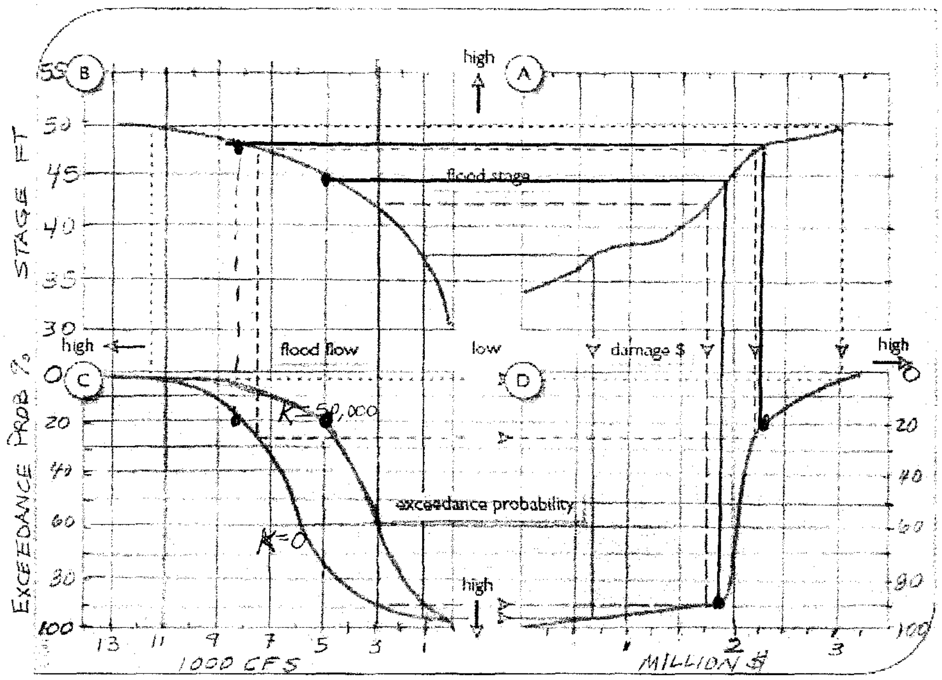
SOLUTION

CVEN 4838/5838 Dam Engineering – Part 1: Hydrologic and Environmental Aspects of Dams
EXAM September 25, 2008

PROBLEMS: 4838 credit – solve 3; 5838 credit – solve 4

Problem 1.



A flood control project with storage of 50,000 Ac-ft is planned on the Great Plains River to reduce the flood damages through Plainville. The frequency and damage data were compiled as shown above.

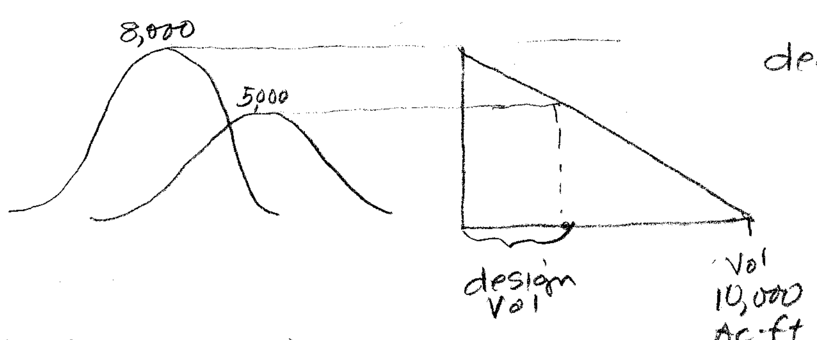
a. What is the reduction in downstream river stage for the 5-year flood?

T= 5-Yr $\frac{1}{5} = .2$ 20% Exceedance Prob Reduction in Flow: 8,000 → 5,000 cfs, Reduction in Stage: 48' → 45' ~ 3.0'

b. What will be the reduction in damages for the 5-year flood?

From ~\$2.25 M to ~\$1.9 M
about \$.35 M reduction

c. The entire 5-year flood has a volume of 10,000 AC-Ft. Assuming a linear outflow function (Volume of flood storage vs Peak discharge), what volume is needed in the flood pool to accomplish the 5-year flood reduction?

