Characterizing Environmental Low Flows in Terms of Magnitude, Duration and Frequency

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ABSTRACT

Increased water demand has led to the need for development of water resources in Mongolia. With the Mongolian government implementation of integrated water resources management approach, assessing environmental flow requirements of major rivers becomes a primary issue. Using Indicators of Hydrological Alteration tools, physical habitat survey at Orkhon-Orkhon gauge site and statistical analysis of annual maximum flows, environmental low flow scenarios have been developed that attempt to reflect more "natural" characteristics of magnitude, frequency and duration. Specifically, minimum seasonal low flows of greater than the 75th percentile flow duration with bankfull flow releases during wet periods that have a duration of 12 to 24 days.

Keywords: environmental flow, bankfull flow

INTRODUCTION

Mongolia has been experiencing extensive growth in urban, agricultural and mineral resource development. This growth has increased the demand and need for development of water resources. Feasibility studies have been conducted or are being conducted on reservoir locations to provide water for these increasing demands (Baldsndorj et al., 2012). Several of these locations are in the Selenge River Basin which represents over 60 percent of the drainage area to Lake Baikal (UNOPS 2013). Environmental low flows in the form of annual constant minimums have been proposed by Baldsndorj et al. (2012). Poff and Zimmerman (2010) provided an extensive review of ecological responses to altered flow regimes. Poff et al. (2010) has recommended that environmental flows reflect "natural" variability (magnitude, frequency and duration) and that specified environmental flows be recognized as initial values and have the flexibility to be changed as observations are made in the future, i.e., adaptive management. In this study we have collected physical habitat data, conducted geomorphological characterization and statistical analysis of daily flow data at the Orkhon-Orkhon gauge site on the Orkhon River at Bulgan. Using this information we have developed

environmental low flow scenarios that attempt to reflect more “natural” characteristics of magnitude, frequency and duration.

METHODS

Daily flow data for the Orkhon River Orkhon-Orkhon gauge site (Orkhon *soum*, Bulgan *aimag*) were used for this analysis. The flow data have a 33 year period of record from 1978 to 2010. This characterization uses the Indicators of Hydrologic Alteration (The Nature Conservancy, 2009) to characterize flow duration percentiles and seasonal characteristics of those flow percentiles based on monthly flow duration analysis (Searcy 1959). Field identification of bankfull flow was done following methods described in Wadeable Stream Assessment: Site Evaluation Guidelines (US Environmental Protection Agency, 2004). Bankfull flow was estimated by calibration of channel hydraulics to field discharge measurements and then calculating the discharge that would fill the channel to the bankfull elevation identified in the field. Hydraulic analysis was carried out using HECRAS (Brunner, 2010). The daily long-term flow record was then used to determine the frequency (percent of years) bankfull flow is exceeded and when it is exceeded, the duration (number of days) it is exceeded. Log Pearson III Frequency analysis (US Department of Interior, 1982) of annual maximum peak flow data was done to characterize the annual frequency of low level floods. The objective behind bankfull flow is to provide a magnitude and frequency of flood events that provides for river flushing and riparian enrichment.

RESULTS

Flow Duration

Flow duration analysis was done on daily flows for each month over the period of record. Figure 1 shows the monthly flow duration for exceedance durations of 10, 25, 50, 75 and 90 percent. These represent the percent of time (days) the associated flow value is exceeded for that month. From Figure 1 we can see that the percent duration flows vary with season. Visually we identify three seasons, low flow (November – March), medium flow (April – June and October) and peak flow (July – September) periods. Thus individual monthly flow duration percentiles could be averaged to represent seasonal flow duration percentiles. This would enable seasonal management versus monthly management. For a flow duration of 75 percent the seasonal flow durations would be 4.8 cms (low), 30.1 cms (medium) and 53.3 cms (high).

