CEE7430 Homework 2: Storage Yield and Reservoir Reliability

Due: 1/22/09

Reading:

- Feynman: Cargo Cult Science
- Linsley et al., (1982) sections 14.1, 14.2, 14.3, 14.7, 14.8.
- Loucks et al., (2005) chapter 7, sections 8.1, 8.2 and 8.3

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1. We all need to have some fun, while learning. Write a summary (1/2 page or less) of key points from Feynman (1985) Cargo Cult science (available at http://www.gorgorat.com/).

2. View the 2001 Langbein Lecture by Stephen Burges entitled: "Hydrologic Variability and its Societal Importance" and available as a webcast at: http://www.agu.org/meetings/sm01/webcasts/burges.html. Write an abstract summary (1 page or less) of this. This lecture is in place of class on 1/20/09 when I will be out of town.

Monthly Naturalized Streamflow from the Colorado River System is available from: http://www.usbr.gov/lc/region/g4000/NaturalFlow/current.html. Click on the current natural flow data link. This data is described at the link under documentation, where the presentation: http://www.usbr.gov/lc/region/g4000/NaturalFlow/NaturalFlowAndSaltComptMethodsNov05.pdf slides 3 and 4 give the station numbers corresponding to control points on the Colorado River. For this exercise use the total Natural flow at Lees Ferry, site 09380000.

3. Statistical characterization of the data. Use this data to calculate and plot the following
   - Time series of the original data
   - Monthly Mean, Monthly Variance, Monthly Skewness (moments)
   - Histogram of the flow in each month
   - Autocovariance and autocorrelation functions.

4. Develop a standardized time series defined as

   $X_t=(Q_t-m_j)/S_j$

   where m_j is the mean for the month and S_j the standard deviation for the month of flow Q_t. Plot the standardized time series (as a single series with all months in a single sequence). Plot the autocorrelation function for the standardized time series.

5. Deterministic Storage-Yield curve using the sequent peak procedure. This was covered in CEE6400 (for some of you) and is also given below. Given a time series of reservoir inflows a computation based on mass balance may be used to determine the reservoir storage required to meet a certain specified yield or demand. Let R_t denote the release volume at each time step t, and Q_t denote the inflow volume at each time step t. Assume a reservoir starts full, with storage depletion $K_t = 0$. Then the depletion of storage at each time step is:

$K_t = K_{t-1} + R_t - Q_t$ (1)

If K_t from this equation is negative it means inflow was larger than release plus available unfilled storage capacity so the reservoir fills up in that time step and the excess water is released as spill, and K_t reset to 0 (a reservoir with negative depletion is impossible). It is common to specify release R_t as a constant fraction of mean inflow

$R_t = y\overline{Q}$

where y is a fraction between 0 and 1. For a given series of inflows the maximum of all K_t is the storage, S, required to sustain the specified releases or yield fraction. A storage-yield curve is constructed by calculating S for a series of yield fractions, e.g. y = 0.1, 0.2, ... 0.9, 0.95 and plotting $y\overline{Q}$ versus S. Note that equation (1) assumes that quantities R, Q and K are in consistent and summable units. (This is the case here where flow is in MAF. However if the flow is a rate (e.g. ft^3/s), to be precise, it should be converted to monthly flow volumes for this calculation.)

6. First Stochastic Streamflow model. An AutoRegressive order 1 (AR1) model for the standardized streamflow time series may be written

$$X_{t+1} = \rho X_t + V\sqrt{1-\rho^2}$$

where ρ is the lag 1 correlation of the standardized streamflow series and V ~ N(0,1). Develop a model to simulate standardized X_t. Then unstandardize the simulations using

$Q_t = X_t S_j + m_j$

to get simulated streamflow for each month. If any flows turn out to be negative, set them to 0. Generate 20 series the same number of years as the historic data. Use boxplots to compare the monthly mean, standard deviation and skewness of the modeled and observed streamflow time series.

7. Use the sequent peak algorithm to estimate the storage required to assure a specific yield from each generated time series as was done at step 3 above. Plot this information in a storage-yield plot that shows:
   - The deterministic storage yield function
   - The stochastic storage yield function as points indicating the uncertainty associated with the deterministic storage-yield estimates.

8. A reservoir reliability plot has on the X axis the probability that storage required to meet a specified yield is less than a given value S. The Y axis has the storage value S. This is commonly plotted for specific yield fractions. Prepare a reservoir reliability plot based on these simulations for yield fractions y=0.5, 0.7 and 0.9.