RESERVOIR DESIGN IN GEORGIA'S PIEDMONT

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Abstract. Reservoirs for water supply in Georgia must be designed to allow a water supply manager to meet demands during a design drought without reducing streamflow when flows are less than the Non-Depletable Flow (NDF), normally the 7Q10 flow. The design drought is typically either a 50 or 100 year drought or a specific drought such as the 1954-55 or 1986-88 drought. This requirement is based on the Georgia Water Quality Control Act (O.C.G.A. Par. 12-5-31, et seq.) and related Water Quality Control regulations 319-3-6-.07.

This paper compares reservoir storage to meet these requirements as calculated by two methods: a probability based design using monthly streamflow data, as compared to daily time series computations using streamflows from a specific drought period. The stream gage with a long history of observation used is the Oostanaula gage near Resaca, Georgia. This gage has a 100 year history, beginning in January of 1893.

This particular comparison showed that the reservoir storage volume calculated by analysis of daily data from the 1954-57 drought was larger that the storage calculated using monthly streamflow data for a 100 year drought.

INTRODUCTION

Surface water is the primary source of water for all major uses in the Piedmont of Georgia. Groundwater is a very important resource for rural areas and as a supplemental source in urban areas, but can rarely be relied on when needs exceed or approach the million gallons per day mark.

EDP Policy for Stream Withdrawals

The use of surface water implies the availability of reservoir storage because the State of Georgia does not allow withdrawals that would reduce the reduce the stream flow below the Non-Depletable Flow (the NDF), normally the 7Q10 flow. The design of reservoir storage in Georgia is still very much the privilege of the water resource manager, although the State recommends certain analytical procedures. The law merely describes the conditions of allowable withdrawals from a stream.

The Environmental Protection Division (the EPD) of the Georgia Department of Natural Resources desires an analysis of a critical drought period based on available data. EPD further states that examples of suitable drought periods include but are not limited to a 50 year recurrence period, the 1954-56 drought or the 1984-1988 drought. Various periods for refilling have been discussed. A one year period will certainly ease the life of a resource manager but analytically longer periods can be readily defended. Four (4) year periods now appear to be acceptable.

Design Considerations in Sizing Reservoir Storage

The determination of the required reservoir size has to be sensitive to over-design as well as under-design. Oversizing causes additional costs and may cause unjustifiable, environmental consequences. Undersizing can lead to water shortages and related shut-downs of industries, causing loss of income to employees. Equally important is the knowledge of design criteria. The reservoir content has to be evaluated according to the time of year. A reduced water level in June is certainly more serious than a low water level in December. A thorough, well documented study will be invaluable to the water resource manager during a severe drought.

With the availability of personal computers, analyses of daily time series spanning several years, aided by flow data readily available on CD-ROM should be routine. However, to develop statistical data to judge the severity of a drought, monthly data analysis is still the method of choice. In addition, sensitivity analyses can be performed by varying various parameters within expected ranges.

The analysis should indicate that there will always be a risk of a water shortage, no matter how small. A well prepared analysis can serve as an early warning system, putting in place mild demand constraints early and avoiding last minute drastic demand restrictions.

It is anticipated that watersheds will be utilized with ever increasing intensity. When only a small percentage of the available water in a system is used, an error in an analysis is quite forgiving, especially when a 7Q10 flow can be accessed during a drought. This will be less acceptable in the future and the demand for more inclusive analyses will become the standard.

This paper only analyses the reservoir volume required to meet municipal water demand. It does not include secondary demands such as net-evaporation, siltation or seepage, nor any other primary uses.

METHODS

Storage Based on Monthly Streamdflow Data

The monthly mean discharge data from the Resaca Gage on the Oostanaula River were analyzed for the period from January 1893 through October 1974. The 1974 cut off is the date when Carters Lake started operations, thereby modifying flow data. This had the effect that the impact of the 1984-88 drought could not be evaluated. Data show the severity of that drought for annual values, but short term data are severely distorted by minimum releases from the Lake.

Monthly data were analyzed to develop non-sequential low flow events for periods of one (1) month through 24 months with monthly intervals and six (6) month intervals thereafter up to 48 month. Using the methodology attributed to Beard (1975), monthly mean low flow events were calculated for both a 50 year and 100 year return period. Figures 1 and 2 show the results. Figure 2 merely enlarges the first twelve (12) month period. The graph shows both the 50 and 100 year recurrence drought flow and compares these flows to the actual minimums, the 1954-56 drought and the average. As to be expected, the actual minimum follows the 100 year drought closely. The 1954-56 drought was very severe for up to six (6) month duration, very often the upper end of a design drought. The 1954-56 drought is generally of interest due to its extensive documentation, although on the Oostanaula it was not a high ranking drought. It ranked third for four (4) periods and second for a five month period (July - November 1954).

