TUNING BANKFULL FLOW TO CLIMATE AS A PATH TO BETTER ESTIMATES OF SOURCE-TO-SINK MASS FLUX

by

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CHAPTER 1

INTRODUCTION

Estimating the discharge of sediment and water from source-to-sink is a central goal of paleohydrology. Whether estimating mass flux independently or validating another independent source-to-sink flux model the need for more accurate estimates sediment flux is evident (e.g. Hutton and Syvitski, 2008; Kettner and Syvitski, 2008; Parker et al, 2008; Whittaker et al. 2010; Holbrook and Wanas, 2014). Refining estimates on sediment flux is particularly significant within continental basin reservoirs where fluvial sandstones are common hydrocarbon targets for exploration (Bohacs, 2012). By improving sediment flux estimates through a channel, and so the amount of sediment expected in a sink, reservoir quantity estimates can also be improved (Mazumder, 2017), saving both time and money through risk mitigation.

Improving water discharge estimates has implications for the sedimentary and hydraulic cycle with both modern and ancient applications. Impact on climate, agriculture and drinking water supply are some of the more pressing drivers to better understand the effects of water discharge on the modern global water cycle (Biemans et al., 2011; Harding et al., 2011; Cohen et al., 2014). Significant stratigraphic implications of improved water discharge estimates include more accurate sediment flux interpretations and refined paleohydraulic relationships (Holbrook and Wanas, 2004; Davidson and North, 2009). Regional hydraulic curves are used to relate channel dimensions to drainage area and water discharge for both modern and stratigraphic channels but are often restricted to a single or limited climates (Andrews, 1980; Castro and Jackson, 2001; Cinotto, 2003). With flood magnitude and frequency being shown to be highly sensitive to climate (Baker and Penteado-Orellana, 1977; Knox, 1993; Plink-Björklund, 2015) analysis focusing on the proportion of water discharged during bankfull flow as it varies between climates regardless of region is merited.

The Fulcrum approach is potentially a widely applicable tool for estimating ancient source-to-sink sediment flux because it relies on data readily available from boreholes and outcrops (Holbrook and Wanas, 2014). The Fulcrum approach, however, provides a mass balance estimate only within an order of magnitude, and requires further refinement to increase this accuracy (Holbrook and Wanas, 2014). The objective of this thesis is to improve the current Fulcrum approach for source-to-sink sediment flux estimation by expanding the existing default value used in Holbrook and Wanas (2014) for days at bankfull (t_{bd}), to climate and drainage area specific values encompassing all major climates through extensive data collection and analysis. A queryable relational database that yields system-specific bankfull variables, and a user interface to make these queries available to a non-technical user, are the deliverables of this project.

CHAPTER 2

BACKGROUND

Source-to-sink evaluates the journey of sediment, from its point of erosion through ultimate deposition (Meade, 1972, 1982; Sømme et al. 2009a; Allen, 2017). For water-transport systems, this also typically incorporates the total discharge of water involed in sediment flux (e.g., Syvitski and Milliman, 2007). The source-to-sink system includes the catchment or drainage area, shelf, slope and basin floor (Sømme et al 2009b). Each segment is independently affected by variables such as regional climate and tectonics (e.g. Wolman & Miller, 1960; Blum & Tornquist, 2000; Whipple, 2009) and yet they are interrelated in that erosion or deposition within one segment will be manifested in morphological alteration within another (e.g., Moore, 1969; Sømme et al 2009b; Allen, 2017). The ability to understand how each segment of this system interdepends on the others depends on accurate estimates of sediment flux through the source-to-sink system. This is critical to understanding stratigraphic systems (Martinsen et al., 2010), and also the impacts of modern communities on sediment flux (Dearing & Jones, 2003; Syvitski & Kettner, 2011).

Established methods for determining sediment flux from source to sink include grain sequestration, catchment approaches, accumulated basin volume, and the Fulcrum approach. Sediment flux estimates based on grain sequestration assumes that as sediment moves further from the source larger grains will be continuously deposited, and so segregated out across distance, leading to overall decrease in grains-size downstream (Parker, 1991; Paola et al.,1992; Hoey & Bluck, 1999; Whittaker et al., 2011). While data collection for the application of this method only requires longitudinal sampling and determining sediment grainsize, this basic approach hinges on knowing the original grain size and method of sediment separation which results in a large margin of error (Toro-Escobar et al., 1996; Hovius & Leeder, 1998; Whittaker et al., 2011). In a catchment approach variables that dictate sediment yield within a drainage area such as catchment area, catchment length, mean annual precipitation and local slope, are used to predict the yield through forward modeling (Walling, 1983; Allen et al., 2013). An example of this being applied to modern fluvial systems would be the BQART approach (Syvitski and Milliman, 2007). Variables for the catchment approach can be estimated from the rock record, but sediment estimates at best will only be accurate within an order of magnitude (Allen et al., 2013). The basin volume approach is based on the assumption that the sediment volume found in the sink must be equivalent to the sediment yield from the drainage basin (Sømme et al, 2009a). This approach can also be problematic as it can be difficult to define the entire drainage basin (Martinsen, 2016) and unless the catchment area and the sink area are closed this approach will not provide valid sediment flux estimates. The basis for the Fulcrum approach is the assumption that for sediment to be moved from source to sink it must pass through a cross sectional point, meaning by estimating the amount of sediment passing through this fulcrum point the amount of sediment moving from the source to the sink can be determined (Holbrook and Wanas, 2014). While there are several established methods for determining sediment flux from source to sink all methods have limitations and are only accurate within an order of magnitude.

The accuracy of the Fulcrum approach relies on estimating the duration of time a stream runs at bankfull flow (t_{bd}) and the proportion of sediment discharged during this flow (b). Mean annual sediment discharge (Q_{mas}) is estimated for a channel by multiplying the variables of (t_{bd}) and (b) against a calculated value for bankfull sediment discharge (Q_{bts}), with full methods for calculation of (Q_{bts}) provided in Holbrook and Wanas (2014) (**Equation 1**).

$$Q_{mas}=Q_{bts}\ (t_{bd})\ b \quad (\mathbf{1})$$

With slight modification, using the proportion of water discharged during bankfull for the variable of (b) and bankfull water discharge for (Q_{bts}), this same equation can be used to estimate total water discharged annually during bankfull flow. Bankfull flow is defined as the channel forming flow (Wolman and Miller, 1960) and fills the channel to the top of the river banks on the brink of spilling onto the floodplain (Williams, 1978). The effective discharge of a stream is defined as the averaged discharge that transports the largest percentage of the sediment annually (Andrews, 1980). Effective and bankfull discharge are not the same but do generally converge on the same value (Andrews, 1980). The bankfull channel dimension is determined by the flood that has sufficient erosive power and reoccurs often enough to be the dominating force shaping the channel, and the effective discharge is the most erosive flood, denoting these discharges would be similar. Accurately estimating days at bankfull flow, and discharge during this time, is critical to the Fulcrum approach.

Input variables beyond t_{bd}, year averaged days at bankfull flow, and b, the bankfull annual proportion of discharged sediment, for the Fulcum approach (i.e. channel fill thickness and grainsize) are very extractable directly from rock record (Holbrook and Wanas, 2014). Channel story thickness can be used to estimate the depth and width of the bankfull channel in ancient fluvial systems (Bridge and Tye (2000), Bridge (2003) and Mohrig et al. (2000). Representative bedload grainsize can be pulled from the base of a channel-belt deposit. A deficiency of the Fulcrum method however, as identified by Holbook and Wanas (2014), is that the Fulcrum approach currently relies on an averaged default value for t_{bd} and b to estimate mean annual sediment discharge. The refinement of the value of t_{bd} that is tuned to paleoclimate is the focus of this work. Data availability constraints impeded the ability to further the default value of b. By minimizing the source of error originating from the use of the generic value for t_{bd}, the Fulcrum approach will progress to become both an accessible and more accurate method of estimating sediment flux within an ancient fluvial channel.

Many workers (Schmidt et al., 2001; Dai & Trenberth, 2002; Wang et al., 2006; Biemans et al.,2009; Fielding, 2009; Wulf et al., 2010; Plink-Björklund, 2015) have started to address the relationship between river discharge and seasonal precipitation. Climate effects both precipitation and in turn vegetation, both of which have significant impact on the amount of denudation that occurs on a landscape, the amount of sediment yield from the landscape and so the amount of sediment that is discharged from a stream. An increase in rainfall will increase sediment flux, while temperature increase can potentially decrease sediment. This balance between precipitation and temperature, as dictated by the climate of the stream environment, can significantly affect the overall sediment flux of the system (Inman & Jenkins, 1999; Lang et al., 2003; Bookhagen et al., 2005; Zhu et al., 2008).

While previous work (Simon et al, 2004) has addressed the impact of climate on the periodicity of effective discharge and suspended sediment transport rate, the effect of climate on bankfull duration has yet to be fully developed (Holbrook and Wanas, 2014).

Due to the impact of climate on sediment flux it can be presumed that the days a stream is at bankfull flow (t_{bd}) will also be largely influenced by the climate of the stream environment. Error will be significantly minimized in the Fulcrum approach for estimating sediment flux by refining the current generic values of t_{bd} to a climate specific value.

CHAPTER 3

METHODS

Estimation of total days at bankfull flow requires knowledge of the bankfull flow value and stream gage records. Bankfull discharge values were collected through literature research and are restricted to gauged sites managed by the USGS or an international entity. Daily water discharges from these gauges, were then compared to the measured bankfull discharge values over multiple years to derive how many days in a year each stream flows at bankfull levels. Gaged flow data was included as bankfull for bins of both ±10% and ±20% of the published value for bankfull discharge. More information on procedures used to collect discharge values at gages is available in Olson and Norris (2007).

Specific days at bankfull are binned based on the criteria of drainage area, bankfull channel depth, bankfull-channel cross-sectional area, and climate. Climate is defined using the Köppen classification (**Figure 1**), which remains the most used climate classification after a century (Peel et al, 2007). Days at bankfull is evaluated for all 1st order climate classifications of Tropical, Arid, Temperate, Cold and Polar, and further derived for all 3rd order classifications (i.e. Tropical Rainforest) where data permits. Climate for each stream is assigned based on Köppen-Geiger style maps made available in Peel et al (2007). Each stream gauge site location is mapped on Google Earth. A kmz file made available at URL: https://webmap.ornl.gov/ogc/dataset.jsp?ds_id=10012 by the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) and a NASA backed Earth Observing System Data and Information System (EODIS) data center, was used to determine and assign a climate to each individual stream gage (ORNL

DAAC, 2017) (see **Appendix I** for further details). Sufficient river examples are available for most climates within the United States (**Figure 2**) but some (i.e. Tropical Rainforest) are not. Additional stream data was acquired internationally to ensure these climates were also addressed within this study.

This study is limited to streams with small and medium drainage areas so that single climates could be assigned to single drainages. Larger drainages typically cross multiple climates and discharge trends record a composite climate signal. Streams used in this study have drainages within single Köppen climate polygons to assure legitimacy in comparison of discharge trends according to climate characteristics. This is made simpler by limiting the size of drainage areas considered in this study to $\leq$ 30,000 km^2.

Stream drainages are assigned a climate and tested for consistency using the Watershed Boundary Dataset (WBD). The WBD is a dataset which uses nested hydrologic units at different scales to capture surface water drainage in the United States (USGS, 2013). This additional quality control step was only considered warranted for US streams because of the diversity of climates within a small geographical area. Internationally sourced streams used are within large Köppen polygons and climate assignment and testing could be completed directly from Köppen maps. The smallest hydrologic unit of HUC 12 made available in the Watershed Boundary Dataset is used as a first pass to review the climate for each contributing drainage area. Only four streams span two climates within a single HUC 12 polygon.

1st Order	2nd Order	3rd Order	Description
A			Tropical
	f		Rainforest
	m		Monsoon
	w		Savannah
B			Arid
	W		Desert
	S		Steppe
		h	Hot
		k	Cold
C			Temperate
	s		Dry Summer
	w		Dry Winter
	f		Without Dry Season
		a	Hot Summer
		b	Warm Summer
		c	Cold Summer
D			Cold
	s		Dry Summer
	w		Dry Winter
	f		Without Dry Season
		a	Hot Summer
		b	Warm Summer
		c	Cold Summer
		d	Very Cold Winter
E			Polar
	T		Tundra
	F		Frost

Figure 1: Köppen climate symbols with description (Adapted from Pell el al, 2007). Full criteria for each classification can be found in Pell et al (2007).

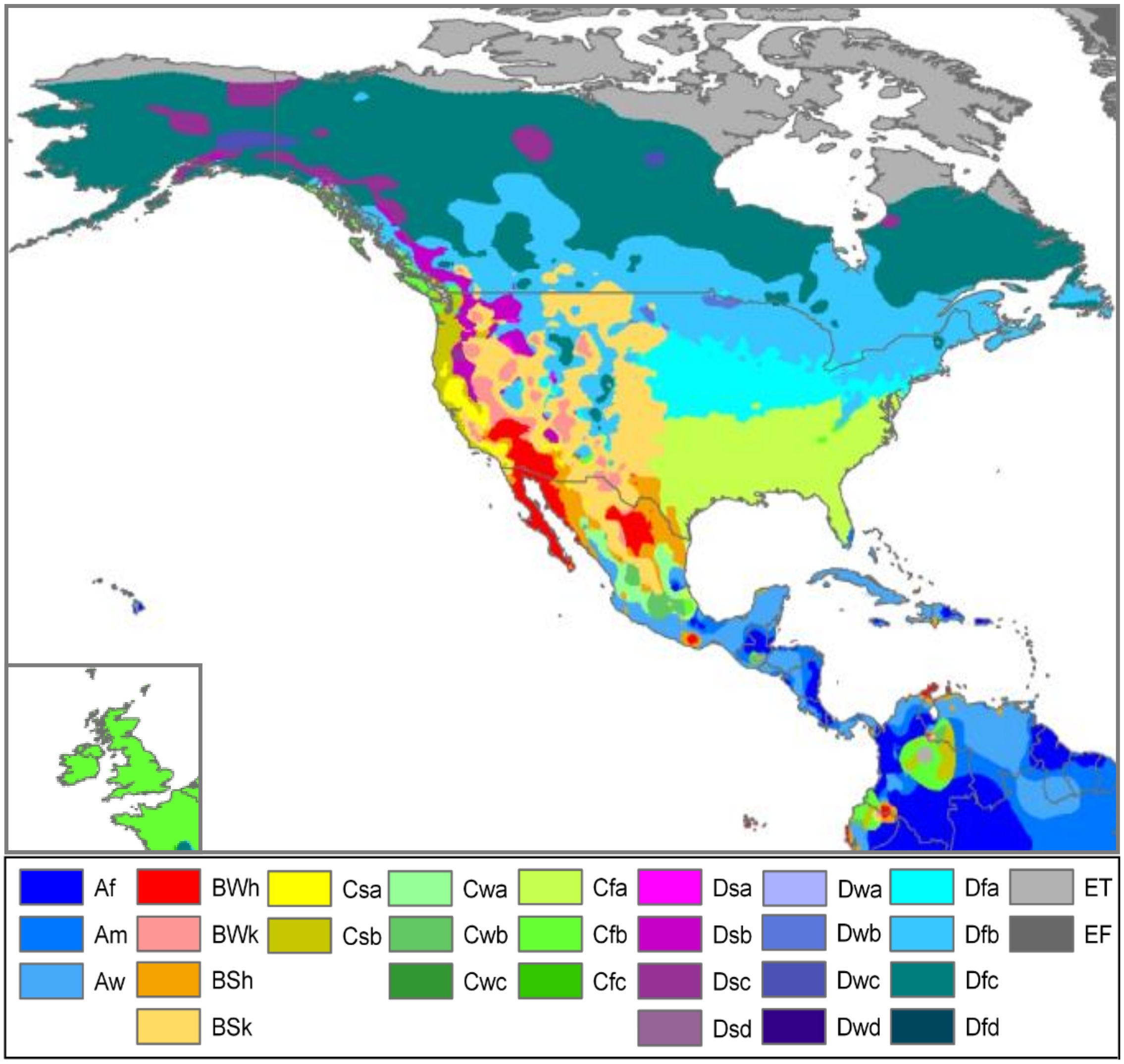


Figure 2: This Köppen-Geiger type climate map illustrates that a majority of all climate classifications, as defined in Figure 1, are present within the United States. The greatest need for additional international data being in the extreme climates of tropical and polar (Peel et al, 2007). Data was acquired for streams in the the United States, Canada, Puerto Rico, Colombia and Ireland (inset).

