Invited Testimony to the SBX2 1 Nitrate Expert Panel

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I am an associate professor of environmental economics and policy at UC Riverside who has worked on nitrate pollution of groundwater in California, and related regulatory and policy issues. Most of my work has focused on nitrogen emissions from large dairy operations but I am also familiar with the broader literature on agricultural nitrogen emissions.

The panel has been charged with answering specific questions that delve into the technical nature of nitrogen management in agricultural systems. For some of these questions I have specific responses. For others I have more general but still relevant comments for the panel to consider. My comments follow the same structure as the questions that have been posed to the panel.

Vulnerability and Risk Assessment: General Comments

Modeling of both the activities that potentially release nitrates into the subsurface environment and the fate/transport of nitrates in that environment is essential for risk assessment. Measures of risk and vulnerability ideally should take into account not only current conditions but also anticipated future conditions. This likely involves assessing regional economic trends. For example, a region may have a currently high nitrogen hazard index but also may be undergoing conversion from agricultural land to other less intensive N uses. Anticipated changes in cropping patterns (e.g. row crops to perennials) also would affect the risk outlook.

Regarding farm size, large farms aren't necessarily a bigger threat than small farms. If a large farm is poorly managed and/or concentrates its waste streams such that discharges are potentially large, then it's probably a bigger threat. But large farms also tend to be better able to surmount the fixed cost barriers to implementing more effective environmental controls; they also tend to be more profitable, more highly scrutinized, and thus have more to lose from not complying with laws and regulations. There is also the question of how size is measured: a dairy with more land for manure spreading could be less of a threat than one with the same (or even smaller) herd size and less land, due to differences in stocking densities.

Application of Management Practices: General Comments

Voluntary BMP subsidy programs have been, and continue to be, the most common policy approach to mitigating NPS pollution. However, such programs have not achieved widespread significant reductions in agricultural nonpoint source pollution. Shortle et al. (2012, p.1316) conclude that "a 'pay-the-polluter' approach to getting farmers to adopt best management practices has not succeeded in improving water quality in many impaired watersheds." A 2009 report by the State-EPA Nutrient Innovations Task Group echoes this sentiment, finding that “current efforts to control nutrients have been hard-fought but collectively inadequate at both a statewide and national scale” (p.1). Part of the problem is that producers are keenly aware of the long run economic consequences of changing production practices when subsidy programs may be short-lived, combined with the fact that “win-win” scenarios—production changes that reduce pollution without reducing profitability—are uncommon (Daberkow et al. 2008). Shortle et al. (2012) recommend moving away from such voluntary subsidy programs and towards the “polluter-pays-principle” with an emphasis on performance outcomes rather than BMPs.

A problem with this approach is that it shifts the cost burden from a large group (taxpayers) to a small one (producers). Furthermore producers view the shift as effectively taking away the historical right they believe they have to freely utilize the waste disposal services of the environment. Daberkow et al. (2008) survey a decade of work (1991-2001) on economic incentives for N pollution control and conclude that while both input and emission charges may be able to bring about moderate reductions in N pollution without large economic impacts, more significant reductions (e.g. to drinking water standards) likely will entail substantial economic losses. Recent work at the regional level supports this conclusion (Medellin-Azuara et al. 2012). However recent work at the field level that accounts for the spatial variability of irrigation systems, crop choice, and the potential to recycle irrigation return flows suggests that the economic losses associated with emission charges may be less than previously thought (Knapp and Schwabe 2008; Baerenklau et al. 2008; Wang and Baerenklau 2014).

Regardless, some compromises may exist in which taxpayers provide the funding but producers face larger incentives to install and maintain BMPs. The first is to make subsidized BMP implementation compulsory. Although past reliance on voluntary participation in BMP subsidy programs has not achieved significant reductions in agricultural nonpoint source pollution, compulsory yet flexible BMP programs have been highly effective in places like North Carolina (USEPA 2013), Florida (Ribaudo et al. 1999; Light 2010), Nebraska (Bishop 1994), and some parts of the European Union (Oenema et al. 2011).

