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ASSESSMENT OF FLOW DURATION CURVES AT DIFFERENT TIME SCALES

ABSTRACT

Flow Duration Curve (FDC) is one of the most fundamental tools that provide information for the design of hydropower projects particularly. Therefore, for practitioners who deal hydropower design, understanding the flow duration curve becomes extremely important. The time scales of FDC can be taken as either daily, ten daily, monthly, or annual. Decision makers decide for the required time scale of the FDC based on the purpose of hydropower project in consideration. In this study, FDCs were produced at daily, monthly and annual time scales from the observed mean streamflow data of a selected gauging station from the Meric-Ergene river basin in the European part of Turkey. The data used were obtained from State Hydraulic Works (DSI) of Turkey. Comparison of flow duration curves at different time scales shows that FDCs at shorter time intervals look more beneficial in getting more accurate quantiles needed for hydropower design. By considering the FDC of the gauging station, it is possible to produce power duration curves of the hydropower plant which is an important practical tool.

Keywords: Flow Duration Curve, Gauging Station, Hydropower, Meric-Ergene River Basin, Power Duration Curve

1. INTRODUCTION

Water is essential for human life every time. There are a lot of studies to take water undercontrol as flood, drought, storage, irrigation, etc. Estimation of extreme events as flood and drought is based on observations and historical events. In some basins, hydrological and meteorological data are available as discharge, precipitation, evapotranspiration, etc. (Burgan, 2016). Widely used in water science the flow duration curve (FDC) indicates frequency distribution of flows graphically. FDC is used in hydrologic studies for hydropower design, flood control, water quality, sedimentation and watershed management. FDC can be acquired from flow data of gauging stations at daily, 10-daily, monthly and yearly time scales (Cigizoglu 1997). Historically long term observed data are necessary to be able to use FDC. In this way, the discharge which is in excess of a percentage of time can be found (Burgan & Aksoy 2016). According to data and requirement of the study, the time scale of FDC should be selected. Especially, the quantiles of daily FDC as 0-10% and 90-100% for low flow and flood events give better results than annual FDC (Figure 1). Flow duration curves are widely used in hydrological behavior estimations and extreme events of basins. The measurements are difficult and if there aren’t enough gauging stations in a catchment, the quantiles can be estimated using morphological and meteorological characteristics in the basin. Therefore, flow duration curves can be produced from estimated quantiles. From another methodology, general power equation can be found using regression

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analysis using parameters as observed mean flow data and drainage area (Singh et al. 2001). For an ungauged basin, mean flow can be calculated using the drainage area in the equation,

$$Q = C\left(A\right)^m$$

where Q mean flow(m^3/s or cms-cumic meter per second), A drainage area (km^2), C and m coefficients. In another way, transfer process can be realized from a gauged basin to an ungauged basin, but similar hydrological characteristics. Finally in the literature, it is possible that delineation of watersheds in terms of homogenous regions and different equations for delineated watersheds can be acquired. Most classification methods are based on climatology (Booker & Snelder 2012, Boscarello et al. 2016). GIS technology can be used to determine characteristics of the basin (Alganci et al. 2009). Also a map-based regional software tool is developed to estimate unregulated daily streamflow at ungauged rivers (Arcfield et al. 2013). In this study, basic and generic FDC methodology is followed and different time scaled FDCs are compared. Decision makers will be used produced FDCs in projects of hydroelectric power plants (HPP) and FDCs are transferrable to power duration curves (PDCs) at the same time.