Gaging data and stream attributes are sourced from the USGS and additional international entities (**Table 1**). Data collected for all streams includes location of the gauging unit and drainage area, as well as daily discharge values. USGS data is collected for monitored streams with an automated java based website scraping tool to query the USGS water data website (URL:

https://waterdata.usgs.gov/nwis/dv?referred_module=sw&search_criteria=search_site_no&search_criteria=site_tp_cd&submitted_form=introduction). Data is imported into a csv file which is then imported into a relational database. All daily discharge values acquired from international data sources were mined through a manual process of acquiring bulk files from the regulatory entity or by requesting data directly from the providing agency.

Number of Sites	**Data Source**
51	HYDAT: The Water Survey of Canada (WSC)
7	IDEAM: Institute of Hydrology, Meteorology and Environmental Studies
39	OPW: The Office of Public Works
514	USGS: United States Geological Survey : National Water Information System
Total Site Count: 611	

Table 1: Distinct counts of number of stream gauge sites where stream description data was able to be acquired for this study from both domestic and international data sources.

A SQL relational database and a web based user interface manage and leverage the acquired gauged stream data, climate data and bankfull estimate values collected from the literature. The database is developed as a senior design project partnering with the Texas Christian University (TCU) Computer Science Department. I provided detailed business rules, data load logic, data maps, user stories and screen mockup documentation (**Appendix I, Appendix II, Appendix III**) to a dedicated team of 4 undergraduate Computer Science majors including: Jim Pfluger, Kaitlin Hendrick, Connor Cox and Kiet Nguyen. This team used the provided documentation to complete all outlined and managed development tasks over the course of the Fall 2017 and Spring 2018 terms. Basic workflow for acquisition and data management and the data structure for the SQL database are illustrated in **Figure 3** and **Figure 4**. The reference tables of REF_CLIMATE, REF_CLIMATE_LOCATION, REF_COUNTRY, REF_STATE, REF_COUNTY, and REF_LITERATURE_SOURCE are populated to manage Köppen climate values, climate location correlation values and literature references, respectively. Primary tables of STREAM_DISCHARGE_DATA, BANKFULL_DISCHARGE_LIT, and STREAM_DESC_DATA are populated to manage stream discharge values, literature bankfull discharge data and stream characteristic attributes including but not limited to drainage areas and latitude, longitude values. Stored procedures are developed to compute how often each specific stream runs within 10 and 20 percent of the bankfull discharge volumes collected from the literature. The database can be queried to analyze the relationship between this derived value of days at bankfull in regard to both stream specific climate and spatial attributes. A full data dictionary for all attributes populated within the database can be found in **Appendix IV**.

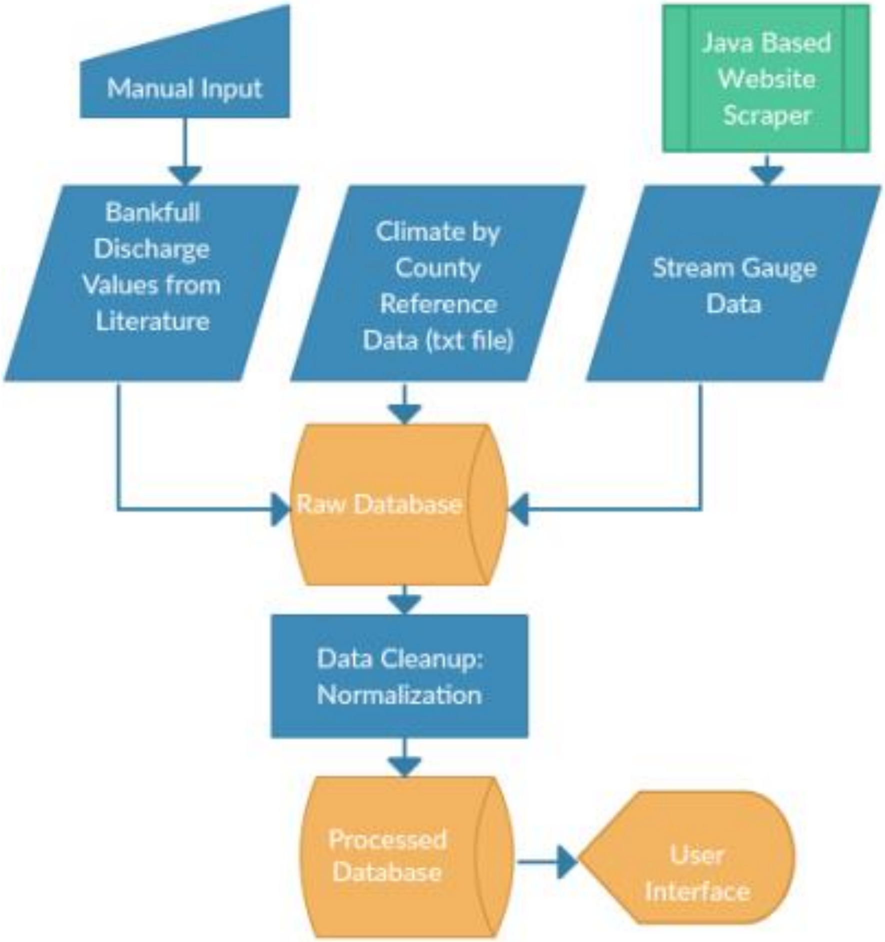
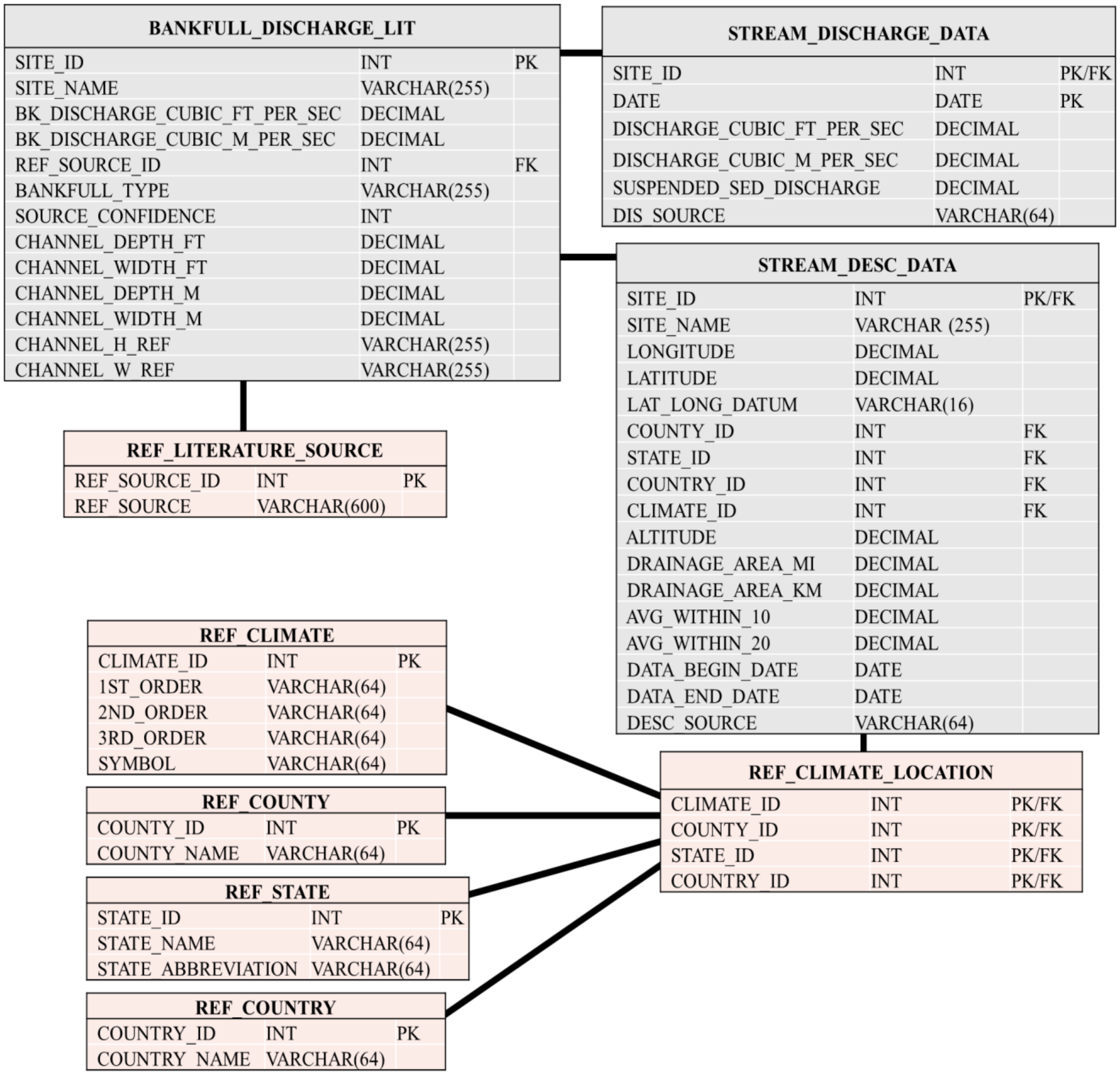


Figure 3: Basic data workflow diagram.



BANKFULL_DISCHARGE_LIT		
SITE_ID	INT	PK
SITE_NAME	VARCHAR(255)	
BK_DISCHARGE_CUBIC_FT_PER_SEC	DECIMAL	
BK_DISCHARGE_CUBIC_M_PER_SEC	DECIMAL	
REF_SOURCE_ID	INT	FK
BANKFULL_TYPE	VARCHAR(255)	
SOURCE_CONFIDENCE	INT	
CHANNEL_DEPTH_FT	DECIMAL	
CHANNEL_WIDTH_FT	DECIMAL	
CHANNEL_DEPTH_M	DECIMAL	
CHANNEL_WIDTH_M	DECIMAL	
CHANNEL_H_REF	VARCHAR(255)	
CHANNEL_W_REF	VARCHAR(255)	

STREAM_DISCHARGE_DATA		
SITE_ID	INT	PK/FK
DATE	DATE	PK
DISCHARGE_CUBIC_FT_PER_SEC	DECIMAL	
DISCHARGE_CUBIC_M_PER_SEC	DECIMAL	
SUSPENDED_SED_DISCHARGE	DECIMAL	
DIS_SOURCE	VARCHAR(64)	

STREAM_DESC_DATA		
SITE_ID	INT	PK/FK
SITE_NAME	VARCHAR (255)	
LONGITUDE	DECIMAL	
LATITUDE	DECIMAL	
LAT_LONG_DATUM	VARCHAR(16)	
COUNTY_ID	INT	FK
STATE_ID	INT	FK
COUNTRY_ID	INT	FK
CLIMATE_ID	INT	FK
ALTITUDE	DECIMAL	
DRAINAGE_AREA_MI	DECIMAL	
DRAINAGE_AREA_KM	DECIMAL	
AVG_WITHIN_10	DECIMAL	
AVG_WITHIN_20	DECIMAL	
DATA_BEGIN_DATE	DATE	
DATA_END_DATE	DATE	
DESC_SOURCE	VARCHAR(64)	

REF_LITERATURE_SOURCE		
REF_SOURCE_ID	INT	PK
REF_SOURCE	VARCHAR(600)	

REF_CLIMATE		
CLIMATE_ID	INT	PK
1ST_ORDER	VARCHAR(64)	
2ND_ORDER	VARCHAR(64)	
3RD_ORDER	VARCHAR(64)	
SYMBOL	VARCHAR(64)	

REF_COUNTY		
COUNTY_ID	INT	PK
COUNTY_NAME	VARCHAR(64)	

REF_STATE		
STATE_ID	INT	PK
STATE_NAME	VARCHAR(64)	
STATE_ABBREVIATION	VARCHAR(64)	

REF_COUNTRY		
COUNTRY_ID	INT	PK
COUNTRY_NAME	VARCHAR(64)	

REF_CLIMATE_LOCATION		
CLIMATE_ID	INT	PK/FK
COUNTY_ID	INT	PK/FK
STATE_ID	INT	PK/FK
COUNTRY_ID	INT	PK/FK

Figure 4: SQL database data structure, primary tables in grey with reference tables in pink. All primary key attributes notated with 'PK' and all foreign key atttributes notated with 'FK'.

Attributed to similar analysis completed in previous works addressing the relationship between bankfull discharge and spatial attributes (Bent and Waite, 2013; Brockman, 2010; Cinotto, 2003; McCandless, 2003a; Mulvihill,2007) a series of statistical values are derived and reviewed in TIBCO Spotfire to analyze the relationship between the selected variables. Linear regression tests were completed in TIBCO Spotfire to analyze individual relationships between the independent variables of drainage area, average annual days of bankfull duration (t_{bd}) and proportion of water discharged during bankfull against the dependent variables of bankfull discharge, mean bankfull-channel depth and bankfull-channel cross-sectional area in aggregrate and binning by climate. Using Aabel statistical software multiple regression tests were completed to determine the impact, if any, of multiple combinations of the dependent variables of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area against the independent variable of $t_{bd.}$

While a SQL database is useful to a technical user a user interface (UI) is also needed to make this data just as easily accessible to a non-technical user. A UI that allows the user to query against the database for more stream specific t_{bd} values based on climate and spatial stream attributes is developed and is available at URL: http://www.rafter.tcu.edu. The UI also allows the input of all variables needed to run the full Fulcrum approach as well as a general query for analogous streams that may be found within the dataset. This UI is accessible outside of the TCU firewall so that workers from other institutions are able to leverage it when using the Fulcrum approach to determine sediment flux for their channel of interest.

This project has resulted in the deliverables of a queryable SQL database and user interface. The SQL database allows for the analysis of daily stream gauge data in conjunction with bankfull discharge data from the literature. This database enables the ability to identify trends in year averaged days at bankfull flow, in relation to the variables of climate and spatial stream attributes. The UI created from this project makes t_{bd} values derived from the database accessible to a non-technical user. Accessibility to the existing Fulcrum approach will also be improved through the UI due to allowing the user to plug in the climate and stream size specific t_{bd} values into the Fulcrum approach calculations, more accurately estimating sediment flux all within the interface.

CHAPTER 4

RESULTS

Regulatory and monitoring agencies, both domestic and international, collect data from hundreds of thousands of streams around the globe. Out of all streams reviewed from a subset of all rivers (**Table 2**), 615 streams have a bankfull discharge volume calculated by workers at a stream gauge site and out of these 615 streams 524 also have the required minimum of five years of daily discharge volumes. These 524 streams are the basis for the following results, these data are acquired from multiple entities **(Table 2)** to ensure a sampling of diverse climates.

Number of Sites in Study	Data Source
46	HYDAT: The Water Survey of Canada (WSC)
7	IDEAM: Institute of Hydrology, Meteorology and Environmental Studies: Colombia
39	OPW: The Office of Public Works: Ireland
432	USGS: United States Geological Survey : National Water Information System
Total Site Count: 524	

Table 2: Distinct counts of number of sites, that met data requirements, included in this study from both domestic and international data sources.

There are a total of 444 small streams, 65 medium streams and 6 large outlier streams within the final dataset. Most of the streams within the dataset are small streams, ‘small’ being defined within this dataset as streams that have a drainage area less than or equal to 2,000 square kilometers. Excluding 6 large outlier streams (all within climate ‘Dfb’), all other streams are medium in size with drainage areas ranging from 2,001-30,000 square kilometers in size. These classifications of stream size were determined based on natural breaks in data availability within this specific dataset.

Due to sourcing the data from multiple entities, available data attributes for each stream differ depending on the source from which it was acquired. Climate was assigned and the value of t_{bd} was calculated and populated for all 524 streams. Attributes of drainage area and bankfull channel size, while not required to calculate t_{bd}, are attributes used to bin the data and are also inventoried (**Table 3**). A total of 406 streams have the attributes of drainage area, channel size at bankfull flow, and climate populated, and are the data set that is available for comparison with this full set of parameters.

Number of Sites	Data Inventory
524	t_{bd} calculated and climate assigned
515	t_{bd} calculated, climate assigned and drainage area populated
425	t_{bd} calculated, climate assigned, drainage area and channel depth at bankfull populated
406	t_{bd} calculated, climate assigned, drainage area and channel area at bankfull populated

Table 3: Distinct counts for all sites included in this study with specified attributes for data inventory.

