KINGS RIVER WATER QUALITY COALITION

A Comprehensive Groundwater Quality Management Plan to Address COC’s identified within the Groundwater Assessment Report

October 17, 2016
I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel or represented Members properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for knowingly submitting false information, including the possibility of fine and imprisonment for violations.

Casey Creamer, Coordinator
Kings River Water Quality Coalition
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Appendix A: MPEP Memo on Management Practices
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This Comprehensive Groundwater Quality Management Plan (CGQMP) for the Kings River Water Quality Coalition (KRWQC) has been revised in response to the comment letter received from the Regional Water Quality Control Board (August 16, 2016) regarding its November 2014 submittal. At the time, the Management Practices Evaluation Program (MPEP) was yet to be developed, so its benefits will be expanded upon in this document. The Kings, Kaweah, Tule, Kern, Buena Vista, Westside-Kern, and Cawelo Coalitions already operate under a single Management Practices Evaluation Program, so a consistent approach to the Comprehensive Groundwater Quality Management Plan is a natural extension for compliance with the Tulare Lake Basin General Order.

The Comprehensive Groundwater Quality Management Plan option was selected because of the large geographic area identified as High Vulnerability within the Kings and Tulare Lake sub-basins covered by the KRWQC and prevalence of a single Constituent of Concern within the coverage area.
Introduction and Background

Groundwater is an important resource to many constituencies within the Kings River Basin. Many of the communities and isolated domestic systems are reliant upon groundwater as their primary domestic water supply, while the majority of the surface water supply within the basin has been diverted for agricultural uses. Agriculture relies on groundwater to make up for (1) shortfalls in surface deliveries, (2) as the primary source of water where surface deliveries do not exist, and (3) as an “on-demand” supply for those who use drip/microsprayer systems, which require water more frequently than surface water delivery schedules permit.

Prior to the development of irrigated agriculture within the Tulare Lake Basin, the major rivers within the basin (Kings, Kaweah/St. Johns, Tule, and Kern) would bring considerable volumes of Sierra snowmelt into the valley and flood vast tracts of land with very clean (low hardness and EC) waters, which would eventually percolate into basin and become groundwater. In areas where the uplifted marine deposits were more dominant (west of the valley trough), salts washed from these soils would also be deposited. The shallow nature of the water tables during this time would bring these dissolved salts back to the surface through capillary action as the Tulare Lake receded, thus leaving a “ring” of saline soils along its western and southern perimeters. These regions are still present today, but the land has been made productive through the use of drainage technologies such as tile drains and salt tolerant cropping.

Irrigation supports approximately 49 major crops within the three counties covered by the KRWQC (plus some minor ones), which for 2013 had a gross value of over $12 billion (2013 Agricultural Commissioner’s Reports). This represents the total crop value (i.e., excludes livestock and milk) for the three counties (Fresno, Kings, and Tulare); the total value within the KRWQC would be less, since only portions of Fresno, Kings, and Tulare Counties are contained within KRWQC.

The Kings River sub-basin is divided along political lines into the “Upper” and “Lower” basins. The Upper basin consists of the Fresno Irrigation District, Alta Irrigation District, and Consolidated Irrigation District, plus some smaller entities. These districts overlay a region with higher soil permeability and have a generally higher reliance on surface water than on groundwater for irrigation. The Lower basin has much lower soil permeability (finer textured soils), and a greater reliance on groundwater for irrigation. The western portions of the basin (outside of the irrigation district boundaries near the North fork of the Kings) are entirely dependent upon groundwater for irrigation.

Irrigation practices for the multitude of crops grown within the Kings Basin have evolved as greater understandings of crop-water relationships have occurred. Knowing that crop growth can be beneficially influenced by the application or withholding of irrigation water at critical times, growers have successfully increased crop yields and quality using less water than in years past.

Changes in cropping patterns over the years has promoted the conversion of irrigation systems from the regularly scheduled surface water deliveries to a more intensively managed micro irrigation system that allows for the maintenance of optimal soil moisture conditions (reduced or eliminated anaerobic soil conditions common to surface irrigation) and the matching of applied water to actual crop usage rates, plus a small leaching fraction. This balancing of the water applied to the water used has led to a reduction in deep percolation of irrigation water during the growing season, and has increased the available soil capacity to absorb winter rainfall. Many growers rely on winter rains to handle the leaching requirements needed to move salts from the root zone. As a consequence of this higher level of management, in-lieu recharge that resulted from previous surface irrigation practices has been reduced, and the overall rate of groundwater replenishment has decreased. The flip side of this is that there is less opportunity for unused nutrients or other soil-applied solutes to migrate out of the root zone and eventually into the underlying aquifer.
Figure One: Coverage Area and Associated Groundwater sub-basins
This CGQMP and the MPEP effort will be used to support the changes that are already underway and to increase adoption of protective management practices, where necessary (i.e., where the potential for losses of solutes to groundwater is significant, and where protective practices are not already in place).

Nitrates are the primary constituent of concern for this management plan. There are multiple sources of nitrates within the KRWQC. The application of fertilizer for agricultural crop production is the primary source that we are considering for this CGQMP. However, confined animal operations, septic systems, municipal and industrial discharges, and naturally occurring sources also contribute nitrate to groundwater. This constituent has not been detected in monitored surface water supplies within the KRWQC.

Total Dissolved Solids (TDS, aka salts) is discussed heavily within the Groundwater Quality Assessment Report (GAR). Salinity management in the KRWQC is a high priority due to natural geologic conditions and crop sensitivity. Salinity is best handled by comprehensive salinity management approaches. KRWQC is actively participating in the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) process to understand and develop mechanisms to balance salt in the Tulare Lake Basin.

Pesticides are monitored by the California Department of Pesticide Regulation and other agencies, and practices that potentially lead to groundwater contamination are addressed through grower education.

**COCs Subject of Plan**

The COC’s identified as causes or potential causes of exceedances of groundwater quality standards are nitrates, pesticides, and salts.

**Nitrates**

Nitrates subject to this plan are related to applied fertilizers that contain nitrogen-based compounds of ammonium (NH₄⁺) and two nitrogen oxides (nitrite (NO₂⁻) and nitrate (NO₃⁻)). Nitrite is not a commercial fertilizer/plant nutrient, but is one ionic form of nitrogen. Nitrogen is classified by plant physiologists as a macronutrient, because plants absorb/consume relatively large quantities of it in order to grow. Atmospheric nitrogen is not directly available to most plants because of its stable nature. To become available, atmospheric nitrogen must be converted to usable forms by natural processes (free living bacteria, bacteria in symbiotic relationships with plants, organic material decomposition, or lightning), or by industrial fixation (e.g., for commercially manufactured fertilizers).

Ammonium is not considered a direct threat to groundwater due to its volatility and adsorption to soil particles. Nitrite is relatively unstable, and therefore rare in soil. Nitrate can be a concern to groundwater because of its solubility in water, and because of its net negative charge, so that it interacts minimally with most soil particles (which predominantly adsorb positively charged ions on their surfaces). Soil organic matter can hold these compounds briefly, as they contain positively charged binding sites. Nitrate is therefore highly mobile within the soil solution, and once leached from the soil profile, can move with water toward the water table.

Other fertilizer forms (phosphorus, potassium, and micro nutrients) are more likely to be bound to soil particles/organic matter once in the soil environment. As such, these materials are more likely to impact surface waters through sediment discharges.

Source of the nitrates vary. They are present naturally from decaying organic matter, and are present in septic system discharges, food processing discharges to surface ponds, confined animal feeding facilities, in manure/compost (both as nitrate/ammonia and organic matter), and in synthetic fertilizers. Irrigated
agriculture can and does make use of several of these sources, often in combination. Nitrogen fertilizer is applied in either liquid, solid, or gaseous forms, and can enter the groundwater via leaching or improper connections/inadequate protections at the well.

The Nitrogen Management Plan requirement has the potential to greatly reduce the nitrate loading being applied by growers by encouraging the growers to actively consider the nitrate content of the soils within their fields and in groundwater used for irrigation, when planning fertilizer applications. Data analysis of the aggregated Nitrogen Summary Report data and its subsequent communication to member growers will further emphasize the benefits of knowing what nitrate is already available before any additional material is added.

Pesticides

Pesticides can reach groundwater either by leaching through the soil profile or by direct transport to groundwater through poorly maintained wellheads, poor housekeeping procedures, or inadequate backflow prevention mechanisms. Many of the compounds used by agriculture are hydrophobic, and must be mixed with certain other agents to get them into an aqueous solution for application. Such compounds typically remain in the soil profile, and can be broken down quickly via microbially mediated reactions, and may be detained in soils through adsorption. Some of the applied materials are extremely persistent within the environment (long half-lives or persistence in food chain), but these compounds are no longer registered for use.

Those that can leach directly through the soil profile to groundwater are limited in number. The California Department of Pesticide Regulation (DPR) has instituted a Groundwater Protection Area program to test and evaluate potential pesticide contamination issues within groundwater basins. Pesticide movement through the soil profile must be evaluated and found to be acceptably slow before product registration in California.

Materials are evaluated relative to risk of movement through the soil profile, type of application (spray or direct injection), amount of usage within a region, and other factors and then ranked for potential sampling. Those found to be of high risk of leaching and in regions where leaching can readily occur have additional usage limitations when used in such areas.

DPR maintains a network of shallow wells that they sample yearly; other pesticide detection data are reported to DPR by the State Water Resources Control Board or other agencies. Locations of the DPR monitored wells are currently not publicized, but they are likely in or near the Groundwater Protection Zones set up under their monitoring program. DPR monitoring results are published yearly, and can be reviewed for any trends that may warrant additional monitoring by the KRWQC.

A review of these reports covering the counties serviced by the KRWQC for 2012-2016 showed that of the 179 constituents monitored by or reported to DPR, 41 showed detections, and most of those were intermittent. This could be a function of the same well not being reported year to year. Additional analysis as to well locations (not readily available) and associated detections is needed to properly evaluate this dataset.

Groundwater Protection Areas were included in the GAR submitted by the KRWQC as part of the consideration as to whether lands would be designated “High Vulnerability” or not. DPR has instituted special requirements for the use of leachable pesticides within these Groundwater Protection Areas, and if monitoring shows that such materials are leaching into the local groundwater, DPR has pledged to increase the regulatory restrictions for their use, up to and including their prohibition.
The KRWQC will use the submitted Farm Evaluation data to refine the Outreach materials regarding Wellhead Protection (Part B of the Farm Evaluation Template) to further educate the growers as to the DPR regulations regarding (1) pesticide storage near wells and (2) backflow prevention requirements for both fertigation and chemigation. Many of these requirements already exist as label restrictions. As the Farm Evaluation templates are received yearly, trends in wellhead protection can eventually be tracked and specific outreach materials can be disseminated.

Salinity

Chemically, a salt is defined as being a metal cation (positively charged) combined with a non-metallic anion (negatively charged, either elemental or a compound) that freely disassociates into individual components (cationic and anionic) in an aqueous solution. Sodium chloride (table salt, NaCl) freely separates into sodium (Na⁺) and chlorine (Cl⁻) once introduced into water. Remove the water, and the salt crystals reappear. Many other naturally occurring compounds do the same within the soil solution. Anything that readily disassociates in solution can be called a salt, and is considered so when measuring salt in soil or water.

Many salts naturally occur within the soil but may be in greater concentrations within groundwater due to irrigated agriculture. Reported as Total Dissolved Solids (TDS), this is a physical measure of the total amount of salts that have been dissolved into solution. It is easily measured as electrical conductivity (EC), and can be mathematically converted from EC to TDS or TDS to EC as desired.

Alluvial deposits fill in the valley floor. The origin of locally derived salts is the marine-based deposits found in the western portion of the San Joaquin Valley. Being the former sea floor, the western alluvium is rich in mineral salts that are easily brought back into solution through rainfall or irrigation. The abundance of fresh water flowing from the Sierra plus the nature of the sediments cause the salt content of the eastern valley to be much lower than that found on the western edge. Many of the salt components present are beneficial to plants when sufficient quantities of fresh water are used for irrigation. Development of salt tolerant crop varieties has expanded the use of such lands even further.

Another significant source of salinity is irrigation water itself. While surface water tends to contain relatively low levels of salinity, groundwater is more variable. In either case, irrigation itself delivers an additional mass of salt into the root zone that, over time, displaces most endogenous salts, and predominate salts held in irrigated soils.

Fresh irrigation water allows plants to better control the environment around their roots by selective uptake of nutrients and the exclusion of harmful constituents. It is the unused water from irrigation that prevents excessive accumulation of salts, and that carries excess dissolved materials downward, sometimes reaching groundwater.

Root-zone salinity may also exchange with shallow groundwater, when poor drainage allows seasonal or perennial rise of groundwater into root zones. The western portions of the Kings River and Tulare Lake sub-basins do possess clay layers that restrict the free movement of water through soils, thus creating “perched” water that can concentrate salts back at the surface. Such layers are either widespread or only present locally. Tile drainage systems (perforated pipes used to intercept and remove excess and deep percolated irrigation waters) help reclaim this land for useful production by removing water with high dissolved salt content from the root zone.

The underlying geology of the KRWQC service area is discussed more extensively in a later section.
The reliance of the western basin on pumped groundwater has depressed the groundwater tables within the region, thus making it necessary to extract irrigation or drinking water supplies from deeper aquifer layers. Standing water in this part of the basin is routinely measured at 200 feet below the surface or greater, and has been steadily falling. Water from such depths is usually quite old, and has had ample time to dissolve some of the more resistant salts (from sediments). Such depths to groundwater also translate into long transit times for waters applied at the surface to reach the groundwater table.

Groundwater salinity is a concern in this portion of the basin. It is recognized that surface irrigation has the potential to move salts further into the vadose zone and eventually into groundwater. Because salinity is a naturally occurring constituent, and because salts are mobilized by the same basic mechanisms as nitrates, the KRWQC will seek to communicate those practices that limit nitrate leaching (a more critical issue in the eastern basin) to the western basin members as they are developed. Water availability issues (increasing depths to groundwater, lack of reliable surface water supplies) has already encouraged many growers in this part of the basin to convert to high-efficiency irrigation practices, thus limiting irrigations to crop need and minimizing leaching fractions (percolation of water below root zones).

Communications of DPR findings regarding pesticide detections (new pesticides and general locations, movements of existing plumes or regions of concern) will be included among KRWQC Outreach activities.

Management practices that are protective of groundwater will be discussed in detail within the Management Practice Evaluation Program workplan. Changing irrigation practices appears to be one of the best ways to reduce the movement of salts and/or nitrates from the soil surface to the underlying groundwater. Shifting from surface irrigation practices to drip/micro irrigation (where feasible) will help to limit the application of irrigation water to what is required to meet crop needs, plus a minimal leaching fraction. Drip irrigation is already widespread in permanent, and some vegetable (e.g., canning tomato) crops. Over time, its use is expected to expand over greater acreage.

Ayers and Westcot (Water Quality for Agriculture, 1989) recommended minimum leaching fractions of about 5-10% above crop need, so that harmful salt accumulation does not occur within the root zone. Use of high-TDS irrigation water requires a greater leaching fraction. Timing of this leaching application varies with the grower; it can occur during each individual irrigation event, or can take place at the end of the crop year (or perhaps in the early spring to take advantage of any winter rains). The best time to do this leaching would be when nitrate levels in the root zone are minimal, usually early spring or late fall. Spring offers the best opportunity to do this with a minimal water application, as the soils should be relatively saturated from winter rains.

Additional groundwater data references were provided in the Conditional GAR approval received from the Regional Water Quality Control Board (April 2016) and will be considered during the development of the Trend Monitoring Workplan and the GAR 5-year update.

Salinity and nitrate issues within the San Joaquin Valley as a whole are being discussed through the Regional Board’s CV-SALTS process, along with the State Groundwater Management Area (SGMA) program. Specific studies on water management as related to nitrate and salt movement and management are being proposed through the CV-SALTS process, specifically the Surveillance and Monitoring Program (SAMP).

Prioritization of COCs

While all of the above categories (fertilizers, pesticides, salinity) are important considerations for a groundwater management plan, their priority should be set according to which is the dominant concern
for the region. When looking at the region from the standpoint of drinking water, one would look at nitrates and pesticides as being the priority, but when looking at the western basin, one might be more concerned with salt accumulation within the root zone over the long term.

The higher population density of the eastern portion of the groundwater basin, and the reliance on groundwater for drinking, makes these constituents the highest priority for action. This portion of the Kings River sub-basin has already been designated as High Vulnerability by the GAR. Thus, looking at the groundwater basin as a whole, the most urgent impact to water quality would appear to be nitrates, followed closely by pesticides. Both of these issues are found within a common region (the eastern portions of the Kings River sub-basin where depth to groundwater is shallowest). Protective irrigation practices for nitrates will also be helpful in minimizing pesticide movement through soils. However, materials already in groundwater will not be affected by changes to surface management practices. Many of the same irrigation practices can be applied to the salinity issues in the western basin, although balancing adequate leaching with soil drainage to manage salts is complex in its own right.

Pesticides will be more difficult to address, particularly for materials that decompose slowly within the soil or groundwater. Unlike plant nutrients, pesticides will not be consumed by plants. Many of the pesticides currently detected in groundwater are no longer registered for use, so they may become less of a threat to public health over time. Among persistent pesticides that have active registrations, restrictions on their use within the defined Groundwater Protection Zones, and changing cropping patterns, will limit their use along with associated risks to groundwater quality.

The KRWQC will begin its prioritization with nitrate control (through the use of the Farm Evaluation and Nitrogen Management Templates/Summary Reports and its Management Practices Evaluation Program, or MPEP) in the eastern regions of the Kings River sub-basin, with particular focus on areas around Disadvantaged Communities (DACs). If sufficient changes to agricultural practices can be made, nitrate loading at the surface can be reduced to the point where other factors (dedicated groundwater recharge, natural groundwater movements due to rainfall) will eventually make improvements to the groundwater quality within the basin. Strategies that have been proven protective of groundwater via the MPEP will be communicated to all growers within the KRWQC. As noted in Appendix A, MPEP outreach activities are scheduled for the 2016/17 fall-winter period, so that practices during the next (2017) growing season can be affected.

Salinity behaves much the same way as nitrate (being highly mobile within the soil), so irrigation management would likely have the strongest influence on its fate. As stated previously, the natural occurrence of salinity within the soils and shallow groundwater of the western portions of the KRWQC require careful management to avoid accumulation and harm to crops. Long-term, regional strategies for salinity management are currently under development in the context of the CV-SALTS process, in which KRWQC is an active participant.

Region Covered by CGQMP and How Determined

The region covered by this CGQMP has been determined by the results of the GAR analysis conducted for the KRWQC. The region will consist of the following land areas as determined by the GAR:

1. Sections determined to have High Groundwater Vulnerability, excluding sections located underneath the Tulare Lake Basin’s MUN/AGR de-designation study
2. Sections determined to have a nitrate exceedance, unless those sections are within identified city boundaries (county islands that may still have irrigated agriculture are left in the program).
Some lands will be excluded from direct program involvement because of potential coverage under another WDR program (such as a specific WDR for a particular site, or the Dairy Order). The KRWQC has excluded these areas due to existing regulatory coverage. Groundwater in impacted areas may nevertheless be monitored as part of a regional groundwater quality trend monitoring network.

Areas designated as “High Vulnerable” (HV) from the GAR analysis were found to be that way through the use of a proprietary “GAR Analyst Tool” developed by GEI Consultants, Inc. This application took intrinsic conditions (fixed values) and combined them with assorted vulnerability (variable) factors to create GIS layers that totaled the assorted risk indices for each category. The values considered are shown in Table One.

The sensitivity of the GAR Analyst Tool can be adjusted to increase or decrease the number of parcels contained within the HV area. Changes to the factors used in the calculations would need sufficient technical justification. The initial HV area designated by the KRWQC and Regional Water Quality Control Board (Conditional GAR approval, April 2016) was highly inclusive of all lands within the region, even if the initial GAR analysis suggested that the land would not be vulnerable. As more data is collected via the Trend Monitoring program and other data sources not readily available during the GAR Analyst Tool development is entered into the model, it is expected that the HV area will be adjusted further. Should the East San Joaquin Petition dictate a removal of High and Low Vulnerability areas for regulatory requirement purposes, the GAR Analysis will be used to further refine the priority areas for KRWQC activity.

Table One: Factors Considered by GAR Analyst for Vulnerability Designations

<table>
<thead>
<tr>
<th>Intrinsic Values</th>
<th>Vulnerability Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Permeability</td>
<td>Regional Vulnerability (artificial recharge, conjunctive uses, imported water,</td>
</tr>
<tr>
<td></td>
<td>reservoir operations). May also include septic systems, wastewater recycling,</td>
</tr>
<tr>
<td></td>
<td>surface or groundwater treatment plants</td>
</tr>
<tr>
<td>Soil Transmissivity</td>
<td>On-Farm Vulnerability (nutrient application and timing, methods of application,</td>
</tr>
<tr>
<td></td>
<td>irrigation system, and cropping</td>
</tr>
<tr>
<td>Depth to Groundwater</td>
<td>Drinking Water Vulnerability</td>
</tr>
<tr>
<td>Aquifer Thickness</td>
<td></td>
</tr>
<tr>
<td>Clay Layer Thickness</td>
<td></td>
</tr>
<tr>
<td>Natural Streamflow</td>
<td></td>
</tr>
<tr>
<td>CVHM Output</td>
<td></td>
</tr>
</tbody>
</table>

Each characteristic is assigned a value, and the layers are tabulated. For example, soils with low permeability would be ranked low (value set at 1) where high permeability soils would be ranked higher (value set at 5 or greater, depending on the number of categories). Greater depths to groundwater would rank low; shallow or perched groundwater would rank higher. Some characteristics may not be present within a particular study unit (square mile), and that characteristic would receive a rank of zero.

Like any other GIS output, the final determination of vulnerability can be adjusted for those factors that on a subjective level can be either factored in or factored out. In the case of determining the which areas are to be considered high vulnerability, it was determined that the impacts of Dairy operations needed to be included within the GAR Analyst Tool’s output, as additional layers. This data, supplied by the Regional Board staff, increased the regions designated as vulnerable. As these are covered by a separate Order, these sections were removed from the vulnerability area efforts that the KRWQC would oversee.