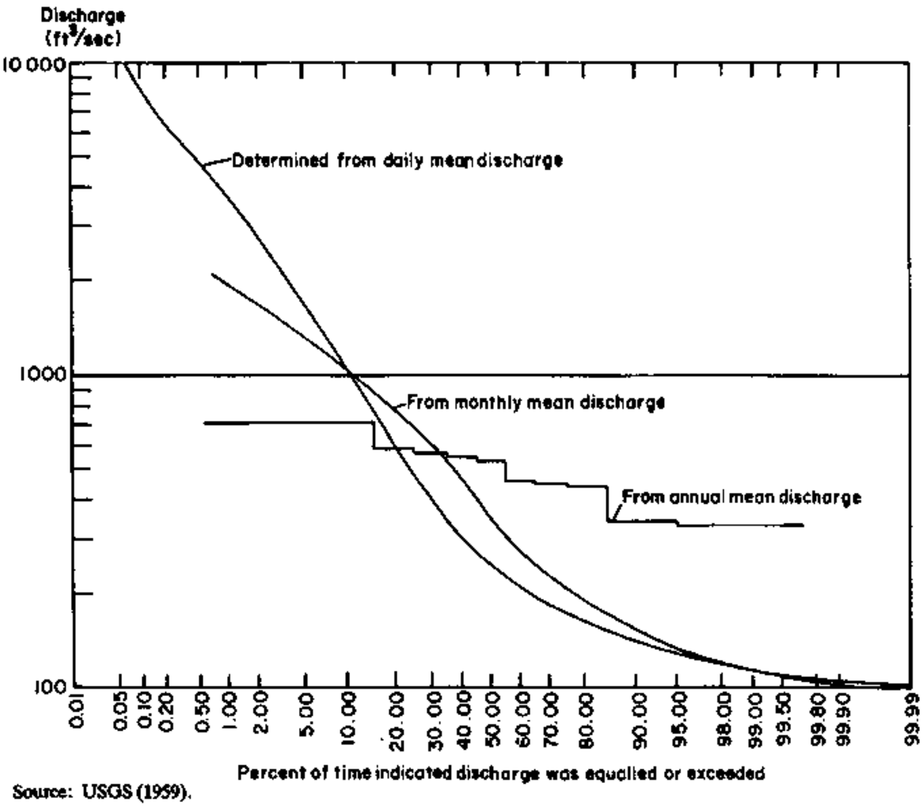


Figure 1. Flow duration curves at different time scales, Bowie River, Hattiesburg, Mississippi, 1939-1948 (Searcy 1959)

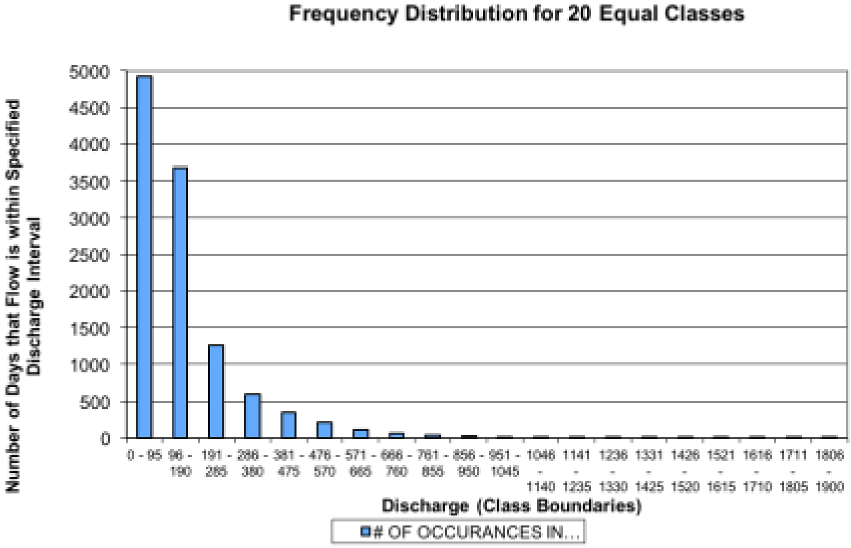
2. RESEARCH SIGNIFICANCE

Flow duration curves can simply be constructed empirically for gauged sites by (1) ranking observed runoff in ascending order and (2) plotting each ordered observation versus its corresponding duration (e.g. in days, years), or its fractional duration (which is dimensionless) (Castellarin 2014). Many applications of flow duration curve models are available in the literature. For example; Singh