Another approach is to utilize competitive bidding for BMP subsidies. An analysis by the USEPA Science Advisory Board (2011) suggests that auction-based contracting for pollution abatement services, in which BMP subsidies are targeted at low-cost providers in high risk areas, may be a useful market-based approach to controlling agricultural nonpoint source pollution. Rabotyagov et al. (2012) demonstrate how this approach could be applied to nutrient management in Iowa.

Question 5: What management practices are expected to be implemented and under what circumstances for the control of N?

It depends on the nature of the control. Our modeling of anticipated responses of large dairy farms to N regulations may be instructive (Baerenklau et al. 2008; Wang and Baerenklau 2014):

- The baseline (no controls) scenario involves flush-lagoon, furrow irrigation, corn-wheat rotation, all waste applied on-site, and periodic high-volume flushing of salts from fields. This is largely consistent with current practice in the Central Valley.
- A NMP that limits land application of N to 1.4 times the agronomic uptake rate produces a switch from flush-lagoon to scrape-tank, a significant amount of off-site waste disposal, and cessation of salt flushing from fields. The opportunity to dispose of N through enhanced volatilization also appears to be an effective, low-cost option when land application is limited; but with obvious cross-media pollution implications.
- An equivalent restriction on field emissions produces a switch from furrow to linear move irrigation, a small reduction in applied water, and cessation of salt flushing.
- An equivalent restriction on downstream emissions produces recycling of return flows and reduced application of surface water except for periodic substitution of surface for groundwater for high-quality (but not high-volume) flushing.

In summary, if N application rates are limited, dairies will try to export concentrated waste off-site, and/or cause more waste N to volatilize. If nitrate leaching to groundwater is the regulatory target, then management of the N stock in soil through irrigation technologies and scheduling looks economical. If off-site migration of nitrates in shallow groundwater is the target, then "pump and fertilize" looks economical.

Importantly, our work finds that the land application control is much more costly for large dairies than the other controls: NMPs produce a 27% net income loss versus less than 1% for the emission-based controls. Greater losses imply greater incentive not to comply, and presumably greater need for enforcement. Anecdotal evidence in California suggests that enforcement may be lacking due to both the complexity of each NMP and limited enforcement resources. Therefore NMPs may fall short of their pollution reduction potential in practice.

For the case of field crops, Knapp and Schwabe (2008) examined changes in N emissions and net farm income associated with a N emissions charge, a N input charge (fertilizer tax), and a water input charge. Within the range of values they considered, the N emission charge looks best: it can achieve a 58% reduction in emissions for a 13% reduction in income. The water input charge is second best: it can achieve a 38% emission reduction for a 14% income reduction. The fertilizer tax is worst: it can achieve only a 16% emission reduction for a 35% income reduction. While it's important to note that the focus of this work was on irrigation system uniformity and thus did not consider other potential changes in management practices aside from applied water and fertilizer, it is well-established that N emissions are highly responsive to water inputs.

Question 6: What management practices are recommended for consideration by growers when they are selecting practices to put in place for the control of N?

In my view, not much has changed since the BMP assessment report by Tanji et al. in 1994. Generally what works is more precise management of water and N inputs. This includes improved irrigation system uniformity, full accounting of N sources, reduction in applied water and N, and proper timing of water and N applications. Such practices have been called the 4Rs of nutrient stewardship: right amount, right time, right place and right form. Some of these methods were used as recently as 2004 to successfully reduce P loads in the Imperial Valley (SWCRB 2010). Arguably what has changed, and for the better, is our ability to accomplish the 4Rs: modern precision farming techniques are well-suited for addressing spatially variable soil characteristics, thus helping to reduce leaching of excess N to groundwater.

In addition to the 4Rs, changes to cropping patterns (including fallowing) can be effective but may involve larger costs to the producer. Return flow capture also looks effective, at least for large dairies.

