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Dear Doug,

As requested, Dave Sumner and I reexamined an article by Trey Grubbs entitled *Analysis of long-term trends from a large spring complex in Northern Florida* as well as other information you've recently provided. You have expressed concern Trey's report is being cited by others to support the idea that consumptive water use in northeast Florida has adversely impacted the environmental health of springs in the Suwannee River basin. That conclusion is, in part, based on reported migration of a regional groundwater flow divide since its predevelopment location.

We must be careful to distinguish between historic and present-day potentiometric surface maps and the data that were used to construct them. As you know, potentiometric surface maps are interpretive and measured water level records are used to construct them, but there is a degree of subjectivity applied in their preparation. Accordingly, the precise location of the regional groundwater divide is subject to considerable uncertainty in older maps and in some areas of modern maps. This uncertainty exists because of the flat nature of the surface in some areas, as well as sparse water-level measurements in some areas or during some data-collection periods. This uncertainty increases historically. Therefore, it is difficult to accurately evaluate temporal movement of the divide and accurately quantify the magnitude of groundwater flow that may have been diverted eastward.

Despite this uncertainty, we feel it is likely that the regional groundwater divide moved westward as groundwater withdrawals increased in northeastern Florida. Support for these conclusions includes the following:

- Post-development water levels from wells and potentiometric surfaces based on these levels indicate that cones of depression, and other depression features associated with groundwater pumping, occur in Nassau County in northern Florida and in Glynn County and the area surrounding Savannah in Georgia. Historic groundwater-level data and pumpage history indicate that groundwater withdrawals have caused declines in groundwater levels regionally. These withdrawals have probably caused a westward expansion of the 'early' depressions in the post-development surface. These declines and the outward expansion of the cones of depression are consistent with concepts that a westward-moving divide is impacting the area of recharge, reducing groundwater head, and potentially causing declines in spring flow west of the divide.

- The most logical orientation of contour lines defining the predevelopment potentiometric surface in Duval and Nassau Counties in Florida, and in the coastal and near-coastal Georgia counties to the north is one in which the contours are roughly parallel to the Atlantic coast. This assumption is based on the fact that diffuse upward discharge to the Atlantic Ocean was the primary sink for the thickly-confined Floridan aquifer system in these areas during predevelopment conditions. This parallel-to-coastline configuration of the potentiometric contours in these areas is evident in the predevelopment potentiometric surface prepared by Johnston and others (1980). Comparison of the Johnston and others (1980) predevelopment surface with post-development surfaces shows a significant head decline in these counties, and that the divide migrated to the southwest.

- Groundwater withdrawals in coastal counties of northern Florida and southern Georgia always have been much larger than in the counties west of the divide. This is coupled with the fact that the Floridan aquifer system is thickly confined with low recharge rates in the eastern, coastal counties and is unconfined with relatively higher recharge rates in the counties to the west. It is unlikely that water levels fell at the same rate east and west of the divide, a condition needed to maintain the divide position during a transient post-development period (pre-1980).

- The western discharges in the Floridan caused by the Suwannee, Ichetucknee and the Lower Santa Fe Rivers are much more prominent than the eastern discharges in the form of leakage from the Floridan through confining layers to the St. Johns River and Atlantic Ocean. Referring to Sepúlveda's (2002) Mega Model report, it appears base flow from the upper Floridan to the three western rivers is approximately 10 fold greater than discharge to the Atlantic Ocean (compare Table 11 and figure 66). This suggests that the predevelopment groundwater divide was probably located east of the midway point between these two sinks under predevelopment conditions.

- Recent applications (in the slideshow you provided me) of the USGS Mega Model (Sepúlveda, 2002) to simulate predevelopment conditions appear to have retained boundary conditions from post-development simulations. Evident from the 'predevelopment conditions' simulation is that the effects of groundwater development extend to the northernmost portion of the model where the potentiometric contours are deflected westward. One concern we have in that analysis is that the Mega Model is being used in a manner for which it was not necessarily designed. This may have led to the inadvertent conclusion that the groundwater divide has not moved with the onset of groundwater withdrawals from pumped or artesian wells. Specifically, it appears that groundwater levels along the northern, lateral boundary (which are specified as model inputs and are therefore not simulated) for the predevelopment simulation are not based on a realistic approximation of predevelopment conditions along this boundary. Boundary conditions can greatly influence flow velocities and groundwater heads within a model area. An important aspect of specified head boundaries is that they provide an inexhaustible amount of water flow. Furthermore, the specified boundary heads appear to be based on post-development or more specifically, on average 1993-1994 hydrologic conditions that were affected by drawdown in the Atlantic coastal areas of Georgia and northern Florida. This reduces the capability of the model to simulate changes in groundwater level that result from changes in groundwater pumping. In other words, the simulated location of the predevelopment flow divide may have been erroneously delineated to a location nearly coincident with its post-development location by using post-development groundwater levels along the northern lateral boundary as input for the model. This problem is also evident when comparing model-simulated groundwater levels in Nassau and Duval counties under predevelopment conditions with hydrostatic measurements made in these same counties in 1910 (Sellards,1910). This comparison indicates that the model-simulated heads underestimated the measured values by 15 to 30 feet.

- Groundwater levels in the surficial aquifer layer of the original Mega Model were specified as model input, and reflected 1993-1994 hydrologic conditions. If this boundary condition was also used in the simulations of predevelopment conditions, then it could similarly reduce the ability of the model to simulate changes in groundwater levels and the flow divide location in response to changes in pumpage because the surficial aquifer heads used to map the water table reflected conditions much different from those of predevelopment.

- It should finally be noted that it does not appear that there has been significant movement of the flow divide since 1980. This conclusion is based on a comparison of the corrected location of the May 1980 flow divide. My understanding is that we've previously advised interested stakeholders, including SJWMD and SRWMD, that its position is static.

A fundamental problem in this discussion regarding a hydrologic analysis of the groundwater divide is that several parameters have not been adequately quantified. The appropriate tools for a hydrologic analysis are not currently available. The Mega Model was not designed to evaluate movement of a groundwater divide, specifically because this model only simulates steady-state conditions and thus ignores changes in aquifer storage. Accounting for changes in aquifer storage is the precursor for movement of the groundwater divide. A better approach for evaluating impacts of withdrawals to the system is to develop a regional-scale transient numerical groundwater model of the Floridan aquifer system with an active surficial layer and lateral model boundaries that are sufficiently far from the area of interest and are conceptually realistic. At a minimum, the existing flow model boundary conditions need to be evaluated to consider their sensitivity to the area of interest. For example, one could exchange a specified head boundary with a no flow condition to assess its impact on the system near the simulated areas of concern. Alternatively, cell-by-cell flows along the lateral boundaries of specified-head cells of the regional-scale model could be analyzed to assess the impact that changes in groundwater withdrawals have on flows along the lateral boundaries, thus allowing a more accurate estimate of the potential movement of the groundwater divide. Predictive uncertainty analyses were not conducted during development of the Mega Model to statistically assess confidence in the model data. Experience with groundwater flow models suggests that there can be a high level of uncertainty in these models, particularly in areas where calibration was performed with very little hydrogeologic data. Model predictions using a calibrated regional-scale transient model could be used to investigate the extent and transient movement of the historical divide. Furthermore, a calibrated transient flow model could be used to quantify relative impacts that different pumping centers have on divide movement and assess future withdrawal impacts on the groundwater divide.

References:

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If you have any additional questions or wish to discuss this further, please feel free to contact us.

Sincerely,

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