# Observations Regarding the Simulation of Monthly Stress Periods in the ESPA

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In my experience, simulation of a system where agriculture or evapotranspiration from native plants are dominant features requires the temporal discretization to follow a season cycle. This requirement increases when attempting to simulate stream-aquifer interaction, especially on streams systems driven by runoff with a relatively short peak such as runoff from snowmelt.

Simulations where there are numerous stress periods within a year is nothing new. While there are obviously some approximations made in how the vadoze zone is treated and the temporal distribution of stresses through the year, such theoretical limitations generally does not deter successful simulation of the system.

The following presents some examples of models where monthly stress periods were used without attempting to explicitly model the vadoze zone other than accounting for soil moisture in the root zone. These examples are models that I have personally worked on that are comparable in scope, setting and purpose than the ESPA. They were selected because I have some familiarity with the work, but there are many more and probably better examples, including the Spokane Valley - Rathdrum Prairie model mentioned by Bryce.

For reference, the ESPA model covers about 7.3 million acres of which about 2 million acres are irrigated. The Spokane Valley - Rathdrum Prairie model covers about 210,000 acres.

**Arkansas River Basin Model (1991):** This is a model of the Arkansas River Basin developed as a result of litigation between Kansas and Colorado in the US Supreme Court. The area covered is about 420,000 acres, most of which is irrigated. It is a single layer model, with depth to water generally in the 6 to 50 foot range. The system was simulated using monthly stress periods for the period 1945 until 1985. A preprocessor was developed to simulate agricultural practices. Recharge was calculated as a function of precipitation, applied surface water, pumped groundwater and crop demands. Conjunctive use was considered and the soil moisture balance in the root zone was tracked. Native ET as a function of depth to water was also simulated explicitly. The model was used to estimate pumping impacts on the Arkansas River.

**AWDI Model of the San Luis Valley (1992):** This is a model of the San Luis Valley that was developed as a result of the AWDI water export project. The purpose of the model was to evaluate impacts of pumping on the Rio Grande, Conejos and smaller streams. The modeled area covers about two million acres of which about 600,000 acres are irrigated. It is a four layer model as a result of a complex confined aquifer system which underlies most of the basin. The system was simulated using monthly stress periods for the period 1970 to 1987. Predictive simulations were made with seasonal (3 month) stress periods. A preprocessor was developed to simulate agricultural practices and estimate recharge based on applied surface water, pumped groundwater and precipitation, but soil moisture was not tracked. Depth to water varies from zero to hundreds of feet, but in irrigated areas are generally a few feet. Native ET as a function of depth to water was simulated as it is a dominant mechanism in the Closed Basin.

**Republican River Compact Administration Groundwater Model (2003):** This is a model of the Republican River Basin developed to settle litigation between Colorado, Kansas and Nebraska. The purpose was to evaluate impacts of pumping on the Republican River system. The model consists of a single layer covering about 20 million acres, of which about 3 million acres are irrigated. The system was calibrated using monthly stress periods for the period 1918 to 2000, and subsequently updated on an annual basis (currently 2006). Depth to water varies from zero to about 100 feet. Due to different types of available data for each state, recharge was calculated differently for each state, but generally involved a calculation based on irrigation demand which included accounting for soil moisture. The basin has no rivers entering it, so a critical component was developing a relationship between precipitation and recharge for both irrigated and non-irrigated lands.

What makes this example especially relevant is that the USGS built a model that attempted to simulate a single stress period for the irrigation season and another for the non-irrigation season, but after seven years of effort failed to adequately predict stream gains and losses. The RRCA model instead used monthly stress period, which significantly improved the results. While the shorter stress periods was just one of many differences between the two models, it was a significant factor in the ability to match observed gains and losses. Furthermore, even though the RRCA model was constructed by a committee of experts representing competing interests, the effort was completed in just thirteen months.

**Rio Grande Decision Support System Groundwater Model (2004):** This is a model of the San Luis Valley developed to support administration of the basin, including the Confined Aquifer Rules and currently the formation of Subdistricts. The purpose is to evaluate all aspects of the system including the effects of pumping on springs and surface streams. The area covered is approximatley two million acres, of which about 600,000 acres are irrigated. There are also extensive areas of sub-irrigated crops, as well as groundwater use by native species, both of which are explicitly simulated. The simulation uses monthly stress periods and approximately weekly time steps to simulate the period from 1950 to 2005. The surface flow system is explicitly simulated using the MODFLOW stream package. Surface streams ranging from the Rio Grande to small streams are represented. Some of the smaller streams enter the valley floor from the mountains, while others result from springs which are explicitly simulated. Agricultural drains and canals are also simulated as part of the surface water system. The aquifer system is represented using five layers to simulate a complex confined aquifer system. Recharge is calculated using a preprocessor that accounts for applied surface water, pumped groundwater, precipitation and soil moisture. Depth to water below the rooting zone is generally a few feet to tens of feet, but no delay is applied to recharge.

**Conclusions:** When modeling an area where there is a significant seasonal signature to stresses as a result of agriculture, native ET or variations in diversions, spring and stream flows, there are numerous examples that demonstrate that the use of stress periods on the order a month are not only practical, but generally result in a more accurate simulation.

Based on the above observations and Bryce's review of the native frequency of data for the ESPAM model, I therefore submit that the ESPAM model should henceforth use a monthly stress period.