MEMORANDUM

To: ESHMC
Fr: B. Contor
Date: 27 April 2007

Re: Recharge data and conceptual-model considerations for monthly stress periods.

This memo is in response to the ESHMC discussion of possible refinements in future versions of the ESPAM model, held on 8 March 2007 at Boise. IWRRI agreed to provide a summary of the native data format and conceptual-model assumptions for components of the well term, along with an estimate of the changes that would be needed to accommodate one-month stress periods. As part of this summary, I put together two simple spreadsheet analyses that suggest that the soil-moisture storage and vadose-zone dampening effects are not as great as I had supposed.

In the following table, the "native frequency" is the frequency of the data that are already on file with IWRRI. In some cases a footnote identifies a different frequency that could be obtained at additional effort. The "conceptual frequency" is the frequency that is inherent in the current calculation methods, either in ESPAM.exe, READINP.exe or in the pre-processing that was utilized in calibration of version 1.1. If this frequency does not include a one-month stress period, the current calculation methods and the modifications needed are discussed in text following the table. The "ESPAM Mod" column indicates components for which some modification to ESPAM.exe (other than selecting a different stress-period length on the first input screen) might be needed. These also are discussed in text following the table.

Table 1
Well-term Components, Data Frequency and
Conceptual Frequency

Component	Native Frequency	Conceptual Frequency	ESPAM Mod
Diversions - Snake River and Wood Rivers	Monthly	Any	

Component	Native Frequency	Conceptual Frequency	ESPAM Mod
Diversions - Other	Annual[1]	Any	
Returns	Monthly[2]	Any	
Fixed-point pumping	Monthly	Any	
Offsite pumping	Annual[3]	Any	
METRIC ET	8 to 32 days depending on satellite availability and cloud cover[4]	Six-month	Yes (soil-moisture storage and vadose-zone dampening)
Conventional ET - Crop Mix	Any[5]	Any	
Conventional ET - reference ET	Monthly[6]	Any	Yes (soil-moisture storage and vadose-zone dampening)
Perched non-Snake seepage	Daily	Any	
Tributary underflow	Long-term	Annual	
PRISM Precipitation	Monthly	Any	
Non-Irrigated Recharge	Monthly	Six-month	

Discussion of Specific Components

1. METRIC ET and conventional ET.

   The current calibration data are based on conventional methods, and METRIC remote-

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1 These entities represent a fairly small part of total diversions. Diversion volumes are generally obtained from paper copies of annual watermaster reports. In some cases the daily watermaster records are available on microfiche, from which daily data could be manually extracted. This would be an overwhelming task for the full 22-year period, however; there is typically a daily entry for each water user, for each district, in these records.
2 This should be double-checked with IDWR hydrology section
3 Daily values may be available from paper watermaster records, at significant effort.
4 A new Kc value is obtained for each satellite image, but these may be interpolated between dates and applied to daily reference ET values for daily ET estimates.
5 The data are available on an annual basis but very few fields are double cropped, so conceptually these data are compatible with any stress-period length.
6 Daily reference ET are available at reasonable effort.

sensing ET is proposed for stress periods after 31 April 2002. METRIC supercedes the need for irrigated lands data, crop mix data, ET adjustment factors and sprinkler percentages. It is anticipated that existing (conventional) data will be used for 1980-2001 of the new calibration data set, and METRIC will be used for subsequent years. Hopefully one or more years of overlap will be available to assess continuity of methods.

In the current ESPAM.exe and READINP.exe calculations, net extraction from ground-water irrigation is calculated from precipitation and ET. An extraction equal to ET is represented in the same stress period as the ET occurs, offset by a recharge from precipitation in the same period as the precipitation occurs. The separate processes of gross pumping and percolation return are not explicitly represented.

The current representation of incidental recharge from surface-water irrigation is somewhat more complex; all the diversions for a water year (even those that may occur in April) are applied as a recharge during the summer stress period, and all ET and precipitation are applied during the stress periods when they occur.

