Basin Management Objective (BMO)
Method Of Groundwater Basin Management

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Background

Future groundwater development in the Sacramento Valley will operate within the constraints of local groundwater management ordinances. Many of the existing ordinances, unfortunately, embrace a safe yield -- overdraft concept. Safe yield and overdraft have widespread intuitive appeal and acceptance with much of the water community. Very few, however, fully understand the concept at a technical level, and even fewer can explain it in detail. In other words, everyone knows what it is, but no one can describe it. Even worse, these terms have been used so loosely for so long that they have come to mean whatever anyone wants them to "... we must be in overdraft because I am having trouble with my well."

In many ordinances these two concepts are used in a circular reference, with overdraft defining safe yield, and safe yield defining overdraft. None of the existing ordinances detail a method for estimating safe yield and overdraft, or how it is measured. As a practical matter, estimating safe yield in the Sacramento Valley is nearly impossible.

Why is Safe Yield a Problem in the Sacramento Valley?

On a technical level, safe yield is typically determined by empirical studies that compare groundwater levels to groundwater use. This requires data on groundwater levels and estimates of annual groundwater extraction. There are reasonably good records of groundwater levels in the Sacramento Valley, however, groundwater extraction estimates can only be made with much uncertainty, because there is a general reluctance to meter and maintain good records of groundwater use in the agricultural community.

Another problem with the safe yield concept is that it is perceived in terms of groundwater levels, or changes in groundwater levels, but is defined in terms of groundwater use. For example, "the safe yield of a groundwater basin is 120,000 acre-feet", which is commonly interpreted to mean that the long-term groundwater levels in the groundwater basin will not decline if annual groundwater use remains below 120,000 acre-feet. Looking at this in terms of a

mass balance, what this really means is that the long-term annual recharge to the basin averages 120,000 acre-feet per year. So when the safe yield is expressed as a single number, which it typically is, then the basin recharge rate must remain nearly constant over-time. This is problematic in the Sacramento Valley because recharge rates are highly variable.

Why is Recharge in the Sacramento Valley Variable?

In the Sacramento Valley, and in other groundwater basins where the surface water and groundwater systems are interconnected, a major component of groundwater recharge is seepage from the surface water system. This recharge can either be positive, when surface water recharges the aquifer system, or negative, where the aquifer system discharges to the surface water system. The general principles governing recharge apply equally to both directions.

The amount of recharge that occurs between the surface water and groundwater systems is governed by the overall permeability of the aquifer system and the hydrologic gradient between the two water sources. The gradient is loosely defined as the slope of the water surface between the surface water and groundwater systems. It is more precisely defined as the change in head over a unit flow distance.

At any location in the basin, the gradient between the surface water and groundwater system is directly proportional to the head differences (water surface elevation difference) between the two hydrologic systems. The larger the head differences the higher the gradient and the higher the recharge rate. In addition, the gradient is also inversely proportional to the horizontal distance over which this head change occurs. The shorter the horizontal distance over which the head change occurs increases the recharge rate dramatically. An example of this would be pumping next to a river would induce a much higher recharge rate from the surface water system than the same pumping many miles away. Clearly this relationship is not constant or linear.

In the case of positive recharge, increased extraction causes the groundwater levels to decline, which increases the head difference between the groundwater and surface water systems, and consequently increases the gradient and recharge rate. In short, the more you pump, the more you can pump, to a point.

Practically, the gradient will increase to a point where the recharge will eventually become constant. This occurs when there is a transition from Darcy to non-Darcy flow, which occurs at very high gradients. This is when turbulent flow develops in the groundwater flow regime as a result of high groundwater flow velocities, or there is a transition between saturated to unsaturated flow. As a practical matter, this occurs when river seepage flows nearly vertical to the groundwater system. In the San Joaquin Valley this is a common occurrence. In the Sacramento Valley many of the existing water wells would be de-watered by

the time these high gradients were achieved. Remember that long-term recharge rate must be constant for the classical definition of safe yield to be applicable.

