APPENDIX F

USE OF THE MASS CURVE METHOD TO IDENTIFY THE CRITICAL PERIOD

F-1. General.

a. The mass curve method is a manual, graphical procedure that is used to identify the critical period and the firm yield (in terms of average sustainable streamflow) for a reservoir of a given storage capacity, or conversely, to identify the storage required to support a given firm yield. Firm yield is maximized by fully drafting available reservoir storage to supplement natural streamflows at some point in time during the most adverse sequence of streamflows. This adverse streamflow period, (the critical period) is identified by examining the historical streamflow record.

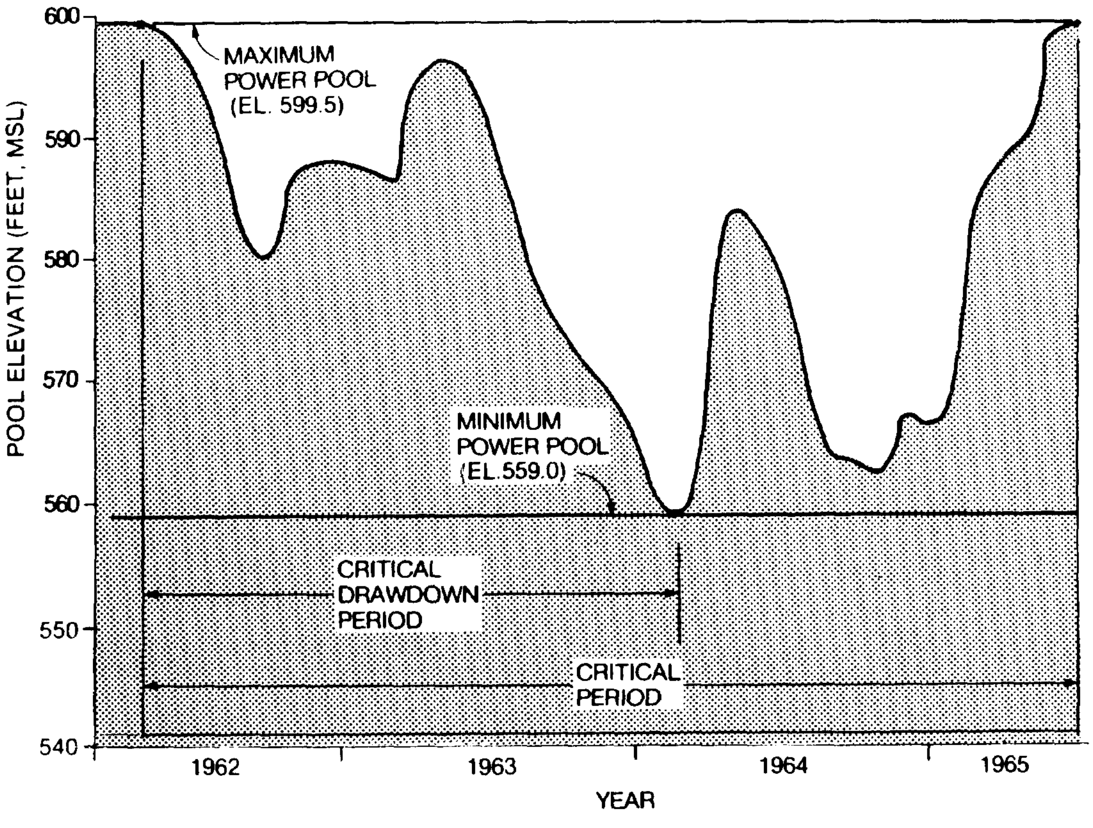

Figure F-1. Critical period and critical drawdown period

b. As noted in Section 5-10d, a critical period always begins at the end of a preceding high flow period which leaves the reservoir full. The end of the critical period is identified as the point when the reservoir has refilled after the drought period. The period beginning with the reservoir full and ending with the reservoir empty is called the critical drawdown period (See Figure F-1).

