Review of

"Draft Conclusions of the Expert Agricultural Panel, Recommendations to the State Water Resources Control Board Pertaining to the Irrigated Lands Regulatory Program"

In Fulfilment of SBX2 1 of the California Legislature

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Introduction

My name is Dr. Mark Kram, and I have been retained by the leaders of the Otter Project to review the document entitled "*Draft Conclusions of the Expert Agricultural Panel, Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program*", which has been released for public comment in fulfilment of SBX2 1 of the California Legislature. As such, review comments have been organized and presented below as General Comments, Recommendations, Specific Comments, and Summary and Conclusions. I have also included references, a brief summary of my background and selected publications, and a list of selected technology vendors and contacts referenced in other parts of this document.

In response to recently observed elevated nitrate concentrations in groundwater resources near and adjacent to critical agricultural regions, the State Water Board developed recommendations in four key areas to promote the remediation of nitrate contaminated groundwater. These areas include:

1) Provide safe drinking water
2) Monitoring, notification, and assessment
3) Nitrogen tracking and reporting
4) Groundwater protection

In addition, the State Water Board recommended that the Legislature approve of the formation of an expert panel to assess existing agricultural nitrate control programs, and to develop recommendations for improvement, as needed, with a focus on protection of groundwater quality. The State Water Board then contracted to a panel of experts, each retained based on key areas of expertise that include familiarity with agricultural practices and understanding of fate and transport of pollutants in soil and water media.

Key objectives of this review report include identifying areas of common ground between the agricultural communities and other stakeholders, evaluating the panel's recommendations as described in their report, and to introduce and propose new technologies that can effectively and efficiently meet key drinking water quality and regulatory objectives with minimal burden to the grower community. Fortunately, the complex nitrate management issue has many features in common with the relatively mature environmental assessment and remediation industry focused on groundwater and soil restoration at hazardous waste release sites. As such, where possible, recommendations will be proposed for leveraging mature and innovative approaches, technologies and policies developed for such endeavors.

General Comments

1) A well-functioning and environmentally sustainable agricultural community is critical for reasons related to societal benefits associated with economic, security, drinking water supply, energy and long-term environmental considerations.

2) Since agricultural practices in California have been granted exemption or leniency regarding addressing the potential nitrate contaminant issues for so long, and a comprehensive nitrate management policy has not yet been developed or implemented by the regulatory community, it is critical to understand that contamination emanating from legacy activities will need to be considered when addressing relationships between cause-and-effect for current and future agricultural practices. In addition, loading studies seem to conclude that legacy sources alone do not account for the nitrates found in the groundwater or vadose zone. As such, implementation of compliance programs will need to be flexible and account for temporal, spatial, and site-specific characteristics, as a one-size-fits-all or even an aggregated (e.g., by crop, region, or common field characteristics) approach may not be appropriate.
3) Any solution proposed will require substantial financial resources for development of policies, integration of new practices, monitoring, education, and implementation of private sector and government programs.
4) It is in the best interest of all parties to derive a balanced approach towards managing agricultural practices that weighs public benefits against the interests of individuals or aggregated parties. For instance, if the privatization of profit overwhelmingly favors socialization of the risks (e.g., contamination of the public drinking water resources), public financial resources will need to be made available to address the unfavorable outcomes. As such, a decision regarding what is a fair level of public financial burden will need to be determined.
5) An ideal outcome of this process should include the use of the most effective technologies and practices that would result in pragmatic policies that can meet key drinking water quality objectives with the least amount of burden endured by the grower community to ensure compliance, continual improvement, and restoration supported by defensible trend analyses.
6) While an enforcement component to drinking water resources management policy will eventually be required, given the complexities involved, many in the environmental community would be willing to accept an initial transitional period that emphasizes education and monitoring network deployment while acknowledging near term improvements to management practices as verified by defensible documentation (e.g., reduction in nitrate amendment exceedance and improved soil/water quality).
7) Given what we know about widespread contamination of our groundwater resources and what we understand about the loading already present in the vadose zone, the environmental community realizes progress will require years, even decades of effort, adding to the urgency to immediately initiate comprehensive monitoring and responses.
8) Low-cost denitrification bioreactors (Diaz et al., 2003; Christianson et al., 2013), engineered wetlands, and other types of passive treatment systems and approaches should be considered for many of the properties to reduce nitrate releases to the environment. Monitoring of these can also be accomplished via the emerging state-of-practice automation technologies to evaluate efficiency and to determine loads that can be tracked over time (Kram et al., 2011).
9) All hazardous material risks are comprised of source, pathway, and receptor components. The panel is advocating against understanding site-specific pathway components. It is impossible to manage what is not measured. Unlike the hazardous waste and groundwater remediation industries, the agricultural community has not yet been required to produce key site

assessments or to develop monitoring programs sufficient to adequately determine cause-and-effect relationships. The panel is suggesting that since this is complex, we should not attempt to pursue this type of relationship. This does not make sense from a scientific perspective, particularly since there exist decades of historical and ongoing related efforts, thousands of experienced practitioners, and comprehensive libraries full of standards and guidance documents available from analogous industries (e.g., groundwater assessment, groundwater and soil remediation, landfill and oil and gas industries), and new and emerging technologies that will greatly facilitate compliance (e.g., sensors, automation, geospatial mapping, remote sensing, drone deployed technologies, high resolution direct push sensing and well installation, etc.).

10) While many of the panel's recommendations (e.g., education, appropriate training for key entities in specific roles, tracking of nitrogen amendments, etc.) are exceptional, and they accurately point to many of the complexities associated with the challenges at hand, unfortunately, their recommendations as presented in the report will not enable the communities involved to meet key drinking water quality objectives. More specifically,
    a. The panel proposes extremely limited monitoring and reporting.
    b. The panel advocates for data collection activities at temporal and spatial scales that are not sufficient.
    c. The panel advocates for data collection and reporting at an aggregated coalition scale, as opposed to supporting site-specific understanding of the fate and transport of nitrate throughout the system at a granular scale sufficient to be able to eventually understand cause-and-effect, and that would allow for the identification of nitrate source areas where specific challenges persist.
    d. The panel appears to emphasize what is not possible, characterizes the application of well-founded scientific principals and methods as futile, and does not consider the important lessons that can be learned from the hazardous waste and groundwater restoration fields as well as the associated regulatory tools already in place (e.g., GeoTracker, ITRC guidance, etc.).
    e. The panel does not consider the many fine technologies available for expedited site characterization, automated sensing, analyses (temporal and spatial), and reporting that are commercially available or in beta testing. These technologies have the potential to greatly improve the understanding of conditions and trends, and could significantly alleviate the majority of the grower's site-specific assessment, monitoring and reporting burden.
    f. With respect to surface water considerations, while the panel advocates for monitoring in downstream areas to determine general locations of pollution sources, they also advocate against monitoring at specific discharge points. With new sensing technologies, an automated monitoring and data processing network at actual discharge points could be extremely helpful in identifying where issues persist, notifying the appropriate entities (not for punishment, but to assist with management decisions [at least initially]), and tracking trends and geospatiotemporal relationships with other factors (e.g., correlations with specific crops, climate, etc.).

g. Beyond modification of the amounts of nitrogen based materials purchased and applied, the panel does not consider alternative nitrate pollution control and containment options such as passive bioreactors, engineered wetlands, and other potential technologies.

Recommendations

Initial recommendations for consideration include the following:

1) Collectively identify a multi-pronged set of pragmatic solution components (e.g., education, monitoring of purchases, site-specific field and groundwater monitoring, changes over time and space, deployment and installation and monitoring of passive bioreactors, etc.) that result in nitrate load reductions while not excessively burdening farmers.
2) It is proposed that the term "non-point source" be discontinued where appropriate, and that new terminology be derived to better define some of these types of pollution sources (e.g., "aggregated source"). If application of an amendment at a specific location (or even materials from a canal or discharge pipe emanating from a specific activity or location) can be identified as the cause of drinking water quality impairment, the description of this type of source should no longer be ambivalent or imply that a pollution source cannot be identified and appropriately addressed.
3) We can't manage what we can't measure. As such, establish a monitoring network that will yield information appropriate for applying quantifiable performance based metrics (e.g., load reduction percentage in soil and concentration reduction in groundwater).
4) Water level maps (past, present, and automated updates) should be developed and maintained/updated to determine direction and flow of nitrate solute plumes. This mapping is synergistic with State initiatives to map, track, and potentially regulate withdrawals from over-tapped groundwater aquifers through programs such as CASGEM.
5) Comprehensive calibrated models need to be developed to specifically identify source terms, predicted nitrate concentration distributions over time and space under various scenarios and assumptions (e.g., nutrient loads, soil storage and fluxes, extraction rates, etc.) and evaluate specific remedial responses (e.g., percentage load reductions for specific agricultural tiles).
6) Need to establish location-specific nitrate reduction objectives based on tile and crop nutrient requirements relative to amounts administered, with detailed attention paid to developing a quantifiable and verifiable amendment allocation program with zero-net-excess and zero nutrient discharge objectives.
7) Comprehensive monitoring for nitrate in groundwater, soil, and at the soil surface should be implemented; preferably automated using innovative technologies for detection, remote reporting, and geospatiotemporal mapping and archiving.
8) An understanding of the spatiotemporal groundwater nitrate mobility and changes in mass discharge (ITRC, 2010; Kram et al., 2011; Suthersan et al., 2011) should be developed at local and regional scales to help determine whether water quality is improving, identify locations

where additional attention is warranted, and to better determine cause-and-effect relationships both in the near term and well into the future.