Bankfull Flow and Frequency Analysis

Various definitions of bankfull flow exist in the literature (Rosgen, 1996). Generally bankfull flow relates to the 1.5 to 2 year annual peak flows. Figure 2 presents a plot of the annual peak flows along with the estimated bank full flow, 1.5 yr and 2 yr frequency peak flows and flow at top of bank. Based on these initial estimates bankfull is less than the 1.5 and 2 year frequency flows which are all less than the top of bank flow. Table 1 gives the number of years over the period of record each flow value is exceeded and when the peak flow exceeds the specified value the number of days the flow exceeds the specified flow. This represents the duration of the “low level flooding period”. Thus from this analysis we can identify the magnitude, frequency and duration of low level flood flows. For example the 1.5 yr frequency flow was exceeded 20 out of 33 years (61 %) and when it was exceeded the average duration was 47 days.

DISCUSSION

Monthly flow duration analysis of daily flow clearly shows the seasonal variability of flows over the range of flow duration percentages. Representation of minimum daily environmental flows on a seasonal basis can represent minimum daily flows and annual seasonal variability. The selection of which specific percent duration to use is a bit more subjective. Percent durations tend to be lower (i.e. 90 %) for arid to semi-arid regions and higher for wetter climate regions (70 to 80 %). Our initial recommendation is on the order of 75 to 80 % with an understanding that the specified minimum percent duration can be adjusted through adaptive management practices.

In addition to establishing a minimum daily seasonal flow, the magnitude frequency and duration of flood flows should be established to provide for river flushing and riparian enrichment (Rosgen, 1996). Based on the frequency and duration of flows exceeding bankfull for the Orkhon River at Bulgan (Orkhon-Orkhon gauge), flood flows that exceed bankfull should occur on average about every 1.5 to 2 years and should have a duration of 33 to 47 days. The storage to provide for the flood flows can be incorporated into the storage requirements of a proposed reservoir. Once a certain minimum storage level is reached an operational release can be triggered to release low level flood flows.

CONCLUSION

We have recommended a two level approach to establishing minimum environmental flows that includes a minimum seasonal daily flow and the magnitude frequency and duration of a low level flood flow that would provide for river flushing and riparian enrichment. The minimum seasonal flows are represented by the seasonal 75^{th} percentile flow duration. The magnitude and duration of low level floods can be well represented by the 1.5 year frequency flow. Our results provide environmental flow characterization that can be used in an adaptive management approach for the development and operation of proposed reservoirs.

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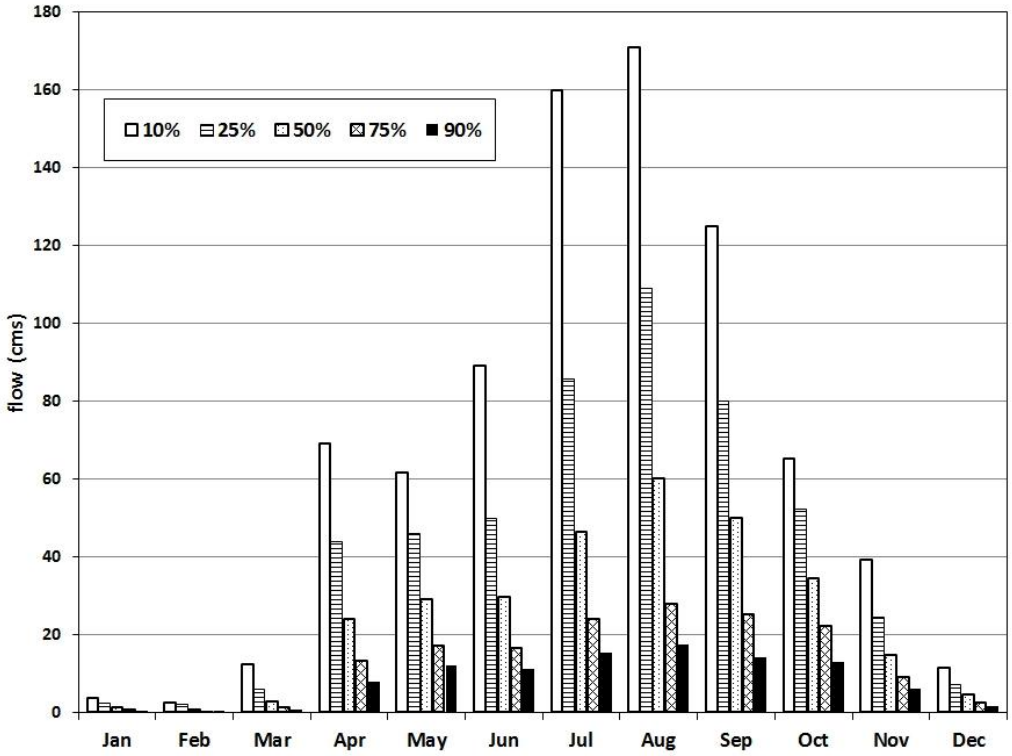

