PRACTICES THAT MINIMIZE NITRATE LEACHING ASSOCIATED WITH ON-FARM RECHARGE

California growers and irrigation authorities are increasingly turning to a combination of dedicated storage and on-farm recharge methods to percolate excess surface water into local groundwater systems. Storing excess surface water, when available, serves dual purposes including the recharge of over-drafted groundwater aquifers and the potential for improvement of groundwater quality. The total land area of dedicated groundwater storage facilities has recently grown to deal with the ever-increasing water demand by environmental, municipal and agricultural uses as well as in response to recent drought conditions in the State. Disadvantages of dedicated recharge facilities include the capital expenses required to develop the infrastructure, the on-going management and maintenance costs and the lost productivity of irrigated lands that are often the target of land conversion. These costs are among the principle reasons agricultural leaders are looking increasingly to on-farm recharge as a method to improve groundwater resource conditions. One of the chief concerns related to on-farm storage is the likely leaching of additional nutrients to groundwater systems and their impact on drinking water quality.

Nitrogen, especially in the nitrate form is particularly abundant in the crop root zone and is the chief nutrient applied by growers to maximize crop yield and quality. Nitrate is also very mobile in soil systems and readily moves with irrigation water. Irrigation water movement that percolates below the root zone is the chief mechanism for the transfer of nitrates to groundwater systems and can lead to maximum contaminant level exceedances established for drinking water. To minimize the movement of nitrates into local groundwater during recharge events, practices can be established that minimize the movement of nutrients and particularly nitrates into groundwater supplies while maintaining highly productive agricultural systems. Improved nitrogen management practices must also consider the timing of applied recharge waters in order to minimize the potential for nitrate leaching as well as the impacts on crop performance.

However no single farm management practice should be considered as a primary means to limit nitrate movement to groundwater, rather a combination of practices can be incorporated into farm management plans that provide the grower the flexibility to adopt the series of practices that conform to the local farming system. The purpose of describing these practices is to identify a list of grower practices that have been field tested and can be considered in reducing the total amount of nitrogen available for leaching from the crop root zone or that have an impact on improving groundwater quality through on-farm recharge activities. And while this is not an attempt to report all potential practices that can be applied, it is intended to provide guidance on practical approaches to improve groundwater quality and quantity. The order in which the management practices are presented does not imply their priority to be applied, nor should they be considered the only practices that can provide protection to groundwater systems. Local site soil and water conditions, available farm resources and the economics of water recharge will help establish the priority and strategy to be used if on-farm storage is to be considered.

Practice 1. ***Incorporate a seasonal nitrogen management plan approach during all years similar to the plan adopted by the Central Valley Regional Water Quality Control Board.***
The Central Valley Regional Water Quality Control Board approved Nitrogen Management Plan is aimed at limiting the amount of nitrate movement to groundwater and provides a means to document individual activities that influence nitrogen balance in the field. This approach works to develop a nitrogen management budget that estimates the total quantity of nitrogen available to the crop, the total amount of nitrogen taken up by the crop and is balanced with the total amount of nitrogen

removed at harvest. By following this approach the remaining nitrogen is understood to be either stored in the crop root zone and available for future crop uptake or has the potential to be leached. This field nitrogen balance estimate assumes that gaseous nitrogen losses to denitrification and volatilization are minor as well as nitrogen that is lost to off-site runoff. Adherence to an in-season nitrogen balance approach can have a significant impact on the systems vulnerability to nitrate leaching since it reduces the quantity of residual soil nitrogen present at the end of the season.

Developing nitrogen balances on a field by field basis allows growers to construct estimates of residual soil nitrate as well as organic nitrogen sources including the nitrogen available from crop residues, organic amendments and background soil organic matter that will be available to the crop during the season. Additionally, there are many cases in which irrigation water contains significant quantities of nitrate and an attempt should be made to quantify this potential source and include it in a nitrogen budget. These combined sources of nitrogen make up the estimate for the supply side of the nitrogen balance which must be weighed with the crop nitrogen requirements before developing a nitrogen fertilizer recommendation. Through this planning process, an initial assessment of crop nitrogen needs can be made early in the season based on anticipated crop yield. Later in the season additional information can be weighed including additional soil nitrate testing and plant tissue testing intended to reevaluate the need for additional or reduced in-season nitrogen fertilizer inputs should established guidelines warrant that change.

Once a good estimate of in-season plant available nitrogen has been made, the estimation of crop nitrogen uptake will aid in identifying any nitrogen balance deficiencies and a valid fertilizer recommendation can be made. Fortunately good information exists on crop nitrogen uptake by many of the key crops grown in the State and nitrogen uptake as well as nitrogen removal at harvest can be reasonably estimated providing additional nitrogen balance information.