A final comment I would like to make is to point out the way in which this question is worded: rather than asking which practices should be *prescribed* to growers, it asks which should be *considered* by growers when *selecting* practices. I support the implied message that flexibility should be built into any regulations. When producers are required to utilize or avoid certain production practices in order to achieve a desired environmental outcome, they are rendered unable to fully utilize the private information they have about their specific operations—information that could lead to a different set of production choices that would achieve the same environmental outcome at lower cost. In other words, rigid BMP standards tend to be cost-ineffective for an individual producer (Sterner 2003, p.76). Furthermore, such standards typically are allocatively inefficient across a group of producers when there is substantial heterogeneity within the group and yet standards are applied uniformly, as is often done to keep administrative costs low (Sterner 2003, p.77). While the panel certainly should evaluate and make recommendations on various practices, those that are most appropriate will differ across producers, so it is desirable to let producers select from an approved "menu" that includes different practices for different conditions.

Question 8: Evaluate and make recommendations regarding the most effective methods for ensuring growers have the knowledge required for effectively implementing recommended management practices. Consider the following: required training, required certifications, third party workshops, paid consultants, UCCE specialists.

Education offers some advantages for addressing nitrate pollution problems. Education-based policies are flexible: they leave decisions in the hands of producers who tend to have the best information about their own decision environments. Education-based policies tend to be relatively easy to implement and receive relatively little opposition from producers compared to other types of regulations. Importantly, education tends to be relatively low-cost for both regulators and producers (Ribaudo et al. 1999). Training and outreach programs benefit from the pre-existing infrastructure of county extension services, Natural Resource Conservation Service field offices, and land grant universities (Daberkow et al. 2008). These institutions can deliver new content to producers without incurring the potentially large fixed costs that characterize the establishment of such infrastructure. They can also facilitate community-based learning efforts. All types of education-based policies also benefit from the falling costs of generating, storing, processing, and disseminating information (Tietenberg 1998); however such policies must nonetheless compete with a host of other diverse information flows for the attention of the producers they target.

Perhaps the main challenge of using education-based policies to bring about large changes in pollution loading is that such policies are essentially purely voluntary. Producers who are targeted by education efforts must first choose to consider the new information and *then choose to act on it*. Both of these choices can be costly, and producers often are under no obligation to comply: even *required* training/certification must be *voluntarily* implemented. For this reason, education-based policies tend to be seen as mechanisms for achieving “win-win” outcomes—outcomes that reduce pollution and increase stakeholder welfare—when such outcomes have not already been achieved. One example is a production practice that both reduces pollution and increases income, perhaps by more efficiently utilizing inputs. But because producers already face private incentives to use such practices (a “green” reputation and more income), the role of education-based policies in promoting adoption of established technologies tends to be limited (Daberkow et al. 2008). However the case of new technologies can be different. Enhanced education and outreach efforts can hasten the rate of adoption of new “win-win” technologies, provided they are not perceived by producers to be significantly risk-increasing and they provide similar benefits in practice as they do under the more carefully controlled settings that tend to characterize technological research and development efforts.

Training and outreach to producers historically has had a major role in efforts to control agricultural nonpoint source pollution (Daberkow et al. 2008). Successful examples of education-based policies include those promoting the adoption of conservation tillage (Gould et al. 1989), soil and tissue N testing (Wu and Babcock 1998), and farm-level information systems (Knox et al. 1995). There are also documented cases of education failing to produce significant differences between treatment and control groups. Examples include water quality protection practices in Wisconsin (Nowak et al. 1997) and nitrate reduction strategies in California: Franco et al. (1994) found that FREP had little effect on fertilizer management practices during its first four years. Ribaudo et al. (2011) also find evidence that the efficacy of soil and tissue N testing depends on operating conditions, and has much less influence on N application decisions when both commercial fertilizer and manure are applied to crops.

Daberkow et al. (2008) conclude that “education by itself cannot be considered a strong tool for water quality protection” (p.904), and cite three conditions needed for effective education efforts: (1) a “win-win” scenario, (2) producers with strong altruistic/stewardship motives, and (3) high private costs of water quality degradation (Ribaudo et al. 1999). Unfortunately the convergence of these factors is not common in practice. Daberkow et al. (2008) recommend that education is probably best used as a component of other pollution control policies, such as a mechanism to help producers meet a pollution standard cost-effectively or to effectively utilize new technologies. For example, Bosch et al. (1995) find evidence that additional education makes producers more likely *to utilize* soil N testing information. The IPCC (2007, ch.13) reaches a similar conclusion in the context of climate change, stating that "there is only limited evidence that the provision of information can achieve emissions reductions, but it can improve the effectiveness of other policies (high agreement, medium evidence)."