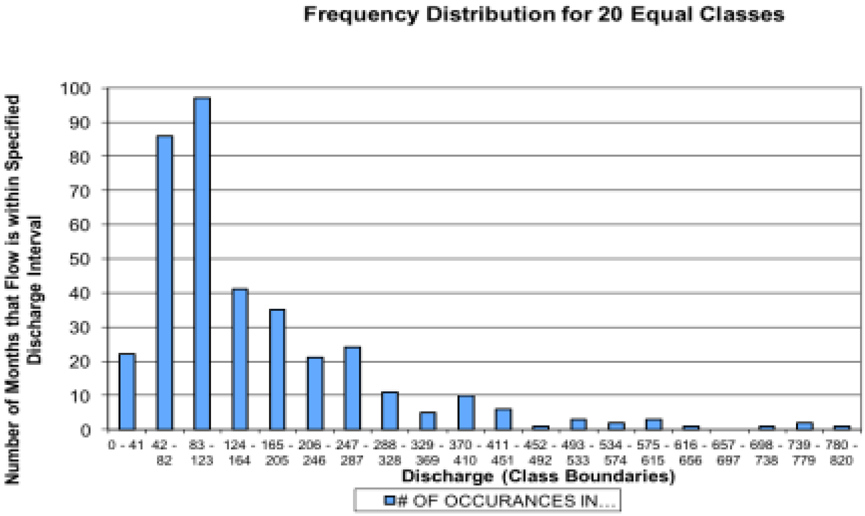
(1971) established flow duration curve models by using streamflow data between 1950-1964 from 120 flow gauging stations in Illinois, USA. Regression equations based on basin area and basin mean elevation were developed to obtain flow duration curves in New Hampshire (Dingman 1978). Hydropower potential and water availability at ungauged sites in Philippines were studied through flow duration curves (Quimpo et al. 1983). FDC and basin characteristics were used to make regionalization were studied based on flow duration curve and other characteristics of hydrological basins in Greece (Mimikou & Kaemaki 1985). In this study, FDCs are acquired from gauged data and they are compared as daily, monthly and annual time scales. The importance and aim of this study is exposure of difference between daily, monthly and annual FDCs. The originality of the study is coming from Meric is a transboundary river and it has still flood risks and sedimentation problems. So, it is known that FDCs give good results and estimations to define low flow and flood discharge values. The scarcity of comparison of different time scaled of FDCs in the literature, the study will be completed this lack.

3. METHOD

As mentioned before three FDCs (daily, monthly, and annual) are used. The daily flow data is acquired from gauging stations of State Hydraulic Works (DSI). Monthly flow data is calculated from daily data as mean. And annual flow data is acquired by calculating mean of flow data for every year. And then the flow data is ranked by magnitude from largest to smallest. Also, maximum and minimum values are calculated. To acquire histogram of the flow data, we need the range of data. It should be 20 to 30 equal classes. Log scale FDCs are very widely used to be able to make good comparison and look to low flow and flood discharges on FDC. At the same time, log cycles are need to determine for histogram (Figure 23). A histogram of the sorted data should take on a general bell shape. If the shape appears drastically different from the bell shape, the data may need to be resorted into smaller or larger intervals (Oregon State University 2005). Frequency distributions are drawn as cumulative (Figure 4). Most of things are not complied with normal distribution. To make it similar to normal shape, logarithmic graph can be used. Frequency distribution curves are looking S shape as expected (Figure 5). The cumulative number of occurrences is converted to a percentage of the time. Finally, the diagram is turned so that discharge is given on the vertical axis and Exceedance Frequency is given on the horizontal axis.