Relationships within and between spatial attributes (i.e., channel size, drainage area, and drainage climate) and temporal attributes (i.e., bankfull discharge, bankfull duration, and proportion of water discharged during bankfull flows) are each tested for confidence and surveyed graphically. The common practice of base10 log-transformation of data to make the data more linear and symmetric (Helsel and Hirsch, 2002) is not applied in this study to avoid minimizing outliers and skewness of the data (Changyong et al., 2014). A value for R and R^2 greater than .70 support a strong positive linear relationship between two variables, and argue the the variance of the dependent variable is explained by the independent variable. Values from .50-.70 indicate moderate correlation and values less than .50 indicate weak to no correlation, respectively (Moore et al., 2013). A p-value and F-statistic value are calculated to further test correlation and variation between selected attributes, along with multiple regression testing. In a linear regression model a small p-value (less than .05) and large F-statistic value (greater than 1) indicate the statistical test is significant and the regression line trend is valid **(Table 4)**. Student’s t-test was not used to analyze variance due to this method being best applied when dealing with only small sample sets (Fisher, 1925). Multiple regression analysis is used to examine the relationship between several selected independent variables and one dependent variable, enabling evaluation of correlation between differing combinations of independent variables (Arnold, 1981).

Variable	Definition	Interpretation of Values
R	The correlation coefficient measures the direction and strength of the linear relationship between two given variables with the value of R always ranging between positive and negative one.	An R value greater than .70 indicates a strong linear relationship, between .50-.70 a moderate relation, .30-.50 a weak correlation and less than .30 nonexistent relation.
R^2	The coefficient of determination, measures the proportion of variance explained by the independent variable, i.e. a R^2 value of .62 indicates 62 percent of the variance can be explained by the independent variable.	An R^2 value greater than .70 indicates a strong linear relationship, between .50-.70 a moderate relation, .30-.50 a weak correlation and less than .30 nonexistent relation.
p-value	The p-value is used to test if there is correlation between the given variables. The p-value is the probability that the test could be attained through random chance assuming the null hypothesis is correct, the null hypothesis being that the tested variables are not relevant.	Per standard statistical practices, a p-value less than or equal to .05 is interpreted as evidence to reject the null hypothesis with a p-value greater than .05 supporting failure to reject the null hypothesis.
F- statistic	The F- statistic value in the linear regression model test the statistical significance of the model. The F-statistic in the ANOVA test determines if the variation between the means of tested bins is significant.	In a linear regression model an F-statistic value greater than 1 indicates significant variation that rejects the null hypothesis, the null hypothesis being that the ratio between two quantities would be expected to be approximately equal. In ANOVA testing for the variance to be significant the F-statistic value must be greater than the calculated critical F value.

Table 4: Definitions for statistical variables computed in this study (Arnold, 1981; Rice, 2006).

4.1 DRAINAGE AREA VS. BANKFULL DISCHARGE AND CHANNEL SIZE

4.1.1 All Samples in Aggregate

Relationships between the spatial attributes of drainage area, mean bankfull-channel depth, and bankfull-channel cross-sectional area are compared here to each other and to bankfull discharge for small to medium streams in aggregate. This includes streams under 30,000 km² in drainage area and excludes the smaller data set of 6 large outlier streams. The correlation between bankfull discharge and drainage area is moderately positive (R^2 value of 0.39 and R value of 0.62). Correlation between drainage area and mean bankfull-channel depth is also weakly moderate but positive (R^2 value of 0.30 and an R value 0.55). Correlation between drainage area and bankfull-channel cross-sectional area is weak (R^2 and R value of 0.19 and 0.43). **(Table 6; Figures 5, 6, 7)**.

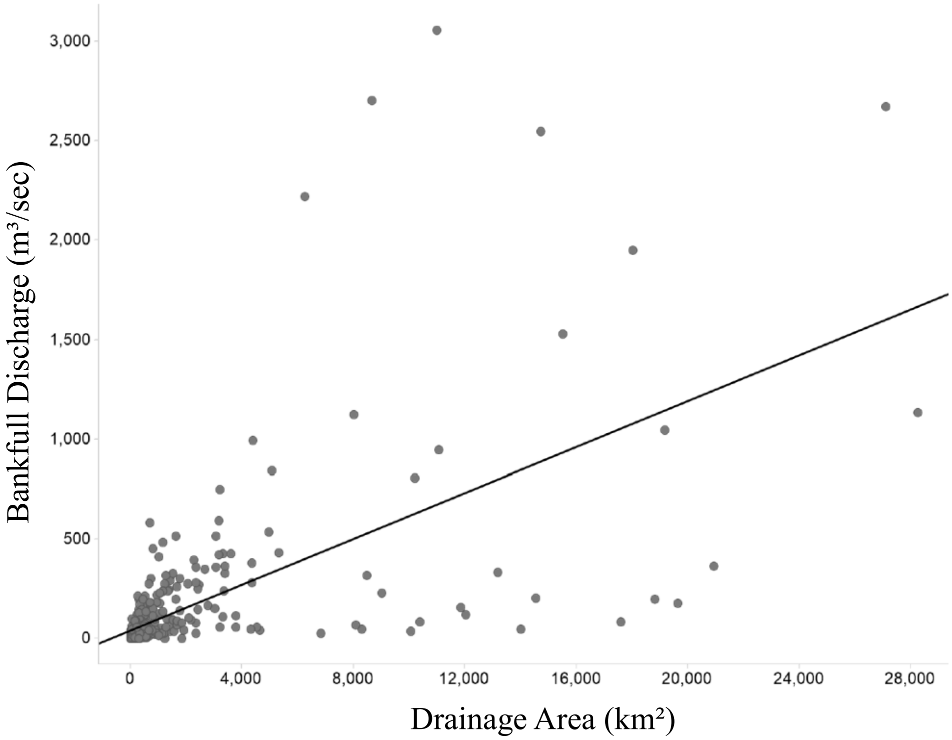


Figure 6: Relation between bankfull discharge and drainage area for small to medium streams. [m³/sec, cubic meters per second; km², square kilometers]

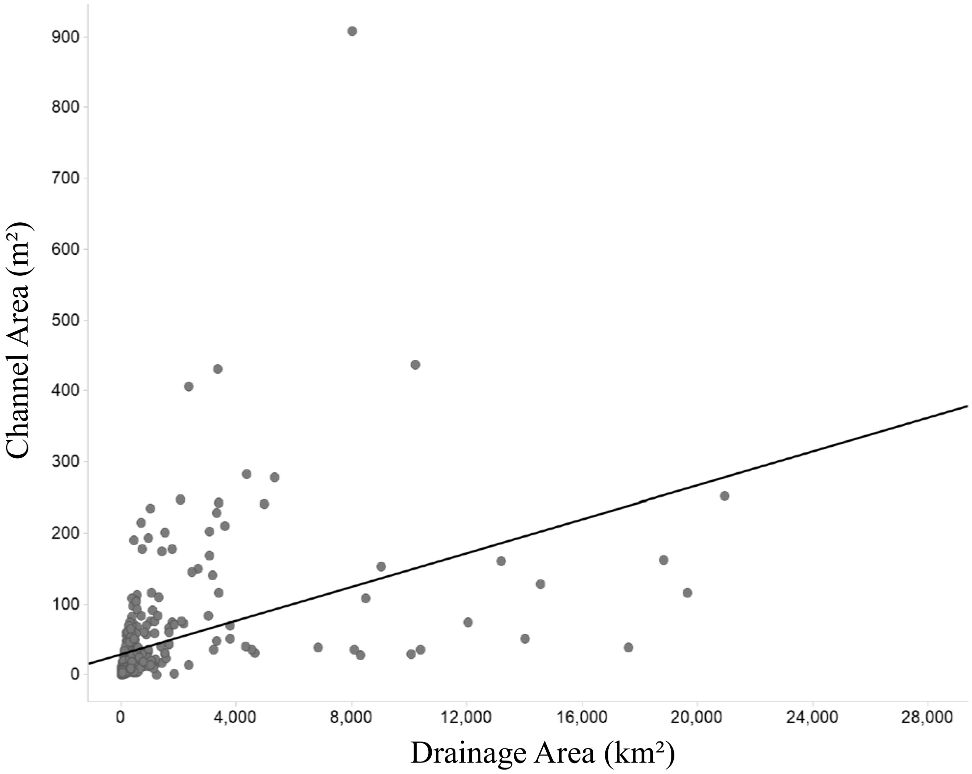


Figure 5: Relation between drainage area and bankfull-channel cross-sectional area for small to medium streams. [m², square meters; km², square kilometers]

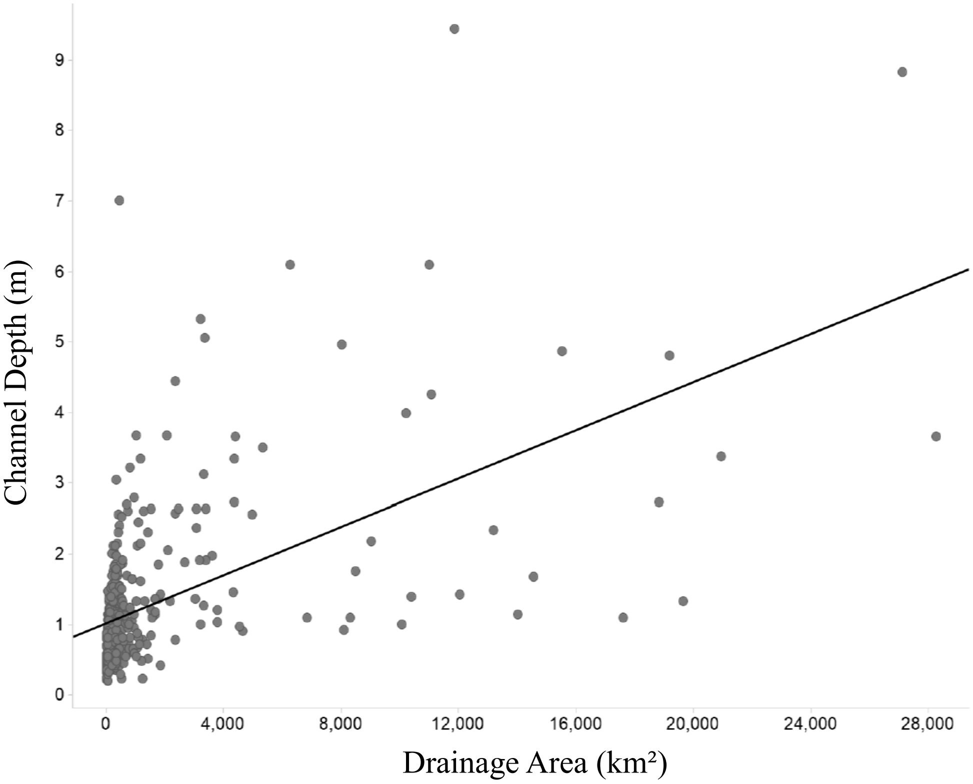


Figure 7: Relationship between drainage area and mean bankfull-channel depth for small to medium streams. [m, meters; km², square kilometers]

4.1.2 Binned by Major Climate

Sufficient data are available from 17 of the total 30 Köppen Climate classifications, to warrant analysis of discharge relationships for these specific climates. The number of sites per climate ranges from less than ten to over a hundred, depending of data availability (**Table 5**). The location of the stream gauge and drainage area are plotted on the Köppen World map (Peel, 2007). Each stream gauge location is plotted within a Köppen climate polygon, or within a margin of error of five miles, and the specified Köppen classification is assigned to that stream accordingly. While a sample of all major (1^{st} order) climates are included in this dataset, not all of the 30 finest divisions (3^{rd} order) Köppen Climate classifications are represented. This is because sufficient gaging information was not found for these climate areas. Some reasons include limited land area, and variations in land use not conducive to installation of a regularly monitored stream gauge, sparse population, and limited and/or unmanageable runoff episodes. For example the climate of Csc never occurs in the updated Köppen world map used for this study and Cwc only represents .0002% of global land area (Peel, 2007). Likewise, stream gauges in arid and other low populations areas are poorly represented.

Number of Sites	Köppen Climate Classification	Climate Description
5	Af	Tropical Rainforest
5	Am	Tropical Monsoon
1	Aw	Tropical Savannah
17	BSh	Arid Steppe Hot
35	BSk	Arid Steppe Cold
4	BWh	Arid Desert Hot
2	BWk	Arid Desert Cold
90	Cfa	Temperate Without dry season Hot Summer
41	Cfb	Temperate Without dry season Warm Summer
8	Csa	Temperate Dry Summer Hot Summer
36	Csb	Temperate Dry Summer Warm Summer
83	Dfa	Cold Without dry season Hot Summer
158	Dfb	Cold Without dry season Warm Summer
12	Dfc	Cold Without dry season Cold Summer
7	Dsa	Cold Dry Summer Hot Summer
17	Dsb	Cold Dry Summer Warm Summer
3	ET	Tundra

Table 5: Köppen climate classifications (Peel et al., 2007) as assigned for each stream included in this study.

The relationship between drainage area and bankfull discharge, mean bankfull-channel depth, and bankfull-channel cross-sectional area was further generally improved by binning all streams based on climate. Streams where binned by overall major climate, i.e. Polar, Cold, Temperate, Arid and Tropical and by specific Köppen climate classifications (**Table 5**). Grouping the data by 1st order major climate provides larger sample sets leading to more statistically significant results. Binning by 3rd order climate fosters the detailed analysis of the relationship between climate and spatial characteristics.

Binning all streams based on the assigned major climates strengthens correlation between bankfull discharge and drainage area compared to unbinned data. The aggregate sample of all streams showed a moderate correlation between bankfull discharge and drainage area. A moderate to strong positive correlation is evident for each discrete correlation when binned by Major Climate (**Figure 8, Figure 9, Table 6**). The derived statistical summaries imply incorporating major climate improves the correlation between bankfull discharge and drainage area size.