9) A comprehensive network of shallow groundwater monitoring wells and transects should be installed for determining mass discharge over time and space (ITRC, 2010).
10) Employ automated monitoring networks to better understanding source terms, mass flux and mobility distributions, to track changes/improvements over time and space, to evaluate bioreactor performance, and to recommend or automate modification of amendment practices (e.g., precision agriculture in the true sense of the concept).
11) Identify funding sources and develop new programs (e.g., establish a Nitrate Cleanup Fund Program, supported by surcharges on all nitrogen amendment purchases) to pay for the educational, monitoring, reporting, and management components required to resolve issues associated with impaired water quality.
12) Directly apply as many aspects as possible developed for the hazardous waste management and groundwater remediation industries. This would include technologies, policies, engagement of recognized expertise, and integration of tracking and regulatory tools such as GeoTracker and discharge permits.
13) Development of new standards and training tools that incorporate best agricultural management practices with an emphasis on reduction in excess nitrate amendment.

Specific Comments

Specific comments are organized by page number and specific section, where applicable, below.

1) p.ii - The expert panel recommends four key programmatic elements comprising a paradigm shift in regulatory attempts to reduce nitrate levels in groundwater. Responses to these components are briefly described below:
    a) I concur with most of Element #1 (e.g., "*All farmers should have good irrigation and nitrogen management plans*"). However, why should there be any exemptions from monitoring? Reducing nitrate loads to be equal to or below the natural attenuation capacity of the soil and surroundings is key, and if there are site specific characteristics associated with growing rice on clay soils, verification of claims associated with relative impact should be part of the process. If the objective is "*to ensure that ongoing efforts are protective of groundwater quality*", it is essential that a detailed understanding of cause-and-effect relationships and relative contributions to the total loads (even if suspected to be negligible) are developed and confirmed within the context of dynamic settings. If these relationships are not developed, it will be nearly impossible to meet the stated water quality objectives.
    b) Regarding Element #2, I concur that reporting should be simple and effective. However, the basic reporting elements should also include nitrogen amounts applied relative to the natural attenuation capacity (which should consist of soil and crop uptake considerations relative to the shortest vertical distance to groundwater and lateral distance to surface water discharge locations as well as residual nitrate resulting from previous amendment campaigns). Once a location-specific sustainable load capacity has been determined, monitoring can be

automated as much as possible so that farmers are not burdened with sampling and reporting requirements. The data could be represented by intuitive geospatial and temporal renderings so that farmers and their consultants can actively determine where the sustainable capacity has been exceeded based on quantified metrics such as nitrate concentrations in runoff and downgradient groundwater monitoring wells, canals and discharge pipes. Eventually, after the residual nitrate in the system stored from past practices has exceeded residence times, a more accurate depiction of the balance between amendment and impact will emerge. This will be different based on site specific conditions, crops, climate and other factors. As such, a granular-scaled monitoring effort will be essential for successfully reducing the nitrate levels within the groundwater and surface water resources.

c) Regarding Element #3, while grouping similar types of fields could be of interest from a broader perspective, and would be supported for general assessment purposes, emphasizing this in a policy driver will not resolve the issues at hand, as each site has very specific qualities that result in a range of impacts. While common characteristics such as crop and soil type may exist among properties in a certain region or coalition, when it comes to fate and transport of chemicals in the environment, heterogeneity prevails due to preferential pathways and other natural and anthropogenic factors. As such, the recommended grouping approach would not allow for data reduction at a level of resolution that is amenable to separating signal (e.g., specific groundwater contaminant sources) from noise. Therefore, it is recommended that the nitrate attenuation capacity be estimated and used as a metric for determining the maximum sustainable nitrate amendment policy for each property and set of growing conditions. This could be accompanied by source-specific monitoring efforts to assess whether the natural attenuation capacity has been properly estimated or exceeded, and then adjusted accordingly through time based on the monitoring results. This iterative granular-scaled approach has far greater probability of achieving the stated objectives that include modification of nitrate application practices to achieve improved water quality conditions.

d) Regarding Element #4, it is agreed that a comprehensive educational program should be implemented. This could include training related to determination of nitrate attenuation capacity, monitoring, striking a balance between amendment application and assimilation capacity, use of innovative technologies, and identifying methods for continuous process improvement. We recommend that the educational program be multi-lingual at all levels. Growers are not only Caucasian and Hispanic, but include Hmong and many tribal ethnicities from Central and South America. We would further add that the educational program must be continually available. The high rate of turnover of growers in some regions such as the Central Coast will require frequent and continuous educational offerings.

2) p.ii – In the General Understanding by the Panel section, the panel points to many challenges with the currently available data and cautions against misinterpreting future trends in groundwater quality. While there is agreement regarding the challenges that currently exist when deriving nitrogen loads and determining causes of observed changes, it is essential that a comprehensive monitoring effort be initiated immediately, that the monitoring campaign

encompasses multiple scales both spatially as well as temporally in both the vadose and groundwater zones, that a better understanding of nitrogen fate and transport be derived and observed, and that specific performance metrics be developed and evaluated based on corresponding data collection activities tied to key questions and irrigated land management strategies. While challenges exist, these objectives are very achievable given currently available technologies combined with newer technologies that have recently become available to understand key geospatial and temporal trends. A multiple-lines-of-evidence strategy can provide exceptional results when the data is collected at an appropriate scale. Had this type of monitoring program been in place years prior to the recent discovery of the nitrate challenges, it is likely that the regulatory and management strategies could have by now been far more effective at protecting drinking water and ecological resources. The longer it requires to initiate and implement such a strategy, the longer it will be before these challenges can be sufficiently resolved.

3) p.iv – While there are concerns with the Panels Key Points, a few highlights are presented below.
   a. The Panel's Point D (whereby the members argue against monitoring of the first water bearing zone) makes very little sense from a scientific perspective. Maintaining that monitoring should be avoided because interpretations are complex is not an effective argument. While it is recognized that the vadose zone can serve as a nitrate storage regime base on past practices, it is essential that observations over time and space in the shallow saturated zone be evaluated and monitored beginning as early as possible and over multiple scales. For reference, in the hazardous waste industry, conceptual models of contaminant distribution are typically developed for the vadose zone based on comprehensive sampling and materials are often excavated to protect receiving groundwater. While this would be cost-prohibitive for many locations, it could be very useful to at least begin monitoring areas with relatively shorter vadose zone residence times (e.g., shallow groundwater regions), develop estimates regarding fluxes and transport timing using multiple lines of empirical evidence, and then to generate projections regarding when to expect chemical signals that reflect current practices. Dynamic work plans and conceptual models identical to those employed in the EPA Triad Approach (ITRC, 2003) would be ideal for this situation.
   b. The Panel's Point F (use nitrogen applied to crop in lieu of NHI and groundwater concentration) is troubling. The NHI and groundwater concentrations relate to risk. While the amount of nitrogen applied is critical to track (and modify accordingly), ultimately it is the groundwater concentration and associated NHI that will be used to determine whether risks exist. It is recommended that both amount of nitrogen be monitored as well as the groundwater concentrations impacted by these soil amendments.
   c. The Panel's Point H (accurate assessments of deep percolation of individual fields are impossible to derive) argues against attempting to develop a range of flux and transport estimates. Without these, how then can management practices be determined to be appropriate? There is a cause-and-effect relationship between the amendment

management practice and the resulting health of the receiving water, and the linkage with respect to timing of the nitrate signal is represented by the specific rate and amount of material flowing through the vadose zone interface. Ideally, a balance between the amendment introduction and the assimilation capacity of the vadose zone must be struck in order to reduce the amount of nitrate infiltrating to the groundwater. Without an appropriate estimate of the maximum suspected transport time (and corresponding adjustment of the amendment introduction practice to err on the side of caution), a prudent and effective nitrate pollution management program will be impossible to develop or implement.