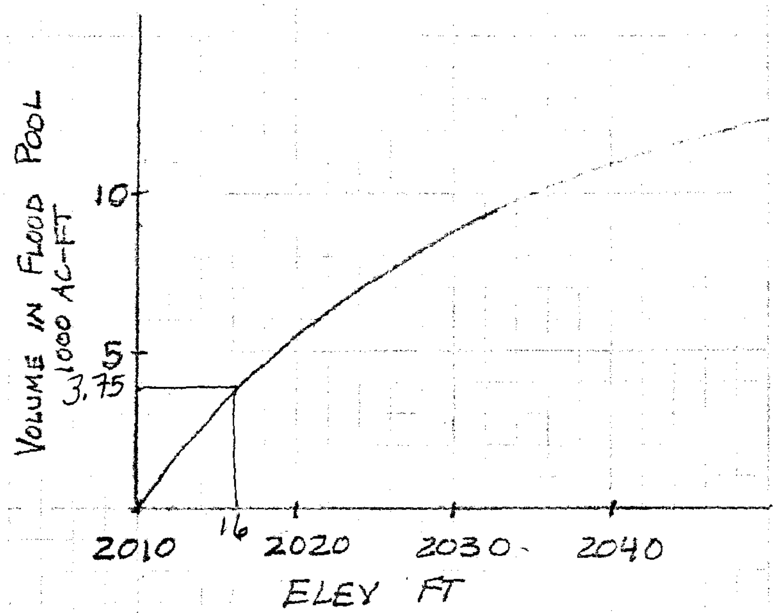


design Vol = $\frac{8000 - 5000}{8,000} \times 10,000$

= 3,750 Ac-ft

(continued on next page….)

d. An uncontrolled spillway is designed with a crest elevation of 2010 ft.
The area-elevation relationship of the flood pool (above the spillway crest) is given in the figure below.



Assuming the coefficient of discharge of the weir is 3.8, what is the length of the weir?
(hint: you have all the info you need from c. above)

$Q = 3.8\, L H^{1.5}$

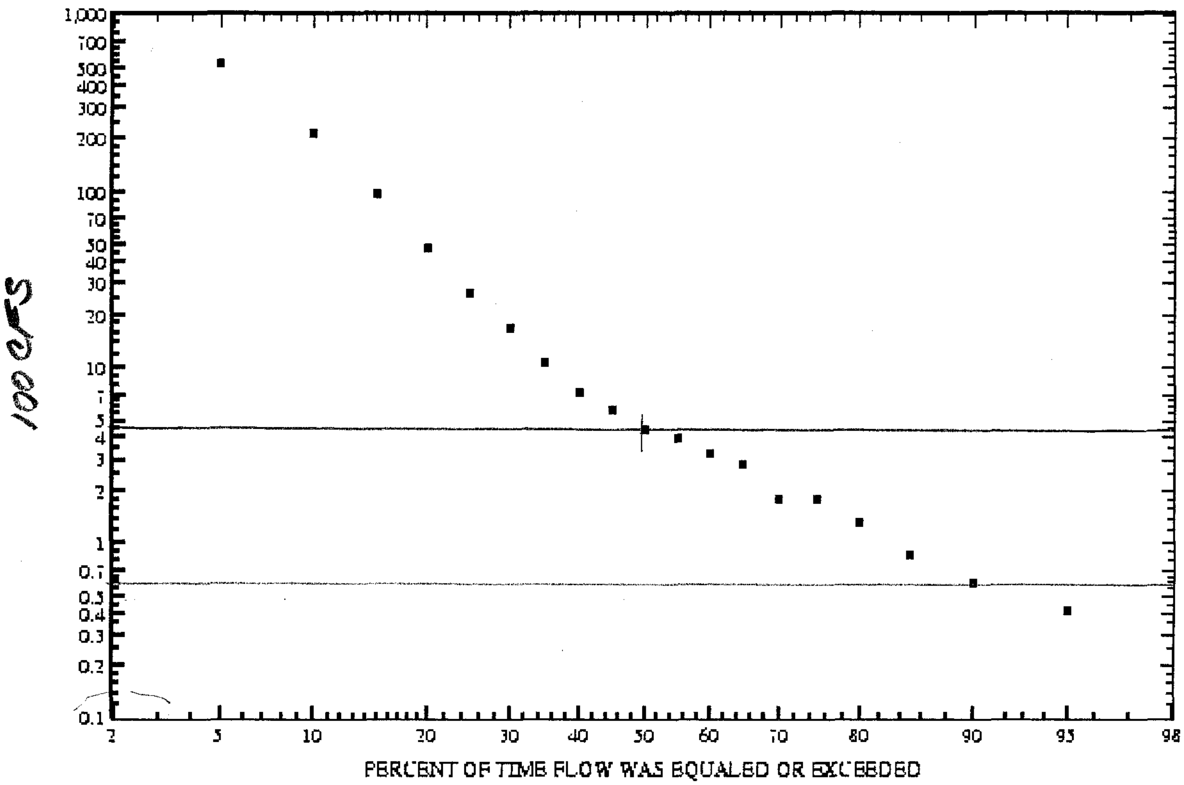
When peak $Q = 5{,}000$
Volume of Flood pool = 3,750
(from c)
From Vol-Elev curve
at Vol = 3,750 Ac-FT
Elev = 2016
$H = 2016 - 2010 = 6'$