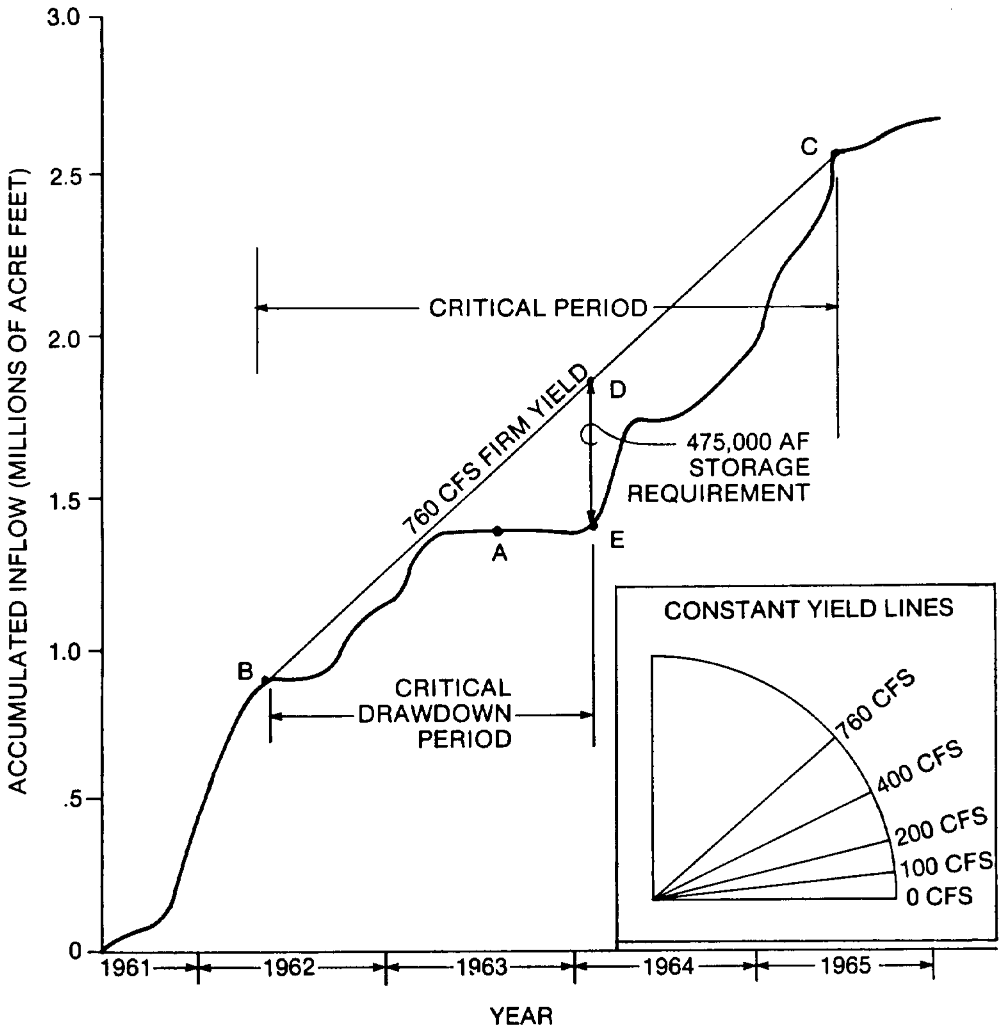

Figure F-2. Mass curve and constant yield lines

F-2. The Mass Curve.

a. A mass curve is a cumulative plotting of reservoir inflow (in acre-feet) over a period of years (Figure F-2). The entire period of record can be plotted, but it is often possible to limit the scope of the study by analyzing only those periods containing the more obvious low flow sequences.

b. The slope of the mass curve at any point in time represents the inflow rate at that time. Demand lines based on a constant yield can also be plotted, and they would have a slope equal to the desired demand rate. A family of yield lines is plotted in the inset to Figure G-2. The firm yield of an unregulated stream occurs at the point on the mass curve having the flattest slope (in the case of Figure F-2, zero cfs at point A).