Two concerns arise in connection with using ET, diversion and precipitation data to estimate net extraction or net recharge. One is the delay of movement of water through the vadose zone, and one is the timing impacts of water stored in the root zone. Figures in the following sections rely upon hypothetical spreadsheet simulations, which have not been thoroughly checked and which rely on some simplifying assumptions.

2. Vadose-zone Dampening.

The vadose-zone spreadsheet simply applies pumping at the time of stress and applies percolation with a lag, then represents the net impact as the algebraic sum.

For stress periods shorter than six months, there are two basic vadose-zone deficiencies in the current methods. The first is that in reality, the stress on the aquifer from pumping occurs as soon as the water is pumped, while the offsetting percolation reaches the aquifer only after moving through the vadose zone. Figure 1 illustrates the conceptual timing of the actual stress versus the current conceptual model (ignoring soil root zone moisture storage) if the current model were to be applied to a one-month stress period, and Figure 2 illustrates a six-month stress period.

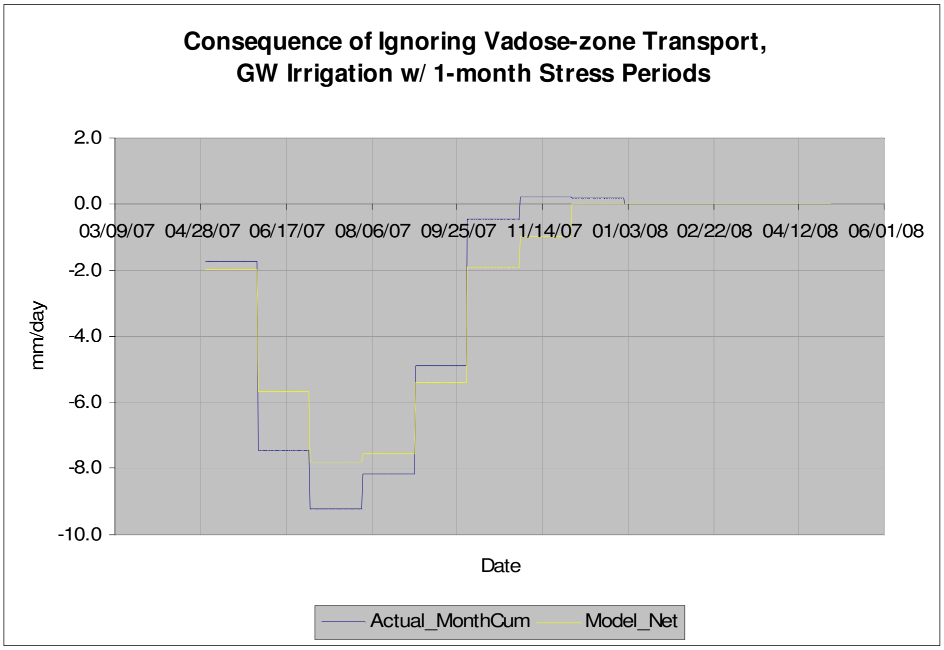

Figure 1.