Verification Measures: General Comments

One advantage of focusing regulations on inputs (BMPs) is that monitoring and verification is relatively inexpensive (USEPA 2011, p.59). But if the BMP requirements are too rigid, then this tends to increase implementation costs for producers. Emission-based regulations typically provide greater flexibility because they leave production choices in the hands of producers. Thus producers are able to take full advantage of their private information and select the most cost-effective set of production practices that achieves the desired outcome. However monitoring and verification has presented a considerable challenge for using emission-based regulations to mitigate agricultural NPS pollution (Ribaudo et al. 1999). This is because NPS pollution is discharged diffusely but monitoring is costly and thus happens only in selected locations. Not only is it problematic to regulate something that isn't measured, but it also creates the opportunity for dischargers to behave strategically near the monitoring sites and/or deny responsibility for problems that arise since their discharges are not perfectly observed. For the case of nitrates, Letey and Vaughan (2013) argue that accurate monitoring requires not simply tracking the N *concentration* but rather the N *load* migrating to groundwater, which is infeasible. Although better information about NPS emissions has been shown to be potentially valuable from a regulatory perspective (Kurkalova at al. 2004), and despite recent applications of remote sensing as a potential monitoring tool (e.g., Idaho DWR 2013; Shaver et al. 2011), in practice verification of NPS emissions remains a significant challenge.

An alternative to an emission-based regulation is to implement an ambient-based regulation by monitoring pollutant concentrations at a limited number of points in the environment. For example, instead of attempting to monitor runoff and leaching throughout a watershed, groundwater or surface water quality would be monitored only at the base of the watershed. While this approach can reduce monitoring costs, other significant administrative costs can arise if/when responsibility for violating the ambient regulation must be assigned to individual producers since individual activities and discharges have not been monitored. Unless a robust model of the regional pollutant transport process exists (which is unlikely given the inherent complexities and uncertainties), this can be very problematic.

A potentially advantageous compromise is a regulation based on estimated (modeled) emissions. In this case, a model of only the farm-level emissions generation process is needed. The model incorporates farm characteristics and management practices, and generates an estimated level of emissions to which the regulation is applied. Monitoring and verification efforts can thus be focused on the more readily observable management practices, while the model is used to estimate the unobservable emissions and to determine compliance. This approach has potentially low monitoring and verification costs because it focuses on BMP implementation, as well as potentially low implementation costs because it allows producers the flexibility to make production choices based on private information. However success is still dependent on the availability of a robust model, specifically one that can incorporate a good amount of site-specific heterogeneity (Ribaudo et al. 1999). Daberkow et al. (2008) also note that there may be legal problems with using estimated rather than measured emissions if an acceptable level of model accuracy cannot be achieved.

Finally it is worth noting an innovative idea by Millock et al. (2002) who propose giving producers the choice of incurring the cost to monitor and verify their own emissions in exchange for a preferable set of regulations. Because producers are given a choice, information will be provided only when it is cost-effective to do so, making this a relatively inexpensive way of reducing at least some of the uncertainty about emissions.

Question 9: What measurements can be used to verify that the implementations of management practices for nitrogen are as effective as possible?

The State-EPA Nutrient Innovations Task Group (2009) undertook a review of nutrient management programs across the country. One of their most striking findings is the lack of information about environmental effectiveness. Some of this is due to the nature of the problem, specifically the time lags, complexities, and uncertainties associated with nutrient fate and transport that make it difficult to discern the ambient environmental impacts of BMPs in practice. There is much better information about program participation rates, funding levels, and BMP installations; but these are imperfect proxies for effectiveness.

To better verify environmental effectiveness, it would be advisable to take a two-pronged approach. Sampling conditions close to sources will help reveal whether specific BMPs are having the desired effects on emissions and local environmental quality. Sampling conditions further downstream will help, in time, determine whether the overall policy approach seems to be mitigating nitrate loading at receptor points such as domestic wells.

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