d. The Panel's Point S (an index should be developed, but groundwater nitrate concentration monitoring over the next 10-20 years may not reflect impact) is very important, as it is recognized that for some sites, nitrate stored in the vadose zone from past practices will continue to impact groundwater resources. It could be helpful, therefore, to select key locations for lysimeter sampling and other types of monitoring to track the nitrate transport front, and determine whether the regions just below the rhizosphere are improving based on adjusted amendment practices. In addition, newly available sensors can help track nitrogen in the soil over time and space. Regarding an index, an attempt to reflect the assimilative capacity of the vadose zone (which can be dynamic) in this metric is recommended. Ideally, the amount of nitrogen added should not exceed the amount that is required for the crop. Sensors can help evaluate whether this has been exceeded and can be monitored remotely to help identify where practices need to be adjusted. In addition, it is possible to use the sensor data to automate the nitrogen amendment activities (e.g., fertigation schedules). Furthermore, tracers may be added to the nitrogen amendment over specific intervals to help derive estimates of nitrate transport timing.
e. The Panel's Point T (only compare multi-year data) does not make sense from a scientific perspective. Data should be monitored on a continuous high-frequency basis, and trends can be identified and interpreted on an ongoing basis. As stated above, amendment practices can even be automated using sensor driven detection and logic based controllers.
f. The Panel's Point W (not to require annual nitrogen cycle computations) is an argument against improvement to the process or condition. To help facilitate farmer documentation and computation efforts with minimal disruption, automation should be pursued as much as possible. This could include software with an intuitive interface and minimal time for completion of the computations. When properly designed, key factors will remain the same over time. As such, the regulatory body can offer assistance to the farmers or their consultants for the first few years of data entry to facilitate computation and compliance. This should be included within the educational component of the nitrate management program.
g. The Panel's Point BB (sampling throughout watershed but not at all discharge points) would not enable practitioners to determine cause-and-effect, as location-specific source identification is essential for facilitating appropriate resolution. While it is agreed

that a sampling or sensor network in key portions of the watershed is essential, it is also essential to deploy sensors or samplers at all discharge points so that the source signal can be elucidated from the data collected. Prioritization can be driven by field teams who perform near real-time watershed load assessments during runoff periods. The term "nonpoint" source is misleading. It is proposed that this should no longer apply for this type of situation. A more appropriate descriptor should be adopted (e.g., "multi-point" or "aggregated" source) to reflect how there is a direct connection between the application practice, location, amount applied, crop, nitrogen consumption potential, and environmental factors at a given time and place, and the contribution to the resulting water quality condition.

4) p.6 – With respect to reporting (Section 2.4), it is important to note that during the Nitrogen Tracking and Reporting Task Force's second public meeting the group was "*urged to focus on identifying types of data that would be most useful to decision makers and provide real-time information while being practical to collect.*" There was a special emphasis on tracking mass balance that includes yield, nitrogen removed and "*on-farm, event based record keeping*". In their data elements descriptions, the Task Force maintains the Water Board right to request and access data at the individual farm scale. Based on the expert panel comments and recommendations presented in this document, the panel opposes many of these Task Force recommended measures, while many stakeholders in the process strongly encourage the Water Board to maintain and exercise these rights when warranted. Furthermore, Water Board implementation of sensor and GIS based reporting technologies to better identify key conditions, dynamics, and to verify positive trends is highly encouraged by the public sector. Furthermore, according to the Task Force, the Regional Water Boards are responsible for ensuring the accuracy of the data. However, measures for ensuring accuracy or quality control were not described.

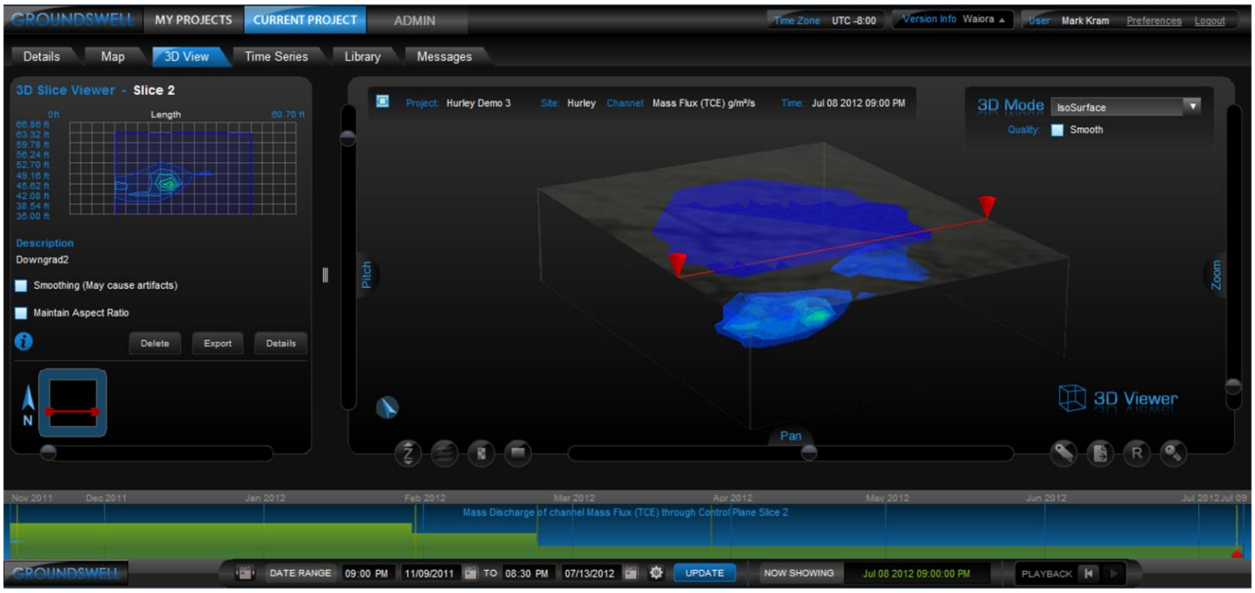
5) p.7 – We are in agreement with Panel Finding Item 1 that just collecting data does not necessarily improve or clarify the situation. However, this should not become an argument against collecting critical data along with necessary and descriptive metadata. The data collected should be aimed at answering specific questions, understanding specific processes, and must be converted to decision-support quality information.

6) p.7 – With respect to Panel Finding Item 2, the argument against tracking nitrogen loads makes several key points. However, without data collection to understand (as best as possible) the range in loading rates, deriving appropriate decisions regarding safe practice becomes impossible, and as such, the resulting policies will be ineffective. It is possible to employ chemical forensics, sensors, sample results, and sufficient spatial distributions of field observations and measurements to determine or estimate worst case risk scenarios (e.g., highest vertical flux, maximum surface discharge, etc.) that can then be utilized to proactively modify nitrogen amendment schedules and volumes. We agree with the comment in 2c that states "*the approach should be directed toward inducing good farm management, not merely tracking and reporting what is being done.*" However, the approach should not exclude or

minimize the value gained by tracking and reporting data collected with specific objectives that result in overall water quality improvement through appropriate nitrate application practices.

7) p.7 – With respect to Panel Finding Item 3, groundwater monitoring for nitrate concentration should be accompanied by water level data to determine gradient and flow direction, and in many cases, hydraulic conductivity assessment to determine groundwater flow velocity and mass flux distributions with a directional component. See Kram et al. (2011) for additional information where this was employed to evaluate performance of a USDA designed passive nitrate pollution treatment cell, and to track the discharge of solute Cr(VI) into the Columbia River. Others (Diaz et al., 2003; Suthersan et al., 2011; Christianson et al., 2013) have successfully applied and advocated for similar approaches (ITRC, 2010). While sufficient data will need to be collected for some of these types of efforts, a phased approach for selected locations suspected of high impact where groundwater is relatively shallow could consist of the following:
   a. initial determination of groundwater flow directions;
   b. deployment of a direct push (e.g., hydraulic profiling tool [HPT] or high resolution piezocone [HRP]) sensor probe system to generate a double transect depiction of hydrogeologic characteristics in the shallow subsurface and aquifer (e.g., to 30' bgs);
   c. installation of direct push groundwater monitoring wells along two transects oriented perpendicular to the local groundwater gradient;
   d. installation of sensors for water level and nitrate concentration in the direct push wells;
   e. automated tracking of water level and nitrate concentration using sensors;
   f. with an understanding of hydraulic conductivity, water levels can be converted to Darcy velocity;
   g. by multiplying Darcy velocity by concentration, it becomes possible to track nitrate discharge through source control planes oriented perpendicular to the direction of groundwater flow;
   h. evaluation of subsurface nitrate discharge values over time to understand changes due to load reduction, vadose zone flushing, a combination of these, or to correlate with specific crop rotation and amendment activities.

