claim for damages related to a release of contamination into a San Francisco Bay Area aquifer that serves a large population of individual well owners (residential and agricultural). The case, filed by a class of plaintiffs, involves releases from a single industrial parcel where multiple RPs operated over time and was heard in the federal court system. Consultation has included document review, quantitative analysis related to the extent of contamination and potential cleanup timeframe, mediation brief preparation, development of computer animation visual aids for mediation discussions, and presentation at mediation.
- Provided consultation for mediation of cleanup cost allocation for petroleum-impacted groundwater and soil at the San Francisco International Airport. The project involved research and strategy development focused on supporting negotiations with some twenty responsible parties.
- Provided consultation for legal defense against a claim concerning financial responsibility for contamination of residential and agricultural water supplies and soil. The case involved two adjacent parcels in northern California, was filed under CERCLA, and heard in the federal court system. Data analysis and discussions with attorneys focused on the plausibility of claims made by the plaintiff with respect to source area locations, site hydrogeology and migration potential of the constituents, and differences in signature assemblages of constituents present at each of the two sites. The case settled before any testimony was given.
- Provided consultation for legal defense against a claim concerning financial responsibility for petroleum and heavy metals present in soil and groundwater. The case involved two adjacent industrial parcels in northern California, was filed under CERCLA and heard in the federal court system. Data analysis and development of arguments focused on the plausibility of claims made by the plaintiff with respect to source area locations, site hydrogeology and migration potential of the constituents, and differences in signature assemblages of constituents present at each of the two sites. The arguments prepared supported successful opposition to motions made by the plaintiff for widespread inspection of the defendant's property, settlement discussions, and the defendant's motion for summary judgment. Prior to a settlement being reached, Mr. Gailey participated in settlement discussions and preparing the expert witness for trial.
- Provided consultation for legal defense against a claim concerning financial responsibility for petroleum contamination at two adjacent retail/industrial parcels in northern California. Data analysis and development of arguments focused upon the adequacy of previously implemented remedial actions for which the plaintiff sought compensation. The technical merits of written arguments developed for the defense resulted in the plaintiff's claim being rescinded prior to the case being heard in court.
- Served as an expert witness for a defendant regarding a cost recovery claim concerning petroleum and chlorinated VOCs present in soil and groundwater. The case was filed under CERCLA and heard in the federal court system. It involved a single property in northern California, an initial owner-operator (the plaintiff), and a subsequent series of occupants (the codefendants). Data analysis and development of written arguments focused on both changes in the chemical composition of materials used for automotive fueling and repair between the 1940s and the 1980s, and the appropriate allocation of cost for site cleanup among the involved parties. Estimation of total cost for the cleanup was also performed. 1,2-Dichloroethane (DCA) was identified as a signature compound for releases to the environment that occurred before the codefendants occupied the site. Data collected by the plaintiff demonstrated that DCA was present across the property and supported arguments that the plaintiff was also responsible for the cleanup. The case settled before any testimony was given.
- Provided consultation in support of a class action suit against the state of California concerning a levee failure. Three-dimensional transient groundwater flow and soil mechanical processes were modeled to show that departure from guidelines for levee maintenance could have caused the failure. Mr. Gailey defended the modeling work in deposition. This work supported testimony of the expert witness.

Insurance Analysis Support

- Conducted a comprehensive assessment and estimation of future remediation costs in support of insurance premium pricing for a cost cap policy on two sites. Annual costs over the life of the policy were developed for three possible scenarios (high, medium, and low costs) based on detailed review and consideration of project characteristics. These characteristics included technical (engineering and science), regulatory and logistical issues. The results were presented and discussed during negotiations between the insurance company and insurance brokers over premium price.

Project Experience – *Insurance Analysis Support (cont.)*

- Conducted several assessments of remediation projects in support of insurance claims analyses. The overall approach and effectiveness of remedial actions were evaluated. In addition, costs incurred were identified and categorized with respect to policy coverage and exclusion categories. General projections of future costs and timelines were also prepared.

Education

MBA, University of California, Berkeley, 2003.
MS, Applied Hydrogeology, Stanford University , 1991.
BS, Geology/Biology, Brown University, 1985.