Practice 2. *In-season water management practices*

Beyond the nitrogen budgeting approaches described in practice 1. additional in-season considerations embraced by the Central Valley water quality coalitions work to limit the movement of nitrate below the root zone and are consistent with supporting high nitrogen use efficiency. The inclusion of specific water management practices that limit the amount of leaching that occurs during the year further limits the need to apply additional late- and post-season fertilizers to the land. The wide variety of water management practices that work to improve distribution uniformity as well as application efficiency are particularly appropriate for use in on-farm recharge systems. Some of these water management practices support proper initial irrigation system design including the selection of an appropriate method for irrigation.

Sites that are often good candidates for on-farm recharge can be poor sites for using surface irrigation and conversion to pressurized systems including sprinklers and micro-irrigation often offer the gains in irrigation system efficiency desired. Proper design, operation and maintenance of pressurized systems will support the uniformity and efficiency objectives most important for in-season water management. It should also be noted that removing surface water delivery infrastructure severely limits the sites capacity for conducting recharge activities. Dual purpose irrigation systems can be highly effective in managing in-season applied water where high efficiency is a desired goal in contrast to the winter and spring recharge goals. The use of a high capacity surface irrigation systems allows water to be applied in a timely manner and increases the flexibility of how rapidly flood water can be used. Retaining high capacity irrigation systems in place can also be useful in supporting techniques such as alternate furrow or alternate check irrigation management which can be particularly useful in managing crop health and limiting crop damage during recharge activities.

Additional water management practices that limit the amount of water moving beyond the root zone include improved irrigation scheduling. The use of tools that provide estimates of crop evapotranspiration or stored soil moisture can be particularly useful in scheduling irrigation events. DWR's CIMIS program in combination with appropriate crop coefficients can improve irrigation scheduling while soil moisture sensors aid in managing soil water deficits during the season. Perhaps one of the most valuable tools that can be used in combination with other irrigation scheduling support systems is the flow meter. Regular tracking of field applied water can provide instantaneous feedback to water managers who wish to compare applied water with that intended for individual irrigation events and can be valuable when evaluating system deficiencies including changes in irrigation system efficiency.

Practice 3. ***Post-season nitrogen evaluation***
Above and beyond using sound in-season nitrogen management practices to limit the amount of post-season soil nitrogen present in the root zone, growers can opt to conduct additional post-harvest sampling that confirms a reasonable in-season nitrogen balance was achieved. In the case of on-farm recharge, this sampling captures an estimate of potentially leachable nitrates during winter recharge events and should be tailored for the intended purpose.

While typical residual soil nitrogen sampling is conducted on the top foot or two of soil, growers may opt to more thoroughly evaluate to total leachable N by sampling at deeper levels of the soil surface. For this purpose, sampling nitrate concentration at each foot of soil to a depth 3 or 4 feet will provide a much better estimate of potentially leachable nitrogen. This sampling can also be conducted just prior to anticipated recharge events.

In some crops such as almonds, there can be a recommendation to apply nitrogen containing fertilizers following harvest. Use soil nitrate or plant tissue tests to confirm the need for post-harvest nitrogen applications and limit those applications according to developed University of California guidelines.

Practice 4. ***Eliminate or delay pre-plant and pre-season nitrogen applications***
It is becoming less common for growers to apply nitrogen fertilizers prior to the planting of annual crops or prior to bloom or leaf-out in permanent cropping systems. Increasingly, research has consistently shown that unless residual soil nitrate levels are extremely low, delayed applications of nitrogen fertilizers are likely not harmful to crop health and seldom lead to a reduction in yield with only a few exceptions. It is even more important in on-farm recharge sites to limit these early applications of nitrogen that might otherwise be leached below the root zone becoming unavailable for its intended purpose. This practice also supports practice #2 since sampling can be used to evaluate the soil nitrogen status prior to considering any early nitrogen fertilizer applications.

Practice 5. ***Limited use of organic amendments***
Many growers use a variety of organic amendments during the season as a nutrient rich source of fertilizer intended to supplement or replace synthetic fertilizers. Further, these amendments can have the effect of improving soil health and improving soil properties such as increasing the soils infiltration rate and soil water holding capacity. These applications are often made during the fall, winter or spring

months to give time for the soil to break down the more complex nitrogen based organic compounds to be converted to crop available nitrogen by soil microorganisms.

The concern with using large amounts of organic soil amendments is linked to the fact that organic amendments are continuously being broken down through the mineralization process followed soon after by nitrification which converts mineralized nitrogen to the soluble and mobile nitrate form. These materials therefore are released during periods when nitrogen is not taken up by the plant and soil nitrate accumulation occurs. Limiting the use of organic amendments to those materials that have high carbon to nitrogen ratios and those that convert relatively high proportions of available nitrogen rapidly can increase early nitrogen uptake by the crop and limit rising soil nitrate concentrations during periods when leaching is more likely to occur. During times when recharge activities are uncertain, delaying or reducing the application of organic soil amendments can reduce N leaching potential.

