Predicting Peak Flow Frequency in Maryland's Western Coastal Plain

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ABSTRACT

This study developed a set of regression equations to predict flood frequency in Maryland's Western Coastal Plain physiographic region using drainage area (DA), saturated hydraulic conductivity (Ksat), and impervious area (IA) as predictors in the form of two equations: Equation 1 (DA, Ksat) and Equation 2 (DA, Ksat, IA). The flood frequency analysis program, PeakFQ, was used to estimate the 2, 5, 10, 25, 50, and 100 year floods at each USGS gauged watershed in the Western Coastal Plain. A Geographical Information System (GIS) was used to determine drainage area and Ksat for each watershed. Numerical optimization was used to develop power law regression equations for each of the six return periods. Statistical analyses of explained variance (EV), bias, relative standard error, and correlation were used to determine goodness of fit for Equation 1 and Equation 2. A previous set of regression equations from the Maryland Hydrology Panel (MHP) were also used for comparison. The MHP equations did not include Ksat as a predictor. Equation 2 was found to be the most accurate at predicting the flood magnitude of smaller flood years when compared to Equation 1 and the Maryland Hydrology Panel equations. The improved goodness of fit predictors results for both Equation 1 and Equation 2 over the MHP equations indicate the value of Ksat as a predictor. The results of this study are useful for hydrologic design where flood magnitude needs to be estimated.

INTRODUCTION

Flood frequency is represented by the equation: P = 1/T, meaning probability is equal to 1/Time. For example, the probability of a 2 year flood occurring has a ½ or 50% chance of occurring in any given year and the probability of a 100 year flood occurring has a 1/100 or 1% chance of occurring in any given year. Research on flood magnitudes are significant as they can be useful to engineers who design and build infrastructure according to how flood estimates. For instance, civil engineers could use the predicted 25, 50, and 100 year flood values to determine how tall a bridge needs to be so that it will not be overtopped by a flood. Research can provide assistance in the future to hydrologists, environmental engineers, civil engineers and those with similar interests. To predict flood frequency and peak flow, regression equations are used. The purpose of the research that was conducted was to develop regression equations that can be used to predict the 2, 5, 10, 25, 50, and 100 year floods in Maryland's Western Coastal Plain region and compare equation performance with existing equations from the Maryland Hydrology Panel.

RESEARCH QUESTION

Which set of regression equations is more accurate at predicting how large peak flow will be during the 2, 5, 10, 25, 50, and 100 year flood?

My hypothesis was that the second equation developed, Ksat equation 2, would be a more effective regression equation based on explained variance (EV), bias, relative standard error (Se/Sy), and the correlation coefficient, because the second equation contains both, Ksat and Impervious Area of land (IA) as predictors.

METHOD

Peak flow time series data was analyzed for 26 watersheds in the Maryland Western Coastal Plain. The PeakFQ (U.S.Geological Survey 2014) program was used to perform flood frequency analysis, using the Bulletin 17B (IACWD 1982) method to estimate the 2, 5, 10, 25, 50, and 100 year floods at each gauge. GIS was then used to delineate the watersheds of each gauge to determine drainage area and the Ksat value for the given gauge. IA was gathered from the Maryland Hydrology Panel Report, (MHP 2016). Numerical optimization was used to calibrate equations of the form $Qp=c0*DA^{c1}*K_{sat}^{c2}$ by relating the x-year flood values across 26 study watersheds to measurements of DA and Ksat. Numerical optimization was used to calibrate equations of the form $Qp=c0*DA^{c1}*(IA+1)^{c2}K_{sat}^{c3}$. Ksat equation 1, Ksat equation 2, and the Maryland Hydrology Panel equations were then compared by their individual goodness of fit for each return period.