The geographic layout of the GAR Analyst’s vulnerability area is not one that can be contained within a simple polygon. The high vulnerability areas are defined as square mile blocks, which makes
identification of the affected parcels more efficient, since parcel boundaries generally don’t cross section lines. This is also a fairness issue, as adjacent parcels within the same section could receive differing vulnerability designations; it is easier to justify the drawing of lines at the section level than at the parcel level since section lines do not change over time.

The blocks do tend to group together, but some are islands or linked by single sections. The largest area of concern is located in an arc from northeastern Fresno County through northwestern Tulare County and northern Kings County. This is essentially the area east of Sanger to the area around Parlier but west of Reedley and Dinuba, circling southwest towards Hanford and westward to Laton, north of Lemoore (following a path almost parallel to the current river channel). Isolated areas west-southwest of Fresno (between Fresno and Kerman, around Biola) are also identified.

Another area is around San Joaquin/Tranquility, but this is likely due to the influence of perched water tables common to Westlands, and is being considered for a lower priority within the KRWQC area. Any studies within this region will be considered at a later date. The area north of the proposed MUN de-designation for the Tulare Lake Basin is also known to have perched water of marginal quality (high TDS), and is also known to be permitted for extensive dairy operations.

The last area is located within Lakeside Irrigation District (west of the Kings County line) which is also heavily influenced by dairy operations.

Other regions of interest are areas of nitrate exceedances that do not overlay geographic areas that the GAR Analyst has identified as vulnerable or the Regional Board has identified as being under the Dairy Order. These regions are home to several Disadvantaged Communities (DACs (rural, low income communities)). The KRWQC, along with the Regional Water Quality Control Board, has selected a HV area that encompasses all of the GAR Analyst’s HV areas, plus those areas in-between, with the boundary lines drawn along the section lines.

The total area covered by the CGQMP is 299 sections (191,360 acres). This was arrived at in the following manner:

<table>
<thead>
<tr>
<th>Category</th>
<th>Sections</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Vulnerability Sections</td>
<td>337</td>
<td>215,680</td>
</tr>
<tr>
<td>NO₃ Outside of HV Sections</td>
<td>157</td>
<td>100,480</td>
</tr>
<tr>
<td>NO₃ Impacted by Dairy</td>
<td>111</td>
<td>71,040</td>
</tr>
<tr>
<td>Dairy Impacted Sections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>outside HV Area</td>
<td>84</td>
<td>53,760</td>
</tr>
<tr>
<td>Totals</td>
<td>299</td>
<td>191,360</td>
</tr>
</tbody>
</table>

The total area is calculated by adding impacted High Vulnerability sections (HV Sections plus NO₃ Outside of HV Sections) and deducting those sections impacted by Dairy operations (NO₃ Impacted by Dairy plus Dairy Impacted Sections outside of HV Area). This was done because Dairy operations are not covered by this General Order. The KRWQC is mandated to address issues related to irrigated agriculture, and this CGQMP is designed to address those issues.

A considerable independent effort is being conducted by landowners within the Tulare Lake sub-basin to remove MUN and AGR beneficial uses from the region’s groundwater. This is based upon the lack of available groundwater above the Corcoran Clay formation within the Tulare Lake bed, the lack of
habitation of the lakebed, and the known risk of periodic flooding of the lakebed. Soil conditions are also a factor, as the heavy clay soils in the region have relatively low infiltration rates.

Previous Work Conducted

The GAR produced by the KRWQC considered all of the major hydrologic research conducted within the Central San Joaquin Valley and Tulare Lake Basins in performing its vulnerability analysis. The list of work referenced by the consultant is included within the GAR. Other efforts that are ongoing includes the Kings River Conservation District (KRCD) coordinated CASGEM (California State Groundwater Elevation Monitoring) program for groundwater elevations (direct monitoring of selected wells by KRCD or the local irrigation districts) for the Kings and Tulare Lake hydrologic basins. Water quality monitoring is ongoing in other regulatory programs (Dairy General Order, individual discharge permits, POTW permits, CDPH/State Water Resources Control Board monitoring, DPR Groundwater Protection monitoring, etc.) as well. These data sets were considered during the initial GAR Analyst Tool development, and updated data will be considered with the 5 year GAR revision.

Much of the data reported under these programs has been uploaded into GeoTracker GAMA at the State Water Resources Control Board.

Much of the Central Valley has been studied by the USGS and other researchers and the groundwater flow patterns analyzed by the Central Valley Hydrologic Model (CVHM). The model then subdivided the study region into individual analysis blocks, laid out in a grid. This grid was the basis for the GAR Analyst, once the orientation of the study blocks was corrected to surface survey lines (Township/Range/Section) rather than magnetic (compass) lines. The data used in the GAR utilized all publically available data sources (outlined in Chapter 3 of the GAR), and extensive QA/QC review of the data was performed prior to analysis. Some data was not initially available for consideration, or could not be properly evaluated in the time allotted for the GAR preparation. Other work performed regarding groundwater quality is outlined in the GAR. Missing data sets will be added to the GAR analysis at the 5 year update.

Groundwater Quality Assessment Report (GAR)

The KRWQC awarded a contract to prepare the GAR to GEI Consultants, Inc. GEI’s approach was to combine “Intrinsic Susceptibility” factors with “Vulnerability” factors to arrive at relative risk for groundwater impairment. Intrinsic factors were defined as the physical characteristics present (those that could not be changed by surface management activities) and includes soil permeability, soil transmissivity, depth to groundwater, aquifer thickness, aquifer confinement, clay layer thickness, and natural streamflow (KRWQC GAR pg. 2-2). Vulnerability covers those factors that can be controlled/influenced by surface activities, such as Regional vulnerability (artificial recharge, stream management, conjunctive use, storage operations, and other potential macro-scale operations), On-farm vulnerability (rate, timing, and material selected of fertilizer applications), and Drinking water vulnerability (municipal and domestic drinking water operations) (KRWQC GAR pg. 2-3).

Each of these factors was expressed as a separate layer within a GIS-based analysis. The first layer considered was the CVHM grid, corrected to surface survey lines. The CVHM is an accepted model of hydrologic performance and is fully peer reviewed and calibrated. It forms a solid foundation for the additional risk considerations added to the GAR analysis.

Each additional layer was subjected to considerable statistical analysis and review, using accepted research and consultation with local experts, depending on the criteria being evaluated. This, in the words of the GAR team, allowed the comparison of “apples to apples” in the overall analysis. In many ways,
the GAR approach used by the KRWQC consultant mirrored that of the NHI analysis used in the Harter report, but with additional risk factors and other considerations added.

CV-SALTS

CV-SALTS (Central Valley Salinity Alternatives for Long Term Sustainability) is a stakeholder process with the goal of finding long term management solutions for the problem of salinity build up within the Central Valley of California. The process has been expanded to address nitrate issues as well, since nitrate behaves in a similar fashion in the soil as salinity, and is a pressing issue for drinking water. The Technical Committee has pursued a pilot study within the Alta Irrigation District (Kings River sub-basin, eastern Fresno and northwestern Tulare County) for the purpose of developing “a monitoring program that will allow for statistically-defensible Ambient Water Quality (AWQ) determinations and trend analysis. The Surveillance and Monitoring Program (SAMP), as part of the Salt and Nitrate Management Plan (SNMP), is designed to fulfill the monitoring requirements of the planned Basin Plan Amendment (BPA) and support its adoption and approval.” (SAMP Final Report, CDM Smith, June 2016).

The management of the KRWQC and the other Southern San Joaquin Valley Coalitions are closely involved in the CV-SALTS process as a voting member.

Isotope Study

The KRWQC funded a study conducted by Lawrence Livermore National Laboratory to study the nature of the nitrate contamination within the Alta Irrigation District. This study, published in July 2016 (Bradley K. Esser, Ate Visser, Amanda Deinhart and Michael J. Singleton (2016) Groundwater Age and Nitrate Isotopic Composition in Alta Irrigation District Water Supply Wells. Lawrence Livermore National Laboratory, LLNL-TR-682246, 59 pp.). Sampled waters were found be of various ages and nitrogen detections from a number of sources.

Addressing Nitrate in California’s Drinking Water (Harter Report)

The California legislature mandated that the State Water Resources Control Board commission a study of groundwater quality for the Tulare Lake and Salinas Valley regions of California. Dr. Thomas Harter from University of California, Davis was selected to conduct this study. Using available data, Dr. Harter’s conclusions were that irrigated agriculture was the primary source of nitrate within the groundwater basins, and that even if all nitrogen fertilizer applications were to stop, the groundwater would take decades, if not centuries, to return to levels below the MCL. He and his team concluded that remediation was economically unfeasible, and that a “pump and fertilize” strategy was the best method to begin the recovery of the groundwater quality. This strategy is the basis for the Nitrogen Management Plans, in that the growers are encouraged to consider the amount of nitrate already available in their irrigation water source prior to purchasing additional materials.

Objectives

Under the Water Quality Control Plan for the Tulare Lake Basin (updated January 2004), the objective for nitrate within a water source in the Tulare Lake basin is tied to its beneficial uses. The majority of the basin lists MUN as a beneficial use (a study to amend the Basin Plan to remove the MUN and AGR beneficial uses for a portion of the Tulare Lake sub-basin region is underway), and as such, the beneficial use must be protected. Larger communities can afford the treatment necessary to remove nitrate from the water supply (or have sufficient other sources (deeper wells e.g.) that can blend the water to below the MCL. Smaller communities and individual domestic wells may not have sufficient resources to treat the water supply, and frequently find that using deeper wells to escape the nitrate issue only creates other
issues (arsenic e.g.). They usually opt to secure alternate drinking water supplies (bottled water). The MUN designation provides the most restrictive water quality standards, and thus will be used as the objective for this CGQMP.

Improvements in water management (conversion to high efficiency systems such as drip/micro instead of flood/furrow) have reduced the amount of applied irrigation water that is available for leaching below the root zone in many crops, regardless of soil type. TDS in pumped groundwater is usually corrected using sulfuric acid, which reacts with any carbonate/bicarbonate compounds, thus freeing the calcium and magnesium to displace any sodium from the soil profile. The sulfur compounds help keep the pH balance within the soil closer to neutral or slightly acidic.

For the purposes of this CGQMP, the objectives are to (1) bring about an increased awareness of the problems created by excess nitrogen application, (2) improve water management such that applied nitrogen is kept within the active root zone by limiting the amount of water available for leaching or changing the timing of nitrogen applications, (3) improvements in Nitrogen Use Efficiency in that more of the applied nitrogen is used by the crop and the amount of residual nitrogen (nitrogen surplus) in the soil profile is minimized without adverse effects on crop yields, and (4) to promote the adoption of demonstrated successful practices to all growers within the KRWQC service area. Successful practices, as determined through the MPEP workplan, would also be communicated to other growers statewide, thus improving agriculture’s environmental footprint throughout the state.

**Land Use**

The following section includes maps of land use within the KRWQC. The last map will include the overlaid vulnerability data. The data is the most current available.

Cropping patterns within the KRWQC are generally zonal. Fruit tree crops (citrus, deciduous trees) are generally located in the eastern portions of the KRWQC (primarily in the Kings Basin), where winter weather patterns (fog layers, risk of frost or freezing temperatures) are minimized due to natural cold air drainage. Citrus dominates the highest portions of the irrigated lands where it can avoid hard freezes. There are orchards in other regions within the central part of the Kings Basin, but as the topography becomes more flat, field crops begin to dominate.

Deciduous nut trees (almonds, pecans, pistachios, walnuts) are more common in the western portions of the Kings Basin, with expanding almond acreages in the central basin areas where fewer salty soils are present and higher quality water (both surface and groundwater) are available.

Vines dominate the lighter textured soils in the central portion of the basin, where conditions are optimal for raisin production. Table grapes and wine grapes are also grown in this area.

The remaining lands are divided into various field crops (cotton, corn, alfalfa, hay, tomatoes, etc.). Many of the crops are grown in support of the large dairy industry present within the basin, and the lands are capable of multiple crops per growing season. A grower may plant wheat in November, harvest it as silage in March, and plant the first of potentially two corn crops immediately afterward. Cotton and tomatoes dominate the cropping in the Tulare Lake area. Permanent crops are not planted in this region due to the continuing possibility of flooding.
Figure Two: Map with HV areas, Nitrate exceedances, Dairy influences, DACs
Irrigation practices vary according to crop type, topography, grower preference, and crop value. In lands that are primarily flat and have good surface water rights (pumped groundwater in regions where surface water is not readily available), surface systems dominate. Permanent plantings are more likely to have drip/micro sprinkler systems, as the value of the crop can support the initial capital investments. Buried drip lines in tomatoes are becoming increasingly common as growers learn how to use the technology properly. Experiments into using this technology in other field crops (cotton, corn, alfalfa) are progressing.

Drip/micro irrigation is very common in vineyard systems, and increasing popular in orchard situations. Such systems can be automated to run based on crop water usage or other weather factors, allowing for more precise water management. It also allows the grower to resume irrigations after harvest much sooner, thus reducing the induced stress on trees and vines.

Potential Sources

A number of sources of nitrates can affect the local groundwater supply. These include synthetic sources (mineral fertilizers), confined animal operations, food processing discharges, septic systems, and naturally occurring sources. Nitrogen’s pathway to groundwater is either by the leaching of excess (applied but not used by plants) nitrogen from fertilizer applications, leaching of nitrogen from decomposing organic matter, or direct fertilizer entry to groundwater via insufficient backflow prevention. Each potential source will be discussed below.

Synthetic fertilizers

Synthetic fertilizer has been a relatively cheap means of supplying nitrogen and other macro nutrients to intensive agricultural operations for many years. Before extensive scientific studies on the use of such materials, a “more is better” approach was sometimes employed as growers observed considerable increases in yields. This evolved in response to the naturally low levels of available N in soil profiles.

Economic concepts from agricultural studies showed that there was a point of “maximum economic yield,” that sometimes differed from “maximum yield.” Maximum economic yield is the point where the additional yield obtained from more fertilizer no longer justified the associated production costs (material cost, pest control costs e.g.) involved.

Yield quality was also studied, and for many crops, it was found that excessive fertilizer inputs actually reduced quality, and often crop value. Combined with other studies looking at the relationship of pest responses to fertilization (i.e., higher nutritional status within the plant created higher pest pressures), it was found that each crop had a fertilizer need that was required for the highest yields, and that this need varied according to stage of development and climatic conditions. Placing all of the nitrogen needed for a high yield in the soil at the beginning of the season was shown in some cases to be inefficient, since the crop did not need or use all of the nutrients early in the season. Heavy early application also opened the door to unwanted leaching losses.

Nitrogen was long recognized as being the primary nutrient required by plants for high yields. Organic nitrogen compounds (amino acids) are essential in protein synthesis, and proteins are found in all plant structures. The form of nitrogen taken from the soil did not seem to matter; so long as it could be taken up by the roots.

One of the least expensive forms of synthetic nitrogen was anhydrous ammonia. This is gaseous or liquid ammonia, injected into the soil or into irrigation water. Some of this applied material escaped into the air as ammonia if soil conditions were not moist enough, but much of what was applied remained within the
soil profile, electrically bound to the negatively charged surfaces of the soil particles. Some of this material was biologically converted to nitrate (NO₃⁻), thus becoming mobile with the soil water. Roots would take up whichever form was available (sometimes forcing a conversion back to another form for uptake purposes, then converting back for translocation purposes) and the nitrogen would be utilized within the plant. This process is temperature dependent and hazardous to the plants when the soil is warm, as more ammonia can escape the soil. Also, direct contact with the injected ammonia by the plant roots could kill the roots, delaying uptake until new root growth takes place and the ammonia is converted to a usable form.

Synthetically produced nitrate fertilizers were produced to provide plants with a quick burst of available nitrogen without the toxic effects of ammonia. Also, nitrate could be combined with a number of other nutrients (potassium, calcium e.g.) to prevent other nutrient deficiencies.

Fertilizers will continue to be soil applied as the roots are more effective at nutrient uptake/storage over a sustained period; foliar materials, while providing a quick shot to correct a sudden deficiency, cannot be applied at sufficient rates to (1) satisfy crop need and (2) be done without causing foliar damage that would reduce yield.

Commercial fertilizers come in both dry and liquid formulations. Dry materials are spread directly on the soil surface, either as a broadcast (wide area) or banded (targeted) application. Liquid materials can be sprayed or injected into the soil, sprayed on foliage, or injected into irrigation water. If injected directly into pumped groundwater used for irrigation, the material must be prevented from following the water back into the well when the pump is shut off. Many growers use standpipes which have an air-gap (a physical separation between the well discharge and the irrigation system intake) which prevents backflow, but newer, high efficiency drip/micro systems inject into the water stream either before or after any filtration. In such cases, a backflow prevention device (or combination of devices) must be present to keep fertilizer products from going down the well. These devices include physical valves that prevent backflow (check valves), vacuum breaker valves (introduces air behind retreating water column), and electrical interlocks that shut off injection pumps when the irrigation pump is not running. It is generally best to inject material downstream of any filtration, so that water within the filters forces any remaining fertilizers out to the field and not towards the well. This risks emitter clogging, but is generally minor. Fertilizer applications should end prior to the completion of an irrigation event, so that clean water can be used to flush the system out before shutdown.

Dairy or Confined Animal Operations

Land application of animal manures in amounts that would release sufficient nitrogen for a high-N-demand crop may have caused some of the nitrate contamination issues in the valley. Such applications are annual (as the dairies needed to dispose of the accumulated waste), and could be followed by substantial irrigation volumes, leading to a leaching of some of the available nitrogen.

Liquid waste, initially stored in large, unlined lagoons, also became a problem as the leachate from these large sources began to impact water quality around each dairy site. Some of this waste water was used for irrigation purposes, usually on lands that already had manure spread upon them earlier in the year. The crops grown could not consume all of the available nitrate provided, and the excess leached away.

Dairy operators are caught in a conflicting situation regarding lagoon management. Aeration is required to combat odor issues, but doing so converts the ammonia/ammonium to nitrate, which potentially leaches into groundwater.
Food processing

Food processing disposes of wash water and other fluids into disposal ponds and other pathways in accordance with discharge permits or other regulatory controls. Such ponds are normally unlined. Many times, crops such as hay or other grain silage are irrigated with waste waters. When the crops do not consume enough of the available nitrogen, or excessive water is applied, and excess nitrogen can be lost to leaching or atmosphere (as ammonia, nitrogen oxide, or nitrogen gas).

Septic systems

Septic systems are found throughout the rural community where houses were built on-farm. Many of these homes are quite old, and the systems that service them are equally old. Such systems are generally reliable, but require servicing on occasion (pumped out or reconstructed). The leach fields are designed to disperse the excess fluids contained within the septic tank (a bioreactor designed to separate and digest the solid wastes), maintaining an equilibrium of sorts. Fluids discharged from such systems are going to be higher in dissolved organic nutrients, and if insufficient root mass is present in the vicinity, this leachate will continue to move downward towards the water table.

In order to avoid clogging issues for such systems, deep rooted or other aggressively growing vegetation was discouraged from around such systems. This allows for the development of a long term static nitrogen source that does not have a consumption component in the disposal cycle. The nitrogen flux is allowed to continue to spread until it reaches the local water table, where it moves laterally in response to the local groundwater gradient.

The problem that has occurred is that the domestic wells for such housing is typically serviced by a shallow aquifer (well drilling for house wells tapped the first reliable water source, not necessarily a stronger, deeper aquifer), one within easy reach of the leachate from the septic fields. The domestic well creates its own local groundwater gradient, even to the point of running in reverse of the natural gradient that is present, pulling leachate towards the well. If the domestic well was drilled in the wrong spot (down gradient or too close to the leach field), then eventually this leachate would reach the well.

Harter’s report concluded that septic systems were a minor factor in the overall groundwater contamination issue. It is likely, however, that such systems could have substantial local impacts on groundwater quality because of their proximity to domestic wells and their long term presence in the soil environment.

Naturally occurring

Nitrogen in groundwater can also be the result of natural processes, such as the decomposition and leaching of organic materials from the upper watershed, and the erosion of nitrogen containing materials from parent rock. Such sources are thought to only comprise a minimal amount within any groundwater chemistry analysis, but Lawrence Livermore’s Isotope Study found that considerable levels of nitrogen in groundwater could be from natural sources.
Figure Three: Land Use
Figure Four: Land Use with HV Area, Dairy Land, DACs
Beneficial Uses

Groundwater within the KRWQC has several beneficial uses outlined within the Water Quality Control Plan for the Tulare Lake Basin (second edition, January 2004). Primary among the uses is MUN. Groundwater is the primary source of drinking water throughout the KRWQC, although the use of treated surface water is increasing in the Fresno area and soon to be available within Alta Irrigation District. Domestic drinking water is typically in the unconfined aquifer above the Corcoran Clay formation (where present), with municipal supplies typically coming from the deeper confined aquifer (below the Corcoran Clay). Multiple aquifers exist below the Corcoran Clay formation level (approximately 500 ft. below the surface), and the water quality varies considerably between each layer.

Other beneficial uses within the Tulare Lake Basin plan include AGR, IND, PRO, REC-1, and REC-2. REC-1 and REC-2 are of limited value, as pumped groundwater is generally too expensive for use as lake water for swimming or other recreation under normal circumstances. AGR and PRO are more common, and IND is only used on a limited basis.

Baseline Inventory of Management Practices

Management practices on agricultural operations vary according to what each individual farmer has found to work best for their operation. Generalized practices can be grouped according to crop type, and an approximate list can be prepared for this management plan. The completion of the Farm Evaluation data analysis will further define the practices used, as well as provide location data for each practice.