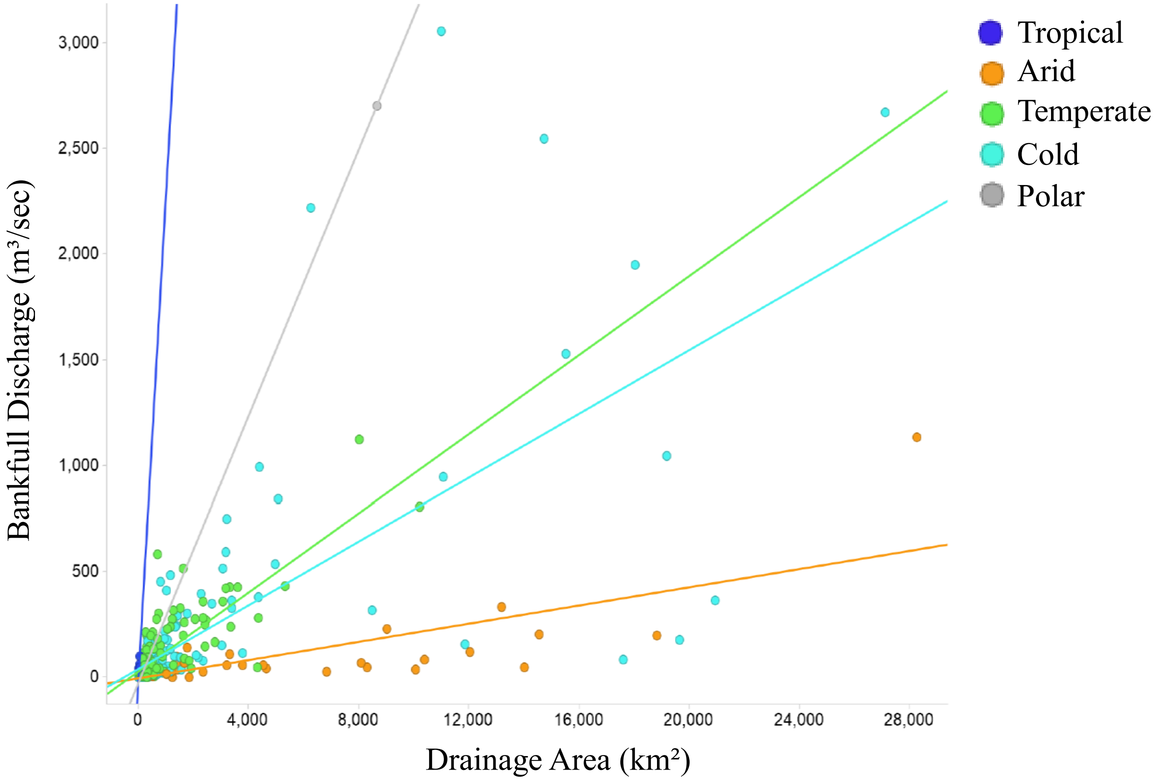


Figure 8: Relation between bankfull discharge and drainage area for all streams with a drainage area < 30,000 km², binned by 1st order major climates. Based on the computed p-value and F-statistic value the correlation for Tropical streams is not statistically significant. [m³/sec, cubic meters per second; km², square kilometers]

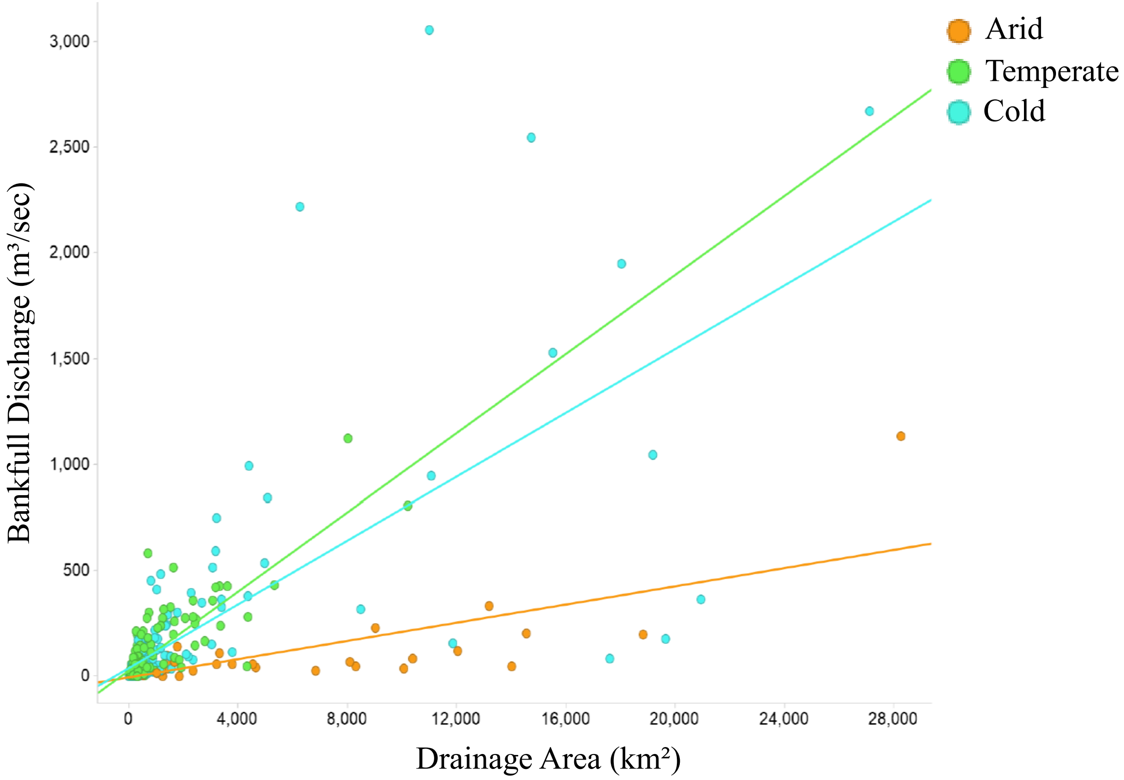


Figure 9 : Regression lines for relationship between bankfull discharge and drainage area for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by 1st order major climates. [m³/sec, cubic meters per second; km², square kilometers]

Correlation between drainage area and mean bankfull-channel depth is strengthened when binned by major climate. Correlations improved for unbinned values in all major categories except for the major climate of Arid based on the derived R and R² values. Correlation is generally improved for all other major climates, and all groups have statistically significant sample sets as indicated by the calculated p-value and F-statistic values. Correlation between these attributes, however, still remains only moderate (**Figure 10, Table 6**).

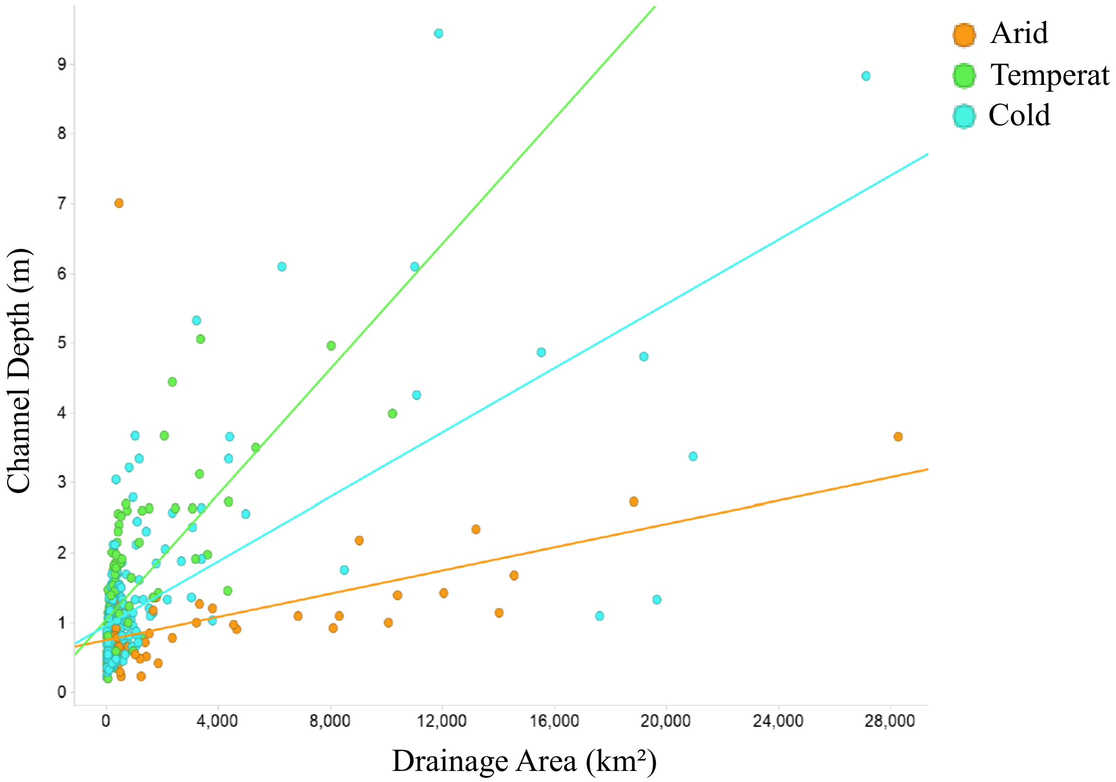


Figure 10: Relation between drainage area and mean bankfull-channel depth for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by 1st order major climates. [m, meters; km², square kilometers]

The correlation between drainage area and bankfull-channel cross-sectional area is also improved when binned by major climate. Cold major climate streams showed similar correlation to the unbinned R^2 value of 0.18. The coefficient of determination for Arid climate streams however indicated significantly improved correlation between drainage area and bankfull-channel cross-sectional area when binned by major climate. The correlation between these attributes is also improved for the major climate of Temperate, which showed a noteworthy increase in correlation from a modest R^2 of 0.19 to a strong correlation (R^2 value of 0.69) (**Table 6, Figure 11**).

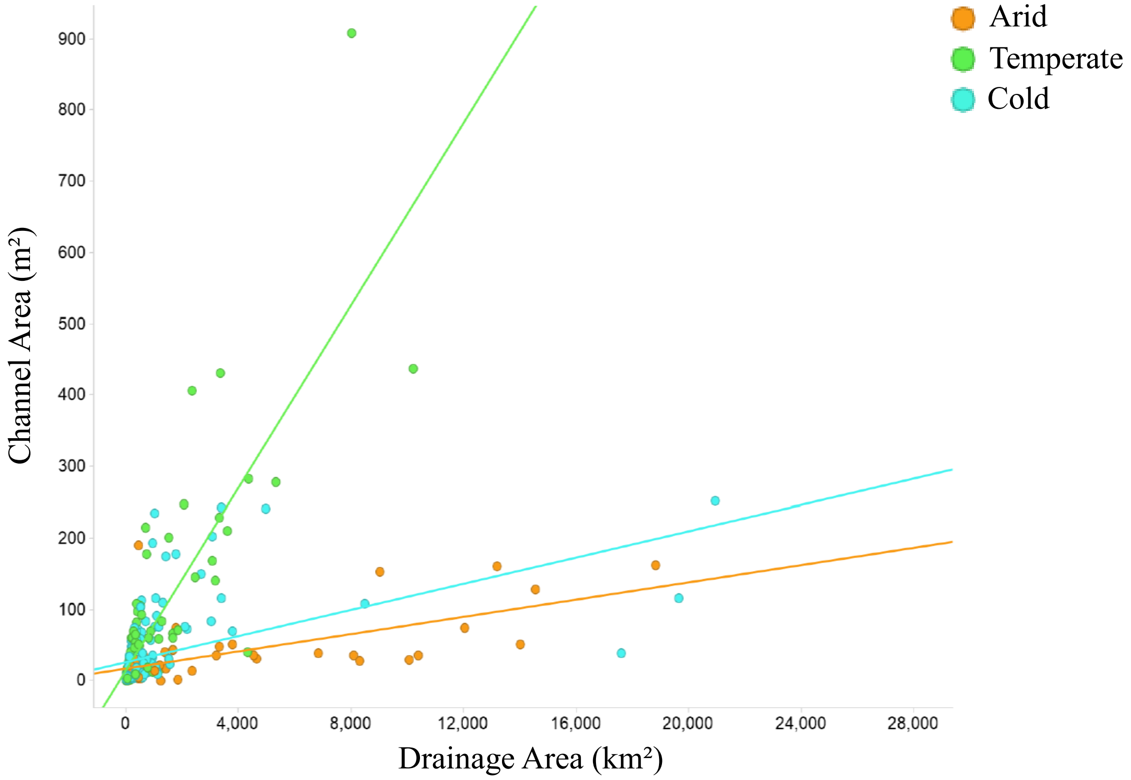


Figure 11: Relationship between drainage area and bankfull-channel cross-sectional area for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by 1st order major climates. [m², square meters; km², square kilometers]

4.1.3 Binned by Köppen Climate

This section evaluates the more granular stream specific attribute of 3rd order Köppen climate classification for the relationship between drainage area and bankfull discharge, mean bankfull-channel depth and bankfull-channel cross-sectional area. This further refinement of the data also means sample sets for this analysis become smaller. Only bins that have a sample set of at least 5 streams are discussed here, with increased emphasis on bins with sample populations considered large (30 sites or greater; after Hogg and Tanis, 2009).

Binning streams based on 3rd order Köppen classification continues to show moderate to strong positive correlation for bankfull discharge and drainage area. Only statistically significant Köppen climate groups with small p values (less than .05) and F-statistic values greater than 1 are considered valid. Moderate to strong correlation is reflected in all calculated R^2 values when outliers and statistically non-significant bins are excluded except for climate Cfa which shows weak correlation based on the statistical summary values (**Table 6**). While the variables of bankfull discharge and drainage area reflect a strong positive linear relationship when binned by Köppen climate the specific line of best fit for that trend can differ significantly. Arid systems for instance generate a bimodal trend with temperate and cold climates generally grouping together (**Figure 12, Figure 13**).

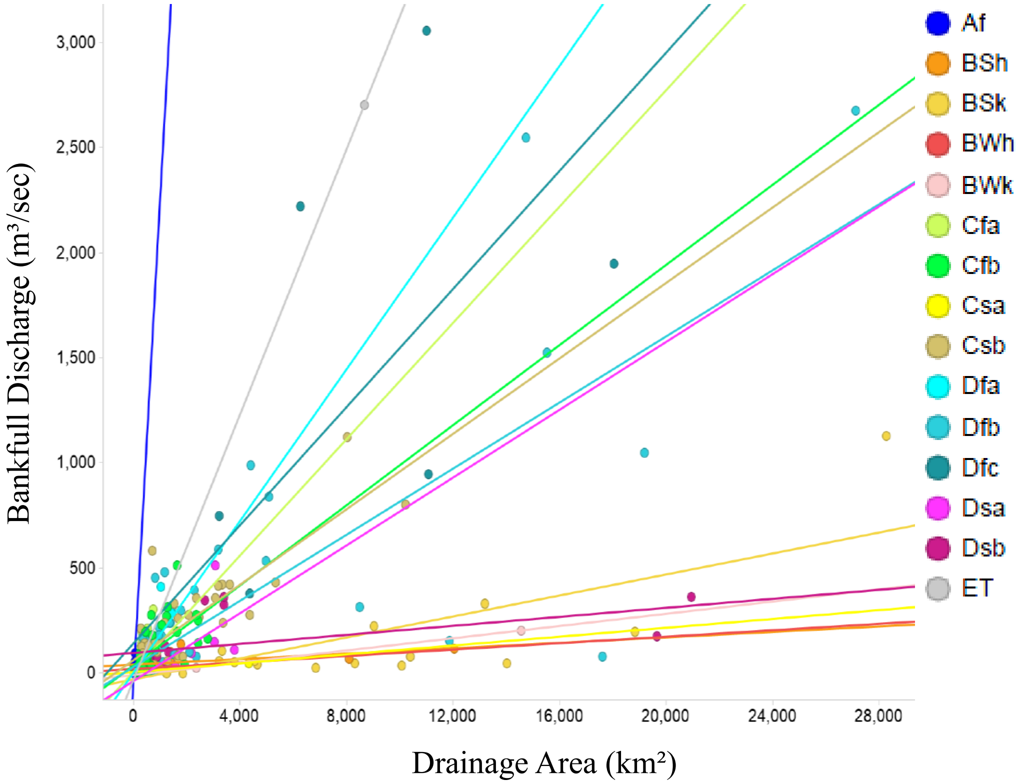


Figure 12: Relation between bankfull discharge and drainage area for all streams with a drainage area < 30,000 km², binned by Köppen climate classifications. Based on the computed p-values and F-statistic values correlations for Af, BWh and Dsa streams are not statistically significant. [m³/sec, cubic meters per second; km², square kilometers]

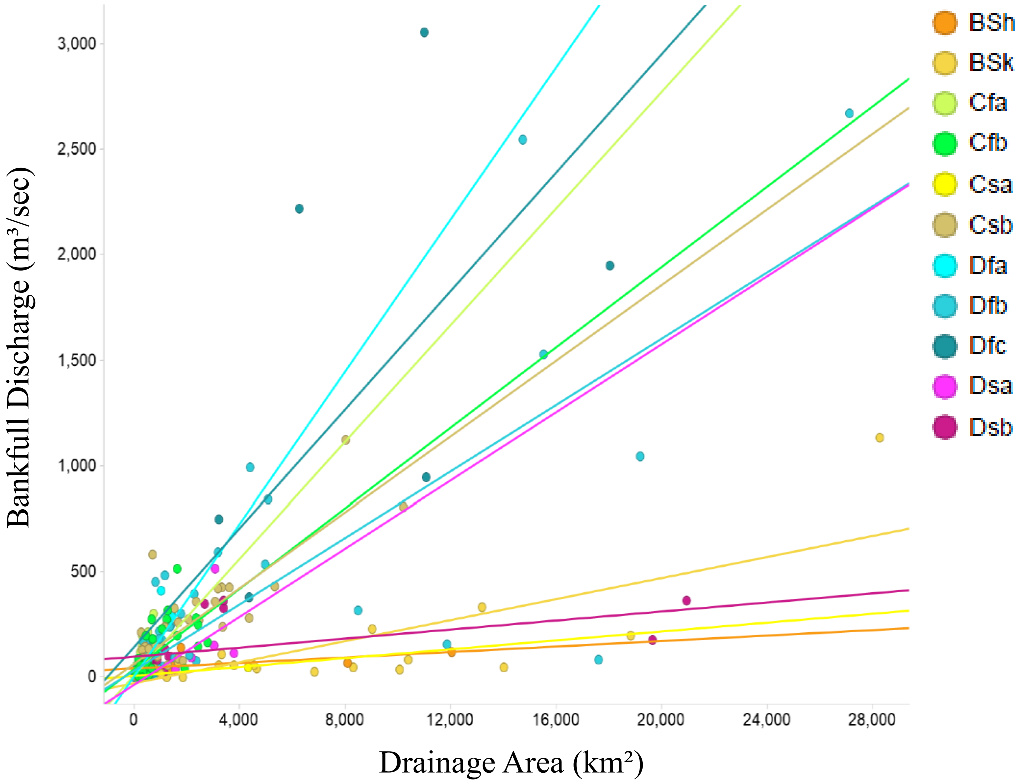


Figure 13: Relation between bankfull discharge and drainage area for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by Köppen climate classifications. Based on the computed p-value and F-statistic value correlation for Dsa streams are not statistically significant. [m³/sec, cubic meters per second; km², square kilometers]

Binning all streams by Köppen climate improves correlation between drainage area and mean bankfull-channel depth compared to binning by major 1st order climate only. Binning by specific Köppen climate classification further decreased the sample sets causing the p-values for some climates i.e. BSh and Dsa to be greater than .05, indicating these bins to be statistically insignificant. The majority of streams have significant populations and also continue to show a moderate linear correlation between drainage area and mean bankfull-channel depth, with the exception of climates Dfc and BSk which show a significantly stronger positive correlation (**Table 6, Figure 14**).