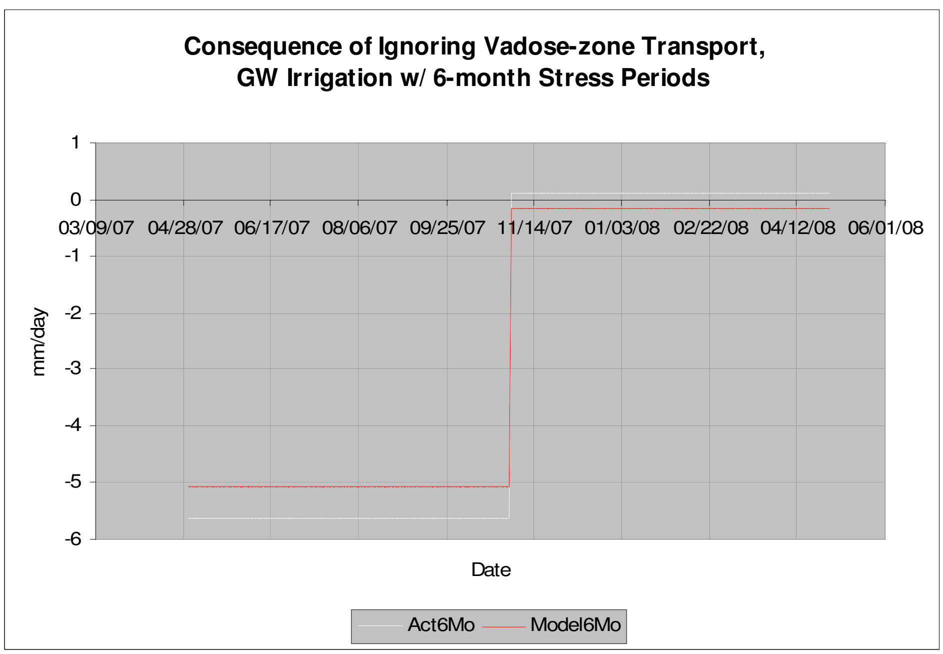

Figure 2.

The second deficiency is that current methods impute incidental recharge on surface-water irrigation as soon as the irrigation occurs (except for the delay of applying April's diversions in the summer period). Again ignoring soil-moisture storage, the vadose-zone implications for incidental recharge from surface-water irrigation are illustrated in Figures 3 and 4.

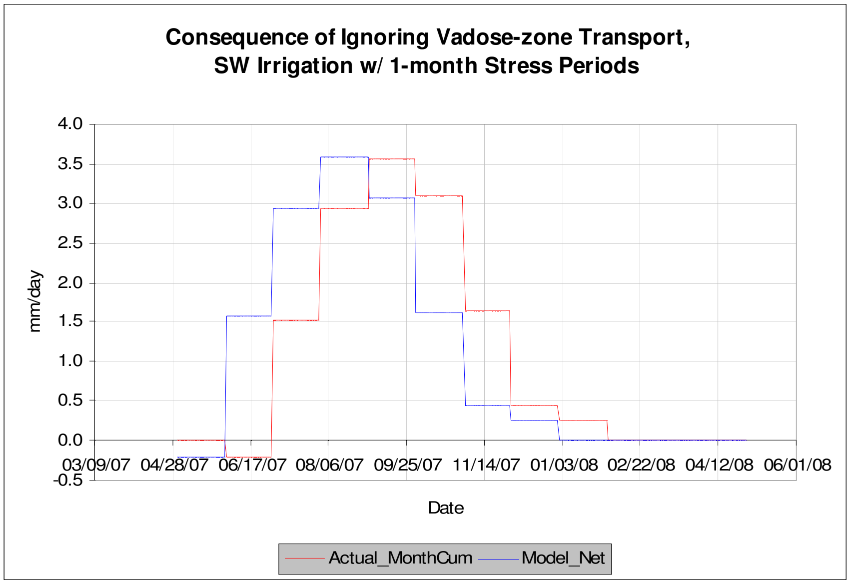

Figure 3.

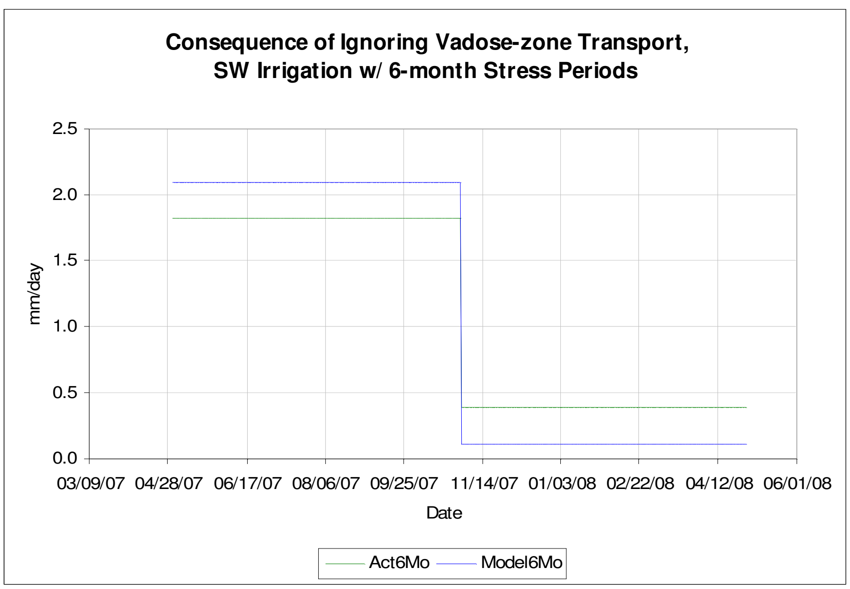

Figure 4.