Pest Control

Herbicides, which are not currently identified as a Constituent of Concern (COC) within the KRWQC, are typically applied in two phases: pre-emergence and post-emergence. Pre-emergent materials are applied to cropland to control weeds before they have a chance to germinate by creating a chemically treated layer at the surface that either kills the weed seeds or kills the weeds as they emerge. Rainfall is a popular method of incorporation, as the herbicide is kept within the top inch of soil, thus creating a “solid” barrier. Mechanical incorporation is used just prior to planting if the grower is unsure of what crop will be planted or the amount of available irrigation water for the upcoming season.

Post-emergent materials are used once the weed species is identified, so that appropriate control chemistries can be selected. Such materials can either be systemic (kills slowly by killing the roots) or contact (burn down, results visible within hours of application). Such materials are not mobile within the soil, as they need to be able to penetrate the waxy coatings of the leaves in order to affect the target plant, and post-emergent materials are not designed to be taken up by the roots.

Nutrition

Nutrients are applied using a variety of methods. The most common is a dry soil application (band or broadcast) of granular fertilizer that is later incorporated by irrigation water. Such materials can be tailored to the needs of the crop (more or less nitrogen, phosphorus, or potassium plus other micronutrients). Broadcast is common for field crops prior to soil tillage in the winter while the soil is still dry; the applied fertilizer prills are kept in the top 6 inches of soil for the next season’s crop. Band applications are used in orchards where a thin strip of fertilizer is placed on the berm, and irrigation water dissolves a small portion of the fertilizer and carries it into the root zone for the tree roots to absorb. Applications occur either in the late fall before the post-harvest irrigation takes place (thus providing nutrients for the tree before it goes dormant for the winter) or in the spring as the nutrient demand of the trees increases following leaf out, or both. Another method of band application is the direct injection of
liquid fertilizer into the root zone (similar to band applications) during either the pre-plant operations or as a side-dress (post-emergent) application in field crops.

Timing is critical for the application of nutrients, since a substantial time lag can exist between the application of a material and its uptake. The grower tries to get the material to the plant prior to the onset of maximum need, so that yield potential can be maintained.

Growers with drip/micro irrigation systems can add fertilizers directly to the irrigation water and insure that fertilizer is applied with high uniformity throughout the field. This assumes that the system is properly designed and in good working order. The application can be set up to distribute the fertilizer such that once the desired amount is applied, the system is shut off and the fertilizer remains in the top soil where the majority of roots exist. In surface irrigated field crops, the fertilizer can be added to the irrigation water, thus covering the entire irrigated field with nutrients for the roots.

Foliar applications are available to apply micro-nutrients (those nutrients needed in small quantities) in situations where a nutrient deficiency is noted mid-season. The nutrients are applied directly to the leaves where it is absorbed. These are typically combined with pesticide applications for efficiency.

Table Three: Tree Fruit (Citrus, Deciduous Tree Fruit) Management Practices

<table>
<thead>
<tr>
<th>Task</th>
<th>Action</th>
<th>Timing</th>
<th>Why</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed Control</td>
<td>Pre-emergent application</td>
<td>Late Fall to Early Winter</td>
<td>Use natural rainfall for incorporation of weed control material without soil disturbance, leaves material in top 1/4 to 1/2 inch of soil surface</td>
<td>Runoff from high intensity rain fall, use of water soluble materials could leach</td>
</tr>
<tr>
<td></td>
<td>Post-emergent application</td>
<td>As Needed</td>
<td>Frost Issues, Insect/Disease Host</td>
<td>Low unless excessive rain after</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Soil Applied</td>
<td>Post-Harvest (previous year), Pre-Plant/Early Season</td>
<td>Replenish nutrients prior to next crop cycle</td>
<td>Runoff from high intensity rain, leaching</td>
</tr>
<tr>
<td>Fertigation</td>
<td>As Needed with irrigation water</td>
<td>Adjust nutrient status based upon better than expected weather, crop growth</td>
<td>Low, unless insufficient safeguards in place at pump</td>
<td></td>
</tr>
<tr>
<td>Foliar</td>
<td>As Needed</td>
<td>Emergency nutrient deficiency correction</td>
<td>Low, overspray into surface water</td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td>Pest Control</td>
<td>As Needed, when target pest reaches economic damage thresholds, preventative applications</td>
<td>Protect cosmetic quality of fruit, tree health and yield</td>
<td>Overspray into surface water</td>
</tr>
</tbody>
</table>

Nutrient applications have been refined considerably over the previous 20 years as increased research and economic pressures (material cost) have encouraged growers to become more aware of the amount of material applied. Excess nitrogen, for example, has been shown to increase pest pressure in certain crops (cotton e.g.). The higher protein content of the plant sap supports higher pest populations, forcing the grower to use additional control measures. The control measures also reduce the beneficial insect populations, thus making it easier for the remaining pest population to recover to previous or higher levels. Growers who utilize Integrated Pest Management (IPM) practices look at the entire picture (nutrient and water stresses, pest and beneficial insect populations, crop growth stage, damage potential) before action is taken. An imbalance in any of these factors negatively affects the others. Excess nutrient levels in a crop can also have a negative impact on yield quality.
Table Four: Deciduous Nut Crops (Almonds, Pistachios, Walnuts, Pecans) Management Practices

<table>
<thead>
<tr>
<th>Task</th>
<th>Action</th>
<th>Timing</th>
<th>Why</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed Control</td>
<td>Pre-emergent application</td>
<td>Late Fall to Early Winter</td>
<td>Use natural rainfall for incorporation of weed control material without soil disturbance, leaves material in top ¼ to ½ inch of soil surface</td>
<td>Runoff from high intensity rain fall, use of water soluble materials could leach</td>
</tr>
<tr>
<td></td>
<td>Post-emergent application</td>
<td>As Needed</td>
<td>Insect/Disease Host</td>
<td>Low unless excessive rain after</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Soil Applied</td>
<td>Post-Harvest (previous year), Pre-Plant/Early Season</td>
<td>Replenish nutrients prior to next crop cycle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fertilization</td>
<td>As Needed with irrigation water</td>
<td>Adjust nutrient status based upon better than expected weather, crop growth</td>
<td>Low, unless insufficient safeguards in place at pump</td>
</tr>
<tr>
<td>Foliar</td>
<td>As Needed</td>
<td>Emergency nutrient deficiency correction</td>
<td>Low, overspray into surface water</td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td>Pest Control</td>
<td>As Needed, when target pest reaches economic damage thresholds, preventative applications (fungicides)</td>
<td>Protect cosmetic quality of fruit, tree health and yield</td>
<td>Overspray into surface water</td>
</tr>
</tbody>
</table>

Fertilizer costs have risen in response to the costs of the energy necessary to produce the fertilizer (oil, natural gas). Other input costs (water, labor) have risen as well. Growers must now choose what inputs they can afford and what their return on that investment will be. In many cases, a grower can fertilize for maximum crop yield, but the cost of the inputs necessary are not recovered by the increased yield obtained (a dollar’s worth of input returns less than a dollar of yield increase). Many growers now aim for maximum economic yield, where the cost of the inputs yields maximum return on investment (one dollar of input yields greater than a dollar of yield return).

These considerations have led to growers reducing their nutrient inputs or changing the timing and methods of inputs so as to match crop need (yield potential, nutritional status of the crop). Bulk applications in early spring are no longer standard practice, as growers realize that much of what is applied can be lost due to leaching from excess water application (irrigation or rainfall) or that the plant did not utilize the inputs because it was not yet needed (stage of growth). Growers are also becoming aware of the nutrient content of their pumped groundwater and residual nutrient load in their soil, and thus factoring that into their nutrient decisions. This will eventually lead to decreases in nutrient concentrations within the groundwater within the affected or high vulnerable areas. The data collected by the Farm Evaluations, Nutrient Management Plans, and the Management Practice Effectiveness Program (MPEP), when combined with groundwater monitoring data, will accelerate this process.
Table Five: Field Crops Management Practices

<table>
<thead>
<tr>
<th>Task</th>
<th>Action</th>
<th>Timing</th>
<th>Why</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed Control</td>
<td>Pre-emergent application</td>
<td>Late Fall to Early Winter, Early Spring prior to planting</td>
<td>Use natural rainfall for incorporation of weed control material without soil disturbance, leaves material in top ¼ to ½ inch of soil surface (Spring – mechanical incorporation)</td>
<td>Runoff from high intensity rain fall, use of water soluble materials could leach</td>
</tr>
<tr>
<td></td>
<td>Post-emergent application</td>
<td>As Needed</td>
<td>Insect/Disease Host</td>
<td>Low</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Soil Applied (band or deep injected)</td>
<td>Post-Harvest/Pre-Plant</td>
<td>Replenish nutrients prior to next crop cycle</td>
<td>Leaching</td>
</tr>
<tr>
<td></td>
<td>Fertilization</td>
<td>As Needed with irrigation water</td>
<td>Adjust nutrient status based upon better than expected weather, crop growth</td>
<td>Low, unless insufficient safeguards in place at pump</td>
</tr>
<tr>
<td>Foliar</td>
<td>As Needed</td>
<td>Nutrient deficiency correction</td>
<td>Low, overspray into surface water</td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td>Pest Control</td>
<td>As Needed, when target pest reaches economic damage thresholds, preventative applications (fungicides)</td>
<td>Protect cosmetic quality of fruit, crop health, and yield in surface water</td>
<td>Overspray into surface water</td>
</tr>
</tbody>
</table>

Irrigation Management

Considerable advances in irrigation management have taken place in the last 20 years. Soil moisture monitoring has evolved from simple “feel” methods using a coring tool (still practiced with great accuracy by some growers) to more sophisticated methods using soil moisture tension, gypsum blocks, neutron probes, and radiometric measurements to monitor changes in the available water level within the soil zone being monitored.

Infrared monitoring of the plant canopy has also yielded increased management efficiencies, by indicating which areas of a field are more stressed for water/nutrients when compared to other areas, and how much sooner these areas require water. If the percentage of affected land is acceptable, you manage for the stronger soils so as to avoid over irrigation. If the area is too great, then the irrigation system should be split so as to create multiple management units and correctly manage each zone.

Crop water usage understanding has also advanced. Water usage can be predicted using local weather conditions, and applying an appropriate crop factor to a known reference crop (itself monitored via multiple sensors, up to and including weighing lysimeters). With this knowledge, it is possible to construct models that will tell the grower how much water has been used in a previous time period (usually daily values over the previous week), and can predict, based on expected climatic conditions plus crop growth stage, the water usage for the next time period (again, usually daily values for the next 7 days). By tracking these values, a grower can see how fast the soil moisture levels are declining within the root zone, and thus schedule his next irrigation to refill the soil profile before the moisture levels reach permanent wilting point (the point where the soil will hold the water with more force than the roots can exert).

The technology for monitoring soil moisture levels (the amount of available moisture for the crop varies with soil type, so each system requires some degree of calibration) has advanced to the extent that a suite
of sensors can be installed into the field (monitoring depletion of available moisture or its return via irrigation events) and the data generated can be electronically delivered to the farm manager in real time. Some systems can do this over multiple fields, thus allowing irrigation managers to cover more ground in less time during peak irrigation demands.

Additional developments in irrigation technology include the changes in how irrigation water is actually applied to the field. Drip and microsprayers are widely known, and improvements in design (less plugging, longer service life) continue to be made. System designs are being adjusted to take advantage of newer emitter technologies, and some systems are designed to account for variations in soils within a field.

Many new orchards have elected to use surface drip (drip lines laid directly on the soil surface) to deliver irrigation water to limit the off-site movement of the water drip (no wind effects). Also, because of harvest operations (tree shaking, sweeping, e.g.), such emitter placement allows for the system to remain in place and be less susceptible to damage. Where such systems are in place, double drip lines (a line on either side of the tree line) is common.

Buried drip is becoming the standard for row crop production, specifically tomatoes. This allows water delivery directly to the root zone (a dense root ball forms around the perimeter of the wetted zone) and reduces the moisture content of the foliage, thus reducing the risk of foliar or fruit disease. Evaporative water losses (direct evaporation from the soil surface) are also eliminated. Its expansion into other cropping systems is currently being studied. Buried drip line in field crops can be recovered after harvest, or left for another season before removal. Water is supplied on near continuous basis (tailored to crop stage and need) such that the soil moisture is maintained at ideal levels (freely available water plus good oxygen content in root zone). Vertebrate pests continue to be an issue for such systems as they are not very resistant to chewing.

The low application rates and limited wetted area of buried drip make it unlikely that it will be made available to cropping patterns with larger water demands, or where larger root systems are required for anchoring purposes, such as orchards.

Use of the older technologies (hand move sprinklers, furrow/surface irrigation) is gradually being replaced in limited areas with overhead sprinklers (center pivot or linear move systems). Technical issues related to center pivots in California are being resolved and some growers have switched over.

Limitations on Changing Management Practices

As mentioned previously, KRWQC participates in the South San Joaquin Valley MPEP, which is the main program for identifying protective management practices and bringing about their implementation. This program, and its applicability to this CGQMP, is described in greater detail in Appendix A. Following are some commentary on some constraints and opportunities that exist for implementing the MPEP in KRWCA.

The conversion of irrigation systems is one way to control the amount of irrigation percolating below the root zone, but is a considerable undertaking by a grower. In permanent crop situations, the conversion from surface irrigation to drip/microsprayer can limit crop production for the next couple of seasons. Trees will grow roots within the wetted area of a field, and under surface irrigation, this area is quite large. The wetted area underneath drip/microsprinkler systems is considerably smaller, and the trees suffer from water stress until the roots reallocate to their new environment.
Some crops are not suited to such systems. Many field crops have yet to be evaluated as to their suitability to be irrigated via buried drip systems. Some soils are not conducive to the use of linear-move or center pivot irrigation systems due to low infiltration rates.

Some regions have groundwater that is phytotoxic to crops when sprayed directly onto their leaves, yet is safe enough for surface or drip irrigation. Under such circumstances, conventional sprinklers or linear move/center pivot systems cannot be used. Microsprinklers may also cause foliar damage to the understory in these circumstances.

Table Six: Pros and cons of alternative irrigation systems

<table>
<thead>
<tr>
<th>Irrigation Practice</th>
<th>Applications</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basin Flood/Furrow</strong></td>
<td>Field crops&lt;br&gt;Orchards on Flat or Gentle slopes</td>
<td>Complete filling of entire soil profile&lt;br&gt;Long duration between irrigation events</td>
<td>Leaching of highly mobile nutrients&lt;br&gt;Larger volume of water required&lt;br&gt;Anaerobic soil conditions immediately after irrigations</td>
</tr>
<tr>
<td><strong>Drip</strong></td>
<td>Orchards, Vines</td>
<td>Precise and even water application&lt;br&gt;Used in undulating topography&lt;br&gt;Limited leaching potential</td>
<td>High capital and ongoing maintenance costs&lt;br&gt;Energy intensive&lt;br&gt;Near daily operation&lt;br&gt;Vertebrate pests damage tubing</td>
</tr>
<tr>
<td><strong>Microsprinkler</strong></td>
<td>Orchards, Vines</td>
<td>Similar to drip&lt;br&gt;Helps with frost control&lt;br&gt;Wider area of application</td>
<td>Same as drip&lt;br&gt;Increased evaporative loss over that of drip</td>
</tr>
<tr>
<td><strong>Buried drip</strong></td>
<td>Row crops</td>
<td>Constant optimal moisture in soil&lt;br&gt;Direct placement of nutrients at roots&lt;br&gt;Practically no evaporative losses</td>
<td>High capital cost&lt;br&gt;Vertebrate pests damage tubing&lt;br&gt;Subsurface work required for maintenance</td>
</tr>
<tr>
<td><strong>Sprinklers</strong></td>
<td>Field Crops on Flat or Undulating topography</td>
<td>Slow rates of application&lt;br&gt;Controls salts at surface&lt;br&gt;Limited deep leaching</td>
<td>High capital cost&lt;br&gt;Higher labor costs&lt;br&gt;Higher evaporative losses</td>
</tr>
</tbody>
</table>

Applicable Groundwater Data

The majority of the analysis of available groundwater data was performed during the preparation of the GAR (Chapter 3). The data is reflected in the defined areas of vulnerability and those areas that show nitrate exceedances. The KRWQC plans to create and monitor a groundwater quality network throughout the Coalition area in order to create a dataset of current water quality data, measured at fixed points on a regular schedule. Development of such a monitoring plan is currently being discussed with other coalitions so that a more robust and technically accurate program can be implemented. The data from such a study will help consolidate where the impacted areas actually are within the basin. Regions with documented exceedances could potentially have higher densities of monitored wells, more frequent sampling, or both.
The available data was reviewed for appropriate QA/QC prior to its uploading into GeoTracker, and data that lacked sufficient levels of review were examined again. The time scale of the available data was also reviewed, so that the most current data available would be used in the analysis.

The available data was subdivided into a variety of categories for analysis, and then the data sources were ranked as to quality. CVHM-ModFlow data consistently scored highest as to quality of data, availability, and usefulness for the overall evaluation of the groundwater basin. Groundwater data from CV-SALTS, GeoTracker, Harter Report, and GAMA also scored high.

The KRWQC has downloaded the available GeoTracker GAMA data for Fresno and Kings Counties. Well over a million records from several thousand wells were obtained. From this list, recent well tests conducted by USGS were isolated for analysis and plotted on a map of the Kings River sub-basin. Staff then randomly selected wells for further analysis based upon groupings into 3 transects through the sub-basin. This is shown in Figure Five.

The wells selected were (1) recent samples (2014), (2) USGS reported data, and (3) along three transect lines through the Kings River sub-basin (no wells showed up using criteria 1 & 2 for the northern Tulare Lake sub-basin (Kings County dataset). Eleven wells were randomly selected (by location, no review of any data took place until the wells were selected) and distributed as follows: 4 along a northwest-southeast line in the eastern sub-basin, 4 along a central axis, and 3 in the western sub-basin. The availability of wells in the western sub-basin using these criteria was limited.

Stiff diagrams were prepared for the eleven wells selected and are presented here. The diagrams were prepared in excel (by hand, as no automated process exists in this software) in accordance with instructions obtained from web sources.

This quick review of the groundwater quality was not intended to be complete or comprehensive; the GAR prepared for the KRWQC would have looked at similar sources of data in its vulnerability analysis. This simply represents a general overview of the available data.
Figure Five: Map of Wells Selected for Stiff Diagrams
East Well 42

USGS Well # 3652001193330001

Cations

Na
Ca
Mg

Anions

Cl
HCO₃
SO₄

Na  1.2  Cl  0.9
Ca  4.2  HCO₃  0.0
Mg  2.3  SO₄  1.1
USGS Well #: 364600119240001

Cations

Na  2.1
Ca  6.1
Mg  3.5

Anions

Cl  4.1
HCO₃ 0.0
SO₄  2.5

East Well 34
East Well 27
East Well 16

USGS Well # 363200119140001

Cations

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USGS Well # 364200119420003

Center Well 43

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Center Well 17
USGS Well # 362800119230001

Na 2.2  Cl 1.2
Ca 6.4  HCO3 0.0
Mg 2.9  SO4 4.1
USGS Well # 364500120050001

Cations

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SO4

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<td>Mg</td>
<td>SO4</td>
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West Well 33
USGS Well # 363100119490001

Cations
Na 0.3
Ca 1.1
Mg 0.1

Anions
Cl 0.0
HCO3 0.0
SO4 0.0

West Well 15
USGS Well # 362400119490001

West Well 2
Figure Six: Map showing Alta ID and DACs
Soil Types, Geology, and Hydrology

The affected areas of the groundwater basin have been evaluated using the GAR Analyst developed by the KRWQC’s consultant, and each of the identified sections has been identified as having a number of intrinsic characteristics that could lead to groundwater being vulnerable. These characteristics include soil permeability, soil transmissivity, depth to groundwater, aquifer thickness, clay layer thickness, and natural streamflow. When combined with vulnerability values such as regional vulnerability (proximity to artificial recharge, imported water use, etc.), on-farm vulnerability (farm management practices), and drinking water vulnerability, individual sections of land could be identified as being higher risk to groundwater than others.

The KRWQC regions where this management plan will be applied consist of the irrigated lands located within the valley portion of the KRWQC service area. This region is composed of alluvial materials of various textural classes that have been deposited over millennia. The sloping nature of these deposits has created aquifer zones of varying thicknesses, with shallow, easily recharged aquifers lining the eastern boundaries, and deeper aquifers being present further west in the deeper alluvium.

The valley was once an inland sea, with fresh water coming from the rivers that originated in the mountains to the east (the current Sierra Nevada and the ranges that existed previously). As uplift continued and the sediments that compose the Coast Ranges were raised out of the shallow sea, fresh water began to dominate the valley and the nature of the deposits changed. The valley divided into two basins, the Sacramento-San Joaquin River basins which naturally drained out to sea via the delta, and the Tulare Lake Basin which found itself cut off except in periods of extreme flooding. This cutting off of the Tulare Lake from the balance of the valley led to very thick clay deposits and relatively impermeable soils and strata.

The deposition of the alluvium was not a constant process, and long periods of stagnant waters were evidently present which created clay lenses of varying thicknesses within the valley. Some layers are only a few inches to a few feet thick and generally do not restrict water movement to any great degree. Some regions have much denser clay layers that actually prevent water movement through them, thus creating a perched water table that moves horizontally until the edge of the clay layer is found before moving downward again.

Within the valley floor portion of the KRWQC, three major clay layers are recognized to exist. The first is the “A” clay, which exists in some regions at a depth of approximately 60 feet below the soil surface. This layer is fairly thick and can impede water movement to such a degree that a shallow aquifer is created. This is known to exist north of the Kings River in the region around Lemoore and out towards Five Points and Helm. This layer is frequently fractured (discontinuous), and water above will move laterally until an edge or crack is found, after which it resumes its downward travels.