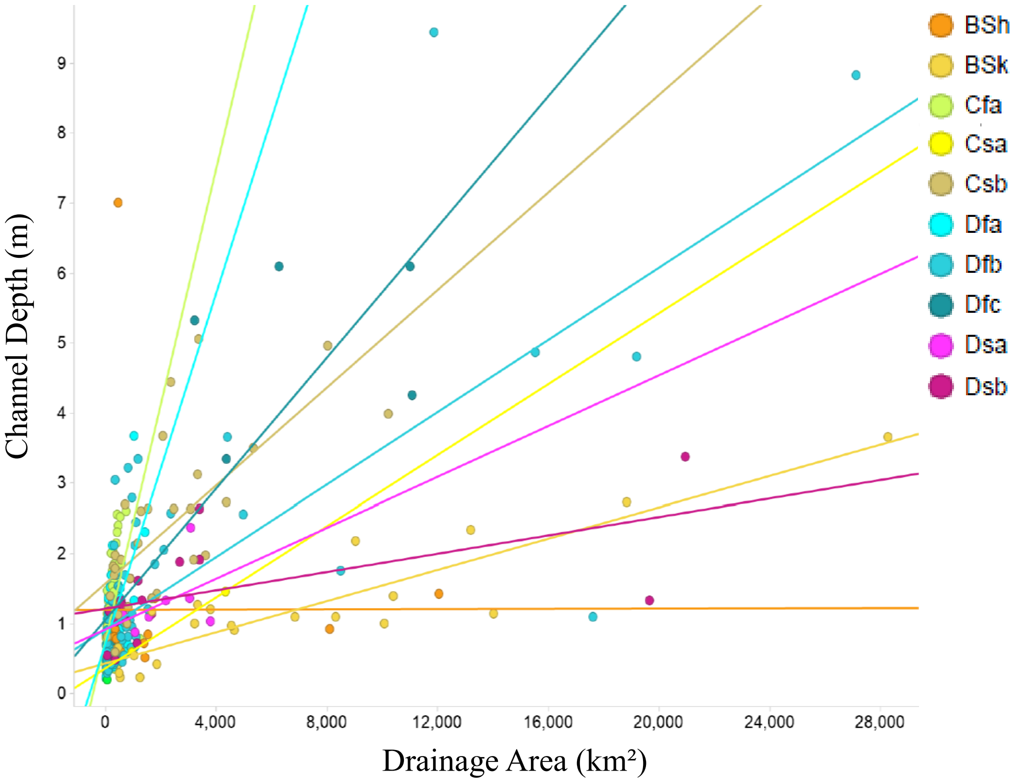


Figure 14: Relation between mean bankfull-channel depth and drainage area for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by Köppen climate classifications. Based on the computed p-values and F-statistic values correlations for BSh and Dsa streams are not statistically significant. [m, meters; km², square kilometers]

Binning by 3rd order Köppen climate strengthened or maintained linear correlation between bankfull-channel cross-sectional area and drainage area for statistically significant populations. Climate Dfb is the exception and shows decreased correlation with values of $R^2= 0.12$ and $R=0.33$. The computed R and R^2 values for Köppen climate Dfc shows the strongest linear correlation with a p-value of 0.009 and F-Statistic value of 22.9 (**Table 6, Figure 15**). All computed statistical analyses indicate leveraging the attribute of either major climate or specified Köppen climate results in improved positive correlation between bankfull-channel cross-sectional area and drainage area overall.

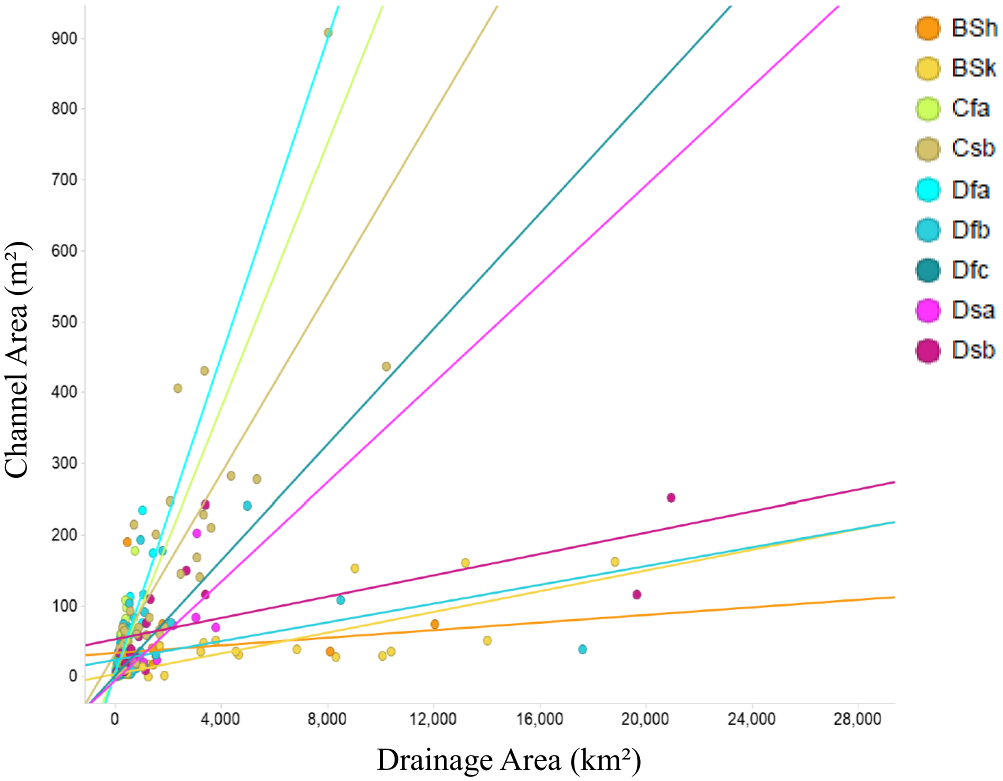


Figure 15: Relationship between drainage area and bankfull-channel cross-sectional area for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by Köppen climate classifications. Based on the computed p-values and F-statistic values correlations for BSh and Dsa streams are not statistically significant. [m², square meters; km², square kilometers]

Table 6: Statistical summary of linear regression model for all streams that met data availability requirements binned. [Q_{bf}, Bankfull Discharge; DA, Drainage Area; D_{bf}, Mean Channel Depth at Bankfull; A_{bf} , Bankfull-channel Cross-sectional Area; FStat, F- statistic; R^2, coefficient of determination; R, correlation coefficient; Df, degrees of freedom; n, number; m^3/s, cubic meters per second; km^2, square kilometers; m, meters; m^2, square meters; †, p-value and F-statistic indicate no significant correlation between the tested variables; * Excluding outlier streams with drainage areas > 30,000 km^2]

Drainage Area vs. Bankfull Discharge and Channel Size: All Streams excluding outliers with drainage area > 30,000 km^2

Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Q_{bf} (m^3/s)	DA (km^2)	4.60E-56	321.6696	0.3882	0.6230	507	509	$Q_{bf} = 39.6524 + (0.0576 * DA)$
D_{bf} (m)	DA (km^2)	5.41E-35	183.9372	0.3051	0.5523	419	421	$D_{bf} = 1.0254 + (0.0002 * DA)$
A_{bf} (m^2)	DA (km^2)	3.96E-20	94.0405	0.1888	0.4345	404	406	$A_{bf} = 29.2852 + (0.0119 * DA)$

Drainage Area vs. Bankfull Discharge and Channel Size: Binned by Major Climate

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Polar	Q_{bf} (m^3/s)	DA (km^2)	4.67E-03	18564.7439	0.9999	1.0000	1	3	$Q_{bf} = -26.3971 + (0.3156* DA)$
Tropical †	Q_{bf} (m^3/s)	DA (km^2)	2.11E-01	3.2930	0.6221	0.7888	2	4	$Q_{bf} = -2.1665 + (2.2911 * DA)$
Arid	Q_{bf} (m^3/s)	DA (km^2)	8.57E-13	84.6460	0.6018	0.7758	56	58	$Q_{bf} = -5.4108 + (0.0216 * DA)$
Temperate	Q_{bf} (m^3/s)	DA (km^2)	7.10E-43	345.1311	0.6687	0.8177	171	173	$Q_{bf} = 26.7015 + (0.0936 * DA)$
Cold	Q_{bf} (m^3/s)	DA (km^2)	3.91E-109	1378.6957	0.8337	0.9131	275	277	$Q_{bf} = 73.9879 + (0.0536 * DA)$
Cold *	Q_{bf} (m^3/s)	DA (km^2)	1.86E-43	278.9906	0.5091	0.7135	269	271	$Q_{bf} = 38.8049 + (0.0754 * DA)$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Arid	D_{bf} (m)	DA (km^2)	1.30E-03	11.7442	0.2034	0.4510	46	48	$D_{bf} = 0.7600 + (0.0001 * DA)$
Temperate	D_{bf} (m)	DA (km^2)	1.65E-19	116.8021	0.4891	0.6994	122	124	$D_{bf} = 1.0590 + (0.0004 * DA)$
Cold	D_{bf} (m)	DA (km^2)	7.04E-49	344.5937	0.5805	0.7619	249	251	$D_{bf} = 1.1315 + (0.0001 * DA)$
Cold*	D_{bf} (m)	DA (km^2)	6.67E-35	210.9814	0.4627	0.6802	245	247	$D_{bf} = 0.9693 + (0.0002 * DA)$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Arid	A_{bf} (m^2)	DA (km^2)	1.90E-06	29.9206	0.3994	0.6320	45	47	$A_{bf} = 17.2909 + (0.0061 * DA)$
Temperate	A_{bf} (m^2)	DA (km^2)	9.06E-33	270.8510	0.6894	0.8303	122	124	$A_{bf} = 15.3432 + (0.0640 * DA)$
Cold	A_{bf} (m^2)	DA (km^2)	2.31E-15	72.3139	0.2384	0.4883	231	233	$A_{bf} = 26.3151 + (0.0092 * DA)$

Table 6 Continued

Drainage Area vs. Bankfull Discharge and Channel Size: Binned by Köppen Climate

Köppen Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Af †	Q_{bf} (m^3/s)	DA (km^2)	2.11E-01	3.2930	0.6221	0.7888	2	4	$Q_{bf} = -2.1665 + (2.2911 * DA)$
BSh	Q_{bf} (m^3/s)	DA (km^2)	2.13E-02	6.6108	0.3059	0.5531	15	17	$Q_{bf} = 41.7610 + (0.0065 * DA)$
BSk	Q_{bf} (m^3/s)	DA (km^2)	3.93E-09	62.7115	0.6552	0.8095	33	35	$Q_{bf} = -28.5422 + (0.0250 * DA)$
BWh †	Q_{bf} (m^3/s)	DA (km^2)	4.33E-01	0.9481	0.3216	0.5671	2	4	$Q_{bf} = 21.0892 + (0.0077 * DA)$
Cfa	Q_{bf} (m^3/s)	DA (km^2)	1.18E-06	27.2600	0.2365	0.4863	88	90	$Q_{bf} = 9.1252 + (0.1384 * DA)$
Cfb	Q_{bf} (m^3/s)	DA (km^2)	1.22E-05	25.4658	0.4077	0.6385	37	39	$Q_{bf} = 38.6584 + (0.0953 * DA)$
Csa	Q_{bf} (m^3/s)	DA (km^2)	1.72E-04	67.9402	0.9189	0.9586	6	8	$Q_{bf} = 6.1096 + (0.0105 * DA)$
Csb	Q_{bf} (m^3/s)	DA (km^2)	9.58E-11	84.5354	0.7132	0.8445	34	36	$Q_{bf} = 63.8792 + (0.0898 * DA)$
Dfa	Q_{bf} (m^3/s)	DA (km^2)	3.30E-17	114.9681	0.5867	0.7659	81	83	$Q_{bf} = 5.4829 + (0.1805 * DA)$
Dfb	Q_{bf} (m^3/s)	DA (km^2)	3.41E-68	948.5624	0.8588	0.9267	156	158	$Q_{bf} = 78.6813 + (0.0534 * DA)$
Dfb *	Q_{bf} (m^3/s)	DA (km^2)	6.08E-37	290.8885	0.6598	0.8123	150	152	$Q_{bf} = 31.5006 + (0.0787 * DA)$
Dfc	Q_{bf} (m^3/s)	DA (km^2)	2.37E-03	16.2998	0.6198	0.7873	10	12	$Q_{bf} = 144.5328 + (0.1406 * DA)$
Dsa †	Q_{bf} (m^3/s)	DA (km^2)	2.06E-01	2.1067	0.2964	0.5445	5	7	$Q_{bf} = -35.4622 + (0.0807 * DA)$
Dsb	Q_{bf} (m^3/s)	DA (km^2)	3.09E-02	5.6755	0.2745	0.5239	15	17	$Q_{bf} = 97.3930 + (0.0107 * DA)$
ET	Q_{bf} (m^3/s)	DA (km^2)	4.67E-03	18564.7439	0.9999	1.0000	1	3	$Q_{bf} = -26.3971 + (0.3156* DA)$
Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R^2**	**R**	**Df**	**n**	**Equation**
BSh †	D_{bf} (m)	DA (km^2)	9.95E-01	0.0000	0.0000	0.0015	15	17	$D_{bf} = 1.2064 + (0.0000 * DA)$
BSk	D_{bf} (m)	DA (km^2)	3.22E-10	109.5179	0.8264	0.9091	23	25	$D_{bf} = 0.4402 + (0.0001 * DA)$
BWh †	D_{bf} (m)	DA (km^2)	3.63E-01	1.3650	0.4057	-0.6369	2	4	$D_{bf} = 0.6551 + (-0.0001 * DA)$
Cfa	D_{bf} (m)	DA (km^2)	5.03E-08	35.5647	0.2878	0.5365	88	90	$D_{bf} = 0.7957 + (0.0017 * DA)$
Csb	D_{bf} (m)	DA (km^2)	1.75E-05	26.3611	0.4762	0.6900	29	31	$D_{bf} = 1.5870 + (0.0003 * DA)$
Dfa	D_{bf} (m)	DA (km^2)	5.89E-09	42.3604	0.3434	0.5860	81	83	$D_{bf} = 0.7426 + (0.0012 * DA)$
Dfb*	D_{bf} (m)	DA (km^2)	9.07E-25	165.5528	0.5659	0.7523	127	129	$D_{bf} = 0.9297 + (0.0003 * DA)$
Dfc	D_{bf} (m)	DA (km^2)	1.30E-03	21.1093	0.7011	0.8373	9	11	$D_{bf} = 1.0704 + (0.0005 * DA)$
Dsa †	D_{bf} (m)	DA (km^2)	3.44E-01	1.0892	0.1789	0.4229	5	7	$D_{bf} = 0.9270 + (0.0002 * DA)$
Dsb	D_{bf} (m)	DA (km^2)	1.53E-02	7.4937	0.3331	0.5772	15	17	$D_{bf} = 1.2220 + (0.0001 * DA)$