With these data computed, reservoir volume was calculated in a normalized, non-dimensional fashion. Average annual demand was expressed as a ratio of average annual flow, and storage was computed as days of storage. Days of storage is defined as storage required divided by average annual flow. The demand assumed sinusoidal annual demand with a peak of 1.15 in July and a minimum of .85 in January.

Figure 2 shows the results of the analysis. For very low demands of 15% or less of average stream flow, storage computes to approximately 70 days. This relates to an apparent correlation between the 7Q10 and 70Q100, roughly being close to each other. Once stream flow exceeds the 7Q10, flow is ample to meet demand without further demands on storage. For an annual refilling cycle, up to 30% of average flow can be utilized, but storage requirements increase to roughly 120 to 125 days.

Sensitivity to Design Low Streamflow

A sensitivity analysis was performed for varying the 7Q10, the recurrence interval and the utilization of the stream. The sensitivity to the 7Q10 is nearly linear, a 100% increase in the 7Q10 will increase the storage requirements by 80%. This means that a 7Q10 of .4 cfsm in lieu of .2 cfsm will require nearly 200 days of storage instead of 110 days. Probability changes are less sensitive. A 100% increase in probability, 2% to 4% (50 years vs. 25 years) reduces storage

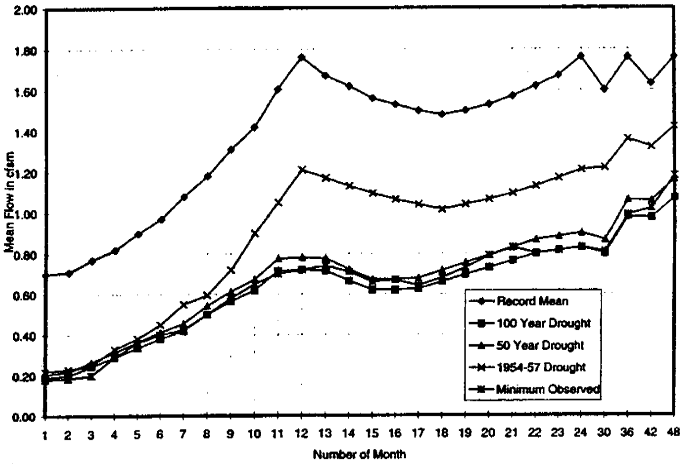

Figure 1: Low Flow Events - 48 Month

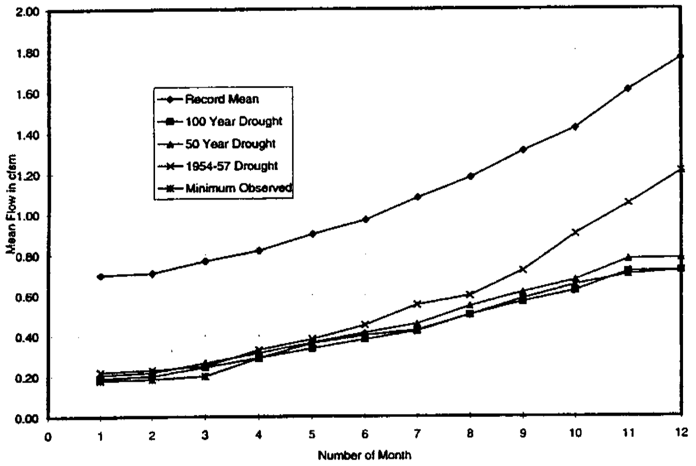

Figure 2: Low Flow Events - 12 Month

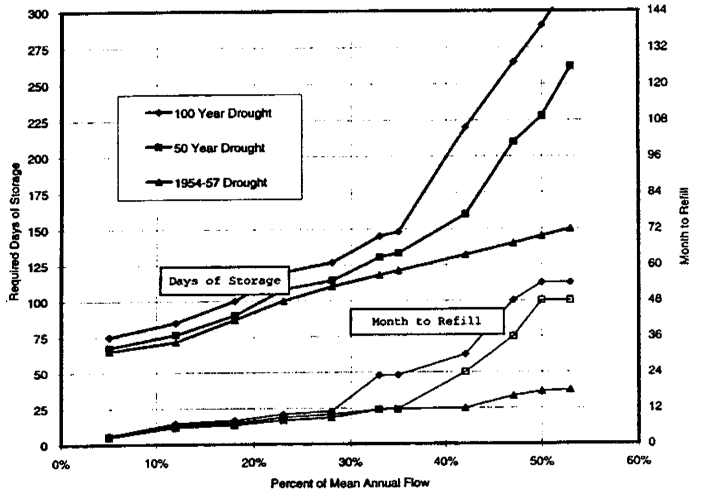

Figure 3: Storage Requirements

by 14% - 96 days in lieu 112 days. Utilization is almost equal in sensitivity to the 7Q10, which is reasonable when considering the 7Q10 a demand.