The second layer is the “C” clay, which is found around 250 feet below the soil surface. This layer is much like the A clay above it, and holds a considerable volume of water above it. It is found in the same areas as the A clay. The aquifer above the C clay is one of the most utilized within the basin due to its great well yield characteristics and ease of access. The A and C clays have higher amounts of sand and silt than other layers, which contributes to their limited permeability.
Figure Seven: Known Clay Layers within the KRWQC
Figure Eight: General Geologic Cross section of Valley
The last layer is the “E” clay or Corcoran Clay layer at about 500-600 feet below the soil surface. The Corcoran Clay is the most restrictive clay layer in the valley, and is the boundary between the unconfined aquifers above and the vast amounts of water in the confined aquifers below. The Corcoran Clay layer is typically sought out because of its restrictive nature, thus insuring that water extracted below it is protected from surface activities. Many major municipalities extract their water supply from below this layer (when present, it does not cover the entire valley), while many agricultural users have wells only as deep as the Corcoran Clay.

A large number of aquifers exist below the Corcoran Clay with varying levels of water quality, many of which are saline (a reflection of the conditions when the sediments were laid down). Very few users tap water from these aquifers due to the cost of well construction and the dissolved constituents found within these ancient waters. These aquifers are not being addressed by this management plan.

Groundwater is recharged via the Kings River channel (recorded by the Kings River Water Association as channel losses), seepage losses from irrigation district canals, dedicated recharge basins used during flood and above normal water years, and by those landowners that continue to use surface irrigation as their primary irrigation method, surface soil conditions permitting. Many landowners have converted to drip/micro irrigation, which is designed to match applied water to crop usage. When operated properly, this method of irrigation does not apply enough water to contribute to groundwater recharge (not to mention that most of these systems are supplied by groundwater, not surface deliveries).

The soils within the KRWQC were originally sourced from erosion of a previous eastern mountain range plus more recent deposits from the Sierra Nevada. As the Coast Ranges were uplifted, deposits that had previously been submerged in a marine environment began to erode into the forming trough that would become the Central Valley. The deposits from the east formed alluvial fans that terminated near the valley trough (near the north fork of the lower Kings River), meeting alluvial fans that formed from the eroding Coastal Ranges. The soils formed from the eastern fans were generally coarse grained soils, readily permeable, and low in salt content. Soils from the Coast Range are higher in clay content and loaded with salts accumulated from their formation in a shallow sea. They are generally less permeable, and more prone to having perched water tables due to dense clay layers.

The Tulare Lake formed in a depression within the lower portions of the southern valley, and the waters from the four major rivers (Kings, Kaweah, Tule, and Kern) plus the many smaller watersheds filled the basin with freshwater each year. The lake would be sufficiently stagnant for prolonged periods, allowing for the suspended clay particles to settle out, creating thick deposits at the bottom of the lake bed. These deposits are excellent farm land, but have very low permeability.

A USGS report (Geology of the Tulare Formation and other Continental Deposits, Kettleman City Area, San Joaquin Valley, California, with a Section on Ground-Water Management Considerations and Use of Texture Maps, Report 83-4000, R.W. Page, May 1983) is appended to this report to support the geology discussion as Appendix C.
Groundwater Basins

The KRWQC covers one Department of Water Resources (DWR) groundwater basin (Tulare Lake) and two sub-basins (Kings River sub-basin and Tulare Lake sub-basin). This CGQMP covers lands identified as vulnerable within the Kings River sub-basin, with the understanding that the current effort to remove the MUN beneficial use designation from the Tulare Lake sub-basin places any designated vulnerable lands as low priority at present. The boundary areas were shown in Figure One.

Water Chemistry

Groundwater chemistry is highly variable within the KRWQC. Depending upon where the sample is collected, the water ranges from odorless, low EC, low hardness, neutral pH to waters with elevated EC, strong sulfur smell, high hardness, and alkaline pH. The aesthetically poor water is generally found on the west side (near marine origin deposits), although deeper water can contain the same poor qualities anywhere within the basin.

A variety of metals are known to exist within the groundwater locally. Arsenic exists at levels both below and above MCL levels; iron, magnesium, calcium, sulfur (as sulfide), carbonate/bicarbonates and other naturally occurring compounds are also present. Nitrates are found in various regions, with multiple possible sources. In those regions where it exceeds the MCL, future isotope testing (if expanded past the pilot program previously conducted) will attempt to pinpoint the source. A mapping of concentrations of major cations/anions, hardness, pH, TDS, and nutrients has not been conducted, but the trend testing mandated by the General Order will provide basin-wide data on such constituents. Stiff diagrams along three transects through the Kings River sub-basin have been included in this plan.

A review of all of the GeoTracker GAMA data for Fresno County showed considerable ranges in values for a number of important constituents. Because it is known that waters in certain layers below the Corcoran Clay formation are saline, some of these reported values are not consistent with the balance of the normally available water located above the Corcoran Clay or in the eastern portions of the Kings River sub-basin.

The following table summarizes the values obtained during a search of GeoTracker GAMA data.

Table Seven: GeoTracker GAMA Reported Water Quality Values for Select Constituents

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<th>Constituent (units)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
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<tbody>
<tr>
<td>Electrical Conductivity (umhos/cm)</td>
<td>2.7</td>
<td>460,000</td>
<td>2056.7</td>
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<tr>
<td>pH</td>
<td>4.95</td>
<td>10.0</td>
<td>7.71</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>0</td>
<td>49,900</td>
<td>1229</td>
</tr>
<tr>
<td>Na (mg/L)</td>
<td>0</td>
<td>18,940</td>
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<td>Ca (mg/L)</td>
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<td>19,840</td>
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</tr>
<tr>
<td>Mg (mg/L)</td>
<td>0</td>
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</tr>
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<td>Cl (mg/L)</td>
<td>0</td>
<td>32,836</td>
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</tr>
<tr>
<td>SO₄ (mg/L)</td>
<td>0</td>
<td>33,000</td>
<td>492.0</td>
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<td>NO₃ (mg/L)</td>
<td>0</td>
<td>2,970</td>
<td>27.5</td>
</tr>
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</table>
As can be seen in the above table, values ranged considerably (from very low to extremely high). This would be indicative of waters collected above and below the Corcoran Clay. Looking at the data set to try to remove outliers (those values on the extreme ends of the data set in order to get a more accurate picture of the true average water quality) proved difficult, as in some cases, many values were both low and high. Also, no mention was made in the data as to depth of collection. With regards to nitrate, there is no mention as to whether it is NO₃⁻ alone or NO₃⁻N, which changes the MCL consideration.

Known Water Bearing Zones

Groundwater levels vary considerably throughout the KRWQC. It is generally shallower to the east (about 20 ft. below the soil surface) and considerably deeper as one moves towards Helm/Five Points (depths in excess of 225 ft. are common). A few groundwater facts regarding the basin are as follows:

1. Perched Water is typically found in the western portions of the basin where discontinuous clay formations near the soil surface inhibit the downward flow of applied irrigation water. Much of this has been corrected through the use of tile-drainage systems and conversion to micro irrigation systems.
2. Multiple unconfined aquifers exist around the Kings River channels. Water can be found above the A clay at 60 ft., in the aquifer between 60 and 250 ft. (C clay layer), and the aquifer between 250 and 500 ft. (E clay or Corcoran Clay). These layers are present north of Lemoore, but rapidly disappear as the clay content rises south of Lemoore. Perched water becomes a problem in this region, and salt deposits are visible at the soil surface.
3. Multiple confined aquifers exist beneath the Corcoran Clay layer. Some of these waters are usable for MUN or AGR, many are saline and unusable. Very few water wells are drilled below 2500 ft.

Recharge occurs in any surface water conveyance (river channel, ephemeral creek, irrigation district canals), and dedicated recharge basins throughout the KRWQC. The Kings River, under normal circumstances, has water present in the upper reaches of the river (Pine Flat to Hwy 99) year round. Additional recharge occurs when irrigation deliveries are made to lower river water rights holders, either through the lower Kings River (Hwy 99 to the Tulare Lake (South Fork) or James Weir (North Fork)) or in the numerous irrigation district canals that pass through the region. Irrigation canals are typically active from May through October, depending on the water year and the irrigation district. With the exception of the Fresno Irrigation District’s canals through Fresno, most of the irrigation canals within the KRWQC are unlined. Several segments of the Friant-Kern Canal are unlined as it passes through the KRWQC, but the soil permeability in these reaches is very low.

Fresno ID, Alta ID, and Consolidated ID maintain extensive recharge basins within their district boundaries. Laguna ID is expanding their recharge capability in the lower basin. Fresno and Alta’s basins are managed as water banks (meaning that only a portion of the recharged water can be withdrawn later); most of Consolidated’s basins are managed for recharge only. Fresno’s most famous recharge basins, Leaky Acres, are filled with the city’s allocation of San Joaquin River water most years, and Kings River water when available. All four districts are looking at expanding their recharge capabilities (along with several other smaller lower river districts) to better capture available flood flows on the Kings River, thus addressing the chronic overdraft present within the Kings Basin.
Figure Nine: 2013-2014 Depth to Groundwater Map
Water Bearing Zones and Uses

Any of the aquifers present within the Kings Basin can be used for Domestic, Irrigation, or Municipal supply. The amount of water demand and the cost of the well’s construction dictate which aquifer is preferred.

Domestic users typically tap into the shallowest available aquifer. During the current drought, many of these wells are going dry as the water tables fall below either the pump setting (how deep the pump itself is within a well), or the water falls below the drilled depth of the well. Domestic wells are typically no deeper than 100 feet in most of the eastern basin, and can be deeper than 150 ft. as one goes further west.

Irrigation wells are drilled to a depth of 300-400 ft. or more in order to produce the volumes needed for agricultural uses (typically 400 gallons per minute or more). The deeper wells allow for more slotted well casing (screens), thus allowing more water to enter the well and be pumped to the surface with a minimal amount of drawdown (the drop in water level caused by pumping). More drawdown means more lift is required, which reduces the volume a given pump can deliver (or increases the energy required).

Municipal wells are drilled much deeper, and have their well screens set as low as possible to avoid any contaminants from the surface. When wells are constructed in the regions where the Corcoran Clay is present, the well will be sealed at the clay layer, and pumping will occur below the clay layer only.

In regions where multiple aquifers are present, some wells are “composite” wells, meaning they draw from multiple aquifers. Such wells will need to be identified prior to any sampling program is initiated, because they do not behave in the same way as single aquifer wells.

Aquifer Characteristics

The Kings Basin is primarily reliant on the unconfined aquifer located above the Corcoran Clay layer. Water levels within the basin typically start at 20 ft. below the surface (east side) and falls at an increasing gradient until it bottoms out at 225 ft. or more near Helm and Five Points. The west side is almost totally dependent upon pumped groundwater for irrigation purposes, and as such, has created an extensive groundwater depression in that region. Some recharge occurs during flood events (depending upon duration) from the Kings River channel, and several projects are underway to increase the utilization of this water supply for irrigation/recharge when available.

The general groundwater flow direction is (1) away from the river channels/canals and (2) from the northeast to southwest in response to the groundwater depression that has formed in the western basin. Some regions have groundwater flows in other directions (Alta ID groundwater can flow southeast towards Visalia), so the direction of flow can be highly localized in a direction other than in general trends.

Recent work for the Kings River Conservation District Groundwater Report has shown that the specific yields of the aquifer within the basin are more highly variable than originally thought. This may allow for faster groundwater movement in some areas, slower in others. This could explain why the groundwater gradients seen in the western basin are sharper than expected, and that recovery does not occur as much as anticipated during flood years.
Water Sources and Chemistry

Surface water available within the majority of the basin is of exceptional quality, based upon ILRP testing since 2006. The water is very low in dissolved minerals, slightly acidic, and very low in electrical conductivity. The quality of the water does not vary greatly as one progresses from upstream to downstream, when the water is flowing. Once stagnant, it can quickly reflect the soil conditions present around it, becoming more alkaline and higher in EC.

A summary of surface water qualities (similar to that of groundwater data mentioned earlier) is provided below.

Table Eight: Kings River Surface Water Quality Values for Select Constituents

<table>
<thead>
<tr>
<th>Constituent (units)</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Conductivity (umhos/cm)</td>
<td>1.6-5,710</td>
<td>1.6</td>
<td>5.710</td>
<td>276.9</td>
</tr>
<tr>
<td>pH</td>
<td>5.89-8.96</td>
<td>5.89</td>
<td>8.96</td>
<td>7.21</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>2.2-826</td>
<td>2.2</td>
<td>826</td>
<td>48.3</td>
</tr>
<tr>
<td>Hardness (mg/L)</td>
<td>0.21-398</td>
<td>0.21</td>
<td>398</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Surface water variability is due to the collection time of the samples (some were from stagnant water at the beginning of an irrigation season, or in a pool known to be impacted by high salt content groundwater) or from early season ephemeral runoff. pH values can be influenced by time of day and algae content within the water. Once Kings River water (released from Pine Flat Dam) is dominant within the system, the water quality is excellent.

Groundwater quality really depends upon where the water is collected from. Water goes from relatively pure (low EC, neutral pH) in the east to alkaline and higher in EC to the west. Hardness varies considerably within the basin. Depth of collection can also impact water quality, as deeper water has had much more time to dissolve naturally occurring metals from the surrounding formations (arsenic and magnesium e.g.). The closer the water source is to the marine deposits of the west side, the greater the chances of higher pH and EC values being found.

Management Plan Strategy

The general Management Plan strategy is to conclusively identify the sources of nitrates (on a local and regional basis), and using the information gathered from the Farm Evaluation and MPEP (see Appendix A), suggest modifications to existing practices for those growers in the target areas. Evaluation of the influence of management practices on landscape-level flux of nitrate from root zones will be performed with calibrated runs of Soil and Water Assessment Tool (SWAT), a family of models developed for this and similar assessments.

Prioritization of Areas

To utilize available resources in an effective manner to achieve the greatest water quality protection as swiftly as practicable, some priorities must be established within the CGQMP area. Successes in these high-priority areas should be mostly applicable to other regions within the KRWQC.

The MPEP workplan defines the following criteria for the prioritization of work:

- Crops that represent the largest land area and economic value;
• Crops and cropping systems with the largest N surplus and/or largest depth of leaching water applied;
• Crops and cropping systems preferentially grown on coarse soils;
• Crops and cropping systems in areas with shallow depth to groundwater;
• Regions of the MPEP area classified as DACs;

Applying these criteria, the initial emphasis in KRWQC would be in the eastern basin, as several of the criteria (shallow groundwater, coarse soils, DACs) are present in this region. Work would be refined based on observed results and expanded into other areas.

Farm Evaluation and the Nitrogen Summary report data will be assessed over time to determine a) where improvements can be made, and b) progress in shifting management practices, where this is indicated. One potential approach may be by matching parcels with irrigation system type, then combining that information with the GAR Analyst Tool rankings for vulnerability for that section, and seeing which HV blocks may need targeted efforts at changing management practices.

A Trend Monitoring program (developed in conjunction with other coalitions) will also be implemented within the CGQMP region to provide additional granular detail on water quality and potential shifts in COC concentrations. The coordinated development of a monitoring plan will ensure that a large geographic region will be monitored in a consistent fashion.

Specialized studies in collaboration with CDFA/FREP, commodity groups, and UCCE complement and inform outreach and assessment efforts. The schedule for the MPEP is shown in the workplan and associated documentation. Early outreach and assessment are featured and consistent with the CGQMP schedule.

Prioritization of COCs

For the KRWQC’s CGQMP, nitrate is the primary COC to be addressed. This is because of the suspected sources of nitrate within the groundwater basin, the low MCLs that exist for the constituent, and the general recognition that adequate drinking water quality is in everybody’s best interest.

Pesticide COCs can be site- or region-specific, and as a legacy water quality impairment, may require specific strategies for addressing them. Surface actions that limit the further leaching of material contained in the vadose zone would often be a preferred approach. Fortunately, such strategies also work well in limiting nitrate movement.

The last COC discussed in the KRWQC’s GAR is TDS, a COC that is naturally occurring and not easily manageable by actions at the soil surface. That is, reductions in leached irrigation water will not decrease the native TDS levels in the groundwater below existing Basin Plan Objectives. Unlike nitrate, TDS is an aesthetic drinking water objective (clarity, smell, and taste), and does not pose health risks. Source treatment can bring this COC under control for domestic purposes. Where TDS contributes to agricultural soil alkalinity, soil or water treatment amendments (gypsum, acid injection) can help resolve the issue. Corrective actions related to nitrate leaching to groundwater are generally helpful with management of other water-soluble COCs that have been identified within the GAR.

Growers in the affected regions will be targets of substantial outreach to inform and motivate them relative to testing of water sources, and adjustment of fertilization programs to account for nitrate in applied groundwater. Data from the Nitrogen Summary Reports can be used to assist in this outreach.
effort. This could help to reduce nitrogen fertilizer application within the region, and the nitrogen surplus (residual nitrogen present in the soil at the end of the season).

Salinity is, as mentioned above, an aesthetic objective for drinking water quality, and can be managed for agricultural uses. It is naturally occurring within the soil environment. Mobilization of salts within the soil profile by irrigation practices is part of the normal leaching process, but is minimized by adoption of higher efficiency irrigation practices and intensified management.

Management Practices, Performance Metrics, and Goals

Collection, application, and in some cases performance of research that proves that certain management practices are more protective of groundwater are goals of the MPEP. Grower adoption of protective practices, where such adoption is necessary to protect groundwater, is the goal of the Outreach program.

Table Nine: Actions, Performance Metrics, and Goals for the KRWQC CGQMP

<table>
<thead>
<tr>
<th>Performance Goal</th>
<th>Action</th>
<th>Metric</th>
<th>Goal</th>
<th>Completion Date</th>
<th>Deliverable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outreach in HV Area</td>
<td>Define HV Area Outreach Meetings</td>
<td>List of parcels, Attendance</td>
<td>100%</td>
<td>Completed On-going</td>
<td>Invoicing Annual Report / Membership lists</td>
</tr>
<tr>
<td>Destruction of Abandoned Wells</td>
<td>Locate Parcels with Abandoned Wells</td>
<td>Map Completion</td>
<td>100%</td>
<td>180 days after CGQMP Approval</td>
<td>Map with Annual Report</td>
</tr>
<tr>
<td></td>
<td>Outreach</td>
<td>Increase in destroyed wells, reduction in abandoned wells</td>
<td>100%</td>
<td>5 years after CGQMP Approval</td>
<td>Annual Report Tracking</td>
</tr>
<tr>
<td>Wellhead Protection</td>
<td>Outreach</td>
<td>Change in Part B reporting</td>
<td>100% of reported wells having all boxes checked</td>
<td>5 years after CGQMP approval</td>
<td>Annual Report Tracking</td>
</tr>
<tr>
<td>Chemigation/Fertigation Practices</td>
<td>Outreach and Surveys</td>
<td>Reported adoption of backflow prevention practices</td>
<td>100%</td>
<td>5 years after CGQMP Approval</td>
<td>Annual Report Tracking</td>
</tr>
<tr>
<td>Nitrogen Outliers</td>
<td>Identification of Consistent Outliers</td>
<td>List of outliers in consecutive years or multiple times in 3- to-5 year period</td>
<td>100% Identification, Elimination is Statistically Impossible</td>
<td>5 years after CGQMP</td>
<td>Annual Report Tracking</td>
</tr>
<tr>
<td></td>
<td>Outreach to Outliers</td>
<td># of Growers Reached</td>
<td>100%</td>
<td>Yearly, Beginning in Year 3</td>
<td>Annual Report Tracking</td>
</tr>
<tr>
<td>Conversion of Management Practices</td>
<td>Identification of Protective Practices</td>
<td>Change in Farm evaluation reporting of irrigation practices</td>
<td>100% Adoption</td>
<td>5-8 Years After MPEP Workplan Approval</td>
<td>MPEP and Farm Evaluation Data, Annual Report Tracking</td>
</tr>
<tr>
<td></td>
<td>Outreach</td>
<td>Attendance of outreach events</td>
<td>100%</td>
<td>Yearly</td>
<td>Annual Report Tracking</td>
</tr>
</tbody>
</table>

The basic structure of the above table was taken from the West San Joaquin Coalition’s CGQMP. Tasks were modified slightly to match the requirements of the KRWQC.

Actions Taken

Compliance with Receiving Water Limitations

The MPEP will attempt to measure the amount of water applied to specific crops and monitor its movement through the root zone and assess its influence on local groundwater. The SWAT model has
been selected to perform the surface (root-zone) loading portion of this analysis. Details regarding SWAT application and development of runs for this region is described in Appendix A and the MPEP Workplan.

Education and Outreach

Landowners and managers within high-vulnerability areas are a particular target for outreach materials and grower meetings. Details regarding planned outreach are described in Appendix A and the MPEP Workplan.

Efforts to have abandoned wells properly destroyed, or at the very least protected against direct groundwater contamination, are ongoing. Some growers retain wells for future use in the event that groundwater levels recover. The capital outlay to use such a well is then a new pump and renewal of electrical service.

Multiple outreach events are scheduled each year, and a video recording of the presentations made is available at the KRWQC website for those who cannot attend in person.

Current nitrate challenges may principally result from practices long since abandoned by growers, in which case the problem will abate over time, partly due to the continued pumping to the surface of the nitrate-laden water. In this case, outreach and assessment are still key program components to verify that protective practices are, and remain in place.

Identification and Validation of Practices that Reduce Loading

The MPEP workplan submitted by the KRWQC (and other cooperating coalitions) discusses in great detail how the available resources will be utilized to study, evaluate, and communicate practices to the growers that are protective of groundwater quality. A great deal of time and effort has been invested in the development of this workplan so that it meets the needs of the coalitions, in part by responding to management practice needs of the CGQMPs.

It is known that high-efficiency irrigation systems are part of the solution in that leaching of excess irrigation water (and materials introduced to irrigated systems) is minimized during the course of the growing season. Such systems do not fit all crops and settings, so that some agricultural activities will continue to rely on older, proven technologies.

Identification of Individuals Involved

The implementation of the CGQMP by the KRWQC will involve a number of people in various capacities. Coordination of MPEP studies with other coalition groups, hiring and supervision of the outside consultant(s), conducting the assorted studies, data collection, analysis, and reporting to the Regional Board. The extent and complexity of the final task list will determine the total number of people involved.