Table 6 Continued

Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R^2**	**R**	**Df**	**n**	**Equation**
BSh †	A_{bf} (m^2)	DA (km^2)	4.46E-01	0.6117	0.0392	0.1979	15	17	A_{bf} = 33.7820 + (0.0027 * DA)
BSk	A_{bf} (m^2)	DA (km^2)	6.81E-06	34.3055	0.6093	0.7806	22	24	A_{bf} = 4.0071 + (0.0073 * DA)
BWh †	A_{bf} (m^2)	DA (km^2)	1.23E-01	6.6620	0.7691	0.8770	2	4	A_{bf} = 10.3717 + (0.0166 * DA)
Cfa	A_{bf} (m^2)	DA (km^2)	1.31E-09	45.9884	0.3432	0.5859	88	90	A_{bf} = 8.4092 + (0.0932 * DA)
Csb	A_{bf} (m^2)	DA (km^2)	6.43E-08	51.7424	0.6408	0.8005	29	31	A_{bf} = 34.0892 + (0.0635 * DA)
Dfa	A_{bf} (m^2)	DA (km^2)	3.28E-19	138.4116	0.6308	0.7942	81	83	A_{bf} = 6.6158 + (0.1119 * DA)
Dfb*	A_{bf} (m^2)	DA (km^2)	2.73E-04	14.0843	0.1066	0.3265	118	120	A_{bf} = 24.0644 + (0.0066 * DA)
Dfc	A_{bf} (m^2)	DA (km^2)	9.16E-03	22.2938	0.8479	0.9208	4	6	A_{bf} = 2.3724 + (0.0407 * DA)
Dsa †	A_{bf} (m^2)	DA (km^2)	1.26E-01	3.3664	0.4024	0.6343	5	7	A_{bf} = -4.4404 + (0.0349 * DA)
Dsb	A_{bf} (m^2)	DA (km^2)	6.67E-03	9.8932	0.3974	0.6304	15	17	A_{bf} = 53.2586 + (0.0075 * DA)

4.2 DRAINAGE AREA AND CHANNEL SIZE VS. t_{bd}

4.2.1 All Samples in Aggregate

This section determines if linear relationships exist between the temporal attribute of days at bankfull (t_{bd}) and the spatial attributes of drainage area, mean bankfull-channel depth and/or bankfull-channel cross-sectional area. None of the linear regression models completed for each of these spatial attributes against the dependent variable of t_{bd} found a valid correlation for all streams in aggregate (**Table 8**). Multiple regression analysis was completed (ANOVA) to determine if any combination of these spatial attributes have a linear relationship to average annual days within 10% of bankfull flow using Aabel statistical software. Multiple regression analysis is a statistical model used to determine if a combination of multiple independent variables can predict the dependent variable. ANOVA tables test significance by quantifying how much variance is predicted by each individual variable (Davis, 2002). In the case of all independent variables of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area in relation to the dependent variable of t_{bd}, average annual days within 10% of bankfull flow, no plausible trend or correlation is evident (**Table 7, Figure 16**). Full statistical analysis and outcome values are provided in **Appendix 1**.

Dependent	**Independent**	**R**	**R^2**	**Adjusted R^2**	**Std. Error of the Estimate**
t_{bd} (Days)	**DA (km^2)** **D_{bf} (m)** **A_{bf} (m^2)**	0.200972	0.04039	0.033486	5.09156
t_{bd} (Days)	**D_{bf} (m)** **A_{bf} (m^2)**	0.156586	0.024519	0.019929	5.09692
t_{bd} (Days)	**DA (km^2)** **A_{bf} (m^2)**	0.103189	0.010648	0.006738	5.39108
t_{bd} (Days)	**DA (km^2)** **D_{bf} (m)**	0.138192	0.019097	0.014404	5.14157

Table 7: Statistical summary of multiple regression model for all streams that met data availability requirements, computed by the Aabel software. [t_{bd}, average annual days within 10% of bankfull flow; DA, Drainage Area; D_{bf}, mean bankfull-channel depth; A_{bf}, Bankfull-channel cross-sectional area; R, correlation coefficient; R^2, coefficient of determination; m, meters; m^2, square meters; km^2, square kilometers]

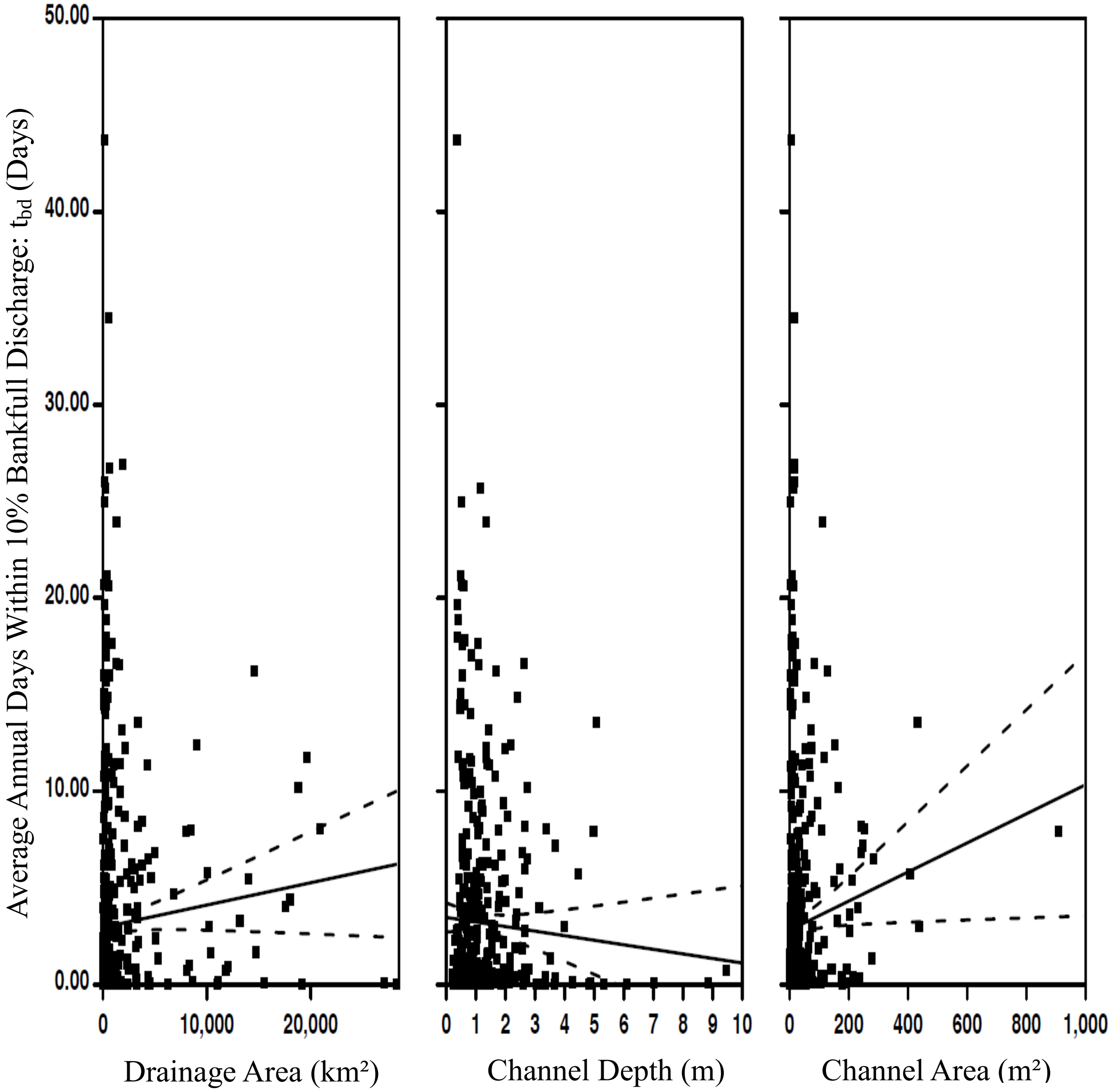


Figure 16: Linear regression models with confidence bands for the dependent variable of t_{bd}, average annual days within 10% of bankfull flow, and the independent variables of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area for all streams with a drainage area less than 30,000km². [m, meters; m², square meters; km², square kilometers]

4.2.2 Binned by Major Climate

Adding the additional parameter of major climate and completing a simple linear regression model no valid correlation was found between drainage area and days at bankfull flow. P-values for climates: Polar, Temperate and Cold reflected values greater than .05 indicating drainage area does not have significant impact on t_{bd} (**Figure 17**). Out of the two remaining major climates of Arid and Tropical both have statistically significant results but only the Arid climate bin has more than 5 sites within the sample set and continues to show no strong evidence of correlation with values of R^2= 0.22 and R= 0.47 (**Table 8**). Days a bankfull appears to be independent of drainage size in aggregate, and even when considered within discrete climates.

Mean bankfull-channel depth and bankfull-channel cross-sectional area similarly show no correlation to t_{bd}. For both major climates of Temperate and Arid the computed p-values show no distinction between observed values and a random data set. No correlation between t_{bd} and mean bankfull-channel depth is sustainable. The p-values derived for climates Temperate and Cold similarly show no relationship between t_{bd} and bankfull-channel cross-sectional area (**Table 8**). Graphically plotting these data further supports lack of evidence of a linear trend or correlation among any collected spatial data attributes and average annual days within 10% of bankfull discharge (**Figure 18, Figure 19**). Largely, whether binned by major climate or not, there is little evidence that any of the tested spatial attributes within this analysis have significant impact on the days on average annually a stream runs within 10% of its bankfull flow.

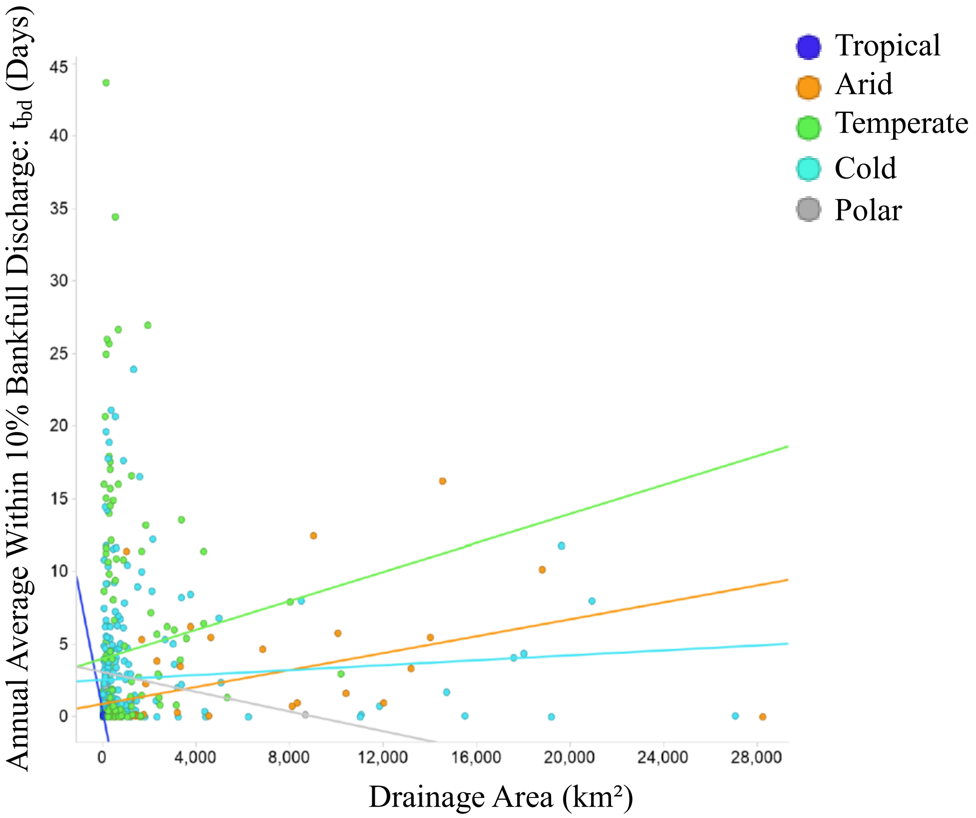


Figure 17: Relationship between drainage area and annual average days within 10% of bankfull flow for all streams with a drainage area < 30,000 km², binned by major climate. Based on the computed p-values and F-statistic values correlations for Polar, Temperate and Cold streams are not statistically significant. [km², square kilometers]

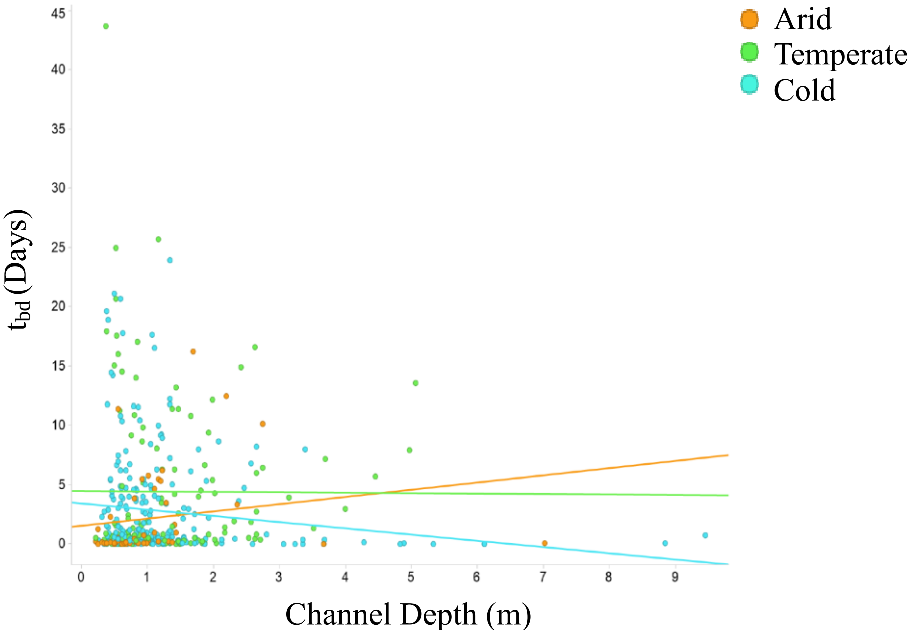


Figure 18: Regression lines for relationship between mean bankfull-channel depth and average annual days within 10% of bankfull flow for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by 1st order major climates. Based on the computed p-values and F-statistic values correlations for Arid and Temperate streams are not statistically significant. [m, meters]

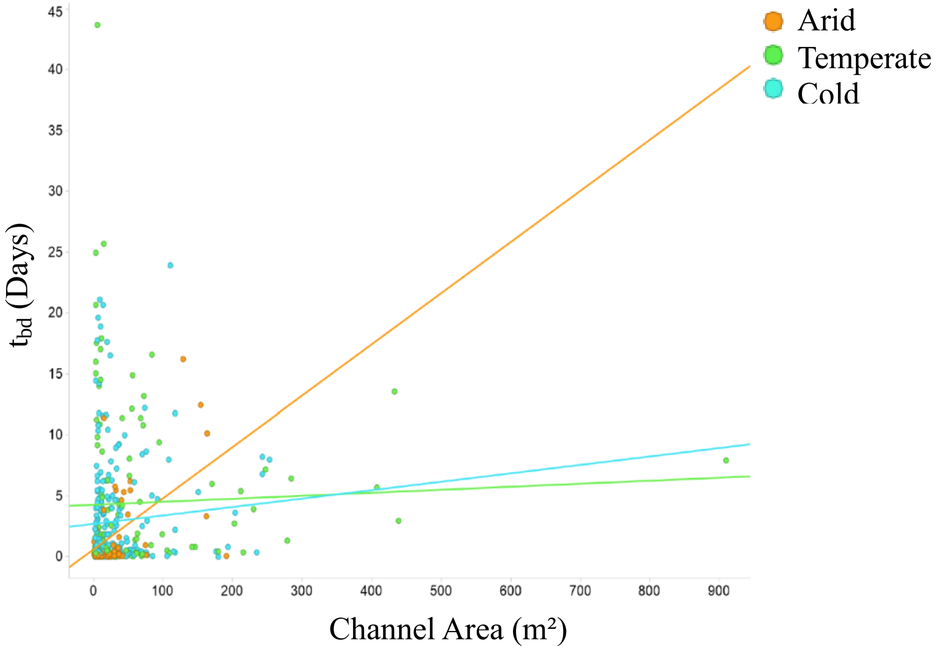


Figure 19: Regression lines for relationship between bankfull-channel cross-sectional area and average annual days within 10% of bankfull flow for all streams with a drainage area < 30,000 km² and a minimum of 5 sites in the sample set, binned by 1st order major climates. Based on the computed p-values and F-statistic values correlations for Arid and Temperate streams are not statistically significant. [m², square meters]

4.2.3 Binned by Köppen Climate

One final iteration of statistical models are ran to evaluate potential impact of drainage area, mean bankfull-channel depth and/or bankfull-channel cross-sectional area on average annual days within 10% of bankfull flow by binning by specific Köppen climate classification. Reviewing all statistical model summaries for the relationship between t_{bd}, drainage area, mean bankfull-channel depth, and bankfull-channel cross-sectional area, respectively, one commonality of p-values primarily greater than .05 emerged, supporting a random relationship (**Table 8**). Exclusively in the statistical model summary data for the relationship between t_{bd} and drainage area is any correlation between a spatial attribute and days at bankfull flow supported, and only in the climates of Af, BSh, BSk and Csa where p-values are significantly less than .05 and R and R^2 values support strong positive correlation (**Table 8**). In the case of all climates that showed a strong positive linear trend between t_{bd} and drainage area the sample sets were less than 35 with the total sites for climates Af and Csa being less than 10 (**Table 7, Figure 20**). With only Köppen climates BSh and BSk having more than 10 streams within the sample set and showing strong correlation, these results appear anomalous and not sufficient to support a relationship between between drainage area and t_{bd}.