$L = \frac{5000}{3.8(6)^{1.5}} = 89.5 \approx 90$ FT

SOLUTION

Problem 2.

The annual flow frequency of a river is shown below, where average annual flow is in units of 100 CFS



We need to determine the potential for hydropower revenues if we could build a low-head hydropower project at this location where the net Head is 10 ft. for a wide range of turbine releases. We estimate plant efficiency to be about 70%.

a. What is the average daily firm energy (reliable 90 percent of the time) that can be expected?

$Q_{90} \approx 60$ CFS

KWH Energy For 24hr $= \frac{.7QH}{11.81} * \text{HRS}$ $\quad \frac{.7(60)(10)}{11.81} \times 24 = 854$ KWH

b. What is the average daily secondary energy?

$Q_{50} \approx 450$ CFS

Energy $= \frac{.7(450)(10)}{11.81} * 24 = 6401$ KWH

Secondary $= 6401 - 854 = 5547$ KWH

(continued on next page)

c. The plant should supply a firm peaking energy that is twice the base load energy for 8 hours per day. What firm peaking energy can be supplied? This wording can be interpreted 2 ways – 2 possible solutions:

$PE = 2 \times BLE$

$PE + BLE = 854$ KWH

$\frac{3}{2} PE = 854$ KWH

PE = 569 KWH

$P = 71.13$

OR

$P = 2BL$

$8P + 16BL = 854$

$8P + 16\left(\frac{P}{2}\right) = 854$

$\rightarrow P = 53.4$ KW

PE = 427 KWH

d. If it is desired to be able to generate power taking advantage of all the (average) secondary energy during the peaking 8 hours per day, what plant capacity is required?

5547 KWH in 8 HRS = 693.4 KW

Plant Capacity = 693.4 + 71.1 = 764.5 KW

OR

693.4 + 53.4 = 746.8 KW

PROBLEM 3.

Sediment Yield versus Drainage Area. Dendy and Bolton studied sedimentation data from about 1500 reservoirs, ponds, and sediment detention basins. In developing their formulas, they used data from about 800 of these reservoirs with drainage areas greater than or equal to 1 mi^2. The smaller watersheds—those of drainage area less than 1 mi^2—were excluded because of their large variability of sediment yield, reflecting the diverse effects of soils, local terrain, vegetation, land use, and agricultural practices.

For drainage areas between 1 and 30,000 mi^2, Dendy and Bolton found that the annual sediment yield per unit area was inversely related to the 0.16 power of the drainage area:

$$\frac{S}{S_R} = \left(\frac{A}{A_R}\right)^{-0.16} \qquad (15\text{-}10)$$

in which S = sediment yield in tons per square mile per year; S_R = reference sediment yield corresponding to a 1-mi^2 drainage area, equal to 1645 tons per year; A = drainage area in square miles; and A_R = reference drainage area (1 mi^2).

For a basin of 14,000 sq miles, what is the sediment yield?

Sed Yield $S = (14{,}000)^{-.16} * 1645 * 14{,}000\ mi^2$

$S = 4{,}998{,}000$ tons/year

What volume of annual yield if the sediment weight 103 lbs per cubic ft?

$Vol/year = 4.998 \times 10^6\ tons/yr * \frac{2000\ lb}{ton} * \frac{1\ FT^3}{103\ lb} = 97 \times 10^6\ FT^3/year$

If the average trap efficiency over the first 50 years (the design life) is .88, what dead storage should be designed (volume)?