Figure 1. Monthly flow duration percentiles of daily flows for the Orkhon River at Bulgan for the period 1978 to 2010.

Table 1. Annual frequency and duration of selected low-level floods (bankfull, 1.5 and 2 year frequencies) for the Orkhon River at Bulgan (Orkhon-Orkhon).

Flow Characteristic	Flow (cms)	# of Years Exceeded	% of Years Exceeded	Statistics of Number of Days exceeded			
				mean	median	maximum	minimum
bankfull flow	30	33	100	131	148	260	3
top of bank flow	177	14	42	19	4.5	129	1
1.5 year return period flow	95	20	61	47	32.5	157	4
2 year return period flow	140	19	58	24	12	143	2

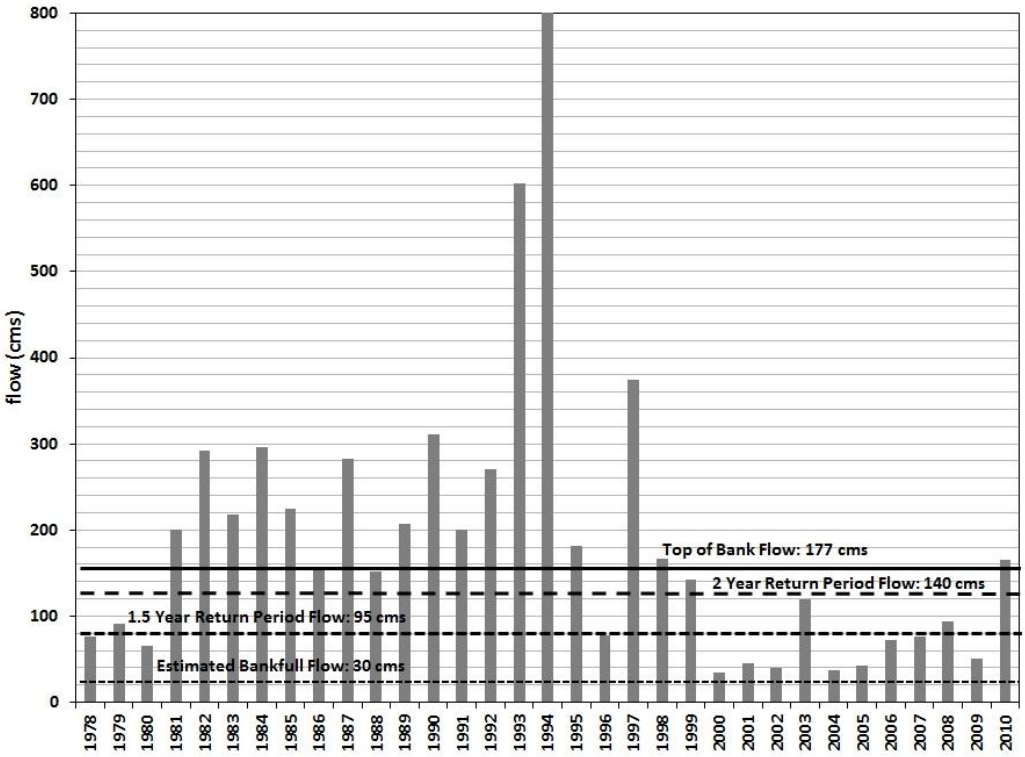

Figure 2. Annual peak flows, bankfull flow, 1.5 and 2 year return period flows with number of years exceeded and exceedance duration in days for the Orkhon River at Bulgan (Orkhon-Orkhon gauge).