# Appendix 4-W

## Initial Heads Datasets for MODFLOW

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This appendix describes the processes used to create a dataset of distributed (cell-by-cell) head values used to define the initial condition of the COHYST 2010 MODFLOW groundwater model. The decision to begin the groundwater simulation period in the fall of 1984 (to be aligned with the water year) presented unique challenges as this was a period of dynamic change resulting from a regionally expansive increase in groundwater irrigation development. To address this challenge, several datasets were compiled to create a composite dataset to reflect regional, local, and hydrologic conditions and serve as a robust approximation of the initial condition of the unconfined aquifer system in the COHYST 2010 area.

## *Background and Issues*

Over the course of the COHYST 2010 project numerous approaches to defining initial heads were tested and discussed among the technical team. Tested approaches included variations on and combinations of the following:

1. using an unmodified 1979 water table surface directly
2. conditioning the 1979 water table surface with a “wind-up” or “warm-up” model (repetitions of 1985 conditions), with the final simulated head surface being used as the initial condition to the main model simulation
3. conditioning the 1979 water table surface with ancillary point data (observed water levels at various points in time, stream elevations)

The schematic in Figure 4-G.1 illustrates the different approaches and combinations considered through the modeling process.

The large regional scale of the model area and the complexity inherent in a system undergoing dynamic stresses made defining an initial condition that exactly matched water levels in fall of 1984 for every half-mile model cell an impossible task. The modeling team recognized tradeoffs with all approaches and, in particular, debated the merits and drawbacks of the use of a wind-up model. The main issue at play was identified as a “ramp up” effect in which simulated heads or baseflows adjusted over the first several years of simulation to an equilibrium condition away from an initial condition improperly matched with the hydrology and stresses of the model. The use of the wind-up model tended to minimize the early simulation adjustments in baseflows but also tended to introduce errors in the matching of historic water levels.

Using measured water levels to modify the spatially distributed, but generalized and interpreted, water table map also introduced issues. Compiling a more complete spatial coverage of point data required that water level measurements from different time periods be used. This, in turn, resulted in a mismatch where large seasonal or interannual variations occur at or among a set of observation wells and subsequent calibration errors.

The mechanism for creating or interpolating the initial head dataset was itself identified as a potential issue. The 1979 water table map was interpreted from a selected set of water level measurements, but was found to introduce significant errors into the model where the regionally interpreted surface did not match local variation. Addressing this required modifying and re-interpolating the surface using additional data. Performing a manual interpretation for each iteration and test was not a feasible option, so GIS interpolation operations were used. These operations required input from the user regarding the weighting of interpolation points and the space over which to apply the weight. By removing more or fewer points derived from the 1979 water table map, and at varying distances from the observation points being used, the influence of an individual observation point could be adjusted. Using an automated interpolation approach such as this, however, can lead to errors as well in places where either the 1979 water table points were removed to give weight to the observation points or where the 1979 water table points failed to capture local variation. This situation is illustrated in Figure 4-G.2. This error results in an early simulation adjustment as an erroneously high (or low) water table adjusts to an intervening boundary condition. This issue was addressed, although not entirely eliminated, by including perennial stream elevations as ancillary data to guide the interpolation.

The COHYST 2010 modeling team eventually settled on an approach that simplified data processing and attempted to minimize errors that would significantly affect model results that directly related to the purposes for which it was being built. Recognizing that any initial head dataset would introduce some errors to the model, but that further adjustments to head and baseflow hydrographs were largely absent after the first 5 years of simulation, a dataset was created that approximated head conditions in October 1984 using perennial stream elevations, measured October 1984 head elevations from the quality-controlled head calibration dataset, and the 1979 water table map elevations. The wind-up model approach was abandoned and instead the 1990-2005 model simulation period became the sole focus of calibration, effectively making the 1985-2000 time period a wind-up period within the main model. The process used to build this dataset is described in further detail in the following sections.