3. Effect of soil-moisture storage.

   This effect is two-fold; irrigation does not commence until crops have used the water stored in the root zone, and percolation does not commence until the moisture deficit in the root zone is satisfied. The first effect is likely to be the most problematic because (except possibly for some center-pivot management schemes), irrigation depths are likely to be great enough to involve some percolation with every irrigation application. Figures 5 through 8 illustrate a simplified spreadsheet illustration of the soil-moisture-storage effect, ignoring the vadose-zone effect.

   The soil-moisture spreadsheet operates a daily water balance in the root zone. It starts the growing season assuming reasonable moisture content, and does not invoke irrigation until the existing soil moisture is depleted. Daily, if (Precip x effective fraction) - ET reduces the soil moisture content sufficiently, irrigation is called for. Irrigation is in depths large enough to saturate the root zone and result in some percolation.

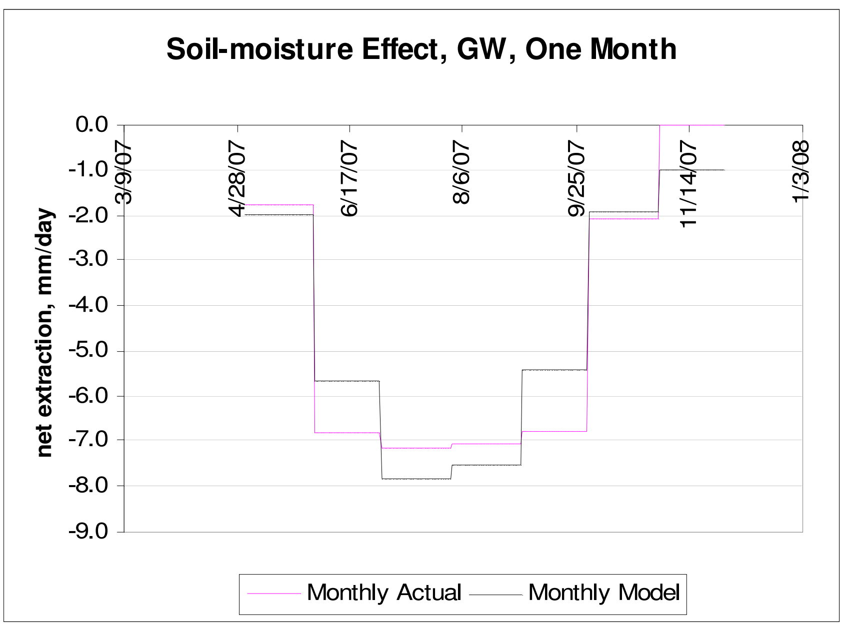

Figure 5.