FINDINGS AND IMPORTANT CHARTS

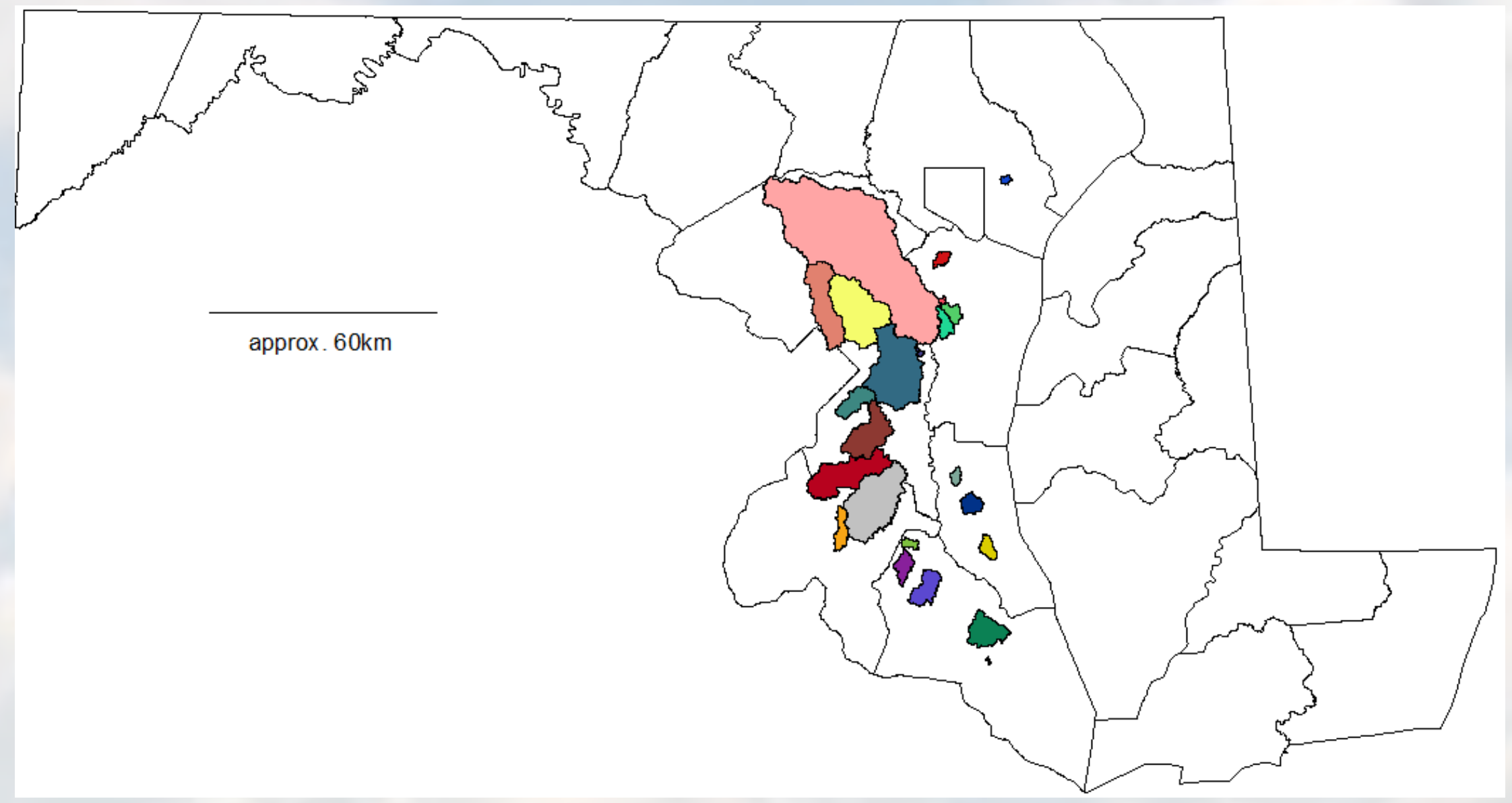

Figure 1. Watersheds that were studied during this research. The watersheds were delineated in GIS software to show this.