Practice 6. ***Consider crop type***

The potential list of crops that can conceivably be used for on-farm recharge is as numerous as the crops currently being grown in areas where surface water is available. Each crop or crop grouping is unique with respect to the magnitude and timing of crop nitrogen needs. Crop nitrogen uptake, utilization and harvested N characteristics are unique to each crop type and can be considered as a nitrogen management tool if the desired result is to limit nitrogen leaching to the groundwater. However not all crops can endure lengthy periods of water ponding and the limited oxygen levels that are associated with more extensive water ponding practices. There are also complex soil reactions and plant metabolic responses that occur in the root zone of flooded systems that can impact crop productivity and quality uniquely across the major crop types. Nitrate leaching potential also varies between crop types based on nitrogen requirements, uptake characteristics and cropping system flexibility.

Grapevines for instance have a much lower requirement for nitrogen than either processing tomatoes or almonds and are therefore less likely to have high levels of residual nitrogen present during the optimum window for recharge. Processing tomatoes on the other hand have a much higher nitrogen requirement but can have the added flexibility of delaying planting dates to accommodate the potential opportunity for on-farm recharge activities. Almonds also have a relatively high demand for nitrogen and have the added concern that there is relatively little known about the metabolic impacts to the crop during the physiologically active period between bloom and early fruit growth when recharge waters are most likely available.

Practice 7. ***Select the right nitrogen fertilizer source***

Eliminating the use of nitrate containing fertilizers during the winter and spring months can delay and limit the movement of nitrogen with the irrigation water. When soil temperatures are low, the use of ammonium and urea containing fertilizers will delay the soils capacity to nitrify ammoniacal sources and limit the conversion to nitrate. Cool winter soil temperatures as well as flooding events with cold water can result in soil nitrogen fertilizer stabilization and limit nitrogen's mobility in the soil. Additionally, there are nitrification inhibitors, urease inhibitors and controlled release fertilizers that reduce the likelihood that soil nitrates will increase in instances when winter or early spring fertilizers are required. As part of a total in-season fertility program, the inclusion of foliar fertilizers can also provide flexibility in the timing and amount of soil or irrigation applied fertilizers.

Practice 8. ***Use of cover crops***

The use of cover crops in irrigated farming systems can serve multiple roles including the improvement of soil physical characteristics, increased nutrient and water holding capacity and enhanced nutrient cycling. A less common role for incorporating cover crop use in cropping systems is the intentional uptake of residual soil nitrogen thereby reducing the amount of surface soil nitrate. Particularly if given an opportunity to establish high root densities in the soil profile, cover crops can essentially act as a sponge by taking up nitrates and immobilizing them in the cover crop plant tissues rendering this nitrogen temporarily unavailable. Leguminous cover crops are being used in many irrigated farming systems to not only enhance soil quality but also to act as a nitrogen source later in the season to supplement or replace synthetic fertilizer use.

Cover crops have also been used to increase infiltration rates in soils providing additional reasons why they might provide value to on-farm recharge activities. Cover crops can reduce the amount of energy imposed on the surface soil layer by irrigation water movement thereby stabilizing the soil surface and limiting the amount of surface aggregate dispersal that occurs during irrigation events. The dispersion of surface soil aggregates is largely responsible for the plugging of large soil pores responsible for the bulk of high infiltration rate soils and works to develop impenetrable soil crusts. Continuous use of cover crops also aid in increasing soil organic matter often associated with promoting high aggregate stability.

Practice 9. *Selecting soil type and infiltration rate capacity*

While reducing the amount of nitrogen in the soil profile through various means is thought to be a key principle in limiting nitrogen movement to the groundwater, the total volume of water that percolates through the soil system can also influence the amount and concentration of nitrate moving below the root zone. Though it can and has been argued that small differences in total infiltrated water may have little impact on reducing nitrogen movement to groundwater, it has also been demonstrated that large differences in total applied water from high quality water sources can significantly reduce the concentration of nitrates to the point that groundwater quality in the local aquifer can be improved. Selecting sites that have high infiltration capacities and utilizing those sites for extended recharge periods can have a significant impact on the quality of water leaching below the root zone. The use of the soil agricultural groundwater banking index (SAGBI) https://casoilresource.lawr.ucdavis.edu/sagbi/ can be a useful tool in identifying sites that are most likely to experience high infiltration rate characteristics. This index uses five factors to evaluate a sites potential for groundwater recharge including its potential for deep percolation in addition to evaluating root zone residence time, surface soil topography, chemical limitations and surface soil condition.

References:

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