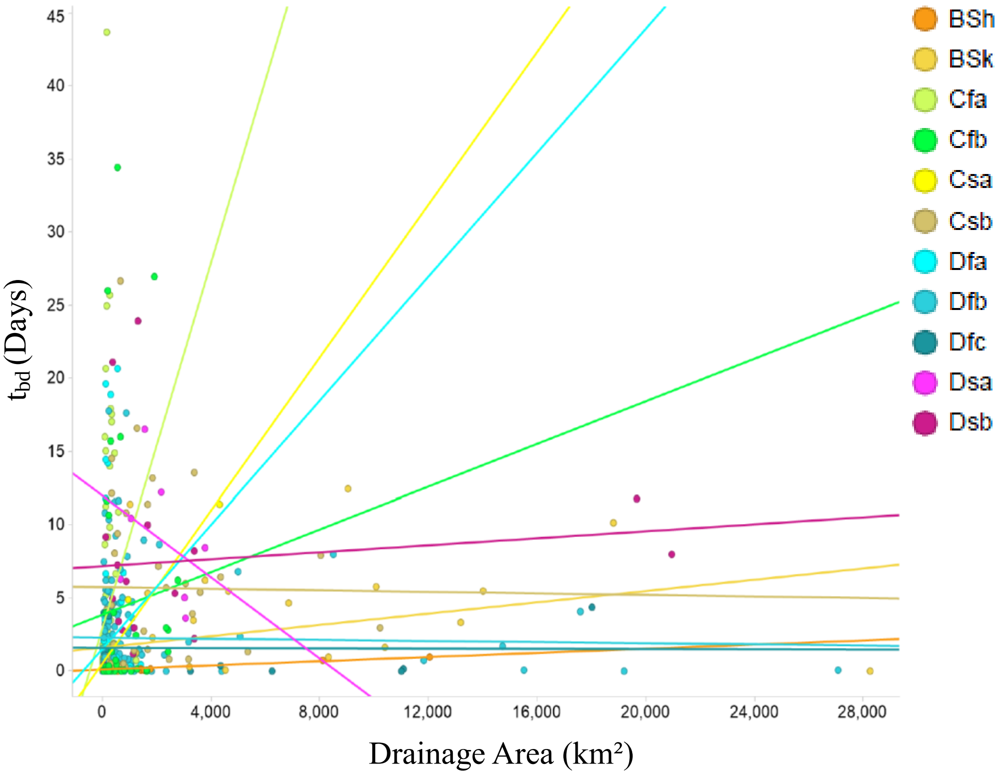


Figure 20: Regression lines for relationship between drainage area and t_{bd}, average annual days within 10% of bankfull flow, for all streams with a drainage area < 30,000 km² and a minimum of 5 sites, binned by Köppen climate classification. Based on the computed p-values and F-statistic values correlations for Cfa, Cfb, Csb, Dfa, Dfb, Dfc, Dsa, Dsb, and ET streams are not statistically significant. A bi-modal trend between Temperate streams and all other streams, similar to that seen in between bankfull discharge and drainage area when binned by Köppen climate, is noted, but due to p-values for these bins the significance of this trend is questionable.

4.3 t_{bd} BINNED BY CLIMATE ALONE

Climate appears to be the most impactful variable to t_{bd}. Bankfull duration is correlated here against climate alone, without consideration of drainage or channel size. The relationship between t_{bd} and Köppen climate is tested with established statistical variance testing, computing outliers, averages, standard deviations, and upper and lower endpoints of confidence intervals. Data clusters around discrete average annual days for each major climate whether using a 10% or 20% error range for bankfull flow binning of

t_{bd}. Using the restrictive range of the water discharge within 10% of bankfull flow, t_{bd} values range from 1.4 average days annually in Tropical climates to 4.3 days in Temperate climates (**Figure 21**). Using the less restrictive range of within 20% of bankfull flow, the range in average t_{bd} values further broadens to 3 days on average annually in Tropical climates to just under 9 days in Temperate climates (**Figure 22**). No outliers, other than the six streams with drainage areas greater than 30,000 km², were removed from the plotted distribution. Outliers skew the data. If the extreme outliers of 43.7 and 34.5 average annual days within 10% of bankfull flow are removed, for the major climate of Temperate, the t_{bd} value would be decreased to an average of 3.88 days annually. Whisker plots are generated to address the impact of these outliers.

4.3.1 t_{bd} Binned by Major Climate

ANOVA testing shows that the values for t_{bd} for major climate are each distinct populations thus distinguishing the average t_{bd} values is valid. For populations to be considered distinct the calculated critical F value must be less than the observed F-statistic in the ANOVA test. The critical F value calculated from the data is 2.39, whereas the observed F-statistic value computed in the ANOVA test is 3.75, indicating the means of each population when grouped by major climate significantly differ and are distinct populations (**Table 9**).

For all streams the data is skewed where average days within 10% of bankfull discharge is on the low end of the distribution for duration. At least fifty percent of all streams in all major climates flow within 10% of bankfull discharge 0-1 days a year (**Figure 23 a, b, c, d**). This skewness is partly dependent on variations per climate. The major climates of Tropical and Arid show 80% of all streams to run on average annually within 10% of bankfull discharge approximately 0-1 days (**Figure 23 a, b**). Temperate climate streams show the majority of all streams running within bankfull range 0-7 days annually with average t_{bd} values for Cold climate streams ranging 0-4 days a year (**Figure 23 c, d**).

Table 8: Statistical summary of linear regression model for all streams that met data availability requirements binned. [t_{bd}, average annual days within 10% of bankfull flow; DA, Drainage Area; D_{bf}, Mean Channel Depth at Bankfull; A_{bf}, Bankfull-channel Cross-sectional Area; FStat, F- statistic; R^2, coefficient of determination; R, correlation coefficient; Df, degrees of freedom; n, number; m^3/s, cubic meters per second; km^2, square kilometers; m, meters; m^2, square meters; †, p-value and F-statistic indicate no significant correlation between the tested variables; * Excluding outlier streams with drainage areas > 30,000 km^2]

t_{bd} vs. Drainage Area and Channel Size: All Streams excluding outliers with drainage area > 30,000 km^2

Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
t_{bd} (Days) †	DA (km^2)	1.04E-01	2.6548	0.0052	0.0722	507	509	$t_{bd} = 2.9591 + (0.0001 * DA)$
t_{bd} (Days) †	D_{bf} (m)	3.07E-01	1.0449	0.0024	-0.0495	426	428	$t_{bd} = 3.4695 + (-.02358 * D_{bf})$
t_{bd} (Days) †	A_{bf} (m^2)	5.60E-02	3.6742	0.0089	0.0941	411	413	$t_{bd} = 3.0111 + (0.0067 * A_{bf})$

t_{bd} vs. Drainage Area and Channel Size: Binned by Major Climate

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Polar †	t_{bd} (Days)	DA (km^2)	3.18E-01	3.3659	0.7710	-0.8780	1	3	$t_{bd} = 3.0777 + (-0.0003 * DA)$
Tropical	t_{bd} (Days)	DA (km^2)	3.78E-02	24.9667	0.9258	-0.9622	2	4	$t_{bd} = 0.3134 + (-0.0083 * DA)$
Arid	t_{bd} (Days)	DA (km^2)	1.81E-04	16.0852	0.2231	0.4724	56	58	$t_{bd} = 0.8906 + (0.0003 * DA)$
Temperate †	t_{bd} (Days)	DA (km^2)	2.40E-01	1.3928	0.0081	0.0899	171	173	$t_{bd} = 4.0084 + (0.0005 * DA)$
Cold	t_{bd} (Days)	DA (km^2)	3.16E-02	4.6652	0.0167	0.1292	275	277	$t_{bd} = 2.5820 + (0.0000 * DA)$
Cold* †	t_{bd} (Days)	DA (km^2)	2.40E-01	1.3869	0.0051	0.0716	269	271	$t_{bd} = 2.5370 + (0.0001 * DA)$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Arid †	t_{bd} (Days)	Dbf (m)	2.23E-01	1.5273	0.0321	0.1793	46	48	$t_{bd} = 1.5304 + (0.6093 * D_{bf})$
Temperate †	t_{bd} (Days)	Dbf (m)	9.55E-01	0.0032	0.0000	-0.0051	122	124	$t_{bd} = 4.4692 + (-0.0368 * D_{bf})$
Cold*	t_{bd} (Days)	Dbf (m)	2.85E-02	4.8541	0.0194	-0.1394	245	247	$t_{bd} = 3.4135 + (-0.5262 * D_{bf})$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Arid	t_{bd} (Days)	A_{bf} (m^2)	1.95E-04	16.4620	0.2678	0.5175	45	47	$t_{bd} = 0.6143 + (0.0421 * A_{bf})$
Temperate †	t_{bd} (Days)	A_{bf} (m^2)	6.47E-01	0.2104	0.0017	0.0415	122	124	$t_{bd} = 4.2722 + (0.0025 * A_{bf})$
Cold* †	t_{bd} (Days)	A_{bf} (m^2)	3.01E-01	1.0734	0.0046	0.0680	231	233	$t_{bd} = 2.7030 + (0.0069 * A_{bf})$

Table 8 Continued

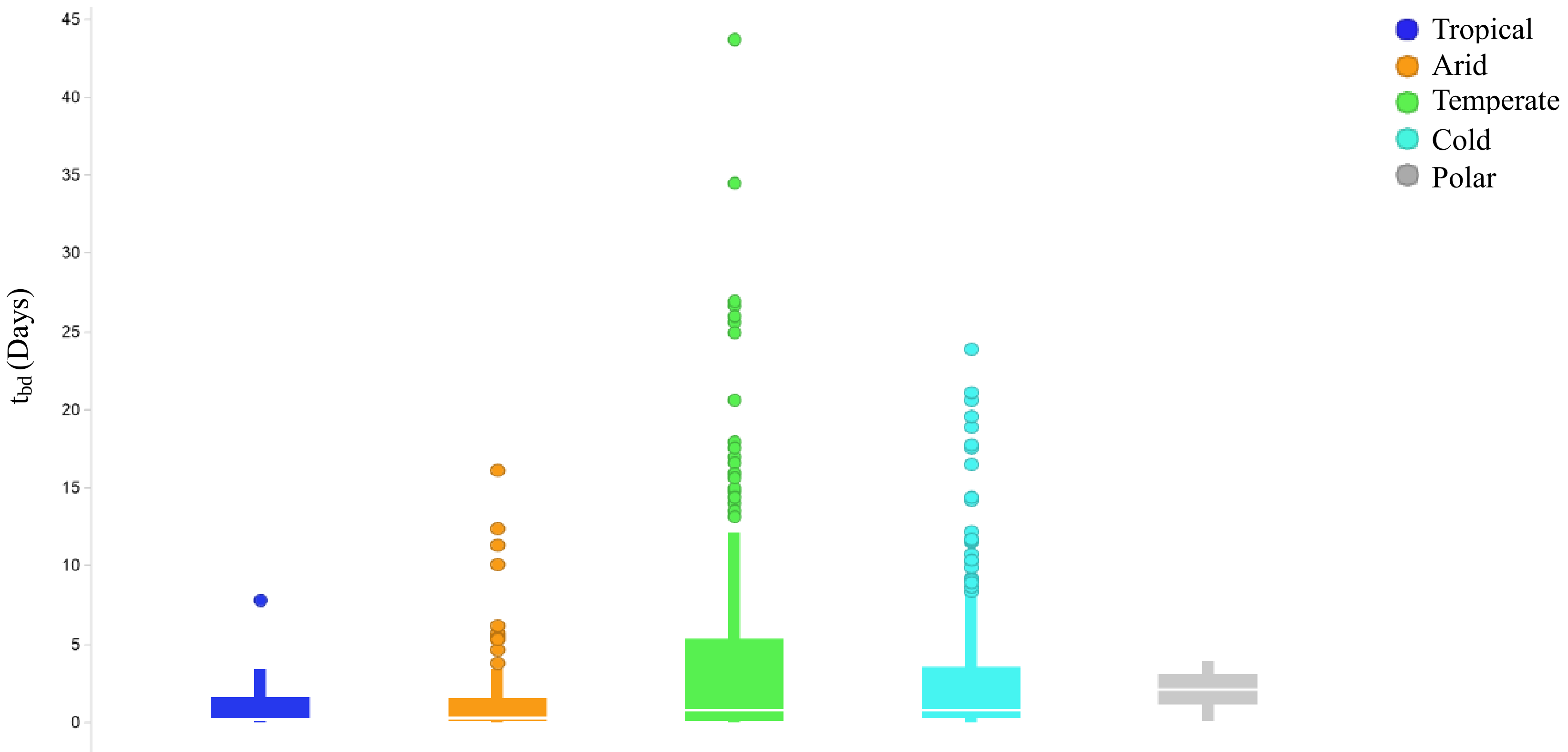
t_{bd} vs. Drainage Area and Channel Size: Binned by Köppen Climate

Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R²**	**R**	**Df**	**n**	**Equation**
Af	t_{bd} (Days)	DA (km²)	3.78E-02	24.9667	0.9258	-0.9622	2	4	t_{bd} = 0.3134 + (-0.0083 * DA)
BSh	t_{bd} (Days)	DA (km²)	1.02E-06	62.2105	0.8057	0.8976	15	17	t_{bd} = 0.0976 + (0.0001 * DA)
BSk	t_{bd} (Days)	DA (km²)	3.35E-02	4.9211	0.1298	0.3602	33	35	t_{bd} = 1.6106 + (0.0002 * DA)
Cfa †	t_{bd} (Days)	DA (km²)	1.41E-01	2.2074	0.0245	0.1564	88	90	t_{bd} = 2.9898 + (0.0063 * DA)
Cfb †	t_{bd} (Days)	DA (km²)	6.86E-01	0.1663	0.0045	0.0669	37	39	t_{bd} = 3.8597 + (0.0007 * DA)
Csa	t_{bd} (Days)	DA (km²)	2.89E-05	127.4032	0.9550	0.9773	6	8	t_{bd} = 0.5444 + (0.0026 * DA)
Csb †	t_{bd} (Days)	DA (km²)	9.55E-01	0.0033	0.0001	-0.0098	34	36	t_{bd} = 5.7373 + (0.0000 * DA)
Dfa †	t_{bd} (Days)	DA (km²)	2.83E-01	1.1677	0.0142	0.1192	81	83	t_{bd} = 1.5335 + (0.0021 * DA)
Dfb* †	t_{bd} (Days)	DA (km²)	7.91E-01	0.0706	0.0005	-0.0217	150	152	t_{bd} = 2.2832 + (0.0000 * DA)
Dfc †	t_{bd} (Days)	DA (km²)	9.61E-01	0.0025	0.0002	-0.0157	10	12	t_{bd} = 1.5909 + (0.0000 * DA)
Dsa †	t_{bd} (Days)	DA (km²)	4.31E-01	0.7341	0.1280	-0.3578	5	7	t_{bd} = 11.9641 + (-0.0014 * DA)
Dsb †	t_{bd} (Days)	DA (km²)	6.52E-01	0.2119	0.0139	0.1180	15	17	t_{bd} = 7.1768 + (0.0001 * DA)
ET †	t_{bd} (Days)	DA (km²)	3.18E-01	3.3659	0.7710	-0.8780	1	3	t_{bd} = 3.0777 + (-0.0003 * DA)

Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R²**	**R**	**Df**	**n**	**Equation**
BSh †	t_{bd} (Days)	D_{bf} (m)	9.26E-01	0.0089	0.0006	-0.0244	15	17	t_{bd} = 0.2271 + (-0.0041 * D_{bf})
BSk †	t_{bd} (Days)	D_{bf} (m)	9.07E-02	3.1187	0.1194	0.3456	23	25	t_{bd} = 1.5991 + (1.5248 * D_{bf})
Cfa †	t_{bd} (Days)	D_{bf} (m)	6.38E-02	3.5232	0.0385	-0.1962	88	90	t_{bd} = 6.5940 + (-2.5003 * D_{bf})
Csb †	t_{bd} (Days)	D_{bf} (m)	6.35E-01	0.2307	0.0079	0.0888	29	31	t_{bd} = 4.7756 + (0.3753 * D_{bf})
Dfa	t_{bd} (Days)	D_{bf} (m)	5.31E-03	8.2074	0.0920	-0.3033	81	83	t_{bd} = 4.4437 + (-2.5327 * D_{bf})
Dfb* †	t_{bd} (Days)	D_{bf} (m)	6.57E-02	3.4456	0.0264	-0.1625	127	129	t_{bd} = 2.9828 + (-0.4334 * D_{bf})
Dfc	t_{bd} (Days)	D_{bf} (m)	1.17E-02	9.9338	0.5247	-0.7243	9	11	t_{bd} = 2.5472 + (-0.4714 * D_{bf})
Dsa †	t_{bd} (Days)	D_{bf} (m)	1.96E-01	2.2204	0.3075	-0.5545	5	7	t_{bd} = 15.5928 + (-5.0367 * D_{bf})
Dsb †	t_{bd} (Days)	D_{bf} (m)	8.20E-01	0.0538	0.0036	-0.0598	15	17	t_{bd} = 8.3609 + (-0.5335 * D_{bf})

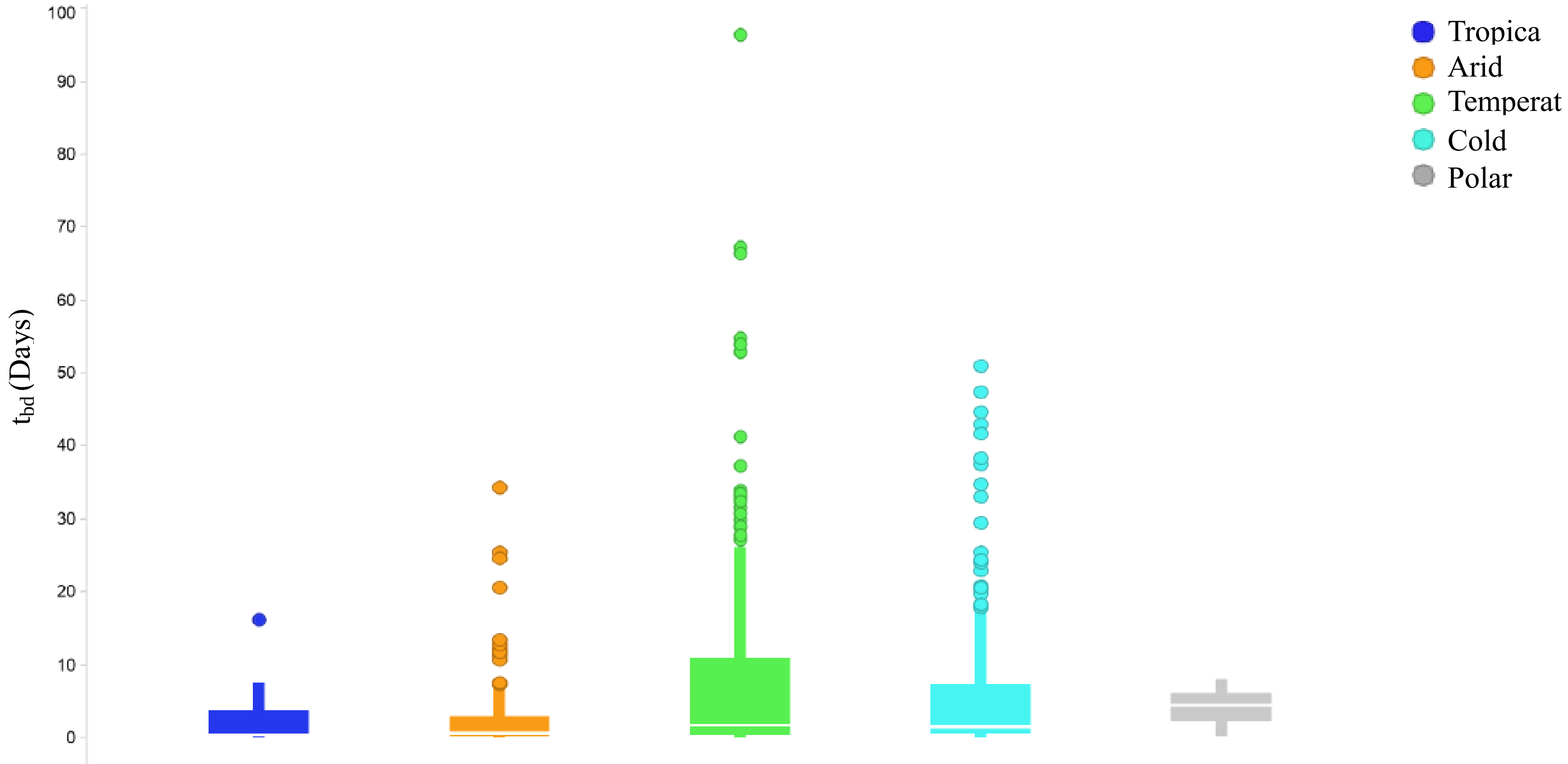
Table 8 Continued

Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R²**	**R**	**Df**	**n**	**Equation**
BSh †	t_{bd} (Days)	A_{bf} (m²)	6.00E-01	0.2876	0.0188	0.1372	15	17	$t_{bd} = 0.1913 + (0.0008 * A_{bf})$
BSk	t_{bd} (Days)	A_{bf} (m²)	1.27E-03	13.6345	0.3826	0.6186	22	24	$t_{bd} = 1.5091 + (0.0473 * A_{bf})$
Cfa †	t_{bd} (Days)	A_{bf} (m²)	7.80E-02	3.1805	0.0349	-0.1868	88	90	$t_{bd} = 5.0247 + (-0.0469 * A_{bf})$
Csb †	t_{bd} (Days)	A_{bf} (m²)	7.35E-01	0.1170	0.0040	0.0634	29	31	$t_{bd} = 5.3609 + (0.0017 * A_{bf})$
Dfa †	t_{bd} (Days)	A_{bf} (m²)	9.60E-02	2.8370	0.0338	-0.1840	81	83	$t_{bd} = 2.6069 + (-0.0232 * A_{bf})$
Dfb* †	t_{bd} (Days)	A_{bf} (m²)	7.50E-01	0.1018	0.0009	-0.0294	118	120	$t_{bd} = 2.7028 + (-0.0027 * A_{bf})$
Dfc †	t_{bd} (Days)	A_{bf} (m²)	4.07E-01	0.8549	0.1761	-0.4196	4	6	$t_{bd} = 3.6052 + (-0.1873 * A_{bf})$
Dsa †	t_{bd} (Days)	A_{bf} (m²)	1.43E-01	3.0146	0.3761	-0.6133	5	7	$t_{bd} = 12.0354 + (-0.0433 * A_{bf})$
Dsb †	t_{bd} (Days)	A_{bf} (m²)	6.45E-01	0.2214	0.0145	0.1206	15	17	$t_{bd} = 6.7796 + (0.0102 * A_{bf})$



	A	B	C	D	E
Count	11	58	175	271	3
Avg	1.41	1.88	4.29	2.64	2.07
Median	0.18	0.26	0.75	0.78	2.14
Outliers	1	11	21	24	0
StdDev	2.39	3.46	7.21	4.18	1.90
U95	2.82	2.77	5.35	3.14	4.22
L95	0.00	0.99	3.22	2.14	-0.08

Figure 21: Statistical analysis of average annual days within 10% of bankfull flow when all streams binned by major climate.



	A	B	C	D	E
Count	11	58	175	271	3
Avg	3.02	3.99	8.97	5.61	4.17
Median	0.36	0.55	1.67	1.53	4.36
Outliers	1	12	21	24	0
StdDev	4.99	7.33	15.15	8.93	3.84
U95	5.97	5.88	11.22	6.68	8.52
L95	0.07	2.10	6.73	4.55	-0.17

Figure 22: Statistical analysis of average annual days within 20% of bankfull flow when all streams binned by major climate.

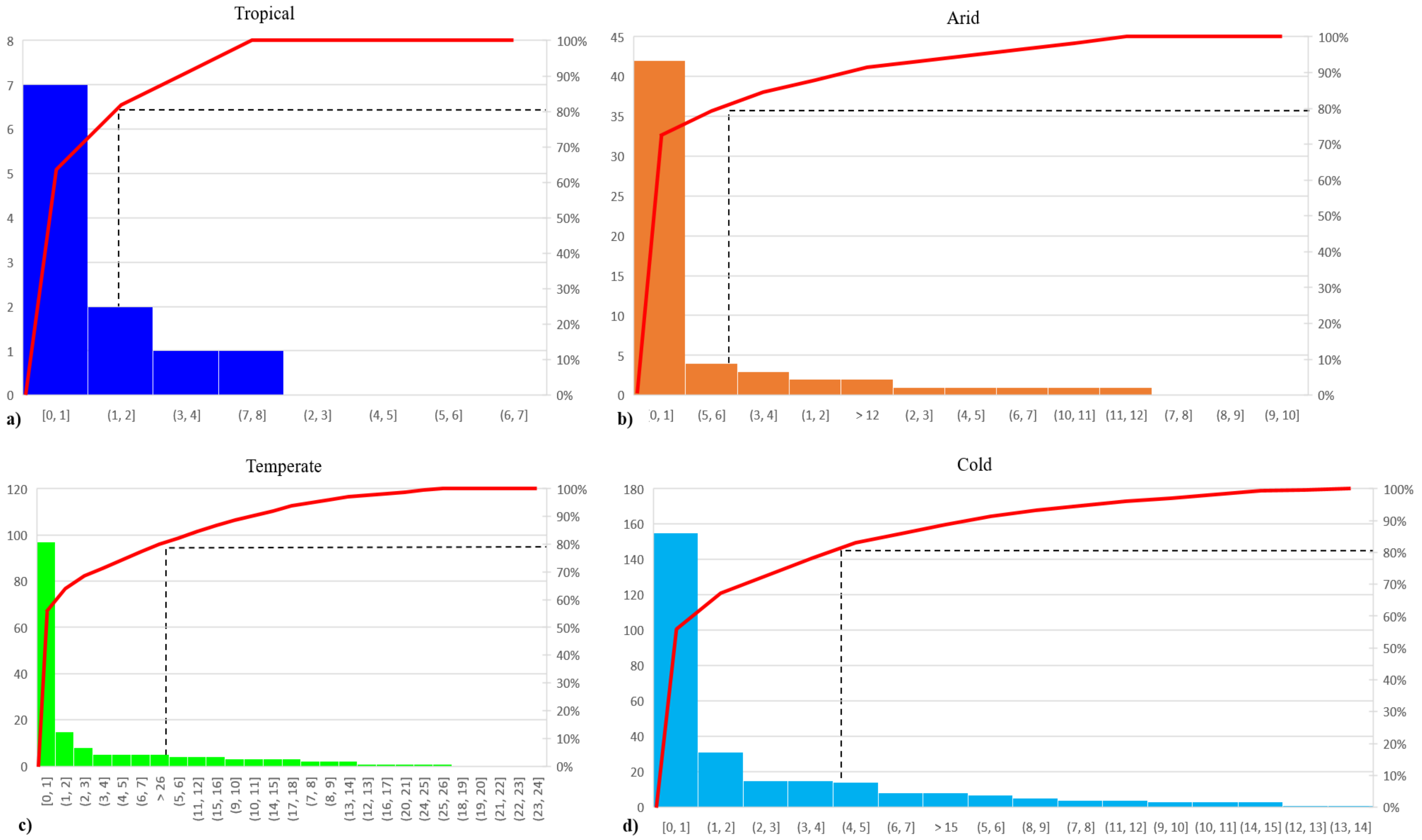


Figure 23 a,b,c,d: Frequency histograms of all major climate reflecting the number of sites that fall within each 1 day interval for annual average days within 10% of bankfull flow. Dashed line indicating the 80 percentile cutoff.

4.3.2 t_{bd} Binned by Köppen Climate

3rd order Köppen climates have distinct populations in average t_{bd} as supported by ANOVA testing (**Figure 24, Figure 25**). The observed F-statistic value computed in the ANOVA test is 3.56, which is greater than the calculated critical F value of 1.66, denoting each population significantly differs (**Table 9**). All stream averages, outliers, standard deviations and confidence intervals were calculated and reviewed for days within 10% of bankfull flow and average days annually within 20% of bankfull flow (**Figure 26, Figure 27**). Average t_{bd} is distinct and defines a distinct population for each Köppen climate bin.

Major climates show internal trends in average t_{bd} when binned by Köppen climate. While the average annual value for days within 10% of bankfull flow for all Arid streams was just under 2 days, when further subdividing by Köppen climate the t_{bd} value for semi-arid cold climate (BSk) streams is more than two times the average duration of bankfull for streams in the semi-arid hot climate (BSh). The overall 10% t_{bd} average of 4.29 days for the Temperate major climate is similar to the individual averages ranging from 2-5 days for 3rd order climates. Upon further binning of Cold climate streams by Köppen climate a bimodal trend emerged. The cold climates of Dfa, Dfb and Dfc all show around 2 days within 10% of bankfull flow annually, while climates of Dsa and Dfb show annual average t_{bd} values of a little over a week (**Figure 24**). Similarly, a bimodal trend in the Cold climate streams continues when binned for the 20% bankfull range (**Figure 25**).

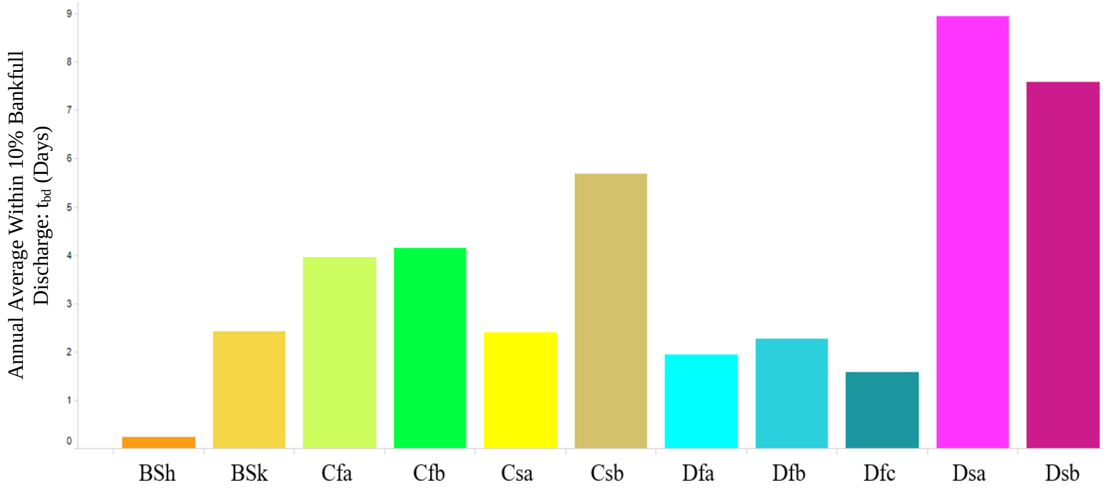


Figure 24 : Averages days annually a stream runs within 10% of bankfull flow when binned by Köppen climate classification, all streams with a drainage area less than 30,000 km² and a minimum of 5 sites in the sample set.