Professional Certifications and Registrations

Professional Geologist, California No. 5338
Certified Hydrogeologist, California No. 259
40-Hour OSHA HAZWOPER Safety Training
8-Hour OSHA HAZWOPER Refresher/Respirator Fit Test
8-Hour OSHA Site Supervisor Certification
First Aid/CPR Training

Continued Education

Isotope Methods for Groundwater Investigation, Groundwater Resources Association of California, 2007
Endangered Species Acts: Meeting the Challenges, Association of California Water Agencies, 1999
Groundwater Use and Management, University of California at Berkeley Extension, 1998
Drinking Water Regulation, University of California at Berkeley Extension, 1998
Water Supply and Fish in the Sacramento-San Joaquin Delta, University of California at Berkeley Extension, 1997
Managing Groundwater into the 21st Century, Association of California Water Agencies, 1997
Watershed Management and Source Water Protection: The First Barrier, American Water Works Association, 1997
Aquifer Storage and Recovery, American Water Works Association, 1997
Graduate Study in Environmental Engineering, Stanford University, 1990
Surveying, Wentworth Institute of Technology, 1986

Professional Memberships and Activities

Association of Ground Water Scientists and Engineers
Groundwater Resources Association of California
Technical reviewer for various journals

Publications

Gailey, R.M. 2000. Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA Site. Proceedings of the International Symposium On Integrated Water Resources Management, International Association of Hydrological Sciences.

Gailey, R.M. 1999. Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA site. Proceedings of the 26th Annual Conference on Water Resources Planning and Management, American Society of Civil Engineers. (Published on compact disc.)

Gailey, R.M. and M. Eisen. 1997. An Optimization-based Evaluation for Groundwater Plume Containment and Water Supply Management at a California EPA Site. p. 138. In: proceedings of XXVIIth IAHR Congress, Water for a Changing Global Community, Theme C: Groundwater An Endangered Resource.

Brogan, S.D. and R.M. Gailey. 1995. A method for estimating field-scale mass transfer rate parameters and assessing aquifer clean-up times. Ground Water 33 (6) 997-1009.

Gailey, R.M. and S.M. Gorelick. 1993. Optimal, reliable plume capture schemes: application to The Gloucester Landfill groundwater contamination problem. Ground Water 31 (1) 107-114.

Gailey, R.M., A.S. Crowe, and S.M. Gorelick. 1991. Coupled process parameter estimation and prediction uncertainty using hydraulic head and concentration data. Advances in Water Resources 14 (5) 301-314.

Publications (cont.)

Gailey, R.M. and D.E. Jones. 1987. The use of sediment permeability variations in the performance of petroleum recovery from glacial sediments. p. 515. In: Proc. of the Focus on Eastern Regional Groundwater Issues, National Water Well Association.

Presentations

A Case for Alternative Groundwater Monitoring under CASGEM in Northeastern California. Session Speaker, Groundwater Resources Association of California, 21st Annual Meeting and Conference, California Groundwater: Data, Planning and Opportunities, October 4 and 5, 2012, Rohnert Park, California.

Water Supply Well Rehabilitation Methods: Alternatives and Successes. Invited Speaker, Groundwater Resources Association of California Managing Wells in California and Protecting Groundwater Resources Symposium, August 22 and 29, 2012, Sacramento, California.

Factors Affecting Nitrate Concentrations in Water Supply Wells. 28th Biennial Groundwater Conference and 20th Annual Meeting of the Groundwater Resources Association of California, California's Water's Future Goes Underground, October 5-6, 2011, Sacramento, California.

Identifying the Sources of Nitrate to a Deep Municipal Water Supply Well Using Stable Isotopes of Nitrate, Groundwater Age Dating and Depth-Specific Sampling. Copresenter with Brad Esser, Groundwater Resources Association of California Environmental Forensics Symposium, April 12, 2011, Irvine, California.

Reducing Arsenic Concentrations from a Municipal Supply Well through Well Screen Modification. Invited Speaker, Arsenic Symposium: Treatment Alternatives and Case Studies, December 8-10, 2009, Bakersfield, Barstow and Ontario, California.

Simulating Flow and Transport Uncertainty Associated with Water Supply Well Modification Based upon Well Profiling and Pumping Test Data. Coauthor with Grace Su, 2010 National Groundwater Association Groundwater Summit, April 12-14, 2010, Denver, Colorado.