Volume Dead Storage $= .88\left(97 \times 10^6 \frac{FT^3}{year}\right) * 50\ year$

$= 4{,}268 \times 10^6\ FT^3$

PROBLEM 4

A storage project is proposed on the Little River. The recorded streamflows provide only 5 years of hydrologic record. The annual flows are: 2, 7, 9, 10, 2 (1000 ac-ft).
Based on this hydrologic record:

1. What is the maximum firm yield that can be delivered if no storage is developed?

2,000 Ac-FT Can be delivered with no Storage

2. What is the maximum firm yield that can be delivered with storage?

Max firm yield is Avg $\frac{2+7+9+10+2}{5} = \frac{30}{5} = 6{,}000$ Ac-Ft

3. What volume of storage is required in order to get the maximum firm yield (ignoring losses)?

Volume to get 6,000 Ac-FT Storage

I	R	K = MAX(0, (K_{t-1}+R−I))
		0
2	6	0+6−2 = 4
7	6	4+6−7 = 3
9	6	3+6−9 = 0
10	6	0+6−10 = −4 → 0
2	6	0+6−2 = 4
2	6	4+6−2 = 8 ←
7	6	8+6−7 = 7
9	6	7+6−9 = 4
10	6	4+6−10 = 0
2	6	

Storage Required is 8,000 AC-FT

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PART 2.

Select a Dam for each question below (10 pts)

a. Guri
b. Tucurui
c. Twin Lakes
d. Grand Coulee
e. Grande Dixence
f. Canyon Lake Dam
g. Itaipu
h. Three Gorges
i. Folsom
j. Sanmenxia
k. Glenn Canyon
l. Dinorwig

_e_ This dam gets most of its water from other drainage basins and it maximizes hydropower profits by pumping water in the summer when power is cheap and generating in the winter when power is more valuable.

_g_ This dam is limited in operation by international treaties and is a major tourist attraction due to the waterfalls it has created.

_l_ Has the fastest "response time" of any pumped storage plant in the world - it can provide 1320 MegaWatts in 12 seconds.

_b_ Built in the neotropics, the construction of this dam resulted in many negative environmental and health effects including malaria, infant mortality and greenhouse gases – but it is the 4th largest hydro plant in the world.

_i_ An engineering error resulted in the failure of a flood gate at this dam.

_j_ This dam was reconstructed to deal with sediment problems.

_c_ Project involves moving water from western slope to front range, supplies irrigation and generates power in a pumped storage facility.

_d_ The largest hydro plant in the US (4th in world), also supplies 0.5 Million acres of irrigation.

_h_ In addition to flood control and hydropower objectives, this dam provides capability for movement of large ships through locks.

_k_ Cavitation caused by unexpectedly large flood flows almost destroyed the spillway tunnels in this dam.

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CIRCLE best answer for each question (10 points)

1. The value of hydropower is determined by:
   a. peaking generation only
   b. the avoidance cost of producing thermal energy
   c. the load factor
   d. the plan capacity
   e. both c and d

2. Spillway design must consider
   a. passing the probable maximum flood
   b. the physical configuration of the dam site
   c. turbulence, energy dissipation, cavitation and trash problems
   d. all of these

3. Reservoir trap efficiency
   a. measures the ability of a reservoir to pass sediment through
   b. depends primarily on the size of the sediment in the river
   c. is a function of the ratio of reservoir capacity to total inflows
   d. increases linearly with the size of the reservoir

any of these are acceptable

4. Operating Rules of a reservoir:
   a. are usually constant throughout the year
   b. vary based on hydrology and changing objectives throughout the year
   c. are developed base on risk analysis
   d. are related to the primary storage zones of the reservoir
   e. are sometimes expressed as guide curves
   f. c and d only
   g. b, c, d, and e

5. Lane's relationship
   a. relates the energy of a stream to its sediment-carrying capacity
   b. predicts the sediment load given Q and size distribution
   c. is applicable for bed load only (not wash load)
   d. all the above.

PART 3. SHORT ANSWERS

4838 credit – answer 4 of 5; 4838 credit – answer all 5

1. What are some common objectives of dams and reservoirs? How do planners go about deciding how to operate the reservoir to meet the various objectives?

