GEOG 3511 – HYDROLOGY -- Review for Final Exam

The final exam will be similar to previous exams, consisting of fill-in-the-blank or short-answer questions, plus one or two questions requiring a 1/2 page answer; a few questions may require calculations. Focus on material covered in lectures- anything presented in lectures is fair game, including points discussed on handouts. The following topics are listed in the order discussed in class.

I. Basic Hydrologic Concepts

- review the water balance equation (eqn. 2-10); know which terms are negligible; know how to apply this equation to various hydrologic problems, e.g. estimation of evaporation;
- <u>don't</u> worry about the rest of the material presented in Chapt. 2 (duration curves, model errors, measurement errors or residence times).

II. Global Climate and Regional Hydrology

- know general aspects of the energy budget (for example, how is the energy received at the earth's surface used in the hydrologic cycle, how is it re-distributed?); be able to explain the latitudinal distribution of radiation, precipitation, and evapotranspiration (Figs. 3-7, 3-18, 3-23);
- review lecture notes discussing the historical and spatial variability of precipitation and streamflow (these topics are discussed on pp. 73-83 in the text; however, you should focus on lecture notes);
- know the basic points about material transport (dissolved load, suspended load, bed load);
- <u>don't</u> worry about the section covering climate, soils and vegetation, pp. 83-90.

III. Precipitation

- review the steps involved in forming precipitation (uplift, adiabatic cooling, fig 4-7; Appendix D);
- make sure you understand the 3 basic meteorological situations that cause precipitation (frontal convergence, convection, and orographic uplift, pp. 95-101); review processes associated with the movement of warm and cold fronts (Figs. 4-1, 4-2).
- be able to list some of the problems involved in rain gauge measurements;
- <u>don't</u> worry about the many methods for making areal estimates of precipitation (pp. 118-130) or discussion of gauge networks (pp. 130-135);
- review the material on extreme rainfall, including relation to storm types, probable maximum precipitation (pp. 146-153);
- review class notes on cloud seeding experiments in Colorado (what were the basic conclusions?);
- <u>don't</u> worry about precipitation quality (pp. 162-164).

IV. Snow

- be able to list conditions required for snow formation; be able to describe the 3 processes of snow formation (especially vapor diffusion, which is not explained in much detail in the book);
- know the processes of snow metamorphism, particularly the formation of depth hoar;
- review techniques for measuring snow and SWE; how/why does SWE vary?
- understand the basic components of the snowmelt energy balance (pp. 190-203), and be able to describe how environmental conditions (aspect, tree cover, relative humidity, etc.) affect various terms; know what the various terms in the turbulent transfer equations represent; you should be able to do a latent-heat or sensible-heat flux calculation, similar to the ones done in class; make sure you understand the relation between SVP, T and RH.
- be prepared to answer a general question about conditions leading to high melt rates (see pp. 202);
- <u>don't</u> worry about the material from pp. 204-218.

V. Water in Soils

- be able to define various soil properties, such as bulk density, porosity and hydraulic conductivity, and various soil moisture states, such as saturation, field capacity and wilting point.

- make sure you understand processes of flow in unsaturated soils (Darcy's law), as well as processes involved in infiltration (p. 227-257). How do various soil properties such as hydraulic conductivity and soil-moisture tension vary with moisture content, and why? Review the derivation of the Green-Ampt model of infiltration (hopefully class notes are clear; if not see pp. 253-255).

- the lab exercise in which you modeled infiltration should have improved your understanding of the infiltration process. If not, review the lab and try to extract the important points (also see Fig. 6-27);

- be able to answer a general question regarding problems resulting from spatial averaging of surface topography and soil characteristics.

- don’t worry about material from pp. 260-270.

VI. Evaporation

- be able to summarize the approaches for estimating evaporation and evapotranspiration (e.g. water balance, energy budget, pans, lysimeters, mass-transfer equations), and discuss their differences;

- be prepared to answer questions regarding the "mass transfer approach", e.g. why is it used? how is a mass transfer equation developed? what does the mass transfer coefficient represent? Hopefully class notes are clear; if not, see pp. 277-280.

- why was the Penman equation developed? why is this called a “combination” equation? (pp. 285-87)

- please read the discussion of transpiration processes, p. 294, and the section on modeling transpiration, pp. 295-99; focus on basic concepts, particularly the discussion of leaf conductance and canopy conductance; don’t worry about the details of the equations.