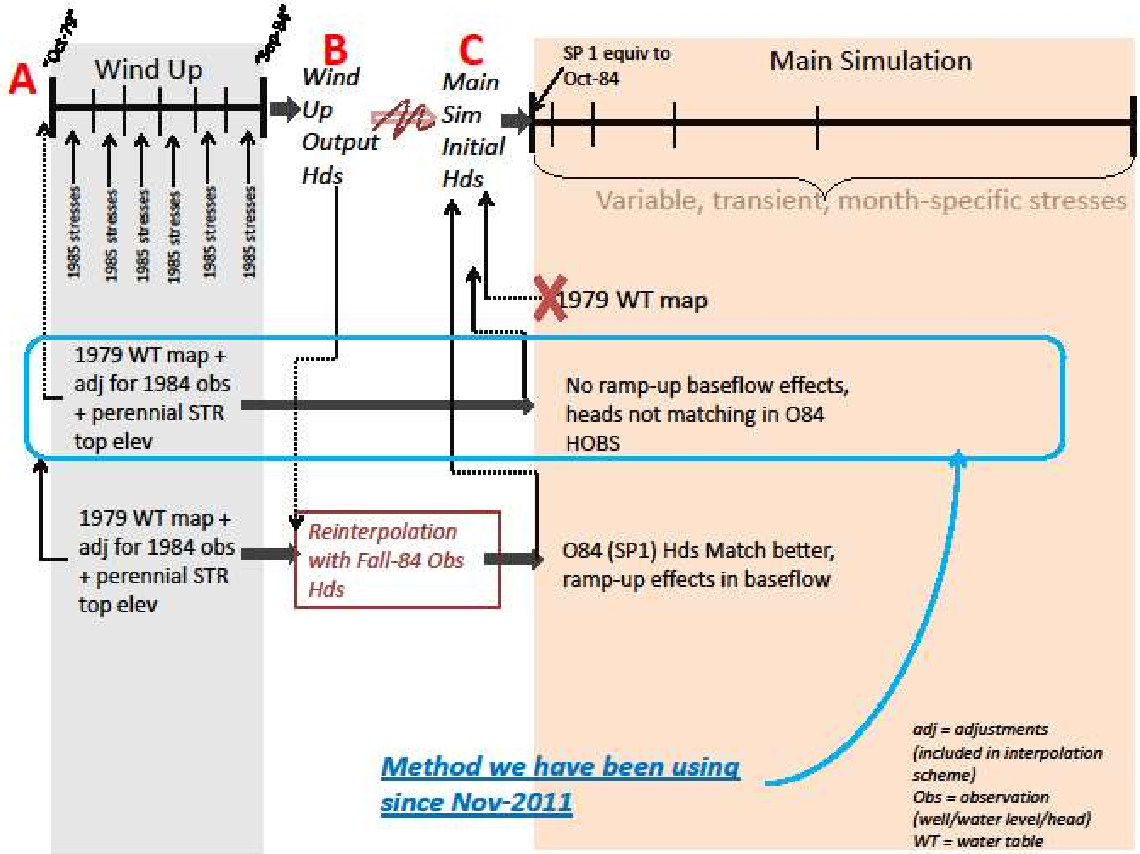


Figure 4-G.1 – Approaches Considered for Initial Head Definition in the COHYST 2010 Groundwater Model Development Process