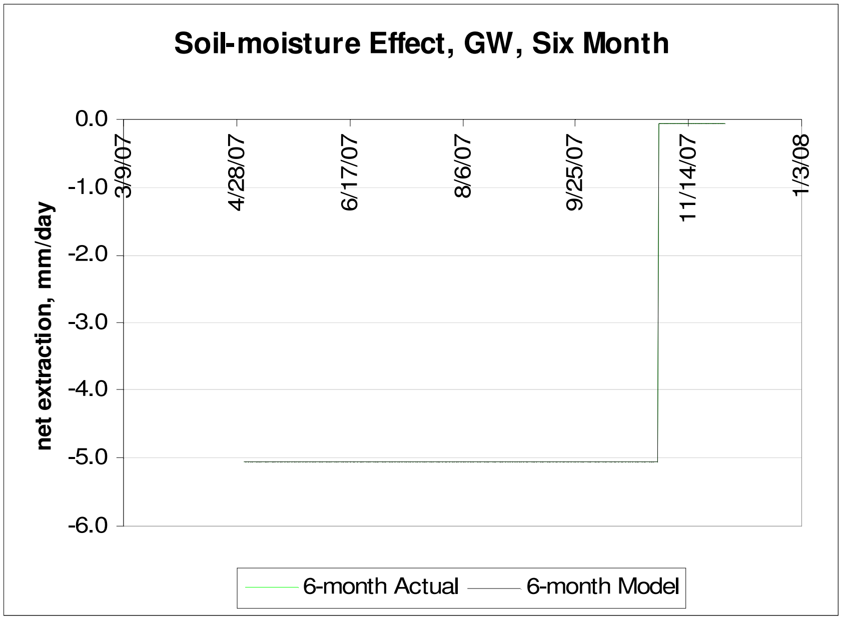

Figure 6.

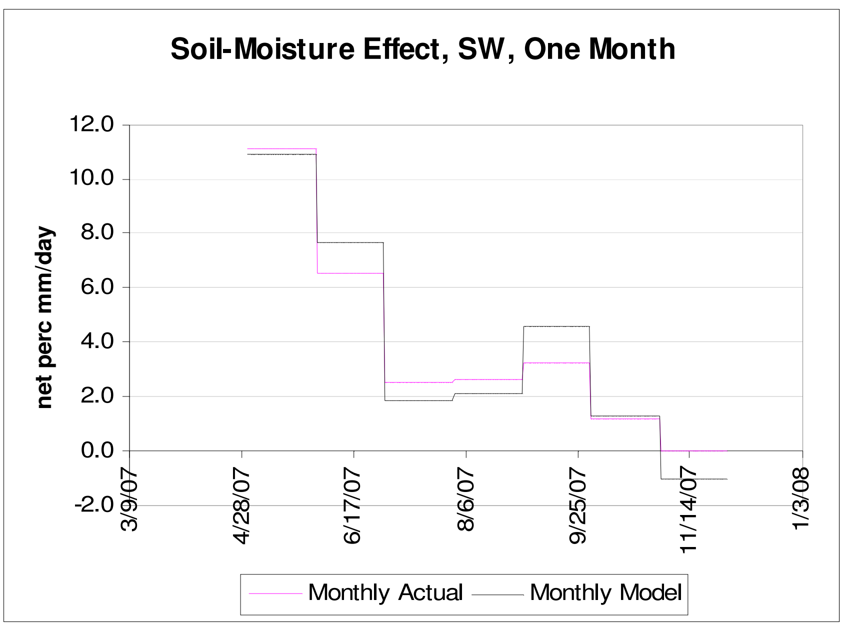

Figure 7.

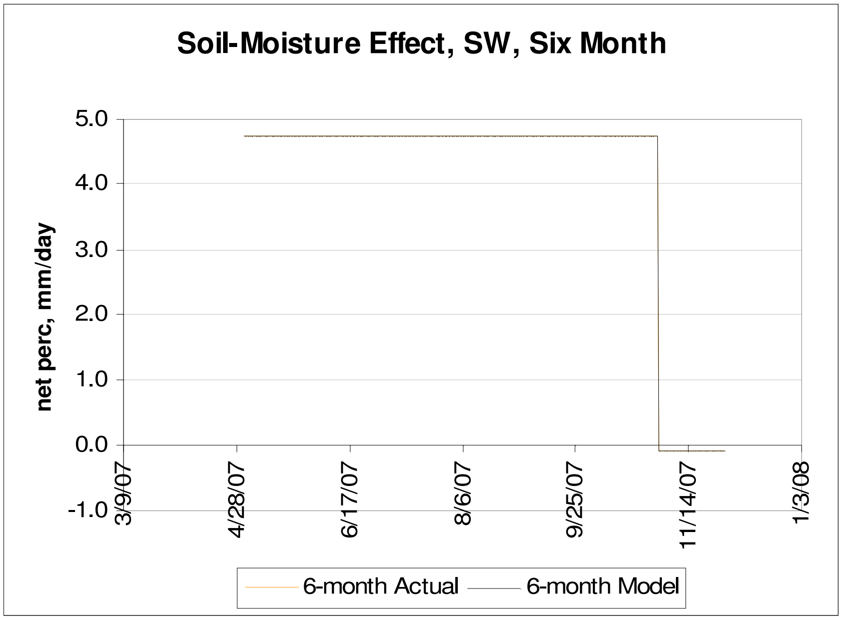

Figure 8.

