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# Groundwater-Surface Water Interaction: Implications for Groundwater Planning and Management

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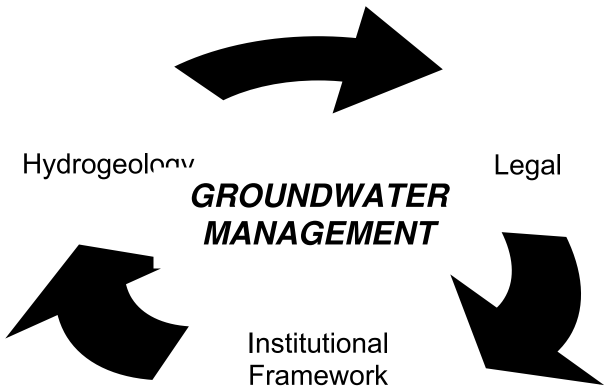
# 1.0 Introduction

Groundwater management combines elements of the hydrogeology of an area, and the legal and institutional framework of the state and region. Texas groundwater law and the statutory framework to manage groundwater are unique. The preferred method for groundwater management is locally organized groundwater conservation districts.




Groundwater planning and management must consider two hydrologic facts: (1) aquifer characteristics and uses vary greatly across the state and often across a district, and (2) the political boundary of a groundwater conservation district does not necessarily coincide with groundwater flow and the effects of groundwater pumping.

In 2005, the Texas legislature addressed these hydrologic management and planning issues by creating a framework for groundwater planning that focuses on a more regional basis, while acknowledging the importance and responsibilities of local groundwater management by groundwater conservation districts. This groundwater management area joint planning process requires groundwater conservation districts within specified groundwater management areas to work together to develop policy goals for groundwater resources within those areas.

The joint planning process requires that groundwater conservation districts adopt desired future conditions for the aquifers within their jurisdiction. The Texas Water Development Board then calculates the modeled available groundwater, which is the pumping that will achieve the desired future condition. Under the current process, groundwater conservation districts must consider nine factors before proposing a desired future condition. Among these factors are the impacts of the desired future condition on spring flow and other interactions between groundwater and surface water.

This paper introduces the technical aspects of groundwater-surface water interactions, and provides some examples of quantitative evaluation of impacts of increased pumping that are useful in groundwater planning and management.

# 2.0 Hydrogeologic Concepts

## 2.1 Regional Inflow/Outflow Relationships

A groundwater system is in equilibrium prior to development (prior to groundwater pumping for irrigation or other human use), as shown in Figure 1. In this condition, groundwater inflow equals groundwater outflow and no change in storage occurs over time. Inflows can include recharge from precipitation, recharge from streamflow, and inflows from adjacent basins (where applicable). Outflows can include discharge to surface water bodies (springs, streams and lakes), evapotranspiration through shallow groundwater vegetation and evaporation, and outflow to adjacent basins.

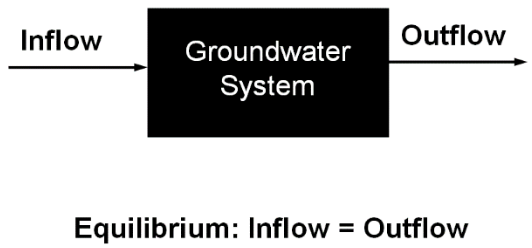



**Figure 1. Groundwater System Prior to Development (after Alley and others, 1999)**

Development of groundwater resources (i.e. pumping of wells) is an additional outflow component, and results in three “impacts” to the system 1) storage decline (manifested in the form of lowered groundwater levels), 2) induced inflow (generally manifested by increased surface water recharge or increased groundwater inflow from outside the area of interest), and 3) captured natural outflow (generally manifested in decreased spring flows, decreased stream baseflow, decreased evapotranspiration, or decreased groundwater outflow outside the area of interest).

The initial response to pumping is a lowering of the groundwater level or a “cone of depression” around the well, which results in a decline in storage. The cone of depression deepens and extends radially with time. As the cone of depression expands, it causes groundwater to move toward the well thereby increasing the inflow to the area around the well. If the cone of depression extends to a stream that is in hydraulic connection with the groundwater, the stream can act as a new source of recharge. Thus, the pumped well causes “induced recharge or “induced inflow” from that stream.

The cone of depression can also cause a decrease of natural groundwater outflow from the area adjacent to the well and acts to “capture” this natural outflow. If the cone of depression extends to a spring, the flow in the spring is reduced as the pumped well captures this portion of natural outflow. If the cone of depression causes water levels to decline in an area of shallow groundwater, evapotranspiration (ET) is reduced and the pumping is said to capture the ET. At some point, the induced recharge and captured outflow (collectively the capture of the well) can cause the cone of depression to stabilize or equilibrate.

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