F-3. Procedure and Example.

a. The procedure for using a mass curve can best be illustrated by examining how the mass curve could be used to determine the storage required to support a given firm yield. Assume for example that the objective of a study is to determine the feasibility of increasing the firm flow of an unregulated stream to 760 cfs (see the 760 cfs constant yield line on the inset, Figure F-2). The 760 cfs firm yield curve is applied to a positive point of tangency on the mass curve (Point B) and is extended to the point where it again intersects the mass curve (Point C). Period B-C thus describes a complete storage draft-refill cycle (which corresponds to the critical period on Figure F-1). The length of the vertical coordinate between the 760 cfs yield curve and the mass diagram represents the amount of storage drafted from the reservoir, at any point in time, and the point where this ordinate is at its maximum length (Point D) represents the total amount of reservoir storage required to maintain a firm flow of 760 cfs during this particular flow period.

b. This same procedure is applied to other low flow periods, and the period requiring the largest reservoir draft is identified as the critical period. Assuming that the period B-C is the most adverse sequence of flows in the period of record, a volume of 475,000 acre-feet is required to assure a firm yield of 760 cfs at the project. The low flow period that is most adverse (the critical period) may extend over several years, and such a multi-year critical period is illustrated by Figure F-2. The period B-E defines the critical drawdown period and B-C defines the total critical period.

F-4. <u>Firm Yield Curve.</u> Alternative firm yields could be tested, and a firm yield versus storage capacity curve could be developed (Figure F-3). A curve of this type would be useful in defining the range of storage volumes to be considered at a reservoir site. It should again be noted that as the available storage volume increases, the length of the critical period will often increase, or the critical period may at some point shift to an entirely different sequence of historical flows.

F-5. <u>Maximum Firm Yield for Given Storage Volume.</u> Another typical problem would be to identify the maximum firm yield that could be obtained for a given storage volume. Figure F-4 illustrates how firm yield is determined for three low-flow periods for a project having 150,000 AF of storage. The 1963-64 sequence produces the lowest firm yield (280 cfs) and hence identifies the critical period for the 150,000 AF project.