It may be possible to address the vadose-zone issue using the new MODFLOW vadose-zone transport package, but this introduces additional parameters. It also possibly may be addressed by applying a delay to the data (as a function of depth to water) as was done in the Spokane Valley Rathdrum Prairie Interagency Aquifer Model, but this requires off-line calculations or adjustments to the GIS and FORTRAN recharge tools.

The soil-moisture-storage issue can probably only be addressed by modifications to the recharge tools. This could require a significant effort.

4. Tributary Underflow. The current conceptual model scales a long-term average value for each tributary based on the annual average discharge of an aquifer-fed stream (Silver Creek). Conceptually, the flow of a spring is a function of the head difference between the aquifer potentiometric surface and the control elevation of the spring. It is expected that a surface spring will have a control elevation near the head elevation of the aquifer and so the discharge of Silver Creek will be highly responsive to small head changes. Conversely, tributary underflow is conceptually a function of the *gradient* in the tributary; if saturated thickness is large relative to typical head changes, total transmissivity will vary little with changes in head. Because head changes in a tributary are likely to follow similar trends at up-gradient and down-gradient locations, it is expected that the change in gradient (and therefore the change in underflow) will be small relative to changes in aquifer water levels. For this reason, the shaping of tributary underflow in the current conceptual model is dampened significantly from the

observed Silver Creek variability.

Because of storage and dampening in the aquifer, and because tributaries have very different geometries, the current conceptual model only varies tributary underflow annually. Preliminary investigation of gradients in the Little Lost Valley suggests that the seasonal trend is very sensitive to the exact location of the location in the mouth of the tributary where the gradient is assessed. At one cross section, where upstream agriculture is dominated by surface-water irrigation, the seasonal trend of gradient is six months out of phase with another cross section ten miles away, which is down-gradient of an area dominated by ground-water irrigation.

One option for representing tributary underflow with one-month stress periods is to retain the current conceptual model of varying underflow only on an annual basis. Another would be to expend more resources trying to identify wells in each tributary that would allow individual assessment of the seasonality of gradient.

In either case, because tributary underflow is calculated off line and presented to the GIS recharge tool as a data table, modifying the conceptual model for tributary underflow does not require modifying either recharge program.

5. Recharge on non-irrigated lands. The current conceptual model applies an empirical relationship that depends on monthly precipitation and general soil types. Parameters were calibrated to match prior investigators' results and were verified with theoretical calculations based on soil storage capacity and interception of precipitation. To accommodate lower winter-time ET rates and temporal accumulation due to snow melt, all winter-time precipitation is accumulated and applied as if it occurred in February. Because monthly recharge depths are summed into six-month stress periods, it is immaterial whether the recharge actually occurred in February or at discrete melting events in January, February and March. The important effect is that winter-time recharge is proportionally greater than summer-time recharge, for a given precipitation depth.

   Applying the current conceptual model on a monthly basis may err if some rain events in November actually produce recharge, or if some recharge from melting events actually occurs in January or March.

   One possible way to adjust recharge on non-irrigated lands for monthly stress periods would be to apportion the calculated February recharge to all the winter months. This would be relatively straightforward.

   Another possibility would be to abandon the current method and calculate non-irrigated recharge in some other way. Dr. Jim Bartolino of the USGS used daily ET, precipitation and soil-storage calculations to estimate non-irrigated recharge in the

Spokane Valley - Rathdrum Prairie area. His method could be adapted to represent snow accumulation and melting and applied to the ESPAM model area.

Because non-irrigated recharge is calculated off-line and presented to the GIS recharge tool as a series of raster data sets, either of these approaches could be taken without modifying the GIS or FORTRAN recharge tools.