Methods of Trend Analysis

Trends in time-series data were analyzed using simple linear regression. Hydrologic data were reduced to a single value for each year of the selected time period. The annual series of values then was related to time by an equation of the form:

$$Y = B_0 + B_1(T)$$

where

Y = a hydrologic variable, such as water level;

T = time, in years; and

B_0 and B_1 = least-squares estimates of the intercept and slope coefficients.

The slope, B_1, indicates the average rate of change in the hydrologic characteristic during each year of the time period. If the slope is significantly different from zero, the trend in the hydrologic variable is equal to the magnitude of the slope and the direction of the trend is defined by the sign of the slope: increasing if the sign is positive and decreasing if the sign is negative. If the slope is not significantly different from zero, there is no trend in the hydrologic variable.

One advantage of this method of trend analysis is that it is easy to apply to a large number of sites. A disadvantage is that it can fail to detect trends that are nonlinear but still monotonic (generally in one direction). Other methods, such as the Mann-Kendall test, could be used to detect trends that are monotonic but not necessarily linear, but these only indicate the direction, and not the magnitude, of significant trends.

The coefficients B_0 and B_1 were estimated for each selected hydrologic characteristic individually at each measurement site. These sites included wells, groups of wells, springs, and streamflow-gaging stations.

TIME-SERIES GRAPHS

In order to illustrate trends at individual sites, values of the hydrologic variables were plotted by time. The trends were shown by plotting a locally weighted scatterplot smooth (LOWESS) through the data (Chambers and others, 1983). The smooth is intended to show the natural trend of the center of mass of the data, not necessarily the trend slope determined by the regression model. A LOWESS smooth that is approximately linear implies that the regression slope is a good estimate of change throughout the time period used for trend analysis. Curves in the LOWESS smooth indicate short-term fluctuations within the time period. The shape of a LOWESS smooth can be affected by the tension, or *f*-factor, used in the weighting function. For this report, smooth lines were computed using an *f*-factor of 0.5, which means that 50 percent of the annual time-series data was used to determine the LOWESS plotting position for each year.

MAPPING TREND RESULTS

Results of the trend analyses for each hydrologic characteristic were plotted on maps of the study area in order to assess the regional distribution of trends. Trends were categorized by ranges of magnitude. In all cases, one of the selected ranges was symmetric around zero. Categorization of trend results was based on the magnitude and statistical significance of the slope coefficient. The actual magnitude of the trend was used if the significance level was less than 0.25. If the significance level was greater than 0.75, the trend was considered to be zero. If the significance level was between 0.25 and 0.75 and the slope was small, the trend was considered to be zero; however, if the slope was large, the trend was considered indeterminate and was not included on the map.