   Common objectives:
   - water supply for irrigation or M&I
   - flood control
   - hydropower generation
   - navigation
   - recreation (boating, fishing, rafting, etc.)
   - water quality (temperature, salinity, DO, etc.)
   - riparian habitats and species protection

   Multi-objective tradeoff analysis is used for making decisions about operating for different objectives, especially competing objectives.

2. Discuss the purpose of NEPA and what it requires of federal agencies.

NEPA's purpose is to foster and promote the general welfare of humans by maintaining conditions in which man and nature can exist in productive harmony. It establishes the protection of the environment as a national priority and mandates the consideration of environmental impacts before the federal government undertakes, or supplies funding to, any action that is likely to significantly affect the environment.

NEPA requires federal agencies, in cooperation with state and local governments and other concerned public and private organizations, to use all practical means and measures to create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements of present and future generations of Americans. It requires agencies to consider a wide range of alternatives to actions with significant impacts and to allow for broad participation in decision-making. Agencies are required to utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decision-making. Agencies must prepare either an EA, EIS or CE if there is a proposed action that may significantly affect the quality of the human environment. For and EIS, the agencies must file a notice of intent in the Federal Register, gather information from the public, study alternatives, issue a draft EIS, get further public comments, issue a final EIS and issue a record of decision.

3. What is the river continuum concept? What was innovative about it? What are the main principles? How can it be used to inform the planning of storage projects (dams) on rivers?

The river continuum concept places river ecosystems within the basic scientific foundation for ecosystem science, i.e., as a system that can be studied as an integrated and self-contained process. The concept recognizes the that there are connections in rivers between upstream and downstream habitats that control the flow of energy and carbon in the fluvial ecosystems, as well as the species of aquatic organisms. A major principal is the role that light availability plays in the changing ecosystems from upstream to downstream. The concept presents a testable hypothesis for physical, chemical and biological changes that occur on a longitudinal gradient from headwaters to lower reaches of the river system. A river system is in a state of quasi-equilibrium that is defined by the hydrologic means and extremes. Also, the stream forms an equilibrium state between physical parameters and biological factors. Since the introduction of dams on a river can change both the hydrologic extremes and means on a river, and the physical parameters of the river, significant ecosystem changes can be expected. The river continuum principals can be used to analyze and predict the effects of a dam on the ecosystem, and to develop operating policies that can to some extent mitigate the harm that may be done to the ecosystem.

4. What are the 2 components of firm power (energy)? What type of analysis is needed to determine the firm energy that can be provided by a hydro project?

The 2 components of firm power are:

1. the available water to produce the power, and
2. the capacity of the power plant

The determination of firm energy generally requires simulation tools that can model the water and water processes (storage, losses, tailwater, etc.) and the hydropower production (capacity and efficiency, varying heads, peaking power, etc.)

5. Why is reservoir routing difficult (without a computer)? What is one useful method for non-linear routing that can be done by hand?

The computation of reservoir routing involves solution of simultaneous non-linear equations, primarily the elevation/storage relationship and the change in storage with inflow and outflow, and the outflow that depends on elevation. Simultaneous solution of nonlinear equations requires numerical techniques. The storage indication method provides a way to discretize the problem and approximate the solution by hand.

SOLUTION

EXTRA CREDIT
(worth up to 4 points to enhance your Homework #1 score)

It is decided to build a reservoir with conservation storage of 8 (1000 Ac-ft). After the dam is built and the reservoir is filled to capacity, the project begins to operate with the objective of supplying Farmer A with 6 (1000 Ac-ft per year). In the first 8 years of operation of the project, the annual inflows to the reservoir are:

3, 10, 5, 2, 3, 5, 7, 4 (1000 Ac-ft per year).

What is the reliability of meeting Farmer A's water demands during this time? Is any water lost to spill during this time?

Demand = 6 $\quad \max[(S_{t-1} + I - \text{Draft}), 8]$

SPILL = EXCESS STORAGE > 8

Inflow	Avail $(S_{t-1} + I)$	DRAFT	SHORTAGE	STORAGE	SPILL
				8	
3	11	6		5	
10	15	6		8	1
5	13	6		7	
2	9	6		3	
3	6	6		0	
5	5	5	1	0	
7	7	6		1	
4	5	5	1	0	

Reliability $\frac{6}{8} = .75 \rightarrow 75\%$

1 000 Ac-FT is LOST TO SPILL