Basin Management Objectives (BMO)

The Basin Management Objective, or BMO, concept was developed to overcome many of the usual problems of defining safe yield and overdraft in the Sacramento Valley. The Department of Water Resources, Northern District Groundwater Section formulated the concept when they assisted Glenn County in developing their groundwater management ordinance. It became very apparent early in the process that the classical definitions of safe yield and overdraft would not work in Glenn County.

The overall BMO concept is outlined below. The discussion is divided into the following six general concept categories:

- Management Areas and Sub-areas
- Key BMO Elements
- Public Input
- Monitoring
- Adaptive Management
- Enforcement

In the discussion below an overview of each of the concept categories is broadly presented. The discussion also outlines how Glenn County chose to implement each of the six concept categories. It is important to realize that there are many ways in which these concepts can be implemented, not just the way Glenn County chose implemented them. The concept categories must also be developed so they do not conflict with County or State regulations. All six-concept categories must be implemented to properly manage the groundwater resource.

Management Areas and Sub-area - The management area encompasses the portion of the aquifer system where groundwater management will be established. The management area can be subdivided into smaller hydrologically similar regions based on local input and need. These may include individual groundwater basins, groundwater sub-basins, or hard rock groundwater areas. If there is a need, these areas can be further subdivided into smaller political sub-areas such as reclamation districts, irrigation districts, cities, or Supervisorial districts if more detailed management areas are needed.

In the case of Glenn County the management area was chosen to be the Sacramento Valley portion of the County. The sub-areas were then chosen as irrigation district by groundwater sub-basin by County Supervisor District. In the non-district portions of the County the sub-areas were chosen as areas that have

similar hydrology. These areas were then further subdivided on the basis of groundwater sub-basin and by County Supervisor District.

The underlying desire when defining sub-areas is to group those in the same management sub-area that have the same vested interest in maintaining the groundwater resource at mutually agreeable levels. These management boundaries can change over time to accommodate changes in basin hydrology, understanding of the basin hydrology, or if hydrologic information collected in the basin provides a justification for doing so. A critical concept of this process is that water management practices or activities in one management sub-area should not negatively impact the water management objectives of another.

Key BMO Elements - For each of the management sub-areas a management objectives are established. The management objective defines the acceptable range of groundwater level fluctuations that should be allowed to occur within the management area, and the acceptable range of groundwater quality change. The management objectives should also define the maximum amount of inelastic land subsidence that may occur. The management objectives can be considered a set of trigger points where action will be taken if the BMO levels are exceeded.

Determining how the BMO levels are established is best left to the locals in each management sub-area. The groundwater level and groundwater quality management objectives can be based on levels from a network of monitoring wells, or from individual "key" wells, or it can be defined in more general terms such as proposed groundwater level contours. The subsidence management objective can be based on a subsidence monitoring benchmark network or by "key" extensometers. **It is the intent that all of the management area objectives be combined into a single countywide or basin-wide objective.** In the case of Glenn County it was decided that the Board of Supervisors would provide general oversight to this process by approving the management objectives annually. It is recommended that the BMO levels are reevaluated and reestablished annually to respond to possible changes in the management area hydrology.

Public Input - Public input to the process is a critical factor for the successful implementation of this management strategy. The public input process must be tailored to fit each individual region where it is applied. It is important to accommodate, if at all possible, the needs and wishes of the local groundwater users in the area being managed.

In the case of Glenn County it was decided that the public input process would be through the Board of Supervisors and the Water Advisory Committee (WAC). The WAC committee is appointed by the Board of Supervisors and includes at least one representative from each of the management sub-areas in the County. The WAC representatives are not affiliated with the County or County

government. It is the primary responsibilities of each WAC representative to establish the management objectives for their corresponding management sub-area and to provide a communication path between the local groundwater users and the WAC and the Board of Supervisors. It was decided in Glenn County that it would be the responsibility of each individual WAC representative to establish individual public input processes for establishment of the management objectives for his or her corresponding management sub-area.

In the case of Glenn County, the WAC also maintains a Technical Advisory Committee (TAC) that provides technical assistance and advises the WAC. The TAC reports directly to the Water Advisory Committee. This group includes technical representatives from appropriate Federal, State, County, local agencies, and the general public. The Board of Supervisors appoints the TAC representatives.