Table 10 shows a list of those involved with projected responsibilities.
### Table Ten: List of Key Individuals, Responsibilities, and Authorities

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Tasks</th>
<th>Reports To</th>
</tr>
</thead>
<tbody>
<tr>
<td>KRWQC Board of Directors</td>
<td></td>
<td>Determine and Approve General Policies relating to KRWQC Activities</td>
<td>KRWQC Board of Directors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Budget Approval (Expenditures and Fee Structures)</td>
<td></td>
</tr>
<tr>
<td>Casey Creamer</td>
<td>Coordinator, KRWQC</td>
<td>KRWQC Policy Implementation, Budgeting, Coalition Activity Coordination, Hiring of Consultant for MPEP, Supervision of Consultant, Review and Approval of Reporting</td>
<td>KRWQC Board of Directors</td>
</tr>
<tr>
<td>Randy Shilling</td>
<td>Secretary-Treasurer</td>
<td>Finances and Budgeting, Administrative Support</td>
<td>Casey Creamer, KRWQC Board of Directors</td>
</tr>
<tr>
<td>Cristel Tufenkjian</td>
<td>Public Relations</td>
<td>Outreach, Scheduling, Newsletter Publication</td>
<td>Casey Creamer</td>
</tr>
<tr>
<td>William Thomas</td>
<td>Legal Counsel</td>
<td></td>
<td>Casey Creamer</td>
</tr>
<tr>
<td>Consultant(s)</td>
<td>Outside Consulting for Required Studies</td>
<td></td>
<td>Casey Creamer</td>
</tr>
<tr>
<td>Eric Athorp</td>
<td>Program Manager</td>
<td>Surface Water Monitoring, Groundwater Monitoring, CGQMP Implementation, MPEP Implementation, KRWQC Studies under MPEP, Laboratory Supervision, Data Analysis and Reporting, Outreach</td>
<td>Casey Creamer</td>
</tr>
<tr>
<td>Jose Soto</td>
<td>Resource Analyst</td>
<td>Membership Relations, Water Quality Monitoring, Outreach</td>
<td>Casey Creamer, Eric Athorp</td>
</tr>
<tr>
<td>Jarrett Winther</td>
<td>Resource Analyst</td>
<td>Membership Relations, Outreach</td>
<td>Casey Creamer, Eric Athorp</td>
</tr>
<tr>
<td>Contracted Labs</td>
<td></td>
<td>Sample Analysis</td>
<td>Eric Athorp</td>
</tr>
<tr>
<td>MPEP Team</td>
<td>Management practice support</td>
<td>Development and outreach, Assessment of efficacy.</td>
<td>Casey Creamer</td>
</tr>
</tbody>
</table>

### Strategies to Implement Management Plan Tasks

The GAR has already identified the high vulnerable areas on a section by section basis. A GIS overlay of the member parcels will identify those growers that have the elevated reporting requirements. This would include the high vulnerable areas that are intrinsically high vulnerable, plus those sections where a nitrate exceedance was reported.

The following steps would be taken once the member parcels are identified:

1. Information packets would be mailed to those parcel owners notifying them of their high vulnerability status, along with the necessary templates (if approved) and due dates for their submittal to the KRWQC. This is included in their annual fee invoicing. Invoicing takes place at the end of August, with payments due to the KRWQC by the end of October.
2. Outreach meetings would be scheduled for these areas to discuss template completion and to discuss the need for intensified groundwater monitoring within these regions. Outreach meetings
begin in October and continue through January-February. This is done to insure that the maximum number of growers can attend, as harvest operations are near completion.

3. KRWQC would develop a workplan for the selection and sampling of groundwater wells within the high vulnerability regions. A coordinated workplan between several coalition groups is planned. Sampling protocols would be added to existing QAPP documents submitted for Surface Water Monitoring Program.

4. Farm Evaluation and Nitrogen Summary template information would be compiled and analyzed for use in developing the MPEP, and for setting the priorities for the MPEP studies.

Management Practices Used

The first step of this process will be to implement early outreach, as described in Appendix A and the MPEP workplan. To complement this and other MPEP efforts in KRWQC, we will develop a listing of practices currently in use, plus a general discussion of how these practices have changed over the years.

Practices that have proven effective in protecting groundwater include the following:

1. Drip/microsprinkler irrigation. Characterized by lower rates of water application and the ability to match applied water to actual crop usage, thus minimizing leaching of water below the root zone. The downside is the high capital costs (system installation, filtration, pumping plant upgrades), plus higher ongoing maintenance and energy costs (systems run daily, rather than once every 2-3 weeks during peak irrigation demand).

2. Split applications of fertilizers. Growers no longer apply all of the plant’s fertilizer needs at once. Rather, they time applications to when the plant needs nutrients most (sometimes based on tissue sampling). There are increased costs for labor to apply materials, and increased risk of soil compaction for tractor applied materials. Irrigation system applied materials require conveyance system improvements (e.g., backflow prevention, injection systems) as well. It does result in reduced loading to the soil profile as excess nitrogen is not contained within the root zone (uptake and utilization is much faster).

3. Increased use of foliar fertilizers. Such fertilizers are applied at very low rates, directly to leaves as needed. These materials are typically added to pest control materials being applied (resulting in two benefits for a single application). However, the timing of a pest control application may not match the nutritional needs of the crop (early, late, or not needed), in which case nutrients are not employed.

Additional practices were identified in the MPEP workplan, Table 3-3, and are also listed in Table 11.

Table Eleven: Irrigation Practices and Considerations for Adoption

<table>
<thead>
<tr>
<th>Irrigation Practice</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Performance Evaluation</td>
<td>Improves efficiency, limited providers</td>
</tr>
<tr>
<td>Flow Meters</td>
<td>Capital and maintenance costs, limited usage once installed</td>
</tr>
<tr>
<td>Pump Tests</td>
<td>Diagnose pumping issues, repair costs</td>
</tr>
<tr>
<td>Weather based Irrigation scheduling</td>
<td>Training, reliable data sources</td>
</tr>
<tr>
<td>Plant based Irrigation scheduling</td>
<td>Training, equipment costs</td>
</tr>
<tr>
<td>Soil moisture based Irrigation scheduling</td>
<td>Equipment costs, Training</td>
</tr>
<tr>
<td>Pre-plant irrigations</td>
<td>Water availability, cost, changes in crop prices/decisions</td>
</tr>
<tr>
<td>Surge irrigations</td>
<td>Limited adoption in this region due to flat lands</td>
</tr>
<tr>
<td>Throttled irrigations</td>
<td>Training, lack of infrastructure on most farms</td>
</tr>
<tr>
<td>Shorten irrigation runs</td>
<td>Equipment costs, leased lands</td>
</tr>
<tr>
<td>Flow uniformity in furrows</td>
<td>Covered under System Performance, Training</td>
</tr>
<tr>
<td>Grading Fields</td>
<td>Capital Costs</td>
</tr>
<tr>
<td>Irrigation Practice</td>
<td>Considerations</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Conversion to drip/micro or sprinkler</td>
<td>Capital Costs</td>
</tr>
<tr>
<td>Monitor flow and pressure in system</td>
<td>Covered under System Performance, Training</td>
</tr>
<tr>
<td>Repair Leaks</td>
<td>Maintenance Costs, Training</td>
</tr>
<tr>
<td>Operate sprinklers in calm conditions</td>
<td>Logistical concerns</td>
</tr>
<tr>
<td>Pressure compensating emitters</td>
<td>Proper system design, capital costs</td>
</tr>
<tr>
<td>Proper lateral line lengths</td>
<td>Proper system design</td>
</tr>
<tr>
<td>Clogging</td>
<td>Maintenance Costs</td>
</tr>
<tr>
<td>Sub-surface drains</td>
<td>Capital Costs, disposal of drainage water</td>
</tr>
<tr>
<td>Backflow prevention</td>
<td>Capital Cost, Maintenance Cost</td>
</tr>
<tr>
<td>Cover Crops</td>
<td>Capital Cost, Management Practice compatibility</td>
</tr>
<tr>
<td>Deep Rooted rotation crops</td>
<td>Economic Considerations</td>
</tr>
<tr>
<td>Perennial crop rotation</td>
<td>Economic Considerations</td>
</tr>
<tr>
<td>Adjust N application based on soil tests</td>
<td>NMP Template, Testing Cost</td>
</tr>
<tr>
<td>Adjust N timing</td>
<td>Training</td>
</tr>
<tr>
<td>Adjust N application based on irrigation water</td>
<td>NMP Template, Testing Cost</td>
</tr>
<tr>
<td>Reduce N by changing application methods</td>
<td>Capital Costs, Management practices</td>
</tr>
<tr>
<td>Variable rate N application</td>
<td>Capital Costs</td>
</tr>
<tr>
<td>Delayed injection during fertigation</td>
<td>Training</td>
</tr>
<tr>
<td>N budget</td>
<td>NMP template</td>
</tr>
<tr>
<td>Controlled release fertilizers</td>
<td>Capital Costs, Training</td>
</tr>
<tr>
<td>Manure/Compost Application</td>
<td>Training, Testing Costs</td>
</tr>
<tr>
<td>Quick Incorporation of Manure</td>
<td>Training</td>
</tr>
</tbody>
</table>

Each of these practices can reduce the nitrogen surplus that potentially can be available to leach to groundwater. Their applicability is partly determined by site-specific management constraints and opportunities. Economic considerations will always be a factor in making such decisions, as capital outlays need to be balanced with capital availability. For example, where land is leased, some investments that would work if land were owned may not make financial sense.

Outreach Strategies

Outreach is a critical component for getting growers to invest in the necessary changes to management practices that are protective of groundwater. Included in this outreach would be the communication of research results conducted by UCCE or other researchers, and the reporting of changes in detections by KRWQC or other monitoring efforts conducted within the region.

Grower meetings currently include instructions on the completion of the various ILRP forms (Farm Evaluation, Nitrogen Management Plan, Nitrogen Summary) mandated by the General Order. Data are entered into a database for analysis. As the database has time stamps for data entry, the KRWQC can track changes over time to reveal trends in management practice application. The Nitrogen Summary template allows the KRWQC to track changes in nitrogen usage, and given a long enough period of analysis, will overcome short-range, inter-annual fluctuations caused by differing rainfall seasons, heat waves, or other climatic variation. This data will be analyzed for the previous calendar/crop year relative to long-term averages, and reported to the Regional Board and the growers. MPEP activities will also be reported.

Results of studies will be included in the KRWQC newsletters to growers, and posted on the KRWQC website (www.kingsriverwqc.org). An extensive listing of Agricultural Management Practice Tools and Resources is already posted for growers’ reference, at
www.ssjwqc.org/Directory%20of%20Online%20Resources.htm. It is anticipated that results of the MPEP studies will also be published by UC Cooperative Extension, and in peer reviewed professional journals. A discussion of the results will also be part of the annual outreach meetings conducted by the KRWQC.

The rate of implementation of protective practices will be evaluated based on reported changes in the Farm Evaluation analysis. Where funding is needed to implement new practices, NRCS or other conservation programs may help offset the costs for smaller growers. In certain areas, no changes in practices may be indicated by MPEP evaluations, if practices in use prove to be protective of groundwater.

Surveys or other methods will be used to evaluate outreach effectiveness. Results will inform refinements to the outreach program.

Schedule and Milestones for Implementation

According to the schedule within the General Order, the MPEP workplan is to be developed and submitted within 2 years of the approval of the GAR. The KRWQC, along with the other coalitions in the Tulare Lake Basin, began the process in 2014 with the hiring of the MPEP Team (led by PlanTierra) to prepare our MPEP Workplan. This process is nearly complete, and only awaits Executive Officer approval to meet or beat timelines in the General Order. A proposed schedule is shown in the MPEP workplan in Figure 3-1A.

Other tasks and statuses are as follows:

1. Members have been notified of their groundwater vulnerability status. Requisite templates have been distributed with the reporting requirements.
2. October 2016: The first of the 2016-2017 outreach meetings will be conducted to discuss the GAR results, the Nitrogen Summary template, updates on regulatory issues and other related topics.
3. A Trend Monitoring conceptual network is being developed among several coalitions so that a unified approach to the monitoring will occur. The KRWQC fully supports this process.
4. Reporting of progress to be made with the KRWQC Annual Report due May 1 of each year.
5. Reporting of water quality results with each Annual Report
6. MPEP status reports will be submitted with each Annual Report

Known management practices that are protective of groundwater quality will be communicated to our membership during outreach meetings.

Protective practices will be disseminated to member/operators within the high vulnerability regions for each coalition group. Farm Evaluation data will show the pace of adoption of the identified practices within the high vulnerability areas.

It is hoped that the MPEP identified practices can be fully adopted within the high vulnerability areas within a reasonable timeframe after they have been identified. We acknowledge that external conditions (drought, groundwater and surface water supply variability, crop pricing, other unknown factors) will affect the rate of implementation, but will work to accelerate implementation, particularly in the highest priority settings.
Monitoring Methods

The MPEP workplan outlines how existing practices will be evaluated relative to protection of groundwater quality. Past field studies are applicable to assess the effects of current management. These will in some cases be supplemented with new field monitoring, where this is deemed necessary. Basic information about field conditions and instrument placement would take place at this time. Expanded implementation of protective practices, as reported in the Farm Evaluations, will indicate changes in management practices.

Groundwater monitoring from a selected network of production wells will be conducted during the spring of each year (currently projected for May). This is the expected for the Trend monitoring program. Well owners would be notified of the sampling schedule at least 2 weeks in advance. The specific approaches for the Trend monitoring program are being discussed among several coalitions, so that a uniform approach can be presented/implemented. A conceptual sampling protocol would be as follows:

Well Running at Arrival

1. Wait 5 minutes to ensure that well casing has been evacuated and water from the surrounding aquifer is being pumped to the surface
2. Collect temperature readings of the discharged water. Attempt to measure Dissolved Oxygen (DO) within the discharge.
3. Once the water temperature or DO readings are stable, collect pH and electrical conductivity (EC) data and record values. Fill supplied sample bottle(s) for desired analysis. Constituents to be as outlined in General Order once every 5 years, nitrate and physical parameters at all others.
4. Collect a duplicate sample daily.

Well Off at Arrival

1. Measure depth to standing water and record (use acoustic sounder as much as possible to avoid cross-well contamination issues).
2. Start well (permission obtained when well was selected) and allow to run 5 minutes to ensure well casing is pumped out, and water is reflective of current aquifer conditions.
3. Follow protocols listed above once the 5-minute waiting period is over.

In either case, samples are to be treated like any other analytical sample, stored in a cooler with “blue ice” for temperature control, eventually to be packed in “wet” ice (cubes) prior to delivery at lab. A Chain of Custody is to be maintained for all samples.

Data Evaluation

The groundwater sampling points will remain fixed for an extended period of time, so a time series trend analysis of constituent values can be performed. The well locations/surface elevations are going to be known to the KRWQC (owner names will not be part of any published data due to privacy), so a GIS analysis of constituent concentrations can be created. These data would be utilized as part of the MPEP performance assessment. Maps in monitoring reports would show well locations and an identifier to link the point to tabular data, but no ownership information will be included.

Hydrographs of each well will be produced showing (1) groundwater elevation (reported as Water Surface Elevation above or below Mean Sea Level), and (2) COC levels beginning with the third year of data. The first round of testing will consist of all required data points as specified in the General Order, then only those required yearly until the 5th year samples are collected.
The MPEP can also provide the necessary supporting data for the nutrient removal calculations, required as part of the Nitrogen Management Plan. These data are available for some crops, and is being developed for others. The KRWQC will report N removal rates back to the growers for crops grown, the A/Y (Applied divided by Yield) ratio, and other metrics that help growers to understand their fertilization programs in the context of their neighbors.

Reporting

Data will be presented within the Annual Reports, as required in the General Order.
TECHNICAL MEMORANDUM

IDENTIFICATION, EXTENSION, AND IMPLEMENTATION OF MANAGEMENT PRACTICES TO MINIMIZE NITRATE LEACHING FROM CROP ROOT ZONES TO SATISFY GROUNDWATER QUALITY MANAGEMENT PLAN REQUIREMENTS

PREPARED FOR: South San Joaquin Valley Management Practices Evaluation Plan Committee
PREPARED BY: MPEP Team
DATE: August 25, 2016

It is anticipated that versions of this document, when appended to a GQMP deliverable by a South San Joaquin Valley (SSJV) Management Practices Evaluation Program (MPEP) member coalition, will serve to inform the Central Valley Regional Water Quality Control Board (Central Valley Water Board) about the management practices component of the coalition’s GQMP.

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LIST OF ABBREVIATIONS

CCA Certified Crop Adviser
CDFA California Department of Food and Agriculture
COC constituent of concern
Committee SSJV MPEP Committee
BACKGROUND AND PURPOSE

The Kaweah Coalition’s GQMP was submitted in February 2015, and comments received from the Central Valley Water Board at the end of June 2016. During this 16-month interval, a great deal transpired as the LTILRP developed. Among these developments, the Kaweah Coalition joined with six others to form the SSJV MPEP Committee (Committee), and hired the MPEP Team to develop a workplan. This process and the Discussion Draft Workplan (2016; Workplan) advanced everyone’s understanding of what the MPEP would entail, and when it would begin to produce results. Kaweah can
now draw on this work to more clearly articulate how management practices will be identified, communicated to growers, implemented, and assessed, as requested in comments received from the Central Valley Water Board.

The Workplan deals explicitly with how that program will interface with individual coalitions, including their GQMPs. Section 2.1.3 (Exchanging Data with Coalitions and Informing Groundwater Quality Analyses) reads as follows:

As mentioned previously, individual LTILRP coalitions are engaged in complementary activities that can inform the MPEP and allow for more rapid, effective work. Examples of data and work products from the coalitions that are potentially relevant to the MPEP include the following:

- Coalitions’ data about the type and location of practices are fundamental to assessing the effects of irrigated agriculture on underlying groundwater. These data might arise from the following sources:
  - Farm Evaluations
  - Nitrogen Summary Reports
  - GARs
  - Trend Monitoring Reports

- Methodology and results (e.g., surface loading, loading to groundwater) from the MPEP can inform Groundwater Quality Management Plans (GQMPs) and other groundwater analyses undertaken by coalitions.

Since the General Order provides for GQMPs to identify priority/urgent areas, and requires an MPEP to develop practices for such areas, it follows that the output of the MPEP should satisfy GQMP requirements related to management practices. The purpose of this memo is to fulfil this requirement for member coalition GQMPs related to nitrate.

The MPEP can satisfy management practice related requirements for any constituent of concern (COC), as evidenced by the following passage from Section 1 of the Workplan:

*The current General Orders focus on controlling nitrate (NO\textsubscript{3}) contamination of groundwater by irrigated agriculture, but the overall program also pertains to other constituents that could be construed as pollutants (e.g., sediment in runoff, salts). Nitrate movement through irrigated lands is therefore the main focus of this Workplan. If at some point other constituents need to be addressed by growers, the MPEP would likely serve the same functions for those constituents. At that time, addenda to this Workplan might be required to supplement and update the general approach with specific considerations relative to those constituents. However, the general approach described here, if successful, would otherwise remain intact.*

Thus, for the Kaweah GQMP, where salinity and pesticides must be addressed, the MPEP will expand to incorporate practices that are protective relative to these COCs, in addition to practices deemed protective relative to nitrate.
The Workplan describes early outreach and assessment components:

- *...the initial inventory of management practices will result in a list of known, protective practices that will move immediately into this outreach process. It will be discussed with advisors and growers during 2016-17 meetings. Information on these practices will also be featured in an organized, accessible fashion on the Grower/Advisor Webpage, which water quality coalition membership will be encouraged to consult.* (p. 3-69)

- *...outreach products and activities will be documented and shared with the Central Valley Water Board in regular communications such as quarterly meetings and as part of required reporting.* (p. 3-69)

- *...benchmarking the current degree of adoption of BMPs across the MPEP area.* (p. 3-36) *...Studies of management practice and production data from Farm Evaluations and Nitrogen Summary Reports, as supported and sanctioned by member coalitions, as well as similar data from packers who may gather such data from growers with whom they work. If these data are of sufficient quality, they could provide extremely powerful information about grower practices.* (p. 3-38)

- *...a Grower/Advisor Webpage on its website, which includes an organized collection of many useful tools and references that already exist. This site will be updated as additional information becomes available from the Committee, member coalitions, partners (including the Central Valley Water Board), and other sources. This handy collection of resources for minimizing loss of applied nitrogen to groundwater will be available not only to member growers, but to growers and grower advisors anywhere. The Committee hopes that such a grower-oriented collection, focused on means to address this problem through sound management, will help growers actually apply these solutions in their practices on their fields, which must be done for actual benefits to be realized. Additional online tools, information, and applications will be developed to meet specific needs. For example:*
  - Helpful information for growers and their advisors to efficiently derive maximum benefit from required Nitrogen Management Planning processes can be provided.
  - Tools to facilitate second-language growers to understand and comply with LTILRP requirements and derive maximum water quality and production advantages.
  - Query-able management practice databases to assist growers in evaluating the potential cost and benefits (production, water quality, labor) benefits of various suites of management practices, applied at their specific management block locations and planting dates.* (p. 3-68)

One purpose and feature of the SSJV MPEP is an efficient, collective effort to identify and increase implementation of protective practices, mainly by working with member coalitions to understand grower needs and to help them with resources to achieve this goal. As stated on page 2-6 of the Workplan:

- *Member coalitions are linked directly to the MPEP by their participation in the Committee. Growers are linked to the MPEP through their membership in their coalitions, meetings, communications, and data gathering. Growers will also participate in commodity, other winter, and special-purpose meetings where MPEP findings will be discussed during outreach sessions. Presenters primarily will*
be technical collaborators from public-sector research and extension, as well as private-sector production and grower experts.

Therefore, it is natural and appropriate that when information and outreach to promote implementation of protective practices is identified as part of a Groundwater Quality Management Plan developed by one of the member coalitions, work of this sort being done as part of the MPEP should be incorporated. It is understood that GQMPs signify high priority areas where a prompt response is required of the coalitions. At this time, as evidenced in excerpts from the Workplan, the corresponding elements of the MPEP are scheduled for the coming months and therefore constitute a timely component of the GQMP. For example, the soonest that growers can be convened to discuss practices for the next (2017) season is fall 2016/winter 2017, the very period targeted in the MPEP for early outreach.