(a)



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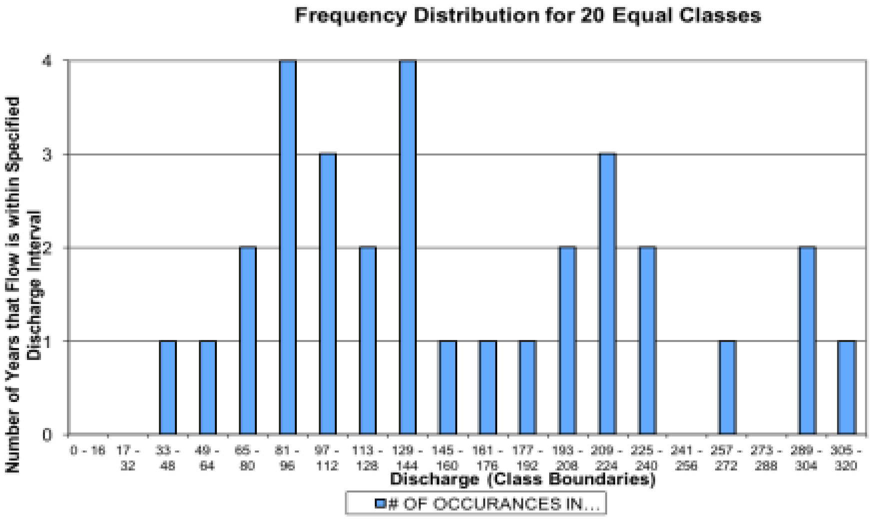


(c)