Below is an example whereby TCE solute discharge was tracked to determine the extent of remediation attributed to a bioamendment injected into the subsurface at an industrial facility:



The three dimensional image represents the distribution of mobile solute for the selected time step. The cross-section represents the distribution of the mobile solute through a source control plane for that time step. The histogram represents the mass discharge through the control plane over time. Notice how a reduction in discharge can be readily observed, quantified, and can be processed in an intuitive format. Deeper groundwater zones can prove to be more expensive for this type of approach, but since the lithology is generally unconsolidated in the regions of interest, these types of monitoring systems can be installed using the same tooling and equipment described above.

8) p.13 – Panel Item #6 is very important, and we are in agreement. As such, it is recommended that more thorough characterization of site specific and regional hydrogeology be determined, that flux and discharge assessments be performed and tracked over time and space, and that a localized and regional understanding of this information continuously improve through support by USGS, USDA, NSF and other funding programs. Fortunately, tremendous progress has been made in the contaminant assessment and remediation industry, and as such, high-resolution expedited characterization (ITRC, 2006; Kram et al., 2008) and automated real-time monitoring and reporting technologies have become cost-effective, accurate, and readily available.
9) p. 14 – Panel Items #7 and #8 point to challenges in understanding key nitrogen fluxes and mass balance criteria. We are in agreement, which is why we are advocating for more appropriate data collection activities to help better understand key factors contributing to the issues at a local level so that correct decisions can be derived and implemented, and metrics employed to continuously improve water quality. The Harter study cited may have resulted in unanswered questions and uncertainties. However, had a data collection network and appropriate infrastructure been in place at the time the study was commissioned, it is highly probable that many of the shortcomings and uncertainties discussed would have been resolved. Given the state of our technology, and the direction of industry (e.g., precision agriculture, smart grid, sensor breakthroughs, DOE/EPA funding for similar endeavors, etc.), we are optimistic that currently available tools and those that are in development will enable stakeholders to derive

solutions to these challenges. However, advocating for less data because past investigations were challenged by lack of data represents a circular argument and will not enable stakeholders to meet the collective water quality objectives. Technologies developed for energy extraction and optimization, remediation, and even security industries can be directly applied to the challenges associated with nitrate water contamination and effective management strategies.

10) p.15 – Panel Item #12 is very important, as understanding the amount of nitrogen removed via crop harvest is a key component required to derive a mass balance. It appears that for some crops, this information is easier to estimate than for others. It is recommended that estimates be derived (as best as possible) by comparing the load to the soil and groundwater to the amount added to the crop where uncertainties exist. Innovative approaches (e.g., optically based remote sensing technologies and data visualization and processing; Quemada et al., 2014) can be explored as well. While this may be a new parameter for farmers to begin to track, it is essential that this be done so that resource managers can readily derive appropriate nitrogen requirements. To-date, these requirements have been over-estimated or applied incorrectly, which is why the groundwater and surface water resources have been impaired. Reporting nitrogen removed via crop harvest together with soil characterization and nitrogen applied will eventually lead to a comprehensive database that will allow for identification of outlier areas requiring additional attention and action.
11) p. 16 – Panel Item #13 is key, as the methods employed to-date are insufficient because appropriate types of monitoring have not yet been required. However, we do not agree with the panel's disregard for data collection activities as proposed by the California State Water Board. More specifically, it is absolutely possible to understand cause-and-effect relationships when appropriate data is collected and transformed into actionable information. For instance, key measurements such as nitrate added to a field, nitrate distributions in the rhizosphere, vadose zone profile, and shallow groundwater, when assimilated and processed in a geospatial and temporal context can yield exceptional information. While some of the sensing technologies are innovative, this is not a new approach to developing site conceptual models, determining fluxes, and responding accordingly with high resolution (both spatial and temporal) refinement of the assessment, and then subsequent responses. The Interstate Technology Regulatory Council (a different ITRC), the American Society of Testing and Materials (ASTM), EPA, and the California Department of Toxic Substances Control (DTSC) have produced consensus-based guidance documents over the past 30 years addressing effective assessment and response strategies for many types of soil and water pollutants. While these efforts will require funding, much can be gained from incorporating similar (and even identical) processes into the nitrate monitoring and management program. At a minimum, when an appropriate monitoring network has been deployed, relative changes over time (e.g., dynamic tracking of mass discharge through aquifer transects) can enable practitioners to understand critical cause-and-effect relationships at local and regional scales. With respect to the panel's proposed paradigm shift, there is a fundamental difference of opinion in that the objective is to restore and protect drinking water resources while burdening the farmer as little as possible. There is a minimum sustainability threshold that is achievable, and anything less will be at the expense of the public at large (e.g., increased taxes to restore impaired resources damaged by private activities). To-date, management practices

have been insufficient. As such, while certain components of the suggestion are warranted, we support an alternative paradigm shift that would emphasize exploitation of technology to simultaneously meet regulatory and public welfare needs while optimizing operations for increased revenues (e.g., reduction in the volume of amendments purchased and applied to the land, fewer notices of violation, penalties and legal expenses, etc.).

12) p. 16 – We are in complete agreement with Panel Item #14, which is why aggregation of fields or crops via consortia or coalition (while appropriate for a component of the management program from an analytical perspective) is not sufficient, as it will preclude resource managers and farmers from identifying specific areas and conditions that may cause impairment on a relative or even absolute scale. In the hazardous waste and groundwater remediation industries, which have many features in common with the challenges posed by nitrogen management, site-specificity is well accepted, and as such, project managers are encouraged to develop and test and continually monitor and revise site conceptual models based on a developed understanding over time and space. This approach has been effective and could directly apply to this situation.

13) p.17 – Section 3.2.1 discusses risks and vulnerability. The panel makes several good points regarding specific hydrogeologic conditions (e.g., exclusion of the Concoran Clay region, where groundwater above this can be impaired; pesticide applications may cover different areas than nitrogen application areas). As such, it is recommended that clarifications be derived by State Water Board representatives such that appropriate locations are accurately represented based on the potential for groundwater impairment either through direct application or via runoff and discharge to groundwater in areas remote from the initial application.

14) p.18 – Section 3.2.1.i presents a solid argument regarding the definition of vulnerability. Since most of the region has undergone extremely limited quantitative data collection activities, it is proposed that the initial zonation as derived be used as a first step, and that as more site-specific data relating to nitrogen sources and transport is compiled, revisions be derived. It is also recommended that this zonation be revised to more accurately reflect observations that exhibit vulnerability as defined in way that incorporates the following: "a weighted measure or index that reflects the susceptibility of an aquifer located below a specific field to become impaired by standard nitrogen amendment practices". While this could be adjusted, it may be a good starting position, as it suggests that some practices and crops may not be appropriate for certain areas (or that specifics crops in these areas warrant additional attention) and leaves open the possibility of incorporating minimum residence time, maximum velocity/imbibition/infiltration, attenuation capacity, and other factors that can be used as metrics to be ranked in a geospatial context and then used as a basis for decision making. With respect to criticisms of extraction well solute data and how this may not always reflect applications to the surface, this is true to a certain extent – particularly when no previous monitoring has been performed to understand the amount of materials introduced into the environment or fate and transport specifics resulting in discharge via the extraction well. There are certainly examples where practices on the surface have impacted groundwater conditions immediately below. These facts argue for installation of monitoring wells (preferably in transects and grid patterns) so that a greater understanding of upgradient sources and most recent vadose zone releases and changes over time can be developed. The data derived from

extraction wells can sometimes be helpful for determining subsurface flow regimes and for model calibration, so it will be important to continue monitoring and remain cognizant of key well construction parameters such as screen depth ranges, extraction rates, and pumping test results. There will undoubtedly be cost considerations when it comes to monitoring well installations. However, in general, installation of direct push monitoring wells in unconsolidated soils is far less expensive than the amounts currently being invested in supply well installations throughout the region.