The purpose of this document is to summarize the following:

- Protective management practices identified to for application as part of GQMPs
- Use of outreach to expand implementation of protective practices, including assessment of barriers to adoption and grower response to outreach
- Assessment of barriers to adoption, the impact of outreach, and the extent of practice implementation

2 MANAGEMENT PRACTICE OVERVIEW FROM WORKPLAN AND EXPANDED MANAGEMENT PRACTICE INVENTORY

Table 3-3, beginning on page 3-28 of the workplan contains a summary of the range of protective management practice types. That table is reproduced here for convenient reference, and will be used to frame more specific and expanded descriptions of practices that will be shared with growers.

<table>
<thead>
<tr>
<th>Management Practice</th>
<th>Barriers to Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation and Drainage Design and Operation</td>
<td></td>
</tr>
<tr>
<td>Irrigation System Evaluation and Monitoring</td>
<td></td>
</tr>
<tr>
<td><strong>1</strong> Conduct irrigation system performance evaluation</td>
<td>Operational cost, land tenure, training</td>
</tr>
<tr>
<td><strong>2</strong> Install and use flow meters or other measuring devices to track water volume applied to each field at each irrigation</td>
<td>Capital cost, operational cost, training</td>
</tr>
<tr>
<td><strong>3</strong> Conduct pump performance tests</td>
<td>Operational cost, training</td>
</tr>
<tr>
<td>Irrigation Scheduling</td>
<td></td>
</tr>
<tr>
<td><strong>4</strong> Use weather-based irrigation scheduling</td>
<td>Operational cost, logistics, training, technology</td>
</tr>
<tr>
<td><strong>5</strong> Use plant-based irrigation scheduling</td>
<td>Operational cost, logistics, training</td>
</tr>
</tbody>
</table>

TABLE 2-3. MANAGEMENT PRACTICES DOCUMENTED TO IMPROVE NITROGEN FERTILIZER EFFICIENCY AND BARRIERS TO THEIR ADOPTION AS MODIFIED FROM DZURELLA ET AL. (2012). TABLE REPRODUCED FROM WORKPLAN.
### TABLE 2-3.  Management Practices Documented to Improve Nitrogen Fertilizer Efficiency and Barriers to Their Adoption as Modified from Dzurella et al. (2012). Table reproduced from Workplan.

<table>
<thead>
<tr>
<th>Management Practice</th>
<th>Barriers to Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Use soil moisture content to guide irrigation timing and amount</td>
<td>Operational cost, logistics, training</td>
</tr>
<tr>
<td>7. Avoid heavy pre-plant or fallow irrigations for annual crops</td>
<td>Risk to yield or quality, logistics, training</td>
</tr>
<tr>
<td><strong>Surface Gravity System Design and Operation</strong></td>
<td></td>
</tr>
<tr>
<td>8. Convert to surge irrigation</td>
<td>Capital cost, operational cost, logistics, training</td>
</tr>
<tr>
<td>9. Use high flow rates initially, then cut back to finish off the irrigation</td>
<td>Operational cost, logistics, training</td>
</tr>
<tr>
<td>10. Reduce irrigation run distances and decrease set times</td>
<td>Risk to yield or quality, capital cost, operational cost, land tenure, training</td>
</tr>
<tr>
<td>11. Increase flow uniformity among furrows (e.g. by compacting furrows)</td>
<td>Operational cost</td>
</tr>
<tr>
<td>12. Grade fields as uniformly as possible</td>
<td>Operational cost, training</td>
</tr>
<tr>
<td>13. Where high uniformity and efficiency are not possible, convert to drip, center pivot, or linear move systems</td>
<td>Capital cost, operational cost, land tenure, training</td>
</tr>
<tr>
<td><strong>Sprinkler System Design and Operation</strong></td>
<td></td>
</tr>
<tr>
<td>14. Monitor flow and pressure variation throughout the system</td>
<td>Operational cost</td>
</tr>
<tr>
<td>15. Repair leaks and malfunctioning sprinklers; follow manufacturer recommended replacement intervals</td>
<td>Capital cost, operational cost, training</td>
</tr>
<tr>
<td>16. Operate sprinklers during the least windy periods, when possible</td>
<td>Logistics</td>
</tr>
<tr>
<td>17. Use offset lateral moves</td>
<td>Operational cost, logistics, technology</td>
</tr>
<tr>
<td>18. Use flow-control nozzles when pressure variation is excessive</td>
<td>Capital cost, land tenure, training</td>
</tr>
<tr>
<td><strong>Drip and Micro-sprinkler System Design and Operation</strong></td>
<td></td>
</tr>
<tr>
<td>19. Use appropriate lateral hose lengths to improve uniformity</td>
<td>Training, capital cost</td>
</tr>
<tr>
<td>20. Check for clogging; prevent or correct clogging</td>
<td>Operational cost, capital cost, training</td>
</tr>
<tr>
<td><strong>Other Irrigation Infrastructure Improvements</strong></td>
<td></td>
</tr>
<tr>
<td>21. Installation of sub-surface drains in poorly drained soils*</td>
<td>Capital cost, technology</td>
</tr>
<tr>
<td>22. Backflow prevention</td>
<td>Capital cost, training</td>
</tr>
</tbody>
</table>

**Crop Management**
### Table 2-3. Management practices documented to improve nitrogen fertilizer efficiency and barriers to their adoption as modified from Dzurella et al. (2012). *Table reproduced from Workplan.*

<table>
<thead>
<tr>
<th>Management Practice</th>
<th>Barriers to Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change Crops to Use Those with Smaller N Requirements and Greater N Efficiency</strong></td>
<td></td>
</tr>
<tr>
<td>23 Cover crops to recover residual soil nitrate and immobilize it in soil organic matter</td>
<td>Risk to yield or quality of cash crop, capital cost, operational cost, training, technology, increased irrigation requirements for the cash crop</td>
</tr>
<tr>
<td>24 Include deep-rooted or N-scavenger crop species in annual crop rotations</td>
<td>Risk to yield or quality, capital cost, operational cost, logistics</td>
</tr>
<tr>
<td>25 Include perennial crop in rotation, e.g., alfalfa or perennial grasses</td>
<td>Capital cost, logistics, land tenure</td>
</tr>
<tr>
<td><strong>Nitrogen Fertilizer Management</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Improve Rate, Timing and Placement of N Fertilizers</strong></td>
<td></td>
</tr>
<tr>
<td>26 Adjust N-fertilizer rates based on soil nitrate testing</td>
<td>Operational cost, training</td>
</tr>
<tr>
<td>27 Adjust timing of N fertilization based on plant tissue analysis</td>
<td>Risk to yield or quality, operational cost, training, lack of robust relationships between tissue test and amount of N fertilizer required</td>
</tr>
<tr>
<td>28 Apply N fertilizer in small multiple doses, rather than one or two large doses, to meet crop demand during the growing season without deficiency or excess</td>
<td>Operational cost, training</td>
</tr>
<tr>
<td>29 Know N content of irrigation water and adjust fertilizer rates accordingly</td>
<td>Operational costs, logistics, training</td>
</tr>
<tr>
<td>30 Reduce total N-fertilizer rates by replacing low-uptake-efficiency N-fertilizer applications to soil with high-uptake-efficiency foliar-N applications</td>
<td>Operational costs, training, technology</td>
</tr>
<tr>
<td>31 Vary N-application rates within large fields according to site-specific needs based on heterogeneity in soil N supply and/or crop growth</td>
<td>Operational costs, capital costs, training, technology</td>
</tr>
<tr>
<td>32 Use delayed injection procedure when fertigating in surface gravity systems</td>
<td>Operational costs, logistics, training</td>
</tr>
<tr>
<td>34 Develop an N budget that includes crop N harvest removal, supply of N from soil and other inputs to guide decisions on N-fertilizer rates and timing</td>
<td>Operational costs, training, technology</td>
</tr>
</tbody>
</table>
This brief list of practices captures most of the categories of practices available to growers to retain mobile nutrients (like nitrogen) in their root zone so that the largest practicable proportion of it is used by the plant, and the least practicable amount percolates downward. Many practices are usable as they are stated (e.g., item 40, calibration of solid manure and compost spreaders could be implemented by any grower using these implements). Some require crop-specific information (e.g., item 27, adjusting timing of N fertilization based on plant tissue analysis requires that reference values for specific tissues be established, along with sampling and analysis protocols that produce consistent results). Not all practices apply to all crops. For example, tissue tests have not been found to be useful when assessing almond N status.

As part of early outreach, the SSJV MPEP is working with CDFA, UCCE, and other partners to inventory known protective management practices. This inventory is informed by the rather substantial knowledge base (literature, scientific and grower expertise) regarding practices that help growers to retain N for crop use and avoid excessive percolation losses. The inventory is being developed in database format so that it can be deployed in prioritizing and developing outreach curriculum, working with coalitions to assess implementation through Farm Evaluations, and to serve as an online resource to help growers explore and develop their management options. Practices tie into MPEP modeling/performance assessments too, since most can be quantitatively captured in model parameters and results. The inventory currently contains over 150 practices associated with various crops and crop classes, has identified 23 high-priority documents for review, posted 22 references in an online collection of grower resources (http://www.ssjwqc.org/_pdf/MPEP%20Tables.pdf), and identified
another 29 to be posted. The inventory is being further augmented and will be posted during the coming months.

GQMP

3 METHODODOLOGY

This section describes methods used for outreach, and for the assessment of how well outreach is working so that it can be improved.

3.1 OUTREACH

Coalitions and partners (UCCE, USDA/NRCS, CSU, CDFA, commodity groups) all have ongoing outreach programs that are partly or wholly devoted to sharing protective management practices with growers with the goal of broader implementation. The MPEP/GQMP outreach program aims to harness and supplement these programs to ensure that ILRP commitments are met, and to document these activities. To this end, MPEP/GQMP outreach will entail the following:

- A database of outreach and outreach-related activities and products, including dates, format (live presentation, video, online tools, or hardcopy literature [mailings, fliers]), practices covered, and number of grower/members participating. To the extent practicable, this will include events that occurred before the inception of the database. This database will periodically be shared with the Water Board so that staff can assess outreach.

- Curricula developed in the form of meeting materials (agendas and presentations), video, fliers, and online tools and informational resources.

- A network of cooperating partners, including other water quality coalitions, CDFA, UCCE, private-sector experts (e.g., CCAs), CSU, NRCS, and commodity groups will be tapped to assist with development and delivery of curricula. The video and online options will help to extend these scarce resources to meet what is a growing need. CDFA staff are currently working with the MPEP Team to expand the practices inventory. One or more protective practices workshops are planned with UCCE in the September/October timeframe, specifically to finalize curricula for the early-outreach period. All of these groups have been involved in developing the Workplan.

- Growers already attend many meetings where protective practices to achieve good environmental performance are discussed. The Workplan specifies that, to make the best use of grower’s and partner’s time, curricula will be delivered at these meetings whenever practicable. The MPEP Team is identifying candidate meetings and working with organizers to include on their agendas protective practice sessions where the curricula can be delivered to growers. Many of the partners listed previously are responsible for convening these meetings and are the focus of these contacts.
3.2 Assessment

While outreach is crucial for reaching growers, follow up and assessment are essential to understanding how effective outreach is. Assessment results will guide refinement of outreach so that it can become increasingly effective at informing and affecting grower behavior, and in expanding implementation of protective practices that are suitable to each crop, soil, climate, and hydrographic setting. Assessment methods are discussed in this section.

The means and methods for assessing outreach consist of the following:

- A database of outreach activities (including sponsor, subject matter, locale, number of participants, and curricula) has been developed to capture past, ongoing, and future activities. All relevant activities will be included, whether sponsored by water quality coalitions or not. This is appropriate since the MPEP strategy is to multiply effort through collaboration with a wide range of partners.

- Barriers to adoption will be investigated by discussing individual practices with key resource persons, including growers and those who work closely with them (CCAs, Farm Advisors, and NRCS staff). Once a barrier is identified, means will be sought to lower this barrier. Some examples of barriers and actions that may be taken to alleviate them include the following:
  - When growers or farmworkers lack information or training, this can be supplemented through outreach.
  - When practices are exceedingly complex, simplified versions, or tools that enable growers to cope with complexity, can be developed.
  - When material resources are lacking, funding and volume pricing can be sought to offset costs.
  - When practices are ill adapted to certain types of operations or soil/topographic/management settings, more workable alternatives will be sought, and the “recommendation domain” (the conditions under which the practice is applicable and necessary) will be adjusted. Ideally, each practice should be associated with a defined recommendation domain. In some cases, questions of applicability and alternative practices will need to be fed back into field research performed by MPEP research partners.

- Grower receptivity and comprehension to outreach topics will be assessed by discussing practices with groups of growers participating in outreach events. Results will be employed to adjust and/or supplement outreach curricula, and to follow up with participants, so that practices as communicated are acceptable and understood by participants.

- Management practice implementation will be tracked through Farm Evaluation data. As mentioned previously, certain practices are already included in Farm Evaluations. As other priority practices are identified, these will be added so that the extent and pace of implementation can be tracked. This information will also inform landscape-level modeling that demonstrates program performance. Many management parameters, when known, can be included among model management parameters, so that model output will reflect performance changes over time that result from management shifts.
4 SCHEDULE

[This section to be developed separately by each coalition, depending on their individual order, GQMP, and program.]

5 REFERENCES

Appendix B
<table>
<thead>
<tr>
<th>MRP-1. Management Plan Development and Required Components</th>
<th>CGQMP Sections</th>
<th>MPEP Sections</th>
<th>GQMP MP Memo</th>
</tr>
</thead>
<tbody>
<tr>
<td>The third-party may develop one SQMP or GQMP to cover all areas where plans have been triggered rather than developing separate management plans for each management area where plans have been triggered. If multiple constituents of concern (COCs) are to be included in a single management plan, a discussion of the prioritization process and proposed schedule shall be included in the plan. Prioritization schedules must be consistent with requirements described in section XIX of the Order, Time Schedule for Compliance.</td>
<td>Section 3.1, Introduction; Section 3.1.1 Initial Prioritization of Constituents of Concern (COCs) N/A Section 3.1.2 Geographic Boundaries of Comprehensive Groundwater Quality Management Plan, Section 3.3 Constituents of Concern</td>
<td>Section 1. Introduction, Section 1.1 Geographic Boundaries of Comprehensive Groundwater Quality Management Plan, Section 3.3 Constituents of Concern</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### I.A. Introduction and Background Section

The introduction portion of the management plan shall include a discussion of the COCs that are the subject of the plan and the water quality objective(s) or trigger(s) requiring preparation of the management plan. The introduction shall also include an identification (both narrative and in map form) of the boundaries (geographic and surface water/groundwater basins or portion of a basin) to be covered by the management plan including how the boundaries were delineated.

### I.B. Physical Setting and Information

#### I.B.1.a Land use maps

- Land use maps which identify the crops being grown in the SQMP watershed or GQMP area. For groundwater, these maps may already be presented in the Groundwater Assessment Report (GAR) and may be referenced and/or updated as appropriate. Map(s) must be in electronic format using standard Arc-geographic information system (ArcGIS) shapefiles.

#### I.B.1.b Identification of the potential irrigated agricultural sources of the COCs

- Identification of the potential irrigated agricultural sources of the COCs for which the management plan is being developed. If the potential sources are not known, a study may be designed and implemented to determine the source(s) or to eliminate irrigated lands as a potential source.

#### I.B.1.c A list of the designated beneficial uses as identified in the applicable Basin Plan

- A list of the designated beneficial uses as identified in the applicable Basin Plan.

#### I.B.1.d A baseline inventory of identified existing management practices in use within the management plan area that could be affecting the concentrations of the COCs in surface water and/or groundwater (as applicable) and locations of the various practices.

#### I.B.1.e A summary, discussion, and compilation of available surface water and/or groundwater quality data (as applicable) for the parameters addressed by the management plan. Available data from existing water quality programs may be used, including but not limited to: Surface Water Ambient Monitoring Program (SWAMP), California State Water Resources Control Board (State Water Board) Groundwater Ambient Monitoring Assessment (GAMMA) Program, United States Geological Survey (USGS), California Department of Public Health (DPH), California Department of Pesticide Regulation (DPR), California Department of Water Resources (DWR), and local groundwater management programs. The GAR developed for the third-party’s geographic area, and groundwater quality data compiled in that document, may serve as a reference for these data.

### I.B.3 Groundwater—Additional Requirements

#### I.B.3.a Soil types and other relevant soils data as described by the appropriate Natural Resources Conservation Service (NRCS) soil survey or other applicable studies. The soil unit descriptions and a map of their areal extent within the study area must be included. The GAR developed for the third-party’s geographic area, and the soils mapping contained in that document, may satisfy this requirement.

#### I.B.3.b A description of the geology and hydrogeology for the area covered by the GQMP. The description shall include:

- Regional and area specific geology, including stratigraphy and existing published geologic cross-sections.

#### I.B.3.c Groundwater basins

- Groundwater basin(s) and sub-basins contained within the GQMP area, including a discussion of their general water chemistry as known from existing publications, including the GAR (range of electrical conductivity, concentrations of major anions and cations, nutrients, total dissolved solids (TDS), pH, dissolved oxygen and hardness). The discussion should reference and provide figures of existing Piper (tri-linear) diagrams, Stiff diagrams and/or Durov Diagrams for the GQMP area (see definitions contained in Attachment E of the Order).

#### I.B.3.d Known water bearing zones, areas of discharge and recharge to the basin/sub-basin in the GQMP area (rivers, unlined canals, lakes, and recharge or percolation basins).

#### I.B.3.e Identification of which water bearing zones within the GQMP area are being utilized for domestic, irrigation, and municipal water production.

#### I.B.3.f Aquifer characteristics such as depth to groundwater, groundwater flow direction, hydraulic gradient, and hydraulic conductivity, as known or estimated based on existing information (see definitions contained in Attachment E of the Order).
**I.B.3.c Identification, where possible, of irrigation water sources (surface water origin and/or groundwater) and their available general water chemistry (range of EC, concentrations of major anions and cations, nutrients, TDS, pH, dissolved oxygen and hardness).**

**Section 2.1.3 Geology, Section 2.1.4 Hydrology**

**I.C. Management Plan Strategy**

<table>
<thead>
<tr>
<th><strong>I.C.1</strong> A description of the approach to be utilized by the management plan (e.g., multiple COC’s addressed in a scheduled priority fashion, multiple areas covered by the plan with a single area chosen for initial study, or all areas addressed simultaneously [area wide]). Any prioritization included in the management plan must be consistent with the requirements in section XII of the Order, Time Schedule for Compliance.</th>
<th>Section 5.1 Approach and Prioritization</th>
<th>Section 3.1.1 Master Schedule; Section 3.1.12, Initial Prioritization of Investigations; and Section 3.13, Regulatory Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I.C.2</strong> The plan must include actions to meet the following goals and objectives:</td>
<td>Section 5.3.3 Outreach Strategy</td>
<td>Section 3.9.4, Summary Rationale for a Multi-Pronged Approach Section 3.9.5, Outreach Approach and Section 3.9.6, Sharing Findings with Coalition Members (Outreach)</td>
</tr>
<tr>
<td><strong>I.C.2.a</strong> Compliance with the Order’s receiving water limitations (section III of the Order).</td>
<td>Section 5.3.2 Protective Management Practices</td>
<td>Section 3.6.3, Benchmark Existing Levels of BMP Adoption; 3.6.4, Focused Field Studies; 3.9.5, A Multi-Pronged Approach to Assessing the Influence of Irrigated Lands on Groundwater Quality; Section 3.10, Landscape-level Performance Assessment; Section 3.12, Assessing Adoption, Data Exchange with Coalitions</td>
</tr>
<tr>
<td><strong>I.C.2.b</strong> Educate Members about the sources of the water quality exceedances in order to promote prevention, protection, and remediation efforts that can maintain and improve water quality.</td>
<td>Section 8.2 Individual Responsibilities</td>
<td>Section 2.2.2, Institutional Approach and Appendix A</td>
</tr>
<tr>
<td><strong>I.C.2.c</strong> Identify, validate, and implement management practices to reduce loading of COC’s to surface water or groundwater, as applicable, thereby improving water quality.</td>
<td>Section 8.2 Individual Responsibilities</td>
<td>Section 2.2.2, Institutional Approach and Appendix A</td>
</tr>
<tr>
<td><strong>I.C.3</strong> Identify the duties and responsibilities of the individuals or groups implementing the management plan. This section should include:</td>
<td>Section 8 Duties &amp; Responsibilities</td>
<td>Section 2.2.2, Institutional Approach and Appendix A</td>
</tr>
<tr>
<td><strong>I.C.3.a</strong> Identification of key individuals involved in major aspects of the project (e.g., project lead, data manager, sample collection lead, lead for stakeholder involvement, quality assurance manager).</td>
<td>Section 8.1 Identification of Project Administration</td>
<td>Section 2.2.2, Institutional Approach and Appendix A</td>
</tr>
<tr>
<td><strong>I.C.3.b</strong> Discussion of each individual’s responsibilities.</td>
<td>Section 8.2 Individual Responsibilities</td>
<td>Section 2.2.2, Institutional Approach and Appendix A</td>
</tr>
</tbody>
</table>

To comply with this section, we need to add a project team section to the MPEP. It can be an appendix, and should include 1) coalitions (don’t name them), their coordinators & staff/consulting teams, 2) Committee Program Manager (Casey), and 3) Technical PM (me) and ATPM (Andrea). Can include org chart from proposal too. Date the org chart, so that if it changes, we can simply explain that the one in the MPEP is particular to that date. Cite in Section 2.2.
I.C.3.c. An organizational chart with identified lines of authority. 

I.C.4 Strategies to implement the management plan tasks.

I.C.4.a Identify the entities or agencies that will be contacted to obtain data and assistance.