Reducing Arsenic Concentrations from a Municipal Supply Well through Well Screen Modification. Invited Speaker, Arsenic Symposium: Treatment Alternatives and Case Studies, December 8-10, 2009, Bakersfield, Barstow and Ontario, California.

Considering the Consumption of Energy and Other Resources during Pumping at the Well and Wellfield Scales. Invited Speaker, 27th Biennial Groundwater Conference and 18th Annual Meeting of the Groundwater Resources Association of California, Water Crisis and Uncertainty: Shaping Groundwater's Future, October 6-7, 2009, Sacramento, California.

Planning Combined Municipal Use of Groundwater and Surface Water: Technical and General Results from a Case Study. Session Speaker, Groundwater Protection Council Annual Forum 2009, Water/Energy Sustainability Symposium – Water and Energy Policy in the 21st Century, September 13-16, 2009, Salt Lake City, Utah.

Optimal Conjunctive Use of Surface Water and Groundwater Resources: A Tale of Two Cities. Session Speaker and Symposium Co-Chair, Applications of Optimization Techniques to Groundwater, a Groundwater Resources Association of California Symposium, October 16, 2008, Sacramento, California.

Details of Optimization and Applications to Groundwater Projects. Course Instructor and Co-Chair, a Groundwater Resources Association of California Short Course, October 15, 2008, Sacramento, California.

Application of a Simulation-Optimization Approach for Water Supply Wellfield Management and Plume Containment. Session Speaker, Groundwater Resources Association of California, 13th Annual Meeting and Conference, Managing Aquifers for Sustainability – Protection, Restoration, Replenishment, and Water Reuse, September 23-24, 2004, Rohnert Park, California.

Application of Mixed-Integer Linear Programming Techniques for Water Supply Wellfield Management and Plume Containment at a California EPA site. Session Speaker, International Association of Hydrological Sciences, International Symposium On Integrated Water Resources Management, April 9-12, 2000, Davis, California.

Application of Mixed-Integer Linear Programming Techniques for Water Supply Well Fixed Management and Plume Containment at a California EPA site. Session Moderator and Speaker, American Society of Civil Engineers Water Resources Planning and Management Division Annual Conference, June 6-9, 1999, Tempe, Arizona.

Presentations (cont.)

Wellfield Optimization: A Case Study. Session speaker, American Water Works Association, California-Nevada Section, Fall Conference, October 6-9, 1998, Reno, Nevada.

A Linear Programming Application for Water Resource Management at a Mining Operation. Session speaker, 25th Annual Conference on Water Resources Planning and Management, American Society of Civil Engineers, June 7-10, 1998, Chicago, Illinois.

Water Disposal Concerns with a Well Rehabilitation Project. Invited Speaker, American Water Works Association, California-Nevada Section, Water Well Monitoring and Rehabilitation Seminar, May 20-21, 1998, Stockton, California.

Quantifying Rate-Limited Mass Transfer Effects in the Field: Challenges Faced by Environmental Science Practitioners. Session speaker, American Geophysical Union Fall Meeting, December 8-12, 1997, San Francisco, California.

An optimization-based evaluation for groundwater plume containment and water supply management at a California EPA site. Session speaker, American Water Resources Association Annual Conference and Symposium on Conjunctive Use of Water Resources: Aquifer Storage and Recovery, October 19-23, 1997, Long Beach, California.

An optimization-based evaluation for groundwater plume containment and water supply management at a California EPA site. Session speaker, XXVII in IAHR Congress, Water For A Changing Global Community, August 10-15, 1997, San Francisco, California.

A method for estimating field-scale mass transfer rate parameters and predicting aquifer clean-up times. Session speaker, 1994 Groundwater Modeling Conference, August 10-12, 1994, Fort Collins, Colorado.

Design of optimal, reliable groundwater capture schemes. Session speaker, solving Ground Water Problems with Models, February 11-13, 1992, Dallas, Texas.

Design of optimal, reliable groundwater capture schemes. Lecturer, National Research and Development Conference on the Control of Hazardous Materials, February 4-6, 1992, San Francisco, California.

Design of optimal, reliable plume capture schemes: application to the Gloucester Landfill. Invited speaker, American Geophysical Union Fall Meeting, December 9-13, 1991, San Francisco, California.