Figure 2. Histogram of (a) Daily, (b) Monthly, (c) Annual flow data

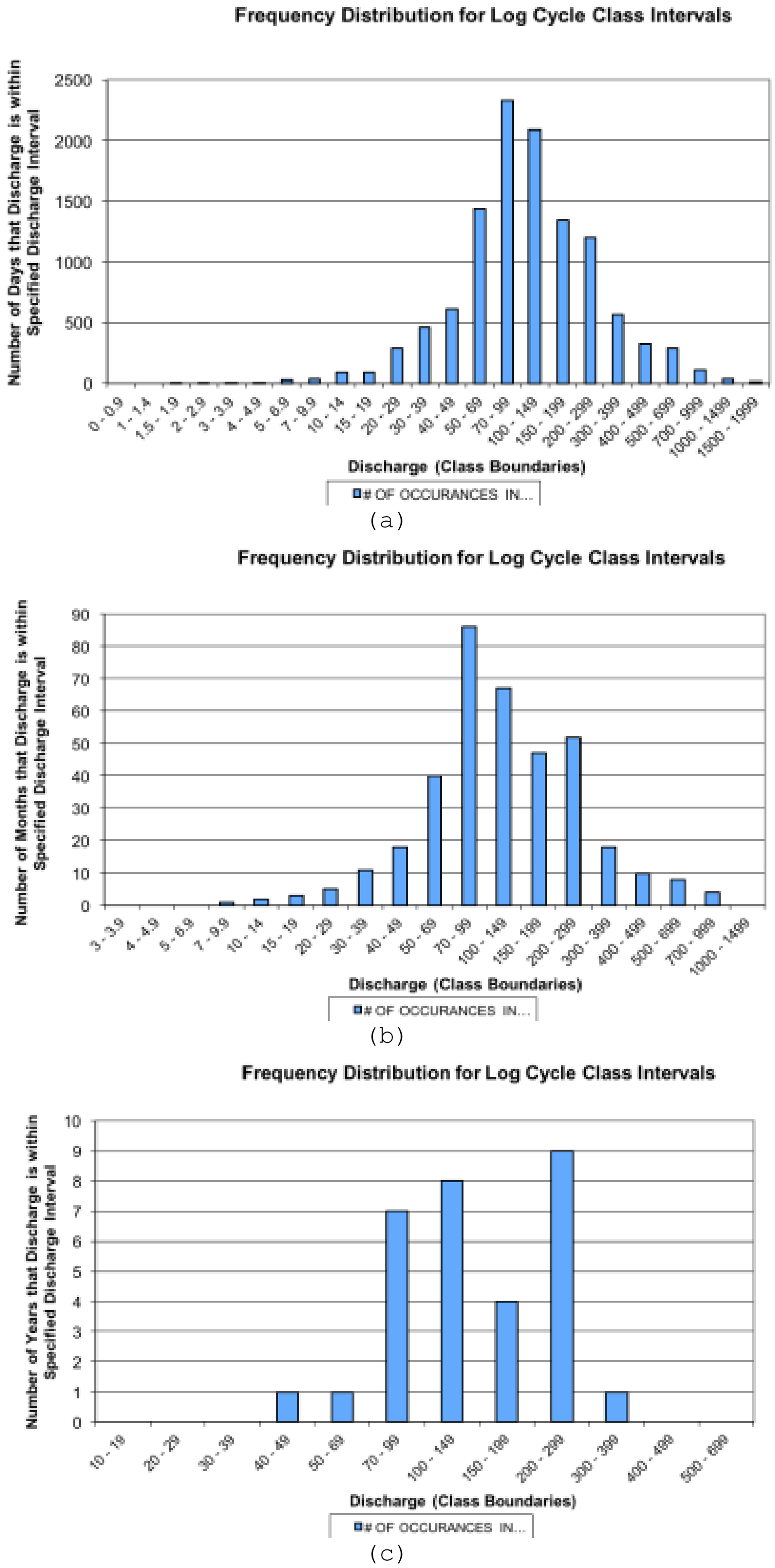


Figure 3. Histogram for log cycle class intervals (a) Daily, (b) Monthly, (c) Annual flow data