I.C.4.b Identify management practices used to control sources of COCs from irrigated lands that are 1) technically feasible, 2) economically feasible, 3) proven to be effective at protecting water quality, and 4) will comply with sections III.A and B of the Order. Practices that growers will implement must be discussed, along with an estimate of their effectiveness or any known limitations on the effectiveness of the chosen practice(s). Practices identified may include those that are required by local, state, or federal law. Where an identified constituent of concern is a pesticide that is subject to DPR's Groundwater Protection Program, the GQMP may refer to DPR's regulatory program for that pesticide and any requirements associated with the use of that pesticide provided that the requirement(s) are sufficient to meet water quality objectives.

I.C.4.c Identify outreach that will be used to disseminate information to participating growers. This discussion shall include: the strategy for informing growers of the water quality problems that need to be addressed, method for disseminating information on relevant management practices to be implemented, and a description of how the effectiveness of the outreach efforts will be evaluated. The third-party may conduct outreach efforts or work with the assistance of the County Agricultural Commissioners, U.C. Cooperative Extension, Natural Resources Conservation Service, Resource Conservation District, California Department of Food and Agriculture, or other appropriate groups or agencies.

I.C.4.d A specific schedule and milestones for the implementation of management practices and tasks outlined in the management plan. Items to be included in the schedule include: time estimated to identify new management practices as necessary to meet the Order’s surface and groundwater receiving water limitations (section III of the Order); a timetable for implementation of identified management practices (e.g., at least 25% of growers identified must implement management practices by year 1; at least 50% by year 2); an estimate of their effectiveness or any known limitations on the effectiveness of the chosen practice(s); Practices identified may include those that are required by local, state, or federal law. Where an identified constituent of concern is a pesticide that is subject to DPR's Groundwater Protection Program, the GQMP may refer to DPR's regulatory program for that pesticide and any requirements associated with the use of that pesticide provided that the requirement(s) are sufficient to meet water quality objectives.

I.D. Monitoring Methods

I.D.1 The monitoring system must be designed to measure effectiveness at achieving the goals and objectives of the SQMP or GQMP and capable of determining whether management practices changes made in response to the management plan are effective and can comply with the terms of the Order. Management practice-specific or commodity-specific field studies may be used to approximate the contribution of irrigated lands operations. Where the third-party determines that field studies are appropriate or the Executive Officer requires a technical report under CWC 13267 for a field study, the third-party must identify a reasonable number and variety of field study sites that are representative of the particular management practice being evaluated.

I.D.3 The third-party’s Management Practice Evaluation Program and Groundwater Quality Trend Monitoring shall be evaluated to determine whether additional monitoring is needed in conjunction with the proposed management strategy(ies) to evaluate the effectiveness of the strategy(ies). This may include commodity-based representative monitoring that is conducted to determine the effectiveness of management practices implemented under the GQMP. Refer to section 6 of the MRP for groundwater monitoring requirements.

I.E. Data Evaluation

To comply with this section, we need to add a project team section to the MPEP. It can be an appendix, and should include 5) coalitions (don’t name them), their coordinators & staff (consulting teams), 2) Committee Program Manager (Casey), and 5) Technical PM (me) and ATPM (Andrea). Can include org chart from proposal too. Date the org chart, so that if it changes, we can simply explain that the one in the MPEP is particular to that date. Cite in Section 2.2.
Methods to be used to evaluate the data generated by SQMP/GQMP monitoring and to evaluate the effectiveness of the implemented management practices must be described. The discussion should include at least the following: (1) Methods to be utilized to perform data analysis (graphical, statistics, modeling, index computation, or some combination thereof); 2. Identify the information necessary to quantify program effectiveness going forward, including the tracking of management practice implementation. The approach for determining the effectiveness of the management practices implemented must be described. Acceptable approaches include field studies of management practices at representative sites and modeling or assessment to associate the degree of management practice implementation to changes in water quality. The process for tracking implementation of management practices must also be described. The process must include a description of how the information will be collected from growers, the type of information being collected, how the information will be verified, and how the information will be reported.

### I. F. Records and Reporting

By 1 May of each year, the third-party must prepare a Management Plan Status Report that summarizes the progress in implementing management plans. The Management Plan Status Report must summarize the progress for the annual reporting period. The Management Plan Status Report shall include the following components:

1. Title page
2. Table of contents
3. Executive Summary
4. Location map(s) and a brief summary of management plans covered by the report
5. Updated table that tallies all exceedances for the management plans
6. A list of new management plans triggered since the previous report
7. Status update on preparation of new management plans
8. A summary and assessment of management plan monitoring data collected during the reporting period
9. A summary of management plan grower outreach conducted
10. A summary of the degree of implementation of management practices
11. Results from evaluation of management practice effectiveness
12. An evaluation of progress in meeting performance goals and schedules
13. Any recommendations for changes to the management plan

### I.G. Source Identification Study Requirements

Should the third-party conduct a Source Identification Study to comply with this Order, the third-party must first receive approval from the Executive Officer. Once approved, the third party may proceed with its study. The minimum components for a source identification study are:

1. An evaluation of the types of practices, commodities, and locations that may be a source
2. Continued monitoring at the management plan site/area and increased monitoring if appropriate.
3. An assessment of the potential pathways through which waste discharges can occur.
4. A schedule for conducting the study.

Commodity specific and/or management practice specific field studies (including edge-of-field studies) may be required to approximate the contribution of irrigated agriculture. At a minimum, the third-party must evaluate the feasibility of field studies as part of their source identification study proposal. Where field studies are deemed appropriate, the third-party should identify a reasonable number and variety of field study sites that are representative of the particular commodity or management practice being evaluated. If field studies are not proposed, the third-party must demonstrate how the alternative source identification method will produce data or information that will enable the determination of contributions from irrigated agricultural operations to the water quality problem.

If an approved study shows that irrigated lands are not a source, then the third-party can request the Executive Officer to approve completion of the associated management plan. Where irrigated lands are identified as a source, a full SQMP/GQMP shall be prepared and implemented.
Appendix C
GEOLOGY OF THE TULARE FORMATION AND OTHER CONTINENTAL DEPOSITS,
KETTLEMAN CITY AREA, SAN JOAQUIN VALLEY, CALIFORNIA,
WITH A SECTION ON
GROUND-WATER MANAGEMENT CONSIDERATIONS AND USE OF TEXTURE MAPS

By R. W. Page

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 83-4000

Sacramento, California
May 1983
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Plate 1. Geologic map and sections, showing depth to base and thickness of the Tulare Formation and other continental deposits, Kettleman City area, San Joaquin Valley, California.
2. Texture maps of the Tulare Formation and other continental deposits, Kettleman City area, San Joaquin Valley, California.

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For readers who may prefer to use the International System of Units rather than inch-pound units the conversion factors for the terms used in this report are listed below:

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>acres</td>
<td>0.4047</td>
<td>ha (hectares)</td>
</tr>
<tr>
<td>ft (feet)</td>
<td>0.3048</td>
<td>m (meters)</td>
</tr>
<tr>
<td>inches</td>
<td>25.4</td>
<td>mm (millimeters)</td>
</tr>
<tr>
<td>mi (miles)</td>
<td>1.609</td>
<td>km (kilometers)</td>
</tr>
<tr>
<td>mi² (square miles)</td>
<td>2.590</td>
<td>km² (square kilometers)</td>
</tr>
<tr>
<td>Ωmho/cm at 25°C</td>
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<td>μS/cm at 25°C (microsiemens per centimeter at 25°C Celsius)</td>
</tr>
<tr>
<td>(micromhos per centimeter at 25°C Celsius)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Degrees Fahrenheit are converted to degrees Celsius by using the formula

\[
\text{Temp } ^\circ C = \frac{(\text{temp } ^\circ F - 32)}{1.8}.
\]

National Geodetic Vertical Datum of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. The datum is shown as sea level in the geologic sections.
GEOLOGY OF THE TULARE FORMATION AND OTHER CONTINENTAL DEPOSITS,
KETTLEMAN CITY AREA, SAN JOAQUIN VALLEY, CALIFORNIA,
WITH A SECTION ON
GROUND-WATER-MANAGEMENT CONSIDERATIONS AND USE OF TEXTURE MAPS

By R. W. Page

ABSTRACT

The Tulare Formation and other continental deposits of Pliocene to Holocene age crop out over most of the 1,040 square-mile area near Kettleman City in the San Joaquin Valley of California. These deposits range in thickness from 0 to more than 4,000 feet and overlie the upper Mya zone of the San Joaquin Formation of Pliocene age. Some features of the base, which ranges in depth from 0 to more than 4,000 feet, include a trough in the central part of the area, a steep, northeastward-sloping surface in and near the Kettleman Hills, and a deep, northwestward-trending trough just east of the hills. These features reflect structural deformation during Quaternary time.

Many freshwater fossils are found in the Tulare Formation itself, including the largest fossil assemblage of clams and snails known on the Pacific Coast.

Sediments in the Tulare Formation and other continental deposits consist mainly of unconsolidated deposits of clay, silt, sand, and gravel. In the study area, these sediments have been deposited as alluvial-fan, deltaic, flood-plain, lake, and marsh deposits.

Texture maps of the Tulare Formation and other continental deposits show that most of the sandy and gravelly coarse-grained sediment lies beneath the northern, eastern, and southern parts of the study area to depths greater than 1,800 feet. Most of the silty and clayey fine-grained sediment lies beneath the western and central parts of the area to depths of about 1,400 feet. Below 1,400 feet the fine-grained sediment becomes more widespread, and at depths of 2,400 to 2,800 feet it underlies most of the area.

Texture maps made during this study can be useful in making water-management decisions, such as where to drill wells in order to get large yields. The maps also can be used by ground-water modelers for determining relative values for hydraulic conductivity and storage coefficient.

Other factors involved in making water-management decisions in the area include the gas that occurs in the Tulare Formation and other continental deposits, and saline water that underlies the entire area.
INTRODUCTION

Purpose and Scope

The purpose of this report is to compile the available geologic information on the Kettleman City area of the Central Valley that would aid others in the proper management of the valley's ground-water resources.

The scope of the study included the collection, assembly, and evaluation of data (1) to determine the depth to the base and the thickness of the Tulare Formation of Pliocene and Pleistocene age and other continental deposits of Pliocene to Holocene age; (2) to describe the types of sediment in those deposits; (3) to show the relative proportions of coarse-grained to fine-grained sediment in the Tulare Formation and other continental deposits; and (4) to consider the geology as related to the management of ground water and the design of hydrologic models in the area. The investigation did not include any fieldwork.

Location and General Features

The study area comprises about 1,040 square miles in the Kettleman City area of the San Joaquin Valley (fig. 1). Boundaries of the area were determined by the extent of a fossil zone in the underlying San Joaquin Formation of Pliocene age (see p. 7). Lake bottoms, or beds, are the principal landforms in the area (fig. 2) and are characterized by very gentle slopes of the land surface (Davis and others, 1959, p. 29). At times the lake bottoms are flooded, but throughout most of the year they are farmed. Davis and others (1959, pl. 1) mapped overflow lands and lake bottoms as one unit, but their text (p. 28-29) indicates that Tulare Lake bed is the principal landform in the study area. Other landforms in the area are Goose Lake bed and overflow lands to the south, low alluvial plains and fans that bound the lakebeds on the north, east, and west, and dissected uplands that lie along the western and southern edges of the area (fig. 2). The Kettleman Hills, lying along the northwestern boundary of the area, have been mapped by Davis and others (1959, pl. 1) as part of the Coast Ranges. Summers in the area are hot and dry, and winters are cool and relatively moist (table 1).
FIGURE 1.  Study area.
FIGURE 2. — Landforms in the Kettleman City area.
### TABLE 1. Normal temperature and precipitation, Kettleman Station
(from [U.S.] National Oceanic and Atmospheric Administration 1979, p. 4 and 18)

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature (°F)</th>
<th>Precipitation (inches)</th>
<th>Month</th>
<th>Temperature (°F)</th>
<th>Precipitation (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>47.3</td>
<td>1.17</td>
<td>July</td>
<td>84.5</td>
<td>0.02</td>
</tr>
<tr>
<td>February</td>
<td>52.2</td>
<td>1.26</td>
<td>August</td>
<td>82.5</td>
<td>0.04</td>
</tr>
<tr>
<td>March</td>
<td>56.3</td>
<td>.88</td>
<td>September</td>
<td>77.6</td>
<td>.05</td>
</tr>
<tr>
<td>April</td>
<td>62.5</td>
<td>.67</td>
<td>October</td>
<td>68.1</td>
<td>.21</td>
</tr>
<tr>
<td>May</td>
<td>69.6</td>
<td>.26</td>
<td>November</td>
<td>56.7</td>
<td>.68</td>
</tr>
<tr>
<td>June</td>
<td>77.0</td>
<td>.03</td>
<td>December</td>
<td>47.9</td>
<td>.85</td>
</tr>
<tr>
<td>Total</td>
<td>------------------</td>
<td>------------------------</td>
<td>----------</td>
<td>------------------</td>
<td>------------------------</td>
</tr>
</tbody>
</table>

1Normals are climatological normals based on the period 1941-70 ([U.S.] National Oceanic and Atmospheric Administration, 1979, p. 27).

### Previous Reports

In any study of an area, a knowledge of the works of others is essential for gaining an understanding of that area and for ensuring that work is not duplicated. Geologic reports pertinent to the study area include the following:

- American Association of Petroleum Geologists, 1958, geologic section through the eastern part of the study area;
- Croft, 1972, discussion of geology, maps showing the structure of three extensive clays;
- Croft and Gordon, 1968, discussion of geology, geologic map, and geologic sections in northern part of area;
- Davis and others, 1959, discussion and map of landforms, discussion of geology, map of an extensive lake clay, and geologic sections;
- Frink and Kues, 1954, discussion of a lake clay of Pleistocene age;
- Hill, 1964a and b, discussion of geology, structure map of the upper Mya zone—a fossil zone containing clams, and geologic sections in the central part of the area;
- Hilton and others, 1963, discussion of geology, and geologic sections in southeastern part of area;
- Hoots and others, 1954, structural contour map of the lower Pliocene;
- Kaplow, 1940, discussion of geology, structure maps of the upper Mya zone, and geologic sections in the central and southern part of area;
- Lofgren and Klausing, 1969, discussion of geology and geologic sections in eastern part of area;
- Miller and others, 1971, discussion of geology, and geologic sections in northeastern part of area;
- Page, 1981, basic-data report for the upper Mya zone in the study area; and Woodring and others, 1940, discussion of geology, geologic map, and geologic sections of the Kettleman Hills along the northwestern part of the study area.
Well-Numbering System

Wells are identified according to their location in the rectangular system for the subdivision of public lands. For example, in the number 26S/23E-6J, the part of the number preceding the slash indicates the township number (T. 26 S.); the number after the slash indicates the range (R. 23 E.); the number after the hyphen indicates the section (sec. 6); and the letter after the section number indicates the 40-acre subdivision of the section as indicated on the diagram below. Locations of most wells were taken from published maps and reports (Page, 1981a). Wells were not field located by the Geological Survey except for wells 23S/23E-33A1 and 27S/23E-1R1. The final digit in those well numbers indicates that the wells were the first to be field located in their particular 40-acre subdivision. The entire study area is south and east of the Mount Diablo base line and meridian.
Woodring and others (1940, p. 13) defined the Tulare Formation as the youngest folded strata exposed in the Kettleman Hills. They defined the base of the Tulare Formation as the layer just above the upper Mya zone of the San Joaquin Formation of Pliocene age (Woodring and others, 1940, p. 13-14). Upper Mya zone refers to the uppermost strata in which the burrowing pelecypod, or clam, Mya occurs in the San Joaquin Formation. This base marks a change from a dominantly marine environment to a continental environment of lakes, swamps, and streams. The upper Mya zone can be traced with a reasonable certainty over a considerable distance in the Kettleman Hills (Woodring and others, 1940, p. 13-14).

Kaplow (1940, pis. 3 and 5) mapped the base of the Tulare Formation as the top of the San Joaquin clay of Barbat and Galloway (1934) of Pliocene age. This clay lies about 500 feet above the Mya zone in the area of Buttonwillow and Semitropic Ridges (fig. 2). Kaplow (1940) did not mention an environmental change at the top of the upper Mya zone, but he did say that the upper Mya zone was by far the best subsurface marker in the area.

Later, Hill (1964a, p. 14), following the lead of Woodring and others (1940), defined the upper Mya zone in parts of T. 23 S., Rs. 21 and 22 E. as the top of the San Joaquin Formation, and the base of the Tulare Formation as the layer just above that zone. He indicated that the top of the upper Mya zone marked the greatest environmental change in the area and assumed that the contact between the San Joaquin Formation and the Tulare Formation was conformable (Hill, 1964a, p. 14), suggesting only slight erosional or structural changes over time between the two formations.

In this report, the base of the Tulare Formation is considered to be just above the upper Mya zone, except in the subsurface along the eastern side of the area where sediments from the Sierra Nevada have been deposited (fig. 3). The Tulare Formation is considered by most workers to include only that sediment derived from sources on the west side of the valley (Davis and others, 1959, p. 52); whereas, in the study area, sediments derived from the east side of the valley have, as yet, not been formally defined. The American Association of Petroleum Geologists (1958), however, showed that the eastern part of the study area is underlain by the Tulare Formation or the Kern River Formation, which is probably equivalent to the upper part of the Kern River Series of Diepenbrock (1933).

Nevertheless, without attempting to define the eastern extent of the Tulare Formation, the Tulare and sediments from the east side of the valley are here grouped as the Tulare Formation and other continental deposits. They crop out over most of the area (pl. 1). This grouping also includes the younger alluvium of Holocene age and the older alluvium of Pleistocene age that overlie the deformed Tulare Formation in the Kettleman Hills (Woodring and others, 1940, p. 13). Beneath Tulare Lake bed these two alluvial units cannot be easily distinguished from the Tulare Formation because of similarities in sedimentary material.
FIGURE 3. — Diagrammatic geologic
Continental deposits derived from east-side sources; silt, clay, sand, and gravel (Holocene to Pliocene)

Water-quality line below which dissolved-solids concentration greater than about 2000 milligrams per liter

Marine and nonmarine sedimentary rock (Pliocene)


section west to east through study area.
The depth to the base of the Tulare Formation and other continental deposits (pl. 1) was mapped on the basis of 292 identifications of the upper Mya zone in the study area (Page, 1981), structure-contour maps and geologic sections showing the upper Mya zone by Hill (1964a, pl. 2; 1964b, pls. 3 and 4) and Kaplow (1940, pls. 2, 3, 5, and 7), as well as areas where the base of the Tulare Formation is exposed in the Kettleman Hills (Woodring and others, 1940, pl. 3). Because the depth to the base of these deposits is measured from land surface, their present thickness is also defined. Thus, the Tulare Formation and other continental deposits range in thickness, as well as depth to base, from zero where the Tulare Formation lies in contact with the San Joaquin Formation in the Kettleman Hills to more than 4,000 feet just east of the hills (pl. 1). In both of those areas, the Tulare Formation is the principal deposit.

It should be mentioned that, because the Tulare Formation was eroded as the Kettleman Hills were being uplifted, its present thickness in this area is not its original thickness, and that its thickness of 0 foot at its contact with the San Joaquin Formation does not indicate that the Tulare Formation pinched out in the area of the Kettleman Hills. On the contrary, Woodring and others (1940, p. 16-22) described thick sections of the Tulare on both the east and west flanks of the Kettleman Hills, indicating that the Tulare Formation was quite thick prior to uplift and erosion of the hills. For example, on the east flank of the Kettleman Hills the exposed Tulare is as much as 1,700 feet thick, and on the west flank it is as much as 3,500 feet thick (Woodring and others, 1940, p. 14).

Some of the features of the base of the Tulare Formation and other continental deposits are (1) a trough near Wilbur Ditch in the north-central part of the area, (2) two rather shallow areas at Buttonwillow and Semitropic Ridges, (3) a fairly shallow area between the Homeland Canal and the Liberty Farms East Canal, (4) a steep, northeastward-sloping surface in and near the Kettleman Hills, and (5) a deep, northwestward-trending trough just east of the Kettleman Hills (fig. 2; pl. 1). In addition, the base slopes southwestward near the southern part of the area and northwestward along the long axis of the area (pl. 1). Although a depth and thickness map cannot be used to properly interpret structure, the features shown on plate 1 reflect some of the structure in the area. Furthermore, it is assumed that the top of the upper Mya zone can be used as a structural datum because in the study area it
has been used to successfully define the structure of five gas fields (Hill, 1964a, 1964b, and Kaplow, 1940). Thus, the two shallow areas at Buttonwillow and Semitropic Ridges reflect the structure of two elliptical domes in that area (Kaplow, 1940, pl. 2); the shallow area between the Homeland Canal and the Liberty Farms East Canal partially reflects the structure of a dome and an anticlinal nose (Hill, 1964a, pl. 2); the rather steep, northeastward-sloping surface in and near the Kettleman Hills reflects the uplift that occurred at the close of the deposition of the Tulare Formation in Quaternary time (Hoots and others, 1954, p. 128); and the deep, northwestward-trending trough just east of the Kettleman Hills reflects a syncline, or downwarping, that also occurred as an effect of that uplift (Hoots and others, 1954, p. 129, pl. 5).

Furthermore, Davis and Green (1962, p. 90) postulated that the Tulare Lake area is an area of downwarping. Parts of the area have not only been sinking structurally, they also have been subsiding as fine-grained beds compacted because of ground-water overdraft (Poland and others, 1975, figs. 1, 5, and 12-17).

**Fossils**

Many freshwater fossils are found in the Tulare Formation itself. Woodring and others (1940, p. 104) said that the lower part of the Tulare Formation contains the largest fossil assemblages of freshwater mollusks, chiefly clams and snails, known on the Pacific Coast. Hill (1964a, table 1) showed that in parts of T. 23 S., Rs. 21 and 22 E. the freshwater clam *Anodonta*, the freshwater and brackish-water snail *Amnicola*, and the freshwater snails *Fluminicola*, *Planorbis*, and *Pyrgulapsis* occur in the Tulare Formation. And Croft (1972, p. 22) reported that the freshwater clam *Sphaerium kettlemanense* (Arnold), and the freshwater snails *Valvata utahensis* (Call), *Lithoglyphus seminalis* (Hinds), and *Tryonia?* occur about 50 feet above the E clay of Pleistocene age at a depth of 600-602 feet in sec. 31, T. 20 S., R. 19 E.