When using daily data for the 1954-55 drought it became obvious that monthly data have a strong potential for underestimating storage requirements. For example, in August of 1954 a thunderstorm in early August caused high flows for a few days and a high monthly average. When looking at daily data, 20 days had to be added for additional storage to adjust for low flow deficiencies in late August.

This fact should not be used to invalidate statistical evaluations based on monthly data but added to the number of facts to be evaluated in determining storage size.

CONCLUSION

A thorough analysis of the available database for flows is mandatory for evaluating required storage size. Both statistical analyses should be performed to be able to evaluate a current drought as to its status early and daily time series are necessary to evaluate short term variations. When pump storage is involved, the latter is even more important because of the inability to capture high flows due to pumping limitations. With such detailed analyses available, the water resource manager should be able to judge droughts early and avoid panic measures. Alternately, it may be a worthwhile effort for the State to analyze all available stream data for storage requirements and to establish "safety factors" for reservoir storage.

LITERATURE CITED

Beard, L.R., January 1975. Non-Sequential Mass Curve Analysis, Hydrologic Engineering Methods for Water Resource Development, Volume 8: Reservoir Yield, published by the U.S. Army Corps of Engineers.

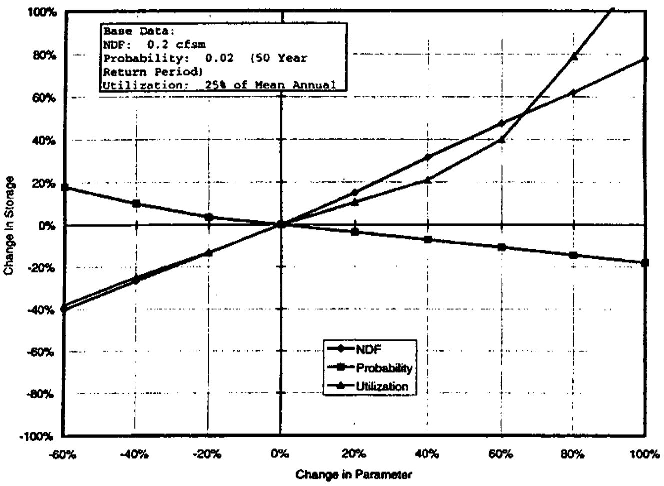

Figure 4: Sensitivity Analysis

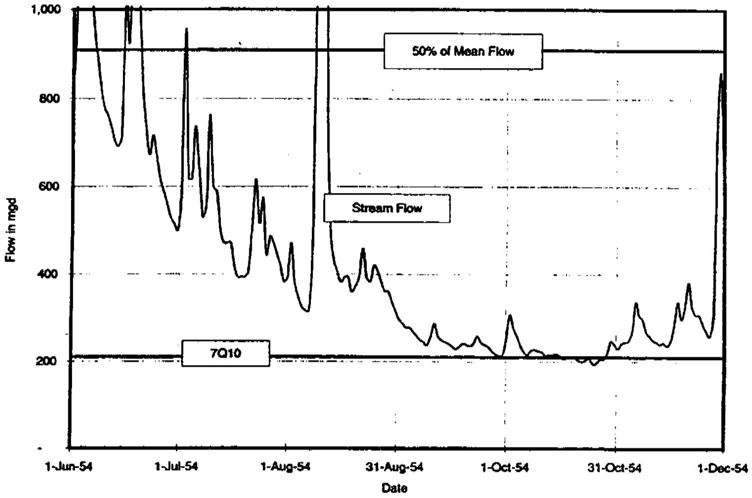

Figure 5: 1954 Low Flow Period