This file contains problem sets for Chapters 2 through 9 of Estimating Groundwater Recharge. These problem sets are still under construction and were last updated on August 3, 2010. Problems for all chapters should be available by October 2010.

Chapter 4

Problem 4.1
Determine streamflow duration curve and base flow index (BFI) for USGS gauging station 01540200, Trexler Run near Ringtown, PA.

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A) Go to the USGS website for streamflow data:
   http://waterdata.usgs.gov/nwis/sw
   select "Daily data"
    for "Choose Site Selection Criteria" select "Site Number"
     and hit submit
    for "Select sites" enter Site Number 01540200
       "Site type"  select Stream
       "Available parameters..."  select Streamflow ft3/s or
                                  Streamflow m3/s
    for "Choose Output Format" select date range of 1963-09-01 to
         1981-03-31
         select "Tab-separated dat" Save to file.
         click submit
    Using a spreadsheet, calculate mean daily flow for the period of
     record.
    Calculate the flow duraction curve according to Equation (4.5).
    Determine Q0.1, Q0.3, and Q0.5.
    If base flow is equivalent to Q0.5, what is the BFI?

B) Go to the USGS website for streamflow statistics:
   http://streamstats.usgs.gov
   read through Streamstas description, limitations, definitions,
    and user instructions.
    Click on "State Applications", and then select Pennsylvania
    (we can actually access NWIS directly from stream gauge summary
    page in streamstats, but I don't see any easy way to download
    into spreadsheet - so let students go to nwis first)
   Zoom to Place Name
    on new window, enter Trexler Run and select Pennsylvania and
     click submit query
    click Zoom and the stream and gauge location are displayed.
    From menu bar select "Gaging Station Information", then
     place cursor over gauge symbol on map and left click.
     Window with stream statistics will be displayed.
     Compare estimates of Q.1, Q.3, and Q.5 in this window with
       those calucated in problem 4.1A.
     Convert Q0.1, Q0.3, and Q0.5 from volumetric flow to inches
      or mm per unit drainage area of stream.  Next, convert
      these numbers to percentage of annual average precipitation.
     Locate any additional sources of data for this watershed.
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Problem 4.2
Apply and analyze streamflow hydrograph separtion methods for USGS gauging station 01540200, Trexler Run near Ringtown, PA by using the Web-based Hydrograph Analysis Tool (WHAT).

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 Access the WHAT web page at:
  http://cobweb.ecn.purdue.edu/what/
  Select 1) WHAT Using USGS Daily Flow Data
          i) I will enter USGS gaging station number
  Enter station number 01540200 and select i
    Select "local minimum" option
  From the results, determine the base flow index (BFI) for
    the entire period of record, for each year based on average
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annual flow, for the month of May over the entire period of record, and for the month of May for each year.
Draw a hydrograph of daily total flow and base flow for one year
Rerun hydrograph analysis using One Parameter Digital Filter and Recursive Digital Filter. Calculate BFI for entire period of record.
Compare and discuss the different estimates of BFI.

Problem 4.3
Apply and analyze streamflow recession curve displacement method for USGS gauging station 01540200, Trexler Run near Ringtown, PA.

Download the USGS programs Recess (for calculating the Recession Index, K) and Rora (for estimating recharge) from:
http://water.usgs.gov/software/lists/groundwater
Following directions in problem 4.1, download streamflow data in cfs for station number 01540200 Trexler Run near Ringtown, PA
Run program Recess to determine the Recession Index; set number of days in recession to 21.
Run Rora to determine base flow on a monthly and annual basis by using the value of Recession Index determined with Recess. Note, the drainage area for the gauging station must be added to file station.txt for Rora to run.
Perform some sensitivity tests:
How sensitive is the value of calculated Recession Index to the number of days that are specified for the recession period?
How sensitive are estimates of base flow to values of Recession Index?
How do estimates of baseflow and BFI compare between the Recession curve displacement method and hydrograph separation methods?
Referring back to the flow duration curve calculated in Problem 4.1, what recurrence levels do the different BFIs determined in these examples reflect? Would this produce a useful range of using Qxx as an estimate of BFI?

Chapter 8

Problem 8.1
Using temperature profiles to estimate vertical flux within the geothermal zone.

In the 1970 and 1980s salt beds in the Paradox Basin of south eastern Utah and south western Colorado were considered for storage of hazardous waste by the U.S. Department of Energy. Numerous geologic and hydrologic studies were undertaken to study the salts. The most favorable locations identified were anticlines where salts beds covered a depth interval of up to 4,000 m. The following table contains temperature measurements at several depths in a borehole in the Salt Valley anticline of eastern Utah (Sass et al., 1983).

Following the approach of Stallman (1967) (as shown in Figure 8.4b) plot the data with dimensionless depth (z/L) on the y axis and dimensionless depth minus dimensionless temperature (T(z) - T0)/(TL - T0) on the x axis, where L is thickness of the measurement interval, z=0 at the top of the interval, and T0 and TL are temperatures at the top and bottom of the interval, respectively.

Determine the value of B in Equation (8.4) that most closely matches the plotted data. The function, f, in Equation (8.4) is given as:
f(B, z/L) = [exp(Bz/L) - 1]/[exp(B) - 1]

The best fit value of B can be determined through visual inspection or by application of a formal parameter estimation routine, such as PEST.

The interval over which the temperature measurements were made is within the unsaturated caprock. Thermal conductivity is estimated at 3 W/mK on the basis of data provided in Sass et al. (1983) and Rush et al. (1980). No data on volumetric water content are provided, but for purposes of this exercise assume a value of 0.02. Determine values of vertical velocity and flux for the best-fit value of B.

Table of temperatures measured in well DOE6 (Sass et al., 1983)

Depth (m)	Tempurature (C)
30	15.15
35	15.28
40	15.45
45	15.6
50	15.78
55	15.99
60	16.16
65	16.35
70	16.52
75	16.73
80	16.87
85	17.12
90	17.32
95	17.49
100	17.7
105	17.9
110	18.14
115	18.29
120	18.51
125	18.73
130	18.96

Rush, F.E., Hart, I.M., Whitfield, M.S., Giles, T.F., and D'Epagnier, T.E., 1980, Results of hydraulic test in wells DOE-1, 2, and 3, Salt Valley, Grand County, Utah, U.S. Geological Survey Open-File Report 80-205.

Sass, J.H., Lachenbruch, A.H., and Smith, E.P., 1983, Temperature profiles from Salt Valley, Utah, thermal conductivity of 10 samples from drill hole DOE 3, and preliminary estimates of heat flow, U.S. Geological Survey Open-File Report 83-455.