Monitoring - The key to the BMO concept is objective scientific monitoring and rapid dissemination of all data collected as part of this process. A regional monitoring network is established that includes sufficient data collection points to determine representative conditions in the aquifer system for each of the management areas. The networks may consist of existing wells for monitoring groundwater levels and groundwater quality. In areas where no wells exist or the existing coverage is poor, new dedicated monitoring wells may be installed if resources permit. An important element in establishing this network is to assure that all participation by individual landowners is strictly voluntary.

A monitoring program should also include a subsidence-monitoring component if land subsidence is considered a potential problem. A subsidence-monitoring program might include the establishment of a network of benchmarks, which are differentially resurveyed at specified intervals using global position satellite (GPS) technology or conventional leveling. The GPS survey can achieve 2-centimeter vertical accuracy if done in accordance with NOS NGS-58 procedures. Subsidence can also be monitored with borehole extensometers, which are special wells that are instrumented for detecting subsidence. Pipe extensometers would be used when precision continuous monitoring is needed, otherwise the less expensive cable extensometers would provide sufficient continuous monitoring with acceptable accuracy.

In the case of Glenn County, it was decided to use the groundwater level and quality-monitoring networks of the Department of Water Resources initially to determine compliance with the management objectives. The DWR monitoring network was chosen to provide comparative time-history of groundwater levels and groundwater quality over time in the County. It is anticipated that additional wells will be added to the network to fill in areas where data is lacking, or in areas were more definition is needed. At the current time the County is assessing how best to establish the land subsidence monitoring network portion of the program. It is anticipated that cable extensometers will be installed if resources permit.

All components of the overall monitoring network can increase, decrease or change to reflect a growing understanding of the groundwater system. In the case of Glenn County, the Board of Supervisors provides oversight to this process by requiring their approval for any changes to the monitoring network.

The frequency of monitoring is an important consideration in the overall monitoring program. The local organization that is formed to provide oversight to the process should carefully consider all the hydrologic factors that impact the groundwater resource and develop a monitoring frequency that is capable of tracking those factors. In the case of Glenn County the WAC and TAC establish the monitoring frequency for water levels, water quality, and subsidence.

At a minimum, it is suggested that groundwater levels be monitored at least three times a year:

- Once in the spring when groundwater levels are at their highest.
- Once in the summer during the peak irrigation season when groundwater levels are at their lowest.
- Once in the fall to assess the change in aquifer storage over the course of the irrigation season.

This measurement schedule corresponds to approximately April, July, and October. It is important that the fall measurements are made before the start of the rainy season. This measurement schedule may be different in other parts of the Sacramento Valley, or different parts of the State.

Water quality sampling should be done a minimum of once a year during the peak irrigation season, usually in July. At a minimum this would require measuring temperature, pH, and electric conductivity. Additional laboratory water quality analysis, such as total mineral and minor elements, or testing for particular contaminants may also be done if a need arises.

Subsidence monitoring can be done on a continuous basis with extensometers. GPS subsidence monitoring is usually done on a five or more year basis because of relative high cost. It is recommended that the initial and subsequent GPS surveying be done in the spring prior to the start of the irrigation season.

As with all data collection programs, quality assurance and quality control is a critical component of the overall monitoring program. This requires developing written detailed standards, protocols, and procedures for measuring groundwater levels in wells and sampling or testing groundwater from wells for water quality analysis. These procedures also need to include protocols for data reduction, computer data entry, and overall data dissemination. The procedures need to be detailed in a document to assure consistency between those performing the various monitoring tasks and to assure a seamless transition between different

data collectors. The QA/QC procedures and monitoring frequency can change over time as the need arises to better determine representative aquifer conditions.

In the case of Glenn County, the WAC and TAC will recommend quality assurance and quality control standards for all monitoring. The Board of Supervisors provides oversight to this process by approving the monitoring schedule and QA/QC standards prior to final adoption by the WAC.