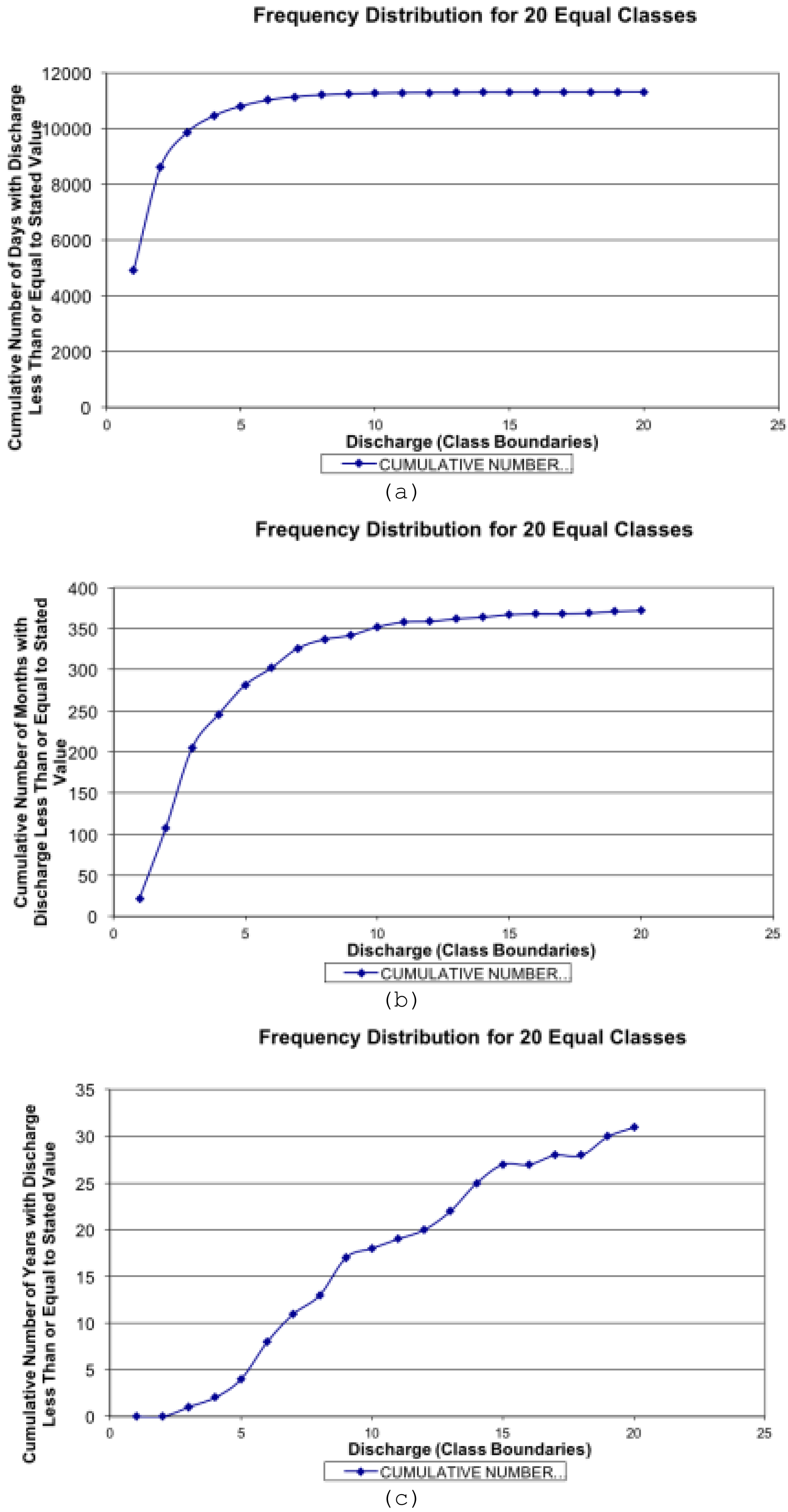
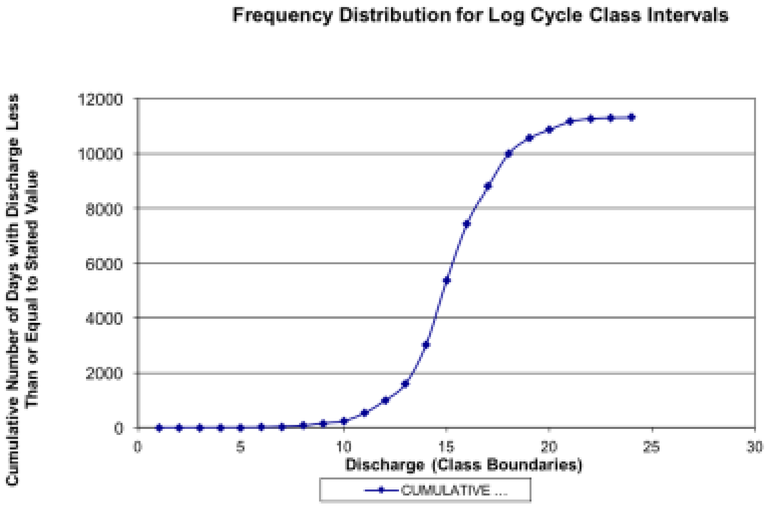
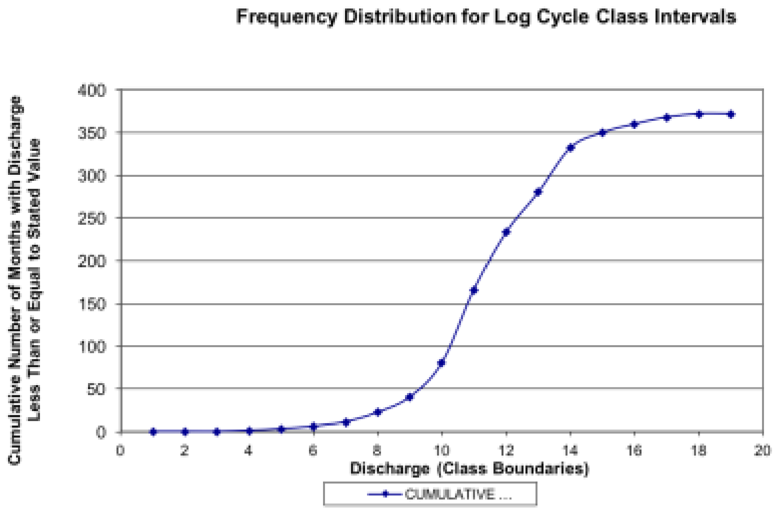