The use of sediment permeability variations in the performance of petroleum recovery from glacial sediments. Session speaker, Focus on Eastern Regional Groundwater Issues, July 14-16, 1987, Burlington, Vermont.

Presentations on aspects of quantitative hydrogeology at the U.S. Geological Survey, Lawrence Berkeley National Laboratory, California Department of Water Resources, and universities (California State University at Sacramento, Harvard, Stanford, and the University of Illinois).

APPENDIX B

CALCULATIONS ON UNSATURATED ZONE TRANSIT TIME AND WATER QUALITY IMPACTS TO FIRST-ENCOUNTERED GROUNDWATER

APPENDIX B

CALCULATIONS ON UNSATURATED ZONE TRANSIT TIME AND WATER QUALITY IMPACTS TO FIRST ENCOUNTERED GROUNDWATER

Unsaturated zone transit time calculations were performed for representative locations within the KRWCA area. This work was accomplished in collaboration with a soil and agricultural scientist hired by the KRWCA (Joel Kimmelshue). From a larger evaluation conducted by Mr. Kimmelshue, entitled Kern River Watershed Coalition Authority Agricultural Return Flow and Nitrogen Transport Estimates and Comparisons, three locations were selected for evaluation (Figure B1). The salient details of each location are presented below.

- Location 1
  - Crop: citrus
  - Irrigation method: drip/micro
  - Soil: medium-grained
  - Return flow: 2.3 inches per year
  - Nitrogen lost below root zone: 15 pounds per acre per year
  - Unsaturated zone stratigraphy: loam in shallow subsurface transitioning to clay at depth
  - Depth to first-encountered groundwater: 500 feet
- Location 2
  - Crop: almonds
  - Irrigation method: drip/micro (90%) & flood (10%)
  - Soil: coarse-grained
  - Return flow: 5.0 inches per year
  - Nitrogen lost below root zone: 15 pounds per acre per year
  - Unsaturated zone stratigraphy: interlayered sand and clay
  - Depth to first-encountered groundwater: 330 feet
- Location 3
  - Crop: cotton/wheat
  - Irrigation method: furrow/border
  - Soil: coarse-grained
  - Return flow: 16.4 inches per year
  - Nitrogen lost below root zone: 55 pounds per acre per year
  - Unsaturated zone stratigraphy: interlayered sand and clay
  - Depth to first-encountered groundwater: 150 feet

