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Assuring a Long Term Groundwater Supply: Issues, Goals and Tools

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Introduction

Groundwater is a hidden, but important resource. We can practicably define groundwater as water beneath the ground surface that can be extracted by wells. Other water in the ground that is not considered to be available for man's direct use is commonly called "subsurface water." Subsurface water includes moisture within the root zone.

Groundwater is contained in geologic strata termed aquifers. Aquifers can be composed of a wide range of materials, including sand, gravel, limestone, and fractured granite. The more permeable the aquifer to water (the greater its hydraulic conductivity), the more easily groundwater flows through it. Groundwater generally moves through aquifers relatively slowly, except in fractures or solution channels. Solution channels form where water dissolves the materials around a fracture, gradually increasing the size of the underground channel. Although underground streams can result, they are the exception, rather than the rule. The chance that a well will intersect an underground stream is slight.

Generally, wells extract groundwater that is contained in the pore spaces or interstices between particles of the aquifer material. The more interconnected pore spaces in the aquifer, the more water can be stored and removed. By knowing the shape, dimensions and effective porosity of an aquifer, one can estimate how much water that layer can hold. But that does not tell us how much groundwater can be removed by wells year after year. How much can be extracted depends on how much is initially in the aquifer, how much new water enters (recharges) and how much water leaves (discharges) in other ways.

Groundwater is part of the dynamic hydrologic system. Most groundwater is continually in motion. Groundwater flows from locations of recharge to locations of discharge (from locations of high water surface to locations of lower water surface)[1]. In Utah, water commonly enters aquifers in or near the mountains. It then flows through the aquifer to eventually emerge downhill: as discharge from springs and naturally flowing wells; as flow to streams or lakes; as

[1]This is a simplification. Groundwater moves from locations of higher potentiometric head to locations of lower potentiometric head. The potentiometric surface describes the potential energy of the water. The potentiometric surface can also be called the water table in an unconfined aquifer, or the piezometric surface in a confined aquifer.

[2] Groundwater velocity = (hydraulic conductivity of the aquifer)(slope of the potentiometric surface)/(effective porosity of the aquifer)

[3]Steady-state conditions exist when water levels no longer change significantly with time.

best use of an aquifer. An aquifer undeveloped by man has natural recharge rates and natural discharge rates. Extracting groundwater by pumping changes those rates. The first groundwater that is pumped comes from storage. However, groundwater pumped later can also come from increasing recharge; and from reducing other discharges.

Some beneficial side effects can result from groundwater mining and declining groundwater levels. Dropping groundwater levels increases flow toward the pumping wells and can: (1) increase recharge to the aquifer from rivers, lakes, or adjacent aquifers; (2) reduce discharge from the aquifer to surface water bodies; (3) reduce groundwater contamination by causing water levels to be below the reach of degradable leaching contaminants; (4) reduce undesirable groundwater loss (discharge) due to phreatophytes or evaporation from the capillary fringe; (5) reduce other undesirable groundwater discharges; improve crop yields in previously waterlogged areas; (6) reduce septic tank problems resulting from high water table elevations; or (7) reduce moisture in basements.

However, excessive mining can be harmful. Problems that can result from declining groundwater levels include: (1) increase in energy required to raise a specific volume of groundwater to the ground surface; (2) reduction in well yield or total loss of well functionality due to diminished aquifer saturated thickness in the well screened interval; (3) increased migration of salty or otherwise contaminated water into previously uncontaminated portions of the aquifer; (4) reduction in flow from springs; (5) reduction of flow in rivers due to induced recharge from river to aquifer or reduction in discharge from aquifer to river; (6) dewatering of wetlands; (7) economic hardship due to previously listed problems; and, last but not least, (8) social conflict and litigation.

Goals of Groundwater Management

Within its legal capacity, a water management agency usually tries to assure that water users will have a long-term reliable source of water of adequate quality and quantity. Since groundwater and surface water resources interact and affect each other, agencies generally try to coordinate management of those resources. Coordinated management of ground water and surface water resources is commonly referred to as conjunctive water management. If done carefully (with appropriate consideration of interactions between the two resources), transferring of water rights between parties can improve conjunctive water management. Transfer can be accomplished by sale or trade.

Agencies attempt to assure that groundwater pumping will not cause significant problems, such as are listed above. They commonly use proven equations or computer simulation models to predict the consequences that will result from continuing current pumping rates, or the pumping rates that would result if everyone that wants to use groundwater is permitted to do so.

Computer simulation models contain equations describing how groundwater levels and flows respond to groundwater pumping, changes in recharge rates, or changes in other hydrologic features, such as rivers or lakes. The models also contain estimates of aquifer parameters (such as hydraulic conductivity, effective porosity) and recharge rates, and the locations at which these occur. Computer simulation models are not used to predict the future, until they have been acceptably calibrated for the region of interest and have been proven to acceptably simulate what happened in the past.

Agencies frequently use properly calibrated simulation models to predict what the consequences will be of any increase in pumping rates. An agency might use a model after receiving a request from someone wishing to drill a new well, or increase pumping. If the model predicts that approving the new request will harm those already pumping (or other legal or environmental interests), the agency may deny the new request. This is a common appropriate use of a simulation model.

If the model predicts that continuing current groundwater pumping will cause significant regional problems, it might be the agency's responsibility to attempt to reduce groundwater extraction. Because the aquifer is not a uniform and homogeneous system, reducing pumping in one part of the region might cause more beneficial results than reducing pumping in another region. However, that does not

Figure 2. Discretization of study area into cells within a groundwater computer model (modified from Waddell et al., 1987; Gharbi and Peralta, 1994).