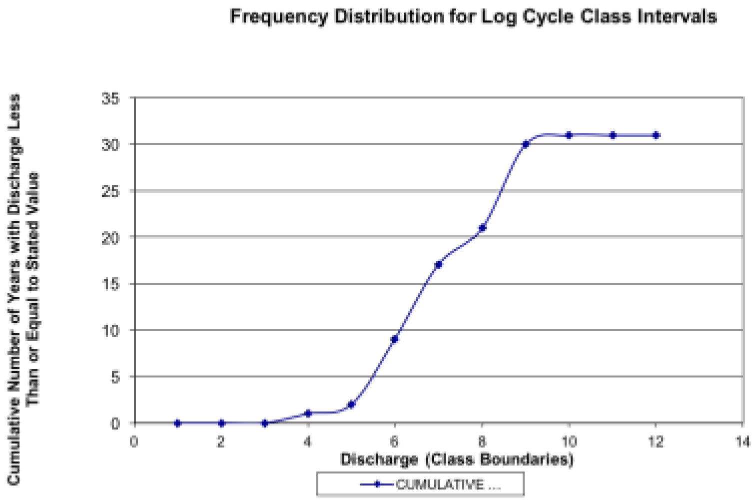
Figure 4. Frequency distributions as daily, monthly, annual, respectively



(a)



(b)



(c)

Figure 5. Frequency distributions for log cycle class intervals as daily, monthly, annual, respectively

4. RESULTS

The steps are applied to produce daily, monthly and annual FDCs. In figure 6, daily FDC is starting at 1800m^3/s, monthly FDC is starting at 800m^3/s and annual FDC is starting at 300m^3/s. 1965-2014 water years are used. Especially 1965-1966 years have big discharges if it is looked at the data. Log scaled FDCs are most widely used (Figure 7). It is looking that Meric River has high discharge values according to FDC. It can be said that Meric River is also a non-intermittent river by looking non-zero low flows. High flows bring sediments from Bulgaria to Saros, Aegean Sea passing through Edirne, Turkey. Also there are 5 dams at Bulgarian side. On like this transboundary rivers, dam construction is difficult in terms of lack of information about water demand. Source of income in Edirne is mostly agriculture and livestock. Agricultural lands needs more water for irrigation because of growing rice which needs much more water. Also, the studies continue to protect people from flood hazard.