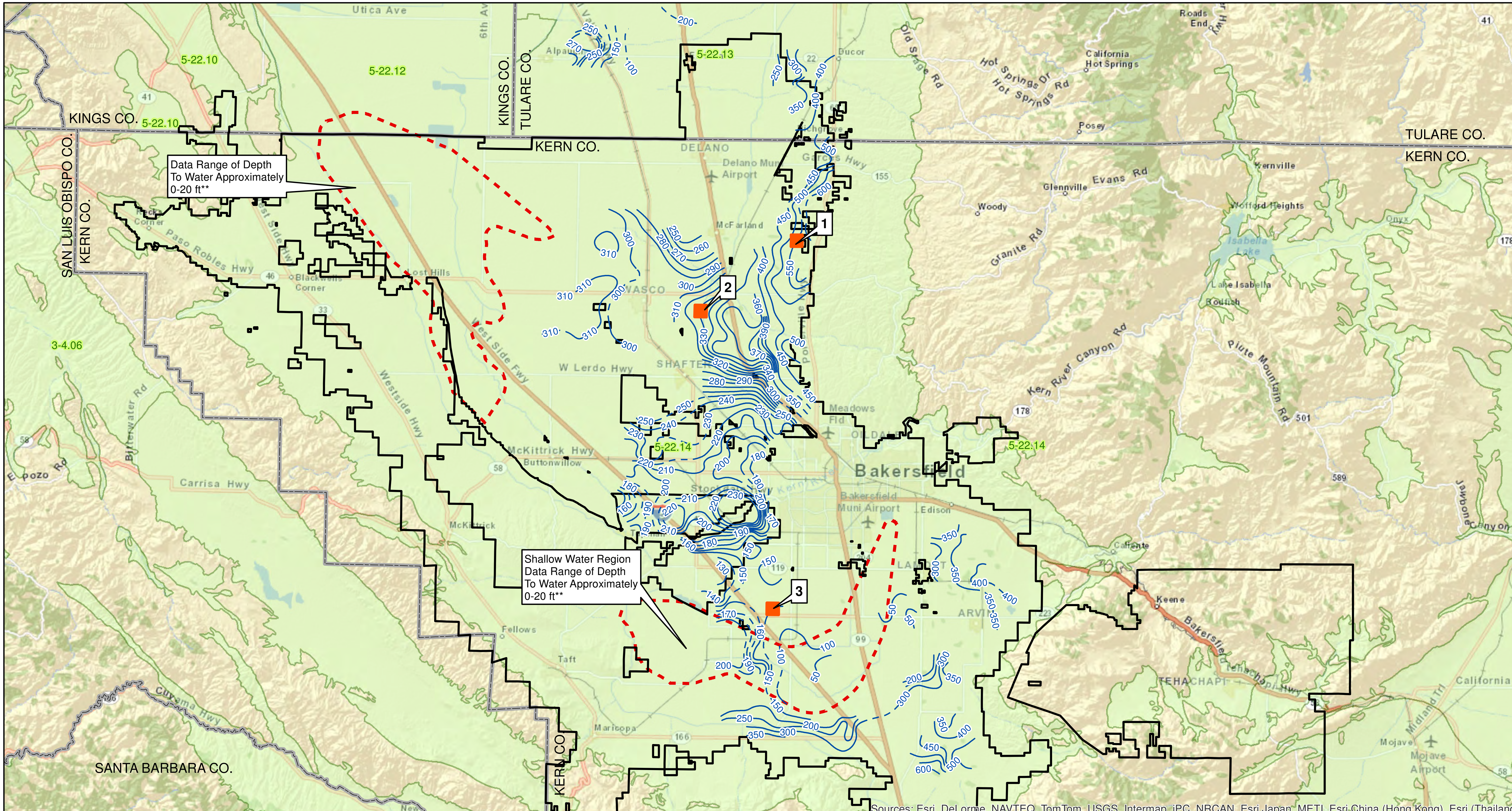
Unsaturated flow and nitrogen transport was simulated using the Hydrus 1D software. Estimates of monthly return flows and annual nitrogen losses below the root zone were obtained from Mr. Kimmelshue and used to specify upper boundary conditions for the flow and transport simulations (variable flux for flow and constant concentration for transport). Depth to first encountered groundwater was obtained from Department of Water Resources data (Figure 2a) and used to develop lower boundary conditions for the flow and transport simulations (constant head for flow and zero gradient for transport). Stratigraphy was included for each of the three locations based upon information from well completion reports obtained from KRWCA members, and physical properties were assigned based upon database values provided through the Hydrus 1D software. Initial conditions for flow were developed by running the flow model once before the flow and transport simulation was performed[15]. It was assumed that 1) all nitrogen occurred as nitrate, 2) no attenuation occurred by denitrification, diffusion or other processes and 3) no acceleration or deceleration occurred by anion exclusion, physical interaction with the sediments or other processes. This approach appears to be similar to that taken as part of the UC Davis nitrate study (Boyle et al., 2012); however, the two approaches differ in one important aspect. The present work included stratigraphic variability based upon field information instead of assuming a homogeneous soil column. This information adds a site-specific element to the results.

Transit times were calculated for transport from the bottom of the root zone to the bottom of the unsaturated zone. First arrival was considered as the simulated elapsed time when the nitrate concentration reached 1 mg/l at the bottom of the unsaturated zone[16]. Arrival of the 9 mg/l nitrate concentration, considered to be background (Boyle et al., 2012), was also considered. The results indicated a range in transport times[17]. For Location 1 where the depth to groundwater was greatest (Figure B1), arrival times were the greatest ranging from approximately 600 to 700 years (Figure B2). For Location 2 where the depth to groundwater was intermediate (Figure B1), arrival times were intermediate ranging from approximately 45 to 55 years (Figure B3). For Location 3 where the depth to groundwater was least (Figure B1), arrival times were the least ranging from approximately 10 to 15 years (Figure B4).