Adaptive Management - Following the data collection there needs to be a process to analyze the data, and to report any findings or recommendations to the management authority. The management authority then can make sound adaptive management decisions based on the results of the monitoring.

In Glenn County the WAC is the management authority. Following data collection the WAC and TAC reviews the data to assure that the groundwater levels, groundwater quality, and subsidence measurements are within the levels specified in the management objectives. Under the BMO concept, the management area is within "safe yield" if the measured groundwater levels are above the management objective, as discussed earlier. Conversely, if groundwater levels fall below the management objective, the management area is in "overdraft". It is important to remember that in the context of the BMO concept that the classical definitions of safe yield and overdraft do not apply. The same principles also apply to changes in water quality and inelastic subsidence. It is possible to have some management sub-areas in overdraft while others are within safe yield even though they are in the same groundwater basin or sub-basin.

The BMO concept assumes that everyone participating in the process actually wants to properly manage the groundwater resource within his or her management sub-area. This concept allows locals to mismanage their groundwater resource if they choose. That is why the Board of Supervisors in Glenn County chose to provide oversight to the process by approving the management objectives for each management sub-area on an annual basis.

The data collection and scientific analysis should be made available for full public disclosure in order to built public trust and acceptance for the process. This can be in the form of press releases, public meetings, or a site on the World Wide Web.

For this process to work, the results from the monitoring must be the sole basis for determining whether a management area is within acceptable management levels. The concept cannot work if complaints from individual well owners or small groups of well owners drive the process.

Enforcement - Groundwater management has not been too successful in California because no one wants to relinquish his or her control over the resource. For groundwater management to work properly there has to be some controlling authority that can take corrective action to resolve problems when they arise. This is often a contentious issue that can only be resolved at the local level, and only after much public input and discussion.

Glenn County resolved this contentious problem in a somewhat unique fashion. The structure of their management authority is such that the locals maintain control of the groundwater resource outside of County government, while at the same time having a mechanism in place that can utilize the police powers of the County if they ever become needed.

In the Glenn County structure, if a BMO threshold is exceeded, the process sets into motion a series of events. First the TAC reports on the regional extent and magnitude of the non-compliance to the WAC. The TAC then starts a fact-finding process to identify the cause(s) of the non-compliance and makes recommendations to the WAC on how to resolve the situation. The WAC then tries to resolve the problem in the effected area by negotiations with the locals if at all possible. Some of the possible actions that may be taken by the WAC might be to coordinate the following voluntary actions in the effected area:

- Rescheduling groundwater extractions
- Redistribute groundwater extractions
- Terminate groundwater substitution extractions
- Reduce groundwater extraction rates
- Terminate groundwater extractions
- Develop a groundwater recharge program
- Establish alternative BMO levels in management area
- Other

If the WAC cannot resolve the problem at the local level, it then makes recommendations to the Board of Supervisors on how to resolve the non-compliance. The Board of Supervisors may accept the recommendations from the WAC or take what enforcement action they deem necessary to correct the non-compliance. The enforcement may include the following actions within the management sub-area(s) where the non-compliance exists, or in adjacent management sub-areas if they are found to be the cause of the non-compliance:

- Reschedule groundwater extractions
- Redistribute groundwater extractions
- Redefine the management objectives
- Terminate groundwater extractions
- Other

If the noncompliance is the result of groundwater extraction as part of a groundwater substitution program, the Board of Supervisors has the power to reduce or terminate groundwater withdrawals from these wells before action is taken against other lawful groundwater users in a management area. If the Board of Supervisors takes such actions, such as requiring reductions in groundwater extractions, it does so under the County's police powers.

Final Thoughts

In conclusion, the BMO concept must be flexible to be workable. There is not a cookie-cutter approach to proper groundwater management. Groundwater management objectives can and will be different in different parts of the Sacramento Valley or in different parts of the State. A workable BMO approach can only be implemented after much public participation and input. In addition, there must be sufficient flexibility in the final process to respond to changes that certainly will occur. As more is learned about the aquifer system, changes to the overall program are inevitable. This is an adaptive and active management approach that requires public participation. This is not an approach that can be put on the shelf once it is implemented.

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