15) p.19 – When establishing areas of priority for action/attention based on risk, the panel recognizes challenges associated with farmer constraints such as soil and crop type and irrigation source, and recommends that the risk assessment tools proposed by the regulatory community be applied at basin, regional, and coalition-wide scales. While this could help alleviate some of the farmer's burden with respect to monitoring and risk classification, implementing the panel's recommended strategy will prohibit stakeholders from meeting key water quality improvement objectives, as risk classifications need to be established at the scale of nitrate application practices – which is at the field scale. Attribute variabilities and dynamics occur at the field scale. Expanding assessment units to include basins, crop-specific conglomerates, or coalitions will preclude stakeholders from being able to develop dependable references or indices, produce meaningful recommendations, or to gauge progress over time and space. An analogy can be drawn from the hazardous waste and groundwater remediation industries. For instance, if all leaking underground fuel tanks in an urban setting were addressed as an aggregated unit using limited groundwater quality monitoring and hydrogeologic data collection efforts, it would be very difficult to determine source locations or to derive and implement remedial strategies. Implementing the panel's recommendations in this regard would prove to be even more challenging from a source identification perspective, as nitrogen amendment practices occurring in rural settings can be even more spatially dense than leaking fuel storage tanks in an urban environment. As such, it behooves the Water Board to continue to advocate for site-specific cause-and-effect and quality improvement related monitoring endeavors.
16) p.20 – When addressing the probability of nitrate MCL exceedance in drinking water wells, the panel maintains that this should not be the responsibility of the regulated community. If it is discovered that water resources are contaminated by releases of pollutants, the Resource Conservation Recovery Act (RCRA) requires the responsible party to pay for the assessment, remediation and ongoing protection of the receptor community through groundwater monitoring. RCRA describes very specific situations where a waiver or exemption from groundwater monitoring can be issued. However, the owner-operator of the facility must demonstrate that there is very low potential for nitrate reaching the upper aquifer and subsequently migrating to a supply well. A comprehensive report is required, and this needs to be prepared and certified by a qualified geologist or geotechnical engineer. Given the current general lack of information required to make such an assessment at the field scale, and the cost requirements associated with performing such an assessment, it is understandable that the grower community would be concerned about these and related requirements. In the future, once additional information is collected and compiled, it may be easier for specific entities to

obtain waivers from this requirement. However, at present, these types of requirements are consistent with policies administered for hazardous waste releases. One pragmatic approach to minimizing costs would be to incorporate nitrate and other types of sensors in a flow-through configuration attached to the extraction well, and reporting the information automatically on a continuous basis, as the per-analysis costs would become negligible.

17) p.20 – When addressing deep percolation nitrate considerations and recommended methods for assessment, the panel offers a quote from Aristotle that suggests that they are advocating for limited data collection activities. We are not in concurrence with the panel in this regard. Alternatively, an "approximation of truth", as used in the selected quote, can be far superior when utilizing innovative technologies such as automated continuous monitoring, spatiotemporal analyses and appropriate empirically-based estimates (e.g., conservative/buffered estimates of maximum vertical migration rates, etc.) relative to the use of traditional data collection approaches, or even limited or no data.
18) p.21 – The panel's summary regarding vulnerability and risk cover key points addressed above. While many exceptional points are made, the general theme suggests that the panel believes that the nitrate pollution issues can be resolved by *not* collecting critical data, and by *not* investigating key factors at the field scale sufficient to identify location-specific sources. There is not concurrence, as it is believed that supporting the panel's position would result in continued resource impairment. The panel's arguments suggest that because of limited resources, the panel's preferred pathway is to focus on education. While there is agreement that education should be a key component, it would behoove the regulatory community to consider implementing innovative and cost-effective technologies that can help answer key questions related to local and regional water and nitrate flows, water quality changes over time and space, and to use this data to develop relationships that will result in the identification of unsustainable management practices at the field level, where changes can be recommended for the good of all communities involved. While complex and challenging (and imperfect but always subject to improvements), implementation of this type of approach is not impossible (as implied by the panel comments). On the contrary, many of the tools used to manage landfills and hazardous waste sites are readily applicable and available. For instance, nitrate sensors have been developed specifically for agricultural applications (see http://suprasensor.com/about/). When combined with groundwater level information, mass flux and mass discharge renderings can be automatically determined (Kram et al., 2011) to both identify "hot spots" as well as evaluate whether activities are resulting in improvements. Similar applications are about to be initiated in New Zealand (personal communication, Dr. Hugh Canard, Environmental Group Manager, Lincoln Agritech Ltd).
19) p.22 – With respect to management practices, the panel recommends that lists of best management practices be framed within the context of heightened awareness and education, and not be used to derive requirements. While awareness and education are clearly important, we recommend that specific practices also be tied directly to actions that can be implemented at the field level. For example, for a given crop and soil type, an assessment of the nitrate residing in the soil should be performed to gain a general understanding of the pre-application condition, an estimated understanding of the worst case risk scenario (e.g., maximum nitrogen

infiltration rate and minimum residence time) be derived from field measurements at the site or from similar nearby regimes, and then the sustainable volumetric application of nitrogen should be determined. The primary objective should be to reduce the amount of nitrate reaching groundwater or surface water bodies. If after some time of monitoring (depending upon site specific factors), improvements are not observed (terms to be negotiated), then additional restrictions should be considered. At a minimum, a tracking system should be established whereby a set of crop-specific and hydrogeologic condition-specific decision tools could be employed to determine the maximum amount of amendment allowed for each application at each site. Nutrient loads could be carefully tracked and amounts reported to minimize excess nitrate amendment. Since many growers currently use commercially available management information systems (MISs) already, this should not represent an additional or prohibitive burden. However, MIS vendors should be immediately encouraged to amend their platforms to incorporate key features related to soil permeability, maximum vertical transport velocity, climatic information and dynamics, and other features that are directly linked to the issues at hand. The good news is that some of the features (e.g., maximum vertical velocity) will either only need to be measured a limited amount of times (which could also be obtained through shared coalition results from the collective fields in a region), and much of the information can be gleaned from strategically placed sensors (e.g., soil moisture and conversion to saturated/unsaturated hydraulic conductivity, and nitrate concentration distributions). California is the high-tech capital of the world. Sensors, software, and intuitive business practices have already been incorporated into many irrigation practices. As such, much of the communication and software infrastructure is in place or at least somewhat familiar to key field managers who are adept at implementing efficiency strategies. Furthermore, entrepreneurial pursuits at the university level could be encouraged (e.g., prizes or start-up support) to develop specific niche technologies to bridge technology gaps identified through the regulatory process.

20) p.23 – The panel advocates for development and implementation of irrigation and nutrient management plans specific to each grower and similar management unit as well as educational programs. This is an exceptional recommendation and a solid starting point. The panel also recommends <u>using the data only for management purposes, and not for reporting</u>. This is not supported by the environmental community members, as the extent and complexity of groundwater impairment has reached a point where difficult decisions and pragmatic remediation strategies based on localized information need to be implemented. The steps advocated by the concerned communities are not intended to be punitive, as the benefits derived from a vibrant agricultural system are greatly appreciated and recognized as essential. However, a common objective must be to remediate the damaged water supply in a surgical manner within the shortest timeframe possible using the most efficient and effective tools currently available. The Water Board's stated mission reads as follows, "***The State Water Board's mission is to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations.***" Furthermore, "***The mission of the Regional Boards is to develop and enforce water quality objectives and implementation plans that will best protect the State's waters, recognizing local differences in climate, topography, geology and hydrology***." If the State and

Regional Water Boards do not have access to scale-appropriate decision-quality data that can be rapidly converted to actionable information, water quality will not improve in the foreseeable future. Self-regulation has rarely worked in the past, and given the complexities associated with this challenge, it is highly unlikely that implementing the panel's recommendation will result in meeting critical water quality objectives. In addition, industry has a very different mission, which is to generate as much profit as possible. This mission is not always in concert with the Water Board's mission. While there are exceptional examples of good stewardship, and this should be rewarded, it has been demonstrated that private industry will pursue the management pathway that meets the minimum level of requirement to reach compliance. This is not intended to be perceived as a negative statement, but only as a reflection of the economic system that persists in our society. This has been demonstrated in the hazardous waste and groundwater remediation industries, and directly applies to this situation. As such, GeoTracker (http://geotracker.waterboards.ca.gov/) was developed by California regulators to track site-specific assessment and remedial activities, to derive trend analyses, and to archive all reports, communications, and chemical information derived by Responsible Parties and their consultants. GeoTracker is discharge-specific, has been proven to be one of the most effective tools in the world for addressing impaired soil and groundwater challenges, and could be utilized for this situation. The data, information, and plans identified by the panel could be incorporated into the GeoTracker system as part of a new module tailored to meet the needs of the agricultural community. In addition, key performance metrics can be derived and used to help decision makers determine how effectively the plans and adjustments are performing. By maintaining monitoring data on the public-side of GeoTracker, key stakeholders and the public at-large will have the ability see site specific information pertinent to their own interests, and to drill down into the data as they see appropriate.