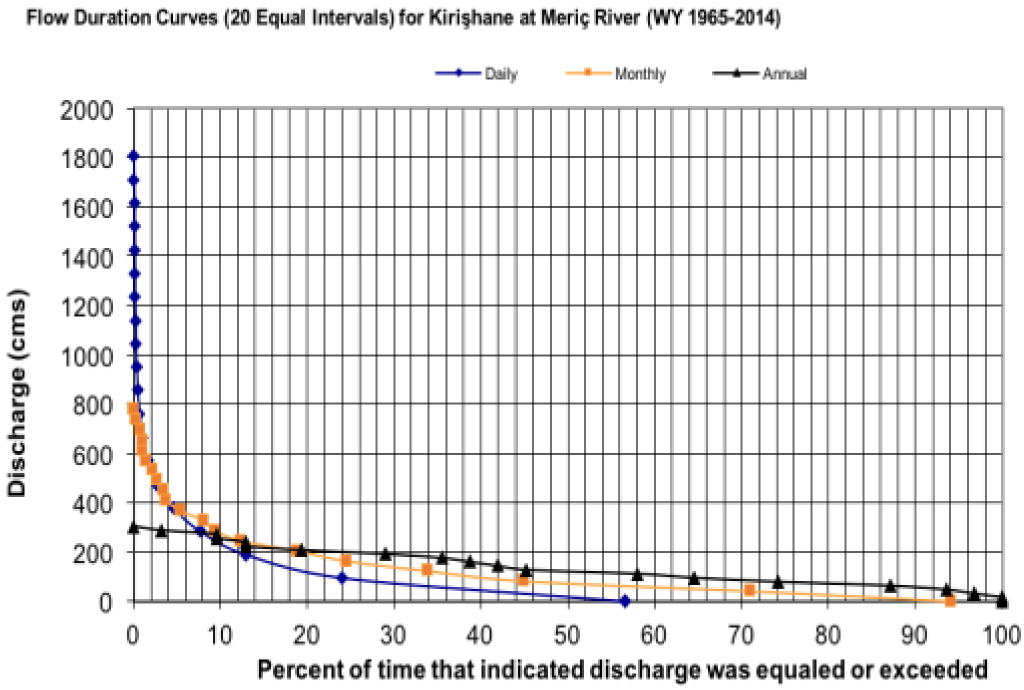


Figure 6. FDCs for Kirişhane at Meriç River as daily, monthly, annual

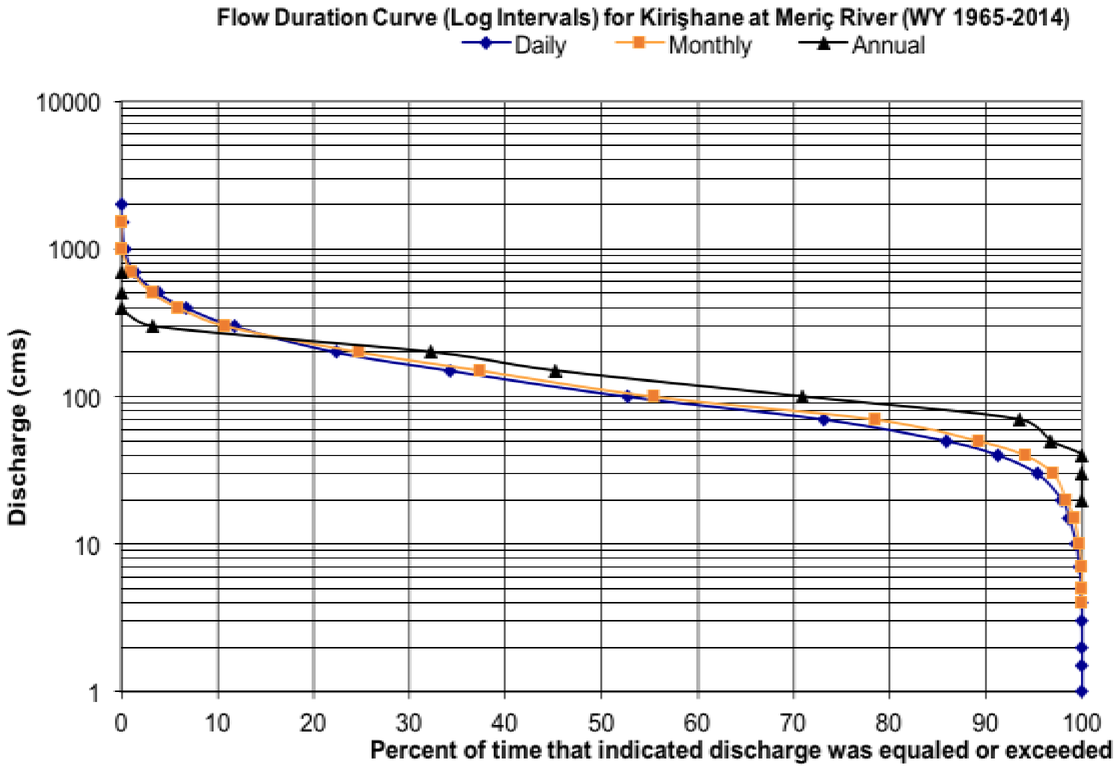


Figure 7. FDCs (log intervals) for Kirişhane at Meriç River as daily, monthly, annual

5. CONCLUSION AND RECOMMENDATIONS

Flow duration curves are widely used to determine any discharge which corresponds to percent of time. So, low flow and flood discharges can be defined from FDC. In this study, daily flow data from gauging stations of State Hydraulic Works (DSI). Also, selected catchment (Kirishane) in Meric-Ergene river basin has gauging stations. But most of time, there is no gauging station especially on small rivers. In these cases, mean flow data (monthly or annual) can be estimated from catchment characteristics or transferred similar catchments instead of daily flow. For future studies, power duration curves can be produced using FDCs. As conclusion, daily flows are required to determine to low flow and flood studies. There are big differences at these parts (0-10% and 90-100%) on FDC.

NOTE

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