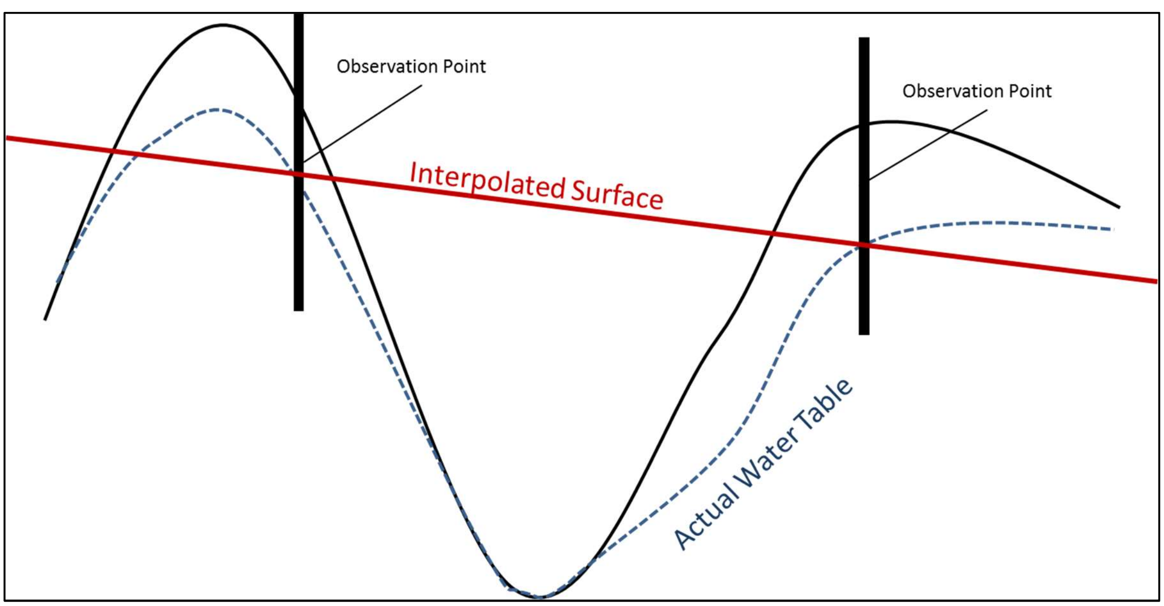


Figure 4-G.2 Illustration of Potential Errors in Initial Head Dataset Resulting from Interpolation Processes

## *Data Sources*

Development of the initial heads dataset relied on three main data sources:

1. The 1979 statewide water table map (UNL-CSD, published via the web at http://snr.unl.edu/csd-esic/download/geographygis/stp/wtable79_stp.zip, 6/12/2013)
2. Water level readings from observation wells in the COHYST 2010 area for the fall of 1984 (available from the USGS via their NWIS web interface). The processing of these data is discussed in further detail below.
3. Elevations of perennial stream and river channels as represented in the model

The process also relied on a corrected version of the 10-meter DEM (described in Section 4 and Appendix 4-B) and the rectilinear model grid on which the groundwater model and other COHYST 2010 components were based (Section 3.2).

## *Process*

### 1979 Water Table Map

The 1979 water table contour map is the only statewide (and thus model-wide) coverage of interpreted water levels as a continuous spatial dataset. This dataset provides the basis for defining an initial condition for the model areas where no other information exists for the fall of 1984. Because several data sets are to be merged and interpolated using GIS operations, the 1979 water table contours were processed into different formats. This involved several steps:

1. Interpolate the 1979 water table contours to a raster using the "Topo to Raster" interpolation tool in ArcGIS 9.3 for the full rectangular model grid (active and inactive cells) to reduce edge effects in subsequent operations
2. Extract the values from the 1979 water table raster to points at the centroids of the model grid cells (again all active and inactive cells)
3. Apply a 3-mile buffer to remove all 1979 water table points near the perennial stream point dataset (described in a following section)
4. Apply a 3-mile buffer to remove all 1979 water table points near the Fall 1984 observation points
5. Select every 4$^{th}$ remaining 1979 water table point by row and column (example expression for use under 'select by attributes':

    ((ROW+ COLUMN)/4)- (round((ROW + COLUMN)/4,0)) = 0 AND

    ((ROW- COLUMN)/4)- (round((ROW - COLUMN)/4,0)) = 0

These steps reduce the density of total points and remove all points around the other datasets for the purpose of balancing the effect of each dataset in the final composite interpolation.

### Fall 1984 Water Level Observations

A selection of measured water levels at observation wells for the fall of 1984 was used as a means to incorporate changes in water levels between 1979 and 1984. Several criteria for selecting and using these points were tried during the model development process. The adopted method used the October 1984 water level measurements from the head calibration dataset. This maintained consistency with model targets and took advantage of a dataset created through extensive review. There were 233 sites in the head calibration dataset with water level measurements in October 1984. Of these, 232 were used as it was found that the measurement for October 1984 at USGS site 41064310573401 was erroneous and was excluded from the process.

## Perennial Stream Elevations

The channel elevations of perennial streams was incorporated into the initial heads development process based on the general assumption that continually flowing streams result from groundwater contributions and that such contributions arise from the intersection of the water table with the land surface at or near a stream channel.

The extent of perennial stream reaches as defined in the NHD (section 4.2, appendix 4-B) was used to select the COHYST 2010 model grid cells containing stream (STR) cells. The elevation of the channel top as defined in the model (STOP) was used as the parameter of interest. The source of these STOP values was the 10-meter DEM cell statistics, described further in Section 7 and related appendices.

## GIS Operations

The three datasets (filtered/buffered 1979 water table map, October 1984 point measurements, and perennial stream channel elevations) were merged into a single point dataset. This point dataset was then used as input to an inverse distance weighting interpolation process with a search radius of 2 miles and a minimum of 2 points included. The resulting raster dataset was then mapped to the centroid of grid cells to yield a complete initial head array. This array is contained in a shapefile **COHYST2010_InitialHeads_r22a_18_23.shp** and text file (formatted as a MODFLOW array) **COHYST2010_InitialHeadsArray_r22a_18_23.txt.**