21) p.25 – The panel describes several vital components of a good grower/farmer education program. This is exceptional information. It is recommended that this list be expanded to include at least a cursory understanding of how to determine vadose zone flow characteristics, how to use nitrate, salinity and water level sensors and information, and how to recognize when nutrient applications exceed sustainable attenuation or uptake capacities. Where possible, the focus on these additional topics should be empirically based and tied to specific measurements that can be made through sensors or analysis of samples. Field trips for technology demonstrations should be part of the required curricula. Key metrics should be developed to help the growers determine whether the management practices they are implementing are still resulting in environmental impairment. The worst possible outcome would be where growers/consultants attend training, and then continue to implement practices that do not result in environmental improvement. The panel acknowledges this in follow-on discussions regarding material retention.
22) p.26 – The panel describes and emphasizes the need for several educational/awareness components that are very helpful. When describing the farmer's documentation obligations, we recommend that automated tracking and reporting be considered. The costs for some of this equipment (e.g., sensors, telemetry, software, etc.) could be reasonable when compared to the time and labor required for this type of tracking. This would significantly reduce the farmer's

burden while ensuring that critical data is not lost or that an important event (e.g., precipitation) is not missed. As such, the farmer and consultant should be trained to determine when the system requires maintenance or component replacement. Some of this information could also be included in the GeoTracker system.

23) p.28 – With respect to compliance, the panel recognizes that an enforcement component should be required, but does not offer a specific recommendation; only a suggestion that the purchase of nitrogen fertilizers be handled similarly to pesticide purchases. It is recommended that much more be required, as uncontrolled pesticide distributions are also prevalent in the environment, so the program has not been successful at removing these from areas they should not be; particularly where exposures in water and air can result in harm to receptors. While training and certification are supported, and training registration for nitrogen fertilizer purchases can be helpful, these steps alone will not result in remediation of the impaired groundwater resources. The growers obviously do not want to face enforcement challenges, and the environmental community aims to improve the drinking water supply and ecological conditions at local and regional scales. One possible plan could include the communities adopting a strategy in stages over the next few years described as follows:

    a) provide comprehensive training,
    b) restrict fertilizer purchases based on certification,
    c) implement comprehensive and properly scaled data collection programs (hydrogeologic, fate and transport, and soil and water quality),
    d) implement a comprehensive program to determine worst case risk scenarios (e.g., maximum nitrate infiltration rates) for key settings (e.g., specific farms, crops, irrigation/precipitation scenarios, etc.),
    e) develop comprehensive site-specific metrics and evaluations of each activity to determine whether localized management practices are improving or impairing groundwater conditions,
    f) provide initial support for farmers who are exceeding the nitrate attenuation capacity (by contact, training, encouragement, peer-pressure, etc.), and then (perhaps in two years)
    g) implement a progressively more strict enforcement program based on automated and other types of required field measurements to ensure that nitrate loads below the rhizosphere are being reduced.

    Would the growers be amenable to this strategy? Under this scenario, once sufficient understanding of the fate and transport can be determined for specific locales, and following the flush of nitrate currently stored in the vadose zone (which will differ depending on each site-specific situation), it may be possible to observe nitrate trends in groundwater that can be attributed to activities in upgradient areas managed by multiple growers. This information can be used to exert localized peer pressure on the entities that are not implementing appropriate policies.

24) p.29 – The panel raises several exceptional issues regarding implementation of an effective educational and awareness plan as well as potential concern about liability. They also

recommend several great ideas, and all of these will require funding. With respect to funding, in the hazardous waste management industry, the State Water Resources Control Board oversees an underground storage tank cleanup fund (http://www.waterboards.ca.gov/water_issues/programs/ustcf/) which "*provides a means for petroleum UST owners and operators to meet the federal and state requirements of maintaining financial responsibility to pay for any damages arising from their tank operations.*" It is recommended that something similar be developed to address the groundwater nitrate issue. For instance, funding for such a program could be derived through a surcharge attached to the sale of nitrogen amendments as has been recommended by previous nitrate panels.

25) p.30 – The panel presents a "Key Point Summary for Application of Management Practices". Many exceptional recommendations are made. Point "J" states that excess complexity and data collection/reporting will likely fail. There is, in general, a consensus about this point. However, the term "excess" is where there is significant disagreement, as the panel is advocating for a level of data collection and reporting at scales and frequencies that will not resolve the problem. All hazardous material risks are comprised of source, pathway, and receptor components. The panel is advocating against understanding site-specific pathway components. It is impossible to manage what is not measured. Unlike the hazardous waste and groundwater remediation industries, the agricultural community has not yet been required to produce key site assessments or to develop monitoring programs sufficient to adequately determine cause-and-effect relationships. The panel is suggesting that since this is complex, we should not attempt to pursue this type of relationship. This does not make sense from a scientific perspective, particularly since there exist decades of historical and ongoing related efforts, thousands of experienced practitioners, and comprehensive libraries full of standards and guidance documents available from analogous industries (e.g., groundwater assessment, groundwater and soil remediation, landfill and oil and gas industries), and new and emerging technologies that will greatly facilitate compliance (e.g., sensors, automation, geospatial mapping, remote sensing, drone deployed technologies, high resolution direct push sensing and well installation, etc.). For instance, deployments of continuous monitoring nitrate sensors in a sump located at the low topographic portion of a field could rapidly help determine whether nitrogen applications are exceeding crop requirements. A time-stamped geospatial rendering of this information from every field would enable managers to know where to immediately focus their efforts, as well as identify geospatiotemporal trends. Deployment of a system like this would even enable growers to reduce their expenses by lowering their costs for nitrogen based materials they will no longer require, collecting fewer samples for analyses, and reporting. Similar types of systems can be deployed to continuously track nitrate infiltration rates in the soil profile, groundwater impacts, and to remotely evaluate performance of passive bioreactors.

26) p.31 – With respect to verification measures, the panel suggests that trend monitoring using existing wells will be helpful, but recommends excluding the first encountered groundwater. From a hydrogeologic and fate and transport perspective, this makes very little sense, as identification of direct causes will not be achievable using this recommended approach. Alternatively, it is recommended that the Water Boards consider deployment and expansion of a comprehensive groundwater monitoring network sufficient to be able to resolve key

uncertainties such as field application impacts on groundwater resources. Monitoring prioritization and scale will need to be carefully considered by key stakeholders, and then revisited as more information becomes available. In addition, instead of requiring samples, the deployment of newer sensor and telemetric technologies and implementation of automated geospatial processing is recommended to facilitate reporting, data analyses and geospatiotemporal processing.

27) p.31 – The panel presents "Key Point Summary for Verification Measures" and emphasizes that nitrogen application data should only be used to provide a multi-year picture of nitrogen use on a regional scale. They advocate for multi-year trend analysis instead of a year-to-year comparison. This recommendation is adamantly opposed by key entities for its' lack of temporal and spatial resolution, inability to contribute much benefit with respect to groundwater quality improvements, and is most likely going to allow for far too much "business as usual", which could result in continued environmental impairment. As an alternative to this, a far more comprehensive monitoring and metrics based evaluation system is advocated for. This would be comprised of high frequency continuous monitoring, automated processing where applicable, nitrogen loading reporting for every crop that is planted in highly sensitive regions (as determined through appropriate groundwater monitoring and other NHI screening criteria), estimates of projected crop uptake percentage for every planting event, estimates of soil attenuation capacity and maximum infiltration rates, field observations that include factors related to nitrate residence time and migration through the soil profile, measurement of local groundwater conditions and trends (including mass discharge analyses through localized control planes as well as in a regional context), measurement of nitrate in runoff, as well as estimates of total nitrate balance and geospatiotemporal trends analyses. This level of comprehensive verification will be prohibitive at first, but it is essential or it will be impossible to enact any meaningful policies that will result in achieving the stated water quality objectives.
28) p.32 – The panel recommends that data collection and reporting be coordinated by a third party, and that growers should not be required to report directly to the Regional Water Boards. The panel also stresses that current groundwater quality should not trigger reporting or regulation of above-ground activity. Their point is that nitrate detected in groundwater cannot be pinpointed to the specific source based on above-ground activities or nitrogen fertilizer purchases. With all due respect, the panel's logic is flawed. The panel is advocating against reporting and monitoring because there is not currently an appropriate monitoring and reporting system in place to be able to connect source and pathway to receptor. While it is recognized that nitrate is currently stored in the vadose zone, and it will require time for the material to move through the soil column, the mature field of fate and transport of pollutants currently utilizes approaches to determine these types of relationships. As such, it behooves the regulatory community to begin collecting this essential data immediately, and to finally begin addressing this serious issue by determining these relationships. This should include an assessment and estimate of the transport and residence times for each field so that entities can anticipate when and where direct causes due to above-ground activities will be observed.