[15] The durations of the initial flow simulations were long enough to include the elapsed times for the transport simulations.

[16] Transport as nitrogen was simulated and the predicted nitrogen concentrations were then converted to nitrate concentrations.

[17] Transport mass balance errors were less than 0.5 percent.



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- Locations of Bulk Unsaturated Flow Estimates
- DWR Groundwater Basin/Subbasin (ID Label)
- County
- KRWCA Boundary
- Shallow Water Region - Approximate**

Depth To Water - Unconfined Aquifer***

- High Degree of Confidence
- Inferred

Data References:

**Areas digitized from CA DWR "Present and Potential Drainage Problem Areas" survey map, 2010
http://www.water.ca.gov/pubs/drainage/2010_shallow_groundwater_map__san_joaquin_valley/sgw10.pdf

***Isopleth lines from CA DWR "Lines of Equal Depth to Water in Wells, Unconfined Aquifer, San Joaquin Valley, Spring 2010"
http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/images/groundwater/sjv2010spr_unc_depth.pdf

Kern County Irrigated Lands Program
Kern Sub-Watershed

Locations For Unsaturated Flow Estimation

FIGURE B1

4/5/2013: V:\Clients\Kern River Watershed Coalition Authority-3484\348412V1-ILRP 2012\GIS\Map\DataProcessingForRobGailey\ReportFigs\figureB1.mxd