Lohman (1938, p. 88) identified 136 species and varieties of diatoms that were found in the Tulare Formation in the Kettleman Hills. Further, Davis and others (1959, p. 78, pl. 14) said that Lohman identified 113 species of diatoms that were found in their diatomaceous clay, which underlies a large part of the San Joaquin Valley. According to Lohman these species represent a dominantly freshwater to somewhat brackish-water flora (Davis and others, 1959, p. 78-79).
Sedimentary Material

Sedimentary material in the Tulare Formation and other continental deposits consists principally of unconsolidated clay, silt, sandy clay and silt, sand, clayey and silty sand, gravel, and clayey, silty, and sandy gravel (fig. 3). Locally, the deposits consist of more consolidated material such as conglomerate and sandstone. Hill (1964a, p. 14) mentioned the occurrence of conglomeratic deposits in parts of T. 23 S., Rs. 21 and 22 E., but most of the deposits in that area consist of clay, sand, and gravel (Hill, 1964a, table 1). In the Kettleman Hills, the Tulare Formation consists principally of sandstone, most of which is cross-bedded, silty, and pebbly, and conglomerate (Woodring and others, 1940, p. 13). There, most of the conglomerate and sandstone is poorly consolidated (Woodring and others, 1940, p. 13); thin-bedded, fine-grained sediments of silt, fine-grained sandstone, tuff, and limestone are also present. Miller and others (1971, p. 21) reported that in the northern part of the Kettleman Hills the Tulare Formation consists principally of sand, much of which is silty, pebbly, and crossbedded; it also contains some gravel, apparently laid down as stream deposits. Beneath Tulare Lake bed, the Tulare Formation and other continental deposits consist principally of silt and clay. Croft (1972, p. 13) considered the boundary between the upper Mya zone and the overlying deposits as probably representing a gradational change from mostly consolidated rocks, such as shale and sandstone, to mostly unconsolidated deposits, such as clay and sand.

Source and Depositional Environment

All the continental sedimentary material in the study area was derived chiefly from either the Sierra Nevada on the east or the Coast Ranges on the west (figs. 1 and 3). Some material probably was derived from those parts of the Sierra Nevada and Coast Ranges that form the southern border of the San Joaquin Valley. The type of material deposited is dependent on controls such as (1) type of rock in the source area, (2) competence of the streams that transported the sediments, and (3) environment of deposition.

The Sierra Nevada are composed of igneous and metamorphic rocks. Sediments derived from them have abundant feldspar, mica, and quartz. The Coast Ranges are composed of gypsiferous marine shale, sandstone, and volcanic rocks. Sediments derived from them are gypsiferous, and contain more rock fragments and are darker than those from the Sierra Nevada (Meade, 1967, p. 5). Sediments derived from the Sierra Nevada were transported mostly by major perennial streams; those derived from the Coast Ranges were transported mostly by ephemeral streams of intermediate to small size (Bull, 1964a). As a result of stream competence and source, sediments derived from the Sierra Nevada are, except for rock fragments, generally coarser than those derived from the Coast Ranges. Climatic change and uplift during the Quaternary have also influenced the competence and capacity of the streams (Croft, 1972, p. 15, and Mack, 1969).

In the study area, sediments have been deposited as alluvial-fan, floodbasin, lake, and marsh deposits (figs. 4 and 5), as well as deltaic deposits (not shown).
FIGURE 4. — Idealized alluvial fan.

FIGURE 5. — Generalized geologic section and view of part of the Central Valley.
Alluvial-Fan Deposits

Alluvial-fan deposits generally grade from coarse-grained material near the head of the fan to finer-grained material near the toe. Depending on source areas, there are boulders, cobbles, gravel, and sand, mixed with some silt and clay, near the fan head. Near the middle of a fan may be found more sand and gravel with clay and silt; near the toe may be found sand, silt, and clay with some gravel. Within any segment of a fan can be found coarse-grained deposits, representing a bar or a main channel of a stream, and finer-grained deposits representing natural levees and overbank deposits. Furthermore, through time the main channel of a stream changes course and cuts and fills across previous deposits. Also, alluvial fans may join together out in the valley. Thus, deposits within alluvial fans comprise a heterogeneous mixture of coarse- and fine-grained material; these deposits tend toward hues of brown, red, and yellow because of oxidizing in subaerial environments.

Alluvial deposits in the study area were formed near the toes of alluvial fans. Miller and others (1971, pls. 3 and 4) showed that alluvial deposits near the northern part of the study area are as much as 1,950 feet deep and 1,650 feet thick. These deposits, as in other parts of the area, are interbedded with and overlie deltaic, flood-plain, lake, and marsh deposits. Woodring and others (1940) described beds of dark brown clay and silt, and beds of yellow and yellowish-brown sandstone as occurring in the Kettleman Hills; these beds probably were deposited as alluvial fans. Lofgren and Klausing (1969, fig. 5) showed that alluvial-fan deposits are as much as 1,050 feet deep and 1,000 feet thick in the eastern part of the area, and Croft (1972, pl. 1) showed that alluvial-fan deposits are as much as 1,050 feet deep and 980 feet thick in the southeastern part. Furthermore, alluvial-fan and some deltaic and lake deposits are indicated in the log of test hole 27S/23E-1R1 (depth 1,160 feet) from depths of 0 to about 890 feet (H. B. Goldman, U.S. Bureau of Reclamation, written commun., 1953).

Deltaic Deposits

Deltaic deposits were formed where the streams of alluvial fans dropped most of the remainder of their coarse-grained load as they entered lakes or marshes in the low-lying area, with the lakes and marshes, as well as the flood plains, receiving large quantities of fine-grained material. Miller and others (1971, p. 28) indicated that in the Tulare Formation near the northern part of the study area deltaic deposits consist primarily of bluish-green or greenish-gray, medium to well-sorted sand that is crossbedded and has depositional dips of 10°-40°.
Miller and others (1971, p. 28, pl. 4) mentioned that sandy deposits of presumably deltaic origin begin just north of the study area at a depth of about 350 feet and are about 2,000 feet thick. Woodring and others (1940, p. 13-26) did not mention deltaic deposits. Lofgren and Klausing (1969, pls. 4 and 5) also mapped reduced flood-plain and lacustrine deposits in the eastern part of the area; presumably, parts of these deposits are of deltaic origin. Croft (1972, p. 23) mentioned reduced deposits of alluvium that are bluish-green, fine to coarse sand, silt, and clay that interfinger with flood-basin, lake, and marsh deposits beneath Tulare Lake bed. Presumably, some of these reduced deposits of alluvium are of deltaic origin. Logs of test holes 23S/23E-33A1 (depth 1,200 feet) and 27S/23E-1R1 indicate beds of olive-gray, greenish-gray, and dark-greenish-gray well sorted sands, as well as some other material, from depths of 255 to 1,200 feet and 890 to 1,160 feet respectively (H. B. Goldman, U.S. Bureau of Reclamation, written commun., 1953). Although crossbedding is not mentioned, most of these beds probably are of deltaic origin as indicated by their color, sorting, and chiefly sandy nature.

Flood-Plain, Lake, and Marsh Deposits

Flood-plain, lake, and marsh deposits consist primarily of olive-brown, bluish-green, and greenish-blue beds of sand, silt, and clay. Miller and others (1971, p. 28) reported that flood-plain deposits in the Tulare Formation are coarser than those now being laid down on the central floor of the valley. Furthermore, lake and marsh deposits are more homogeneous than flood-plain deposits and generally are fine-grained except where mixed with deltaic sands from the Sierra Nevada (Miller and others, 1971, p. 28 and 30). The fine-grained deposits underlying the SW% T. 23 S., R. 20 E. are more than 3,600 feet thick, and their base lies at a depth greater than 3,600 feet (pl. 2).

If it were possible to open the Earth and look at the lake and marsh deposits, as well as some flood-plain deposits, in the study area they would appear as a thick plug of mostly clay and silt with discs of clay and silt emanating from the plug at irregular intervals (fig. 3). Croft (1972, pls. 1-6, p. 17-21) mapped six of these discs and designated them from youngest to oldest by the letters A-F. The A, C, and E clays of Quaternary age are the more extensive.
In the study area, the E clay is equivalent to the Corcoran Clay Member (Pleistocene) of the Tulare Formation and the diatomaceous clay of Davis and others (1959, pl. 14, p. 76-81); it lies below most of the area (Croft, 1972, pls. 1, 3, and 4) (pl. 1). In the northeastern part of the San Joaquin Valley, where virtually all deposits were derived from the Sierra Nevada, Marchand and Allwardt (1981, p. 34) considered that the Corcoran Clay Member of the Tulare Formation was also a member of the Turlock Lake Formation of Pleistocene age. The age of the Corcoran Clay Member or E clay (Croft, 1972, p. 18) is approximately bracketed by two dates determined from K-Ar (potassium-argon) dating techniques. Davis and others (1977, p. 388) reported that an ash found in the basal part of Croft's (1972, p. 18) E clay, in a test hole near Wasco, is about 725,000 years old. They considered this ash to be most probably the Bishop tuff (Davis and others, 1977, p. 388). In addition, they reported that a reversal in polarity occurred about 700,000 to 750,000 years ago represented by strata 12 feet below the ash at the base of the E clay (Davis and others, 1977, p. 388-389); this wide range in age is attributed to "a large margin of uncertainty" in the K-Ar dating of the ash and the sedimentation rate of the clay between the ash and the reversal (Davis and others, 1977, p. 388-389). Because of new decay constants for K-Ar dating techniques, the ash is now considered to be about 730,000 years old (Marchand and Allwardt, 1981, p. 33). The exact date of the reversal in polarity is still unknown. Janda and Croft (1967, p. 164) reported that a volcanic ash and pumice, the Friant Pumice Member of the Turlock Lake Formation (Marchand and Allwardt, 1981, p. 34), can be traced discontinuously from near Friant, where it is exposed, to beneath the axis of the San Joaquin Valley where it conformably overlies the Corcoran Clay Member. Using the new decay constants, G. B. Dalrymple (Marchand and Allwardt, 1981, p. 34) dated two separate collections of the Friant Pumice Member as 612,000±31,000 years and 618,000±31,000 years. Janda and Croft (1967) did not mention the Bishop tuff\(^1\) as being in the area of the Friant Pumice Member, and Davis and others, (1977, p. 385) did not find the Friant Pumice Member in their test holes near Wasco. Therefore, the data concerning the bracketing of the age of the Corcoran Clay Member of the Tulare Formation and the Turlock Lake Formation is not conclusive. Nevertheless, because the Friant Pumice Member was found immediately above the Corcoran Clay Member near the axis of the San Joaquin Valley, and the reversal in polarity was found near the axis of the valley at the base of the Corcoran Clay Member, it can be inferred that the Corcoran Clay Member ranges in age from approximately 615,000 to 750,000 years before present time.

\(^1\)Marchand and Allwardt (1981, p. 34) noted that "Considerable uncertainty exists as to whether the Friant Pumice Member is correlative with the Reds Meadows tuff of the upper San Joaquin drainage and with the Bishop tuff...," but if the Friant Pumice Member overlies the Corcoran Clay Member (Janda and Croft, 1967, p. 164) and if the probable Bishop tuff lies near the basal part of the Corcoran Member (Davis and others, 1977, p. 388) then the Friant Pumice Member and the probable Bishop tuff of Davis and others (1977, p. 388) are not correlative.
Janda and Croft (1967, p. 168) suggested that some of the clays older than the A clay (Croft, 1972, p. 18-20) may have been deposited in large lakes that were coeval with glaciation in the Sierra Nevada (U.S. Geological Survey, 1965, p. A100), but Davis and others (1977, p. 389) suggested that the E clay (Croft, 1972) may represent an interglacial stage.

The C clay of Pleistocene age was mapped beneath the northern, eastern, and southern parts of the area but was not identified beneath Tulare Lake bed because of similarities in sedimentary material (Croft, 1972, pls. 1, 3, and 5) (pi. 1). As one of the older clays of Croft (1972), the C clay may have been deposited in a large lake during a glacial stage in the Sierra Nevada (Janda and Croft, 1967, p. 168, and U.S. Geological Survey, 1965, p. A100).

The A clay of Pleistocene and Holocene (?) age was mapped beneath the northern, northeastern, and southern edges of the study area (Croft, 1972, pls. 1, 3, and 6) (pl. 1). The A clay was not identified beneath Tulare Lake bed because of similarities in sedimentary material. Janda and Croft (1967, p. 168), said that the age of their youngest clay, the A clay of Croft (1972, p. 20-21), was bracketed by radiocarbon dating done by Meyer Rubin of the U.S. Geological Survey. These radiocarbon dates were from wood collected 3 feet beneath the A clay and for wood within the upper part of the clay and are 26,780 ± 600 years and 9,040 ± 300 years respectively (Croft, 1972, p. 21). Janda and Croft (1967, p. 168) considered the A clay to have been deposited in a large lake coeval with the Wisconsin Glaciation.

Croft (1972, p. 18) said that the flood-plain, lake, and marsh deposits range in age from late Pliocene to Holocene; therefore, deposition of these mostly fine-grained deposits has been going on for more than 2 million years. And, except for the expansion of the lake, as represented by the Corcoran Clay Member of the Tulare Formation (Croft, 1972, pl. 4), the ancient lakes and marshes of probable late Pliocene or early Pleistocene age occupied a much larger area for a longer period of time in the eastern and southeastern parts of the study area than later lakes and marshes, as evidenced by the thick deposits of fine-grained material at depths of 2,200 to 2,600 feet and below (pl. 2). Later, alluvial-fan and deltaic deposits from easterly sources encroached on the area formerly occupied by these lake and marsh deposits, as evidenced by the deposition of coarse-grained material above 2,200 feet (fig. 3; pl. 2).

Mack (1969, p. 2535) suggested a minimum rainfall of about 35 to 45 inches per year at the beginning of the deposition of the Tulare Formation in the late Pliocene. Thus, a more abundant rainfall than at present (table 1) and a lower lying area (Hoots and others, 1954, p. 128) probably contributed to the expansion of the ancient lake in the eastern and southeastern parts of the area. In any event, the fine-grained deposits in the central part of the area (pl. 2) were laid down seemingly without interruption throughout the late Pliocene, the entire Pleistocene, and the Holocene. Beneath Tulare Lake bed these deposits would probably yield excellent paleoclimatic data in the form of fossil diatoms, mollusks, and pollens. In turn, paleoclimatic data can help to explain more about the expansions and contractions of this ancient lake.
Texture of the Deposits

Texture as used in this report means the proportion of coarse-grained to fine-grained sedimentary material in the Tulare Formation and other continental deposits. In order to determine texture, geophysical logs, mostly from gas or gas-test wells, were used. These logs show properties of sedimentary material such as resistivity and spontaneous potential. Coarse-grained and fine-grained material, as well as their depth and thickness, can be determined from geophysical logs (Schlumberger Ltd., 1972). For example, in the study area high resistivities are interpreted as representing coarse-grained material, and lower resistivities as representing fine-grained material (fig. 6). The spontaneous potential also is a guide in determining coarse-grained and fine-grained material. Opposite a coarse-grained bed, the spontaneous-potential line, depending on water salinity in the bed and fluid salinity in the borehole, will move either to the right or left of a base line representing fine-grained material. Although the presence of coarse-grained and fine-grained material can be determined from geophysical logs, the logs cannot be used to determine if the coarse-grained material is gravel or sand, nor can they be used to determine if a fine-grained material is silt or clay.

Using geophysical logs and a computer program written by H. T. Mitten of the Geological Survey (written commun., 1980), texture maps of the sedimentary material beneath the study area were generated by computing and plotting the percentage of coarse-grained material in depth intervals of 200 feet (pl. 2). Most of the computations for texture were for depths below 400 feet because the California Division of Oil and Gas requires that before drilling an oil or gas well that a casing be set in the ground from the surface to a depth of 10 percent of the total depth of the well. This casing blocks the recording of resistivity and the spontaneous potential.
TABLE 1

<table>
<thead>
<tr>
<th>SPONTANEOUS POTENTIAL (millivolts)</th>
<th>DEPTH (feet)</th>
<th>RESISTIVITY (ohms per square meter per meter)</th>
<th>CONDUCTIVITY (millimhos per meter = \frac{1000}{\text{ohms per square meter per meter}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0</td>
<td>16&quot; NORMAL</td>
<td>INDUCTION</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXPLANATION

TEXTURE

Coarse-grained material such as gravel, sand, clayey and silty gravel, and clayey and silty sand

Fine-grained material such as clay, silt, sandy clay, and sandy silt

To convert feet to meters multiply by 0.3048

FIGURE 6. — Geophysical logs for part of well 23S/23E–25E.
Texture maps (pl. 2) can be useful in making water-management decisions in the study area. For example, coarse-grained material yields water to wells more rapidly and with less drawdown because in a given time it has a greater ability to take water into or release it from storage than fine-grained material and can transmit larger quantities of water. Using this fact, a water manager probably would not elect to drill wells in the central part of the Tulare Lake bed area because of the underlying thick section of fine-grained sediment (pl. 2). Instead, he or she would limit well drilling to the northern, southern, or eastern parts of the area, and in those areas probably would limit wells to depths above the fine-grained sediment, as indicated on plate 2. In the southeast corner of T. 21 S., R. 20 E. (pl. 2), he might elect to drill wells through the fine-grained sediment indicated at depths of 400 to 1,000 feet in order to test the coarse-grained sediment indicated at depths of 1,000 to 1,200 feet and below. On the other hand, if he were considering injecting wastes, following all State and local regulations, he might consider that the thick and extensive nature of the fine-grained sediment indicated beneath the lakebed would serve as an effective cap.

The texture maps (pl. 2) also can be used by ground-water modelers. Virtually any model of a ground-water system requires values for hydraulic conductivity, or transmissivity, and the coefficient of storage. These values must be placed in discrete units, or nodes, throughout an entire model. By knowing that coarse-grained sediment has a greater ability than fine-grained sediment to take water into or release it from storage and can transmit water more readily, a modeler can use the texture maps (pl. 2) to assign relative values of hydraulic conductivity and storage coefficient to the model nodes. Values for the storage coefficient, of course, would depend on whether conditions were confined or unconfined.

Through time, fine-grained sediment such as silt and clay can yield large quantities of water when the silt or clay is compacted because of an increase in effective stress (Lofgren, 1975, p. 35, pl. 5). Increased effective stress occurs when water levels in an aquifer are drawn down (Lofgren, 1968, p. 222). Compaction of fine-grained beds has resulted in land subsidence in parts of the Kettleman City area (Bull and Miller, 1975, fig. 4, and Lofgren and Klausing, 1969, fig. 50). Beds of silt and clay also can confine water under greater than atmospheric pressure and impede the vertical movement of water. In the study area, the A-F clays of Croft (1972, p. 17-21, pls. 1-6) function as confining beds. Anyone making decisions about recharge or discharge operations in the area should take these beds into account as well as the thick sections of fine-grained material (pls. 1 and 2). Most of the fine-grained material lies beneath the western and central parts of the study area to depths of over 1,400 feet (pl. 2). Below 1,400 feet the fine-grained material becomes more widespread, and at depths of 2,400 to 2,800 feet it underlies most of the area. Below 2,800 feet all the mapped deep areas are filled chiefly with fine-grained material (pls. 1 and 2).
SUMMARY AND CONCLUSIONS

In the Kettleman City area the base of the Tulare Formation and other continental deposits marks a change from an underlying dominantly marine environment to a continental environment of lakes, swamps, and streams (Woodring and others, 1940, p. 13-14). The base is mapped as just above the upper Mya zone of the San Joaquin Formation. The eastern extent of the Tulare Formation is not defined. The Tulare has been grouped with continental deposits from the east side of the valley that interfinger with and overlie it; on the west side of the area the Tulare Formation has been grouped with younger deposits of similar material that overlie it.

The Tulare Formation and other continental deposits range in depth and thickness from zero in the Kettleman Hills to more than 4,000 feet just east of the hills. In both these areas, the Tulare Formation is the principal deposit. Prior to the uplift of the Kettleman Hills and erosion of all the exposed formations, the Tulare Formation in that area was quite thick, as indicated by measured sections of the Tulare on both the east and west flanks of the hills.

Some of the features of the base of the Tulare Formation and other continental deposits reflect geologic structures in the area. Two of the more prominent features are (1) the rather steep, northeastward-sloping surface in and near the Kettleman Hills that reflects the uplift that occurred at the close of the deposition of the Tulare Formation in Quaternary time, and (2) the deep, northwestward-trending trough that reflects a downwarping that occurred as an effect of that uplift.

Sedimentary material in the Tulare Formation and other continental deposits consists principally of unconsolidated deposits of clay, silt, sand, and gravel. These sediments have been derived chiefly from the Sierra Nevada on the east and the Coast Ranges on the west and have been deposited as alluvial-fan, deltaic, flood-plain, lake, and marsh deposits. Alluvial-fan and deltaic deposits, that contain most of the coarse-grained deposits in the area, underlie the northern, eastern, and southeastern parts. Flood-plain, lake, and marsh deposits of mostly fine-grained material underlie chiefly the central and western parts of the area to depths of 1,400 feet where they become more widespread. At depths of 2,400 to 2,800 feet they underlie most of the area.
For most recharge and discharge operations, water managers in the area would choose those areas underlain by coarse-grained material, as indicated by the texture maps. The texture maps also can be used by ground-water modelers for assigning relative values of hydraulic conductivity and storage coefficient to model nodes. Fine-grained material, when compacted, can yield large quantities of water, but compaction of fine-grained beds in the area has resulted in land subsidence. Water managers in the study area would also have to consider the subcommercial quantities of gas that occur in the Tulare Formation and other continental deposits and the saline water that underlies the area. Drilling in gas zones, of course, poses a danger, and wells completed near the saline water would yield water with a large dissolved-solids concentration.

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