With respect to estimation of irrigation water applied to individual fields, sensors for the water distribution activities as well as soil moisture measurements will greatly facilitate the understanding of these critical parameters in a spatiotemporal context. Nitrogen cycle computations are indeed complex. However, with sensor based monitoring and reporting and automated analyses implemented at the field level, a range of estimates can be derived to at least begin to gain an understanding of the sensitivity of key attributes and the potential impacts on water quality.

The panel recommends that the data collected be used for education and development of management plans, but not for enforcement. This runs counter to a common sense strategy. Compliance should be back-stopped by potential enforcement. While not advocated for in the immediate future, eventually, enforcement must come into play. An analogy can be derived from the hazardous waste management and groundwater remediation fields, for which a tremendous amount of experience can be leveraged to resolve this challenge. If enforcement were not incorporated as a driver, some responsible parties (e.g., firms on the receiving end of regulatory enforcement efforts) would continue to exhibit poor practices with impunity, as the costs associated with compliance reduces profits. Economics is a key driver, and appropriate regulatory enforcement can be framed (and accounted for) as an economic ledger component for entities engaged in the agricultural related businesses. Since the regulatory community has avoided this issue for so long, it is agreed that the grower should not be held completely responsible for the current water quality situation. Growers were complying with minimum (or no) regulatory requirements. Note, however, that the courts have many times determined that defendants assuming this position are not insulated from fault, and they have lost cases based on this strategy due to CERCLA's delayed discovery rule. While many groups are willing to grant growers some leeway in this regard, eventually the practices must change, and as such, enforcement must be part of the strategic solution. Contrary to what the panel is advocating for, through a comprehensive monitoring, assessment (including fate and transport estimates at the field scale), reporting, education and management system, it will be possible to attribute above-ground activities to water quality. A perfect example of this is through the sensor based measurement of surface runoff sumps along the low topographic areas of each property. This component of a monitoring strategy will not require years to determine whether nitrate added to the surface is excessive, or whether appropriate controls are in place. This approach could be used to remotely monitor activities, track trends over time and space, and to initially trigger alerts when exceedances are measured. Eventually, after several years of data collection and experience, an enforcement component can be adopted based on very specific performance metrics. This information could also be used to identify where passive and active treatment systems could be installed.

29) p.33 – The panel proposes nitrogen computational variables. They also point to a few shortcomings that could at least partially be addressed by the employment of sensors to determine residual nitrate following crop harvest operations. This information can help growers determine subsequent purchases and amendment practices appropriate for the next crop planting efforts. The panel advocates for extremely limited, low frequency data collection and reporting requirements at scales that will preclude entities from reaching specific management

decisions, identifying specific sources of pollution or poor management practices, or determining appropriate action. The effort recommended by the panel "*purposefully limits data collection to basic information that can be easily obtained and all farmers need and should be knowledgeable of as part of their nutrient management….This data collection effort does not require farmers to account for nitrogen applications to individual fields….It does not necessitate mapping or farm-scale spatial analysis*." Unfortunately, the panel's positon is unacceptable, as it represents status quo, avoids the use of commercially available management technologies for optimization and efficiency, and has an extremely low probability of resulting in improvements to groundwater quality. The panel maintains that their recommended data collection policy "*addresses the probability of nitrogen leaving the crop root zone via deep percolation.*" However, support for this claim was not provided. Without appropriate chemical, moisture, and mass transport information at the field scale, it is unlikely that the probability of deep percolation of nitrogen can be determined.

30) p.34 – The panel presents a Key Point Summary for Reporting. The panel repeats and emphasizes much of what has been presented earlier, including limited monitoring, reporting, and aggregation of fields into units that are not field-specific. The panel unfortunately does not acknowledge that employment of state-of-the-practice automated monitoring and geospatial analytical tools allows for continuous monitoring over more appropriate timeframes than the recommended annual or semi-annual trend analyses. As an alternative, we point to GeoTracker as a proposed initial model for reporting and data management within the agricultural community. This system can be modified to account for agricultural-specific reporting and analytical components. Amendments to include geospatial trend analyses and estimates of fate and transport related computations at the field scale will enable regulators and others within the community to identify where improvements in management practices will be required. It is not a perfect system, will require time and resources to allow for residual nitrate loads to work their way through the strata, but eventually, once this system is rolled out, it should be possible to begin performing cause-and-effect analyses. This, along with the utilization of commercially available sensor based monitoring and geospatial analytical platforms should benefit growers (e.g., less money and time allocated to nutrient amendment, reporting, and enforcement) as well as other community members who are just as concerned about water quality.

31) p.35 – The panel discusses monitoring logistics and recommendations for surface water discharges. The panel mentions the use of continuous sample collection equipment, which can be useful. However, new lower costs sensor based alternatives have recently been developed, and new methods for protecting from vandalism are currently available (e.g., inexpensive GPS placed on all field vehicles and on the sensor communication hardware, alerting when signal is dropped or system is moved, etc.). The panel further states "*The sampling should be of sufficient density (spatially and temporally) to identify general locations of possible pollution. For example, a single measurement point at the downstream discharge of a very large watershed would be insufficient. When/if problems are identified, sampling should move upstream with sampling to locate the source of the problem.*" Furthermore, the panel's key point summary includes the following statement "*A network of sampling points in drains and streams throughout a watershed, with emphasis on downstream areas, is recommended*

to identify if there are pollution problems upstream. This is recommended rather than sampling at each discharge point." We are in agreement to a certain extent. We agree that receiving waters should be routinely monitored and a network of telemetered sensors in receiving waters and drains will be helpful for both urban stormwater and irrigated agriculture programs. We also strongly recommend deployment of sensors at discharge points. Most environmental programs and discharge permits require discharge monitoring and reporting. As such, the irrigated lands program should not be any different, particularly when the data will be critical for monitoring the immediate discharger and evaluating the potential for the discharged water to impact the environment and migrate to surface and subsurface drinking water resources. We advocate for the use of sensors and telemetry so that continuous measurements can be recorded and sent to a Cloud based management platform, automated geospatial analyses be performed, and an immediate alert delivered to key points of contact (e.g., coalition leaders, specific growers, etc.) when water quality thresholds are exceeded. Implementation of the panel's recommendation as described could result in a time lag between detection in the downstream location and mobilization of a sampling entity, thereby prohibiting the team from meeting source detection objectives. Limiting monitoring to only the receiving waters and then tracking back upstream is also complicated by the additional costs and lag time associated with sample collection and addressing the private property rights concerns as the investigation personnel work their way upstream.

Summary and Conclusions

1) A well-functioning and environmentally sustainable agricultural community is critical for reasons related to societal benefits associated with economic, security, drinking water, energy and long-term environmental considerations.
2) Since agricultural practices in California have been granted exemption or leniency regarding addressing the potential nitrate contaminant issues for so long, and a comprehensive nitrate management policy has not yet been developed or implemented by the regulatory community, it is critical to understand that contamination emanating from legacy activities will need to be considered when addressing relationships between cause-and-effect for current and future agricultural practices. As such, implementation of compliance programs will need to be flexible and account for temporal, spatial, and site-specific characteristics, as a one-size-fits-all or even an aggregated (e.g., by crop, region, or common field characteristics) approach may not be appropriate.
3) Any solution proposed will require substantial financial resources for development of policies, integration of new practices, monitoring, education, and implementation of private sector and government programs. As such, financial support for key parties and stakeholders should be procured as soon as possible. This may require expansion of ongoing programs or development of new programs, with an analogy represented by the California UST Cleanup Fund Program. Revenues are derived by adding a surcharge for purchases of gasoline. Similarly, a California Nitrate Cleanup Fund Program could be capitalized by adding a surcharge for all purchases of

nitrogen amendment materials. Legislation may also be needed to fund expansion of the State Water Board's Groundwater Ambient Monitoring and Assessment Program, establish a regulatory framework, and to improve coordination among the various government entities (CA Water Boards, 2013).