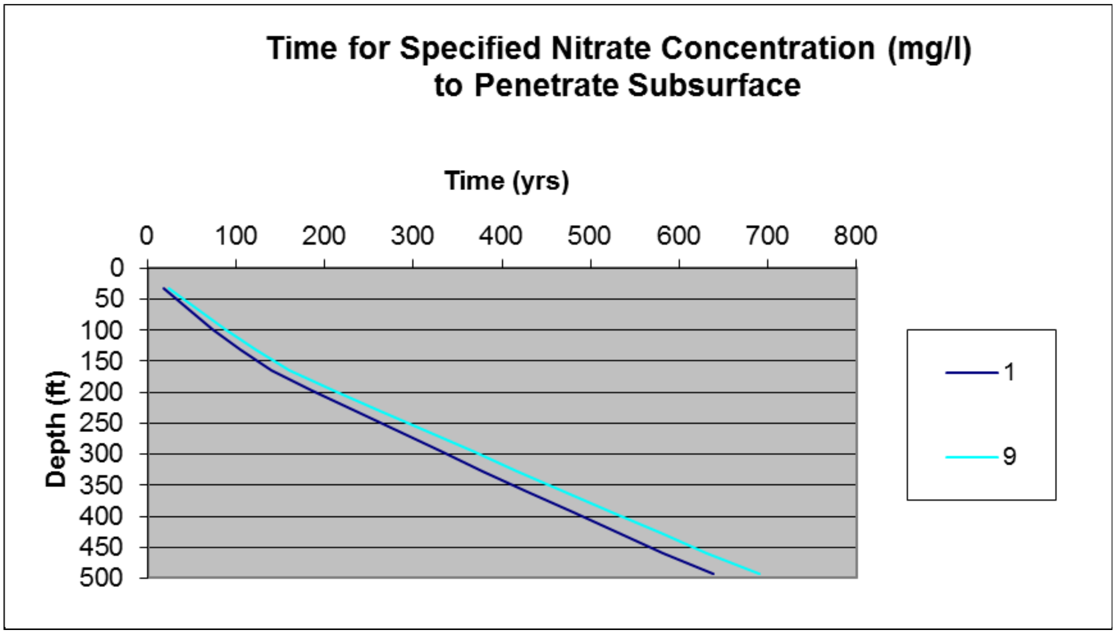

Figure B2: Nitrate Arrival Times for Location 1

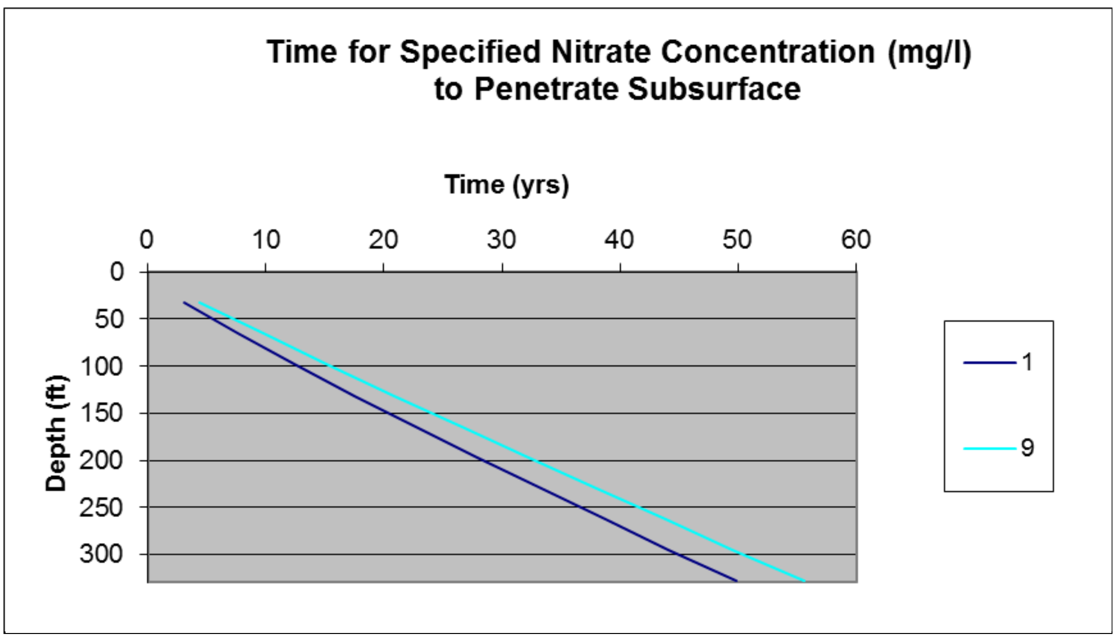

Figure B3: Nitrate Arrival Times for Location 2

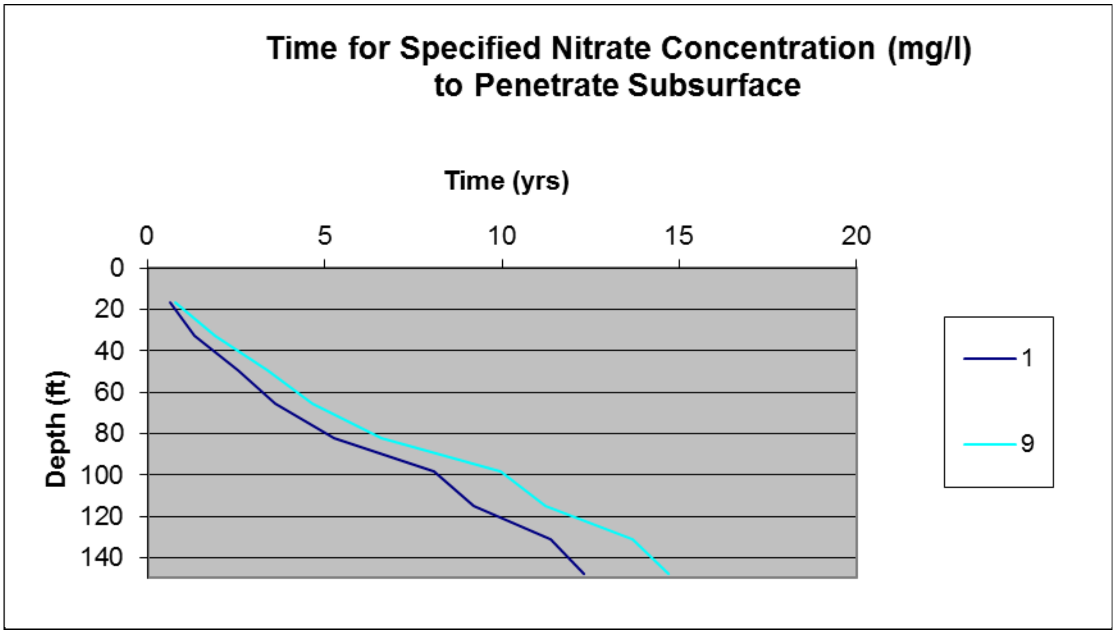

Figure B4: Nitrate Arrival Times for Location 3