- review lecture notes on effects of vegetation change on runoff and floods (Fig. 7-18).

VII. Stream Response to Precipitation

- general comments: I suggest you stick very tightly to the lecture notes. Chapter 9 in the book contains a lot of material that I did not cover in class, plus it is organized very differently from the way I presented it. Specific sections in the book covering these topics are as follows:

- make sure you can explain the differences in hillslope runoff processes (HOF, DOF SSSF); if points made in lecture are not clear, see pp. 408-413. Don’t worry about material from p. 414-423; however you might want to read sec. 9.2.4 summarizing these processes.

- review lecture notes discussing differences between runoff from hillslopes and runoff in large basins (see Fig. 9-3).

- Review notes on drainage basin properties; you should be able to define *drainage density* and draw the basic relations between stream order, numbers of streams, and stream length (Horton ratios, Fig. 9-36). On the basis of the lab exercise can you explain how network properties might vary with climate or some other environmental variable?

- please read the section on event flow volume, pp. 396-399, and be able to list several reasons why runoff from identical precipitation events may be different. I may ask you to convert a volume of runoff (in cubic meters) to a depth (in centimeters), knowing the drainage area (in square kilometers) (refer to the previous lab exercise where you did this for the Yampa River basin).

- review the steps and assumptions involved in flood frequency analysis; the book explains statistical models and techniques in Appendix C, but the explanation is quite long, thus I suggest you rely on lecture notes (pp. 506-08 in Chapt. 10 also discuss flood-freq. analysis; see Box 10-8). Important points: why is this method used? What’s involved? What are the limitations? If I gave you the mean and std. deviation of a sample of floods, could you plot the flood frequency curve? I can envision 20 pts. related to this method, so make sure you understand it.

- we did not discuss the many methods used to model runoff, pp. 443-456; you can ignore this material.

- review lecture notes on open-channel flow; this material is discussed in the book on pp. 424-427, and in appendix B, pp. 548-551.

Additional thoughts:

- we have used three different terms for vapor pressure; these are defined as follows

  e_a: vapor pressure at some height above the surface (ground, snow, lake or vegetation);

  e_s: vapor pressure at the surface;

  e_{sat}: saturation vapor pressure, i.e. vapor pressure at 100% RH; could be with respect to the reference height "a" or the surface;

- example: the turbulent transfer equation for latent heat flux contains the term (e_a - e_s), which is just the difference between the vapor pressure at "a" and the vapor pressure at the surface.

- the mass transfer equations contain the same variables, but reversed, i.e. (e_s - e_a); I assume that this is done simply to give a positive value for the evaporation rate;

- the Penman and Penman-Montieth equations contain the term (e_{sat_a} - e_a), which is different from above; in this case (e_{sat_a} - e_a) represents the difference between the saturation (potential maximum) vapor pressure at "a" and the observed vapor pressure at "a"; think of this as a vapor pressure deficit.

- Another equation that we've seen a lot is the logarithmic equation for velocity:

$$u = u_* \frac{1}{\kappa} \ln \frac{z}{z_o}$$

where u is the velocity at height z , u_* is the shear velocity, k is von Karman's constant (0.4) and z_o is the roughness height. The term u_* has the units of velocity, but it is really a measure of the stress or force per unit area that is creating the flow; it's also a measure of the intensity of the turbulence. If u or u_* go up, the turbulence will be more intense and more sensible and latent heat will be transferred from the surface to the atmosphere. The term z_o is theoretically the height above the surface where the velocity is zero; this is impossible to measure because it is usually a fraction (~1/10) of the height of the roughness. Thus, if the surface gets rougher, z_o gets bigger, and, for the same u_*, u gets smaller.

- the equations for sensible and latent heat transfer both have the following term:

$$\frac{u}{6.25 \left[\ln \frac{z}{z_o}\right]^2}$$

This term is essentially $u_*^{\ 2}$, which is sort-of what you get if you rearrange the above equation.

Simple equations, such as those for bulk density, snow water equivalence, water discharge, etc. you should know. More complex equations, i.e. those with more than about 3 terms, I will provide; however, you should know what the various terms in the more complex equations represent in a physical sense.