4) It is in the best interest of all parties to derive a balanced approach towards managing agricultural practices that weighs public benefits against the interests of individuals or aggregated parties. For instance, if the privatization of profit overwhelmingly favors socialization of the risks (e.g., contamination of the public drinking water resources), public financial resources will need to be made available to address the unfavorable outcomes. However, as with the hazardous waste management industry, private investment to meet regulatory requirements should also be considered part of the business process. As such, a decision regarding what is a fair level of public financial burden will need to be determined.
5) An ideal outcome of this process should include the use of the most effective technologies and practices that would result in pragmatic policies that can meet key drinking water quality objectives with the least amount of burden endured by the grower community to ensure compliance, continual improvement, and restoration supported by defensible trend analyses. As such, this approach cannot be "business-as-usual", but must be developed with the outcomes being amenable to performance metrics for unequivocal demonstration of groundwater quality improvement.
6) While an enforcement component to drinking water resources management policy will eventually be required, given the complexities involved, many in the environmental community would be willing to accept an initial transitional period that emphasizes education and monitoring network deployment while acknowledging near term improvements to management practices as verified by defensible documentation (e.g., reduction in nitrate amendment exceedance and improved soil/water quality). Enforcement actions available to the regulatory community should initially be non-punitive, with an emphasis on data collection, determination of cause-and-effect, establishment of a comprehensive monitoring network and program, and continuous improvements motivated by a rewards structure. After an established amount of time has passed, an enforcement program could include more punitive components similar to what is currently employed in the NPDES and RCRA programs addressing the management of hazardous waste discharges and remediation efforts.
7) Given what we know about widespread contamination of our groundwater resources and what we understand about the loading already present in the vadose zone, the environmental community realizes progress will require years, even decades of effort, adding to the urgency to immediately initiate comprehensive monitoring and responses.
8) Low-cost denitrification bioreactors (Diaz et al., 2003; Christianson et al., 2013), engineered wetlands and other types of passive treatment systems and approaches should be considered for many of the properties to reduce nitrate releases to the environment. Monitoring of these can also be accomplished via the emerging state-of-practice automation technologies to evaluate efficiency and to determine loads that can be tracked over time (Kram et al., 2011).
9) All hazardous material risks are comprised of source, pathway, and receptor components. The panel is advocating against understanding site-specific pathway components. It is impossible to

manage what is not measured. Unlike the hazardous waste and groundwater remediation industries, the agricultural community has not yet been required to produce key site assessments or to develop monitoring programs sufficient to adequately determine cause-and-effect relationships. The panel is suggesting that since this is complex, we should not attempt to pursue this type of relationship. This does not make sense from a scientific perspective, particularly since there exist decades of historical and ongoing related efforts, thousands of experienced practitioners, and comprehensive libraries full of standards and guidance documents available from analogous industries (e.g., groundwater assessment, groundwater and soil remediation, landfill and oil and gas industries), and new and emerging technologies that will greatly facilitate compliance (e.g., sensors, automation, geospatial mapping, remote sensing, drone deployed technologies, high resolution direct push sensing and well installation, etc.).

10) While many of the panel's recommendations (e.g., education, appropriate training for key entities in specific roles, tracking of nitrogen amendments, etc.) are exceptional, and they accurately point to many of the complexities associated with the challenges at hand, unfortunately, their recommendations as presented in the report will not enable the communities involved to meet key drinking water quality objectives. As such, the panel's recommendations fall far short of objectives that include groundwater and surface water improvement in the foreseeable future. More specifically,
    a. The panel proposes extremely limited monitoring and reporting.
    b. The panel advocates for data collection activities at temporal and spatial scales that are not sufficient.
    c. The panel advocates for data collection and reporting at an aggregated coalition scale and receiving surface water scale, as opposed to supporting site-specific understanding of the fate and transport of nitrate throughout the system at a granular scale sufficient to be able to eventually understand cause-and-effect, and that would allow for the identification of nitrate source areas where specific challenges persist.
    d. The panel appears to emphasize what is not possible, characterizes the application of well-founded scientific principals and methods as futile, and does not consider the important lessons that can be learned from the hazardous waste and groundwater restoration fields as well as the associated regulatory tools already in place (e.g., GeoTracker, ITRC guidance, etc.).
    e. The panel does not consider the many fine technologies available for expedited site characterization (e.g., high-resolution direct push characterization, well design and installation), automated sensing, analyses (temporal and spatial), and reporting that are commercially available or in beta testing. These technologies have the potential to greatly improve the understanding of conditions and trends, and could significantly alleviate the majority of the grower's site-specific assessment, monitoring and reporting burden. When properly executed, regulators and other stakeholders can immediately respond to areas of concern or even automate specific activities (e.g., when/where/how long to irrigate, fertigate, etc.).

f. With respect to surface water considerations, while the panel advocates for monitoring in downstream areas to determine general locations of pollution sources, they also advocate against monitoring at specific discharge points. With new sensing technologies, an automated monitoring and data processing network that includes discharge points could be extremely helpful in identifying where issues persist, notifying the appropriate entities (not for punishment, but to assist with management decisions [at least initially]), and tracking trends and geospatiotemporal relationships with other factors (e.g., correlations with specific crops, climate, etc.).
g. Beyond modification of the amounts of nitrogen based materials purchased and applied, the panel does not consider alternative nitrate pollution control and containment options such as passive wood chip denitrification bioreactors and other potential options. The USDA has been extremely active in their installation and evaluation of low cost nitrate effluent bioreactor technologies (Christianson et al., 2012; 2013), and has initiated bioreactor standards development and optimization activities (personal communication, Dr. Thomas Moorman, USDA-ARS). These systems can reduce nitrate loads by up to 90 percent. As such, these treatment options should be considered, as well as performance monitoring metrics and methods for such options.

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gThrive (http://www.gthrive.com/)

Instrumentation Northwest (http://inwusa.com/)

Iowa Soybean Association Denitrification Bioreactors (http://www.iasoybeans.com/environment/programs-initiatives/programs/bioreactors)

Soilmoisture Equipment Corporation (http://www.soilmoisture.com/)

SupraSensor (http://suprasensor.com/)

TrackR (http://stickr.thetrackr.com/)

USDA Bioreactor Expert (Dr. Thomas Moorman, http://www.ars.usda.gov/pandp/people/people.htm?personid=3940)

Dr. Kram's Bio

Dr. Mark Kram is an award winning Hydrogeologist/Geochemist who has worked for the US Navy, UCSB, Groundswell Technologies, as an independent consultant, and has served as an expert witness on high-profile legal cases. Dr. Kram earned his Ph.D. in Environmental Science and Management from the University of California at Santa Barbara, an M.S. degree in Geology from San Diego State University, and his B.S. degree in Chemistry from the University of California at Santa Barbara. He has over 30 years of experience using and developing innovative environmental assessment techniques, has authored articles, national standards and book chapters on the subject, and has taught graduate level courses on related topics. Dr. Kram is an internationally recognized expert in site characterization and remediation, and has been instrumental in the areas of sensor development and implementation, innovative GIS applications, DNAPL site characterization, chemical field screening, well design, mass flux/discharge based remediation performance, and groundwater basin yield and storage change assessment. Dr. Kram has patented inventions for automated sensor based contouring and multivariate analyses, automatic determination of groundwater basin storage change, water sustainability to protect from basin overdraft, seawater intrusion and stream depletion, and for in-situ measurement of groundwater contaminant flow rates and directions. Dr. Kram has been featured in Forbes (http://www.forbes.com/sites/michaeltobias/2012/01/31/environmental-security-sensing-the-world-in-4-d/), is an active member of the National Ground Water Association (NGWA), American Society of Testing and Materials (ASTM Subcommittees D18.21 and E50.02), and the Interstate Technology Regulatory Council (ITRC), and is currently preparing national guidance for vapor intrusion and environmental characterization applications. Dr. Kram recently co-chaired an ASTM International symposium on continuous soil vapor chemical measurements, served as Editor for the ASTM International book entitled "*Continuous Soil Gas Measurement: Worst Case Risk Parameters*" (http://www.astm.org/BOOKSTORE/PUBS/STP1570.htm), is the recipient of the NGWA's prestigious Technology Award (http://www.ngwa.org/Media-Center/press/2011/Pages/Kram-wins-2011-Technology-Award-from-the-National-Ground-Water-Association2.aspx), and received the 2014 ASTM Committee D18 Technical Editors Award.

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