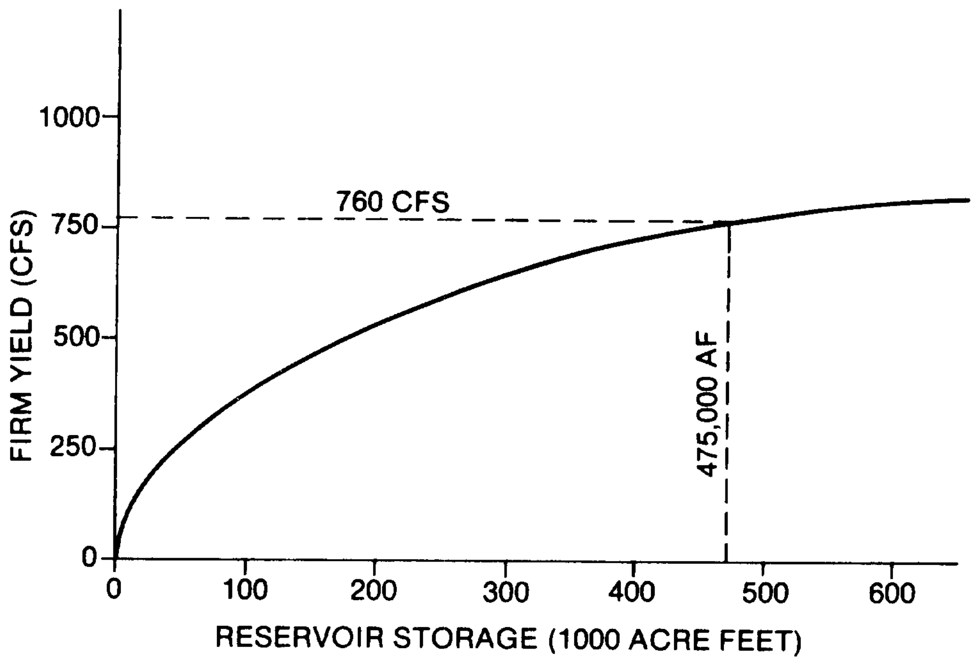

Figure F-3. Firm yield vs. storage capacity curve

F-6. Use of the Mass Curve to Estimate Firm Energy. The mass curve method described above deals with flows and storage volumes. This method could conceivably be adapted to determine a project's firm energy output. However, the procedure would be complicated by the fact that power demand is not constant the year around, but varies from month to month. Furthermore, the head at a storage project varies through the storage regulation cycle, making direct computation of energy impractical. Hence, the mass curve is used primarily to identify the critical period and make a preliminary estimate of the average firm discharge for a project of a given storage volume. This data could be used to make a preliminary estimate of firm energy, which would be followed by a sequential streamflow routing analysis to determine the project's exact firm energy capability (see Appendix H).

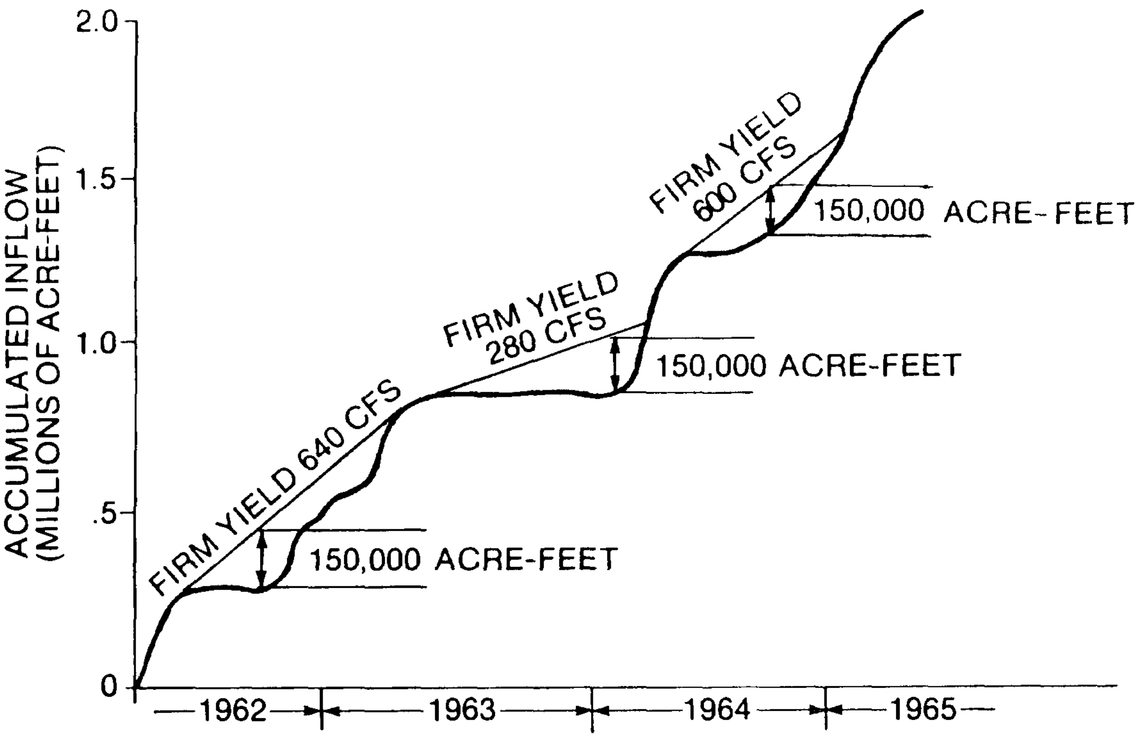

Figure F-4. Firm yield determination with mass curve