Ksat 1 Equations

Equation	EV	Bias	Se/Sy	Correlation Coefficient
$Q_2 = 3408DA^{0.455}K_{sat}^{-1.216}$	0.82	74.4 ft^3/s	0.36	0.905
$Q_5 = 4200DA^{0.437}K_{sat}^{-0.856}$	0.81	112 ft^3/s	0.37	0.903
$Q_{10} = 4591DA^{0.42}K_{sat}^{-0.856}$	0.80	173 ft^3/s	0.39	0.896
$Q_{25} = 4493DA^{0.4}K_{sat}^{-0.62}$	0.76	227.6 ft^3/s	0.45	0.872
$Q_{50} = 4029.5DA^{0.38}K_{sat}^{-0.405}$	0.69	174 ft^3/s	0.53	0.832
$Q_{100} = 3271DA^{0.37}K_{sat}^{-0.146}$	0.571	255.4 ft^3/s	0.65	0.756

Table 1. Calibrated equations and goodness of fit statistics for the Ksat equation 1 regression equation structure for Maryland's Western Coastal Plain.

Ksat 2 Equations

Equation	EV	Bias	Se/Sy	Correlation Coefficient
$Q_2 = 4DA^{0.77}(IA+1)^{1.02}K_{sat}^{0.04}$	0.88	-20 ft^3/s	0.23	0.94
$Q_5 = 33DA^{0.64}(IA+1)^{0.72}K_{sat}^{-0.027}$	0.86	14.6 ft^3/s	0.286	0.926
$Q_{10} = 156DA^{0.55}(IA+1)^{0.504}K_{sat}^{-0.144}$	0.83	68 ft^3/s	0.34	0.91
$Q_{25} = 656.3DA^{0.47}(IA+1)^{0.29}K_{sat}^{-0.194}$	0.77	148.4 ft^3/s	0.44	0.878
$Q_{50} = 1564.5DA^{0.416}(IA+1)^{0.142}K_{sat}^{-0.19}$	0.69	213.5 ft^3/s	0.54	0.832
$Q_{100} = 3062DA^{0.373}(IA+1)^{0.011}K_{sat}^{-0.131}$	0.57	275.75 ft^3/s	0.666	0.755

Table 2. Calibrated equations and goodness of fit statistics for Ksat equation 2 regression equation structure for Maryland's Western Coastal Plain.

Maryland Hydrology Panel Equations

Equation	EV	Bias	Se/Sy	Correlation Coefficient
$Q_2 = 6.73DA^{0.678}(IA+1)^{0.362}(S_{CD}+1)^{0.429}$	0.821	-177 ft^3/s	0.48	0.906
$Q_5 = 10.5DA^{0.665}(IA+1)^{0.29}(S_{CD}+1)^{0.612}$	0.793	230.5 ft^3/s	0.42	0.89
$Q_{10} = 12.1DA^{0.653}(IA+1)^{0.27}(S_{CD}+1)^{0.669}$	0.774	328 ft^3/s	0.47	0.88
$Q_{25} = 17.5DA^{0.634}(IA+1)^{0.264}(S_{CD}+1)^{0.719}$	0.723	441.5 ft^3/s	0.565	0.85
$Q_{50} = 21.2DA^{0.621}(IA+1)^{0.263}(S_{CD}+1)^{0.751}$	0.646	401 ft^3/s	0.677	0.804
$Q_{100} = 25.6DA^{0.608}(IA+1)^{0.262}(S_{CD}+1)^{0.781}$	0.516	181 ft^3/s	0.80	0.718

Table 3. Calibrated equations and goodness of fit statistics for the Maryland Hydrology Panel regression equation structure for Maryland's Western Coastal Plain.

S_{CD}, seen in the Maryland Hydrology Panel Equations, is the percentage of soils classified as being in hydrologic group C or D (Chaney et al. 2016)

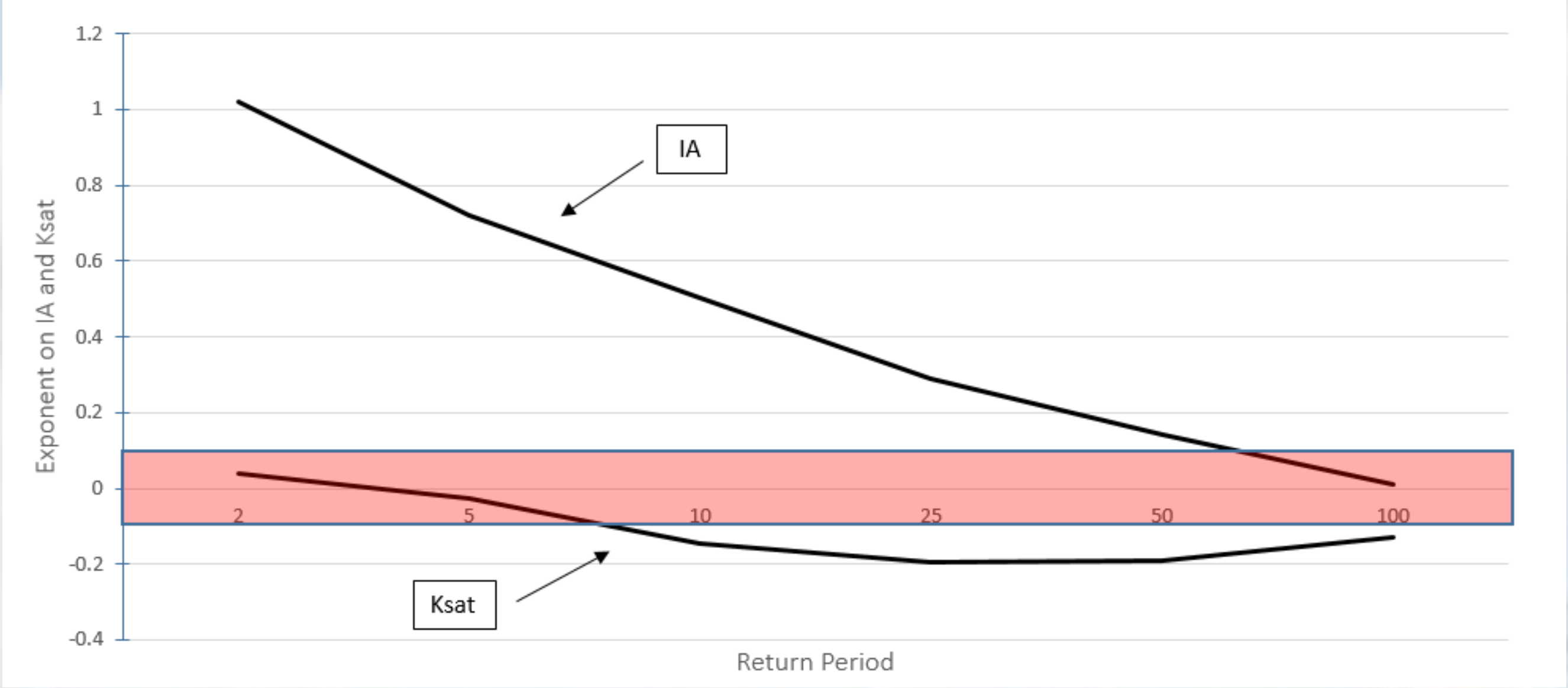

Figure 2. Exponents for Ksat and IA in Ksat equation 2 that appear in the red region indicate that value of an exponent has little to no effect on the estimate made by an equation.

RESULTS

As seen in Ksat equation 2, Ksat seems to have little to no effect on the estimate made by an equation for the return periods 2, 5, and 10. At the return period of 25 years, the exponent associated with IA becomes closer to the number zero and the exponent associated with Ksat, is not as close to zero as it was in the smaller return periods. This could mean that IA is a more effective variable to use when estimating with smaller floods and IA is not a more effective variable than Ksat to use when estimating with larger floods. This is because Ksat equation 1 and 2 generally give the same estimate regardless of Ksat equation 2 including IA, when calculating larger flood values.

CONCLUSION

Findings showed that Ksat equation 2 is more accurate at predicting flood magnitude when it concerns smaller return periods. While Ksat equation 1, seems to be more accurate with larger return periods. As Ksat equation 2 was only more effective to use for the smaller flood years observed, my alternative hypothesis cannot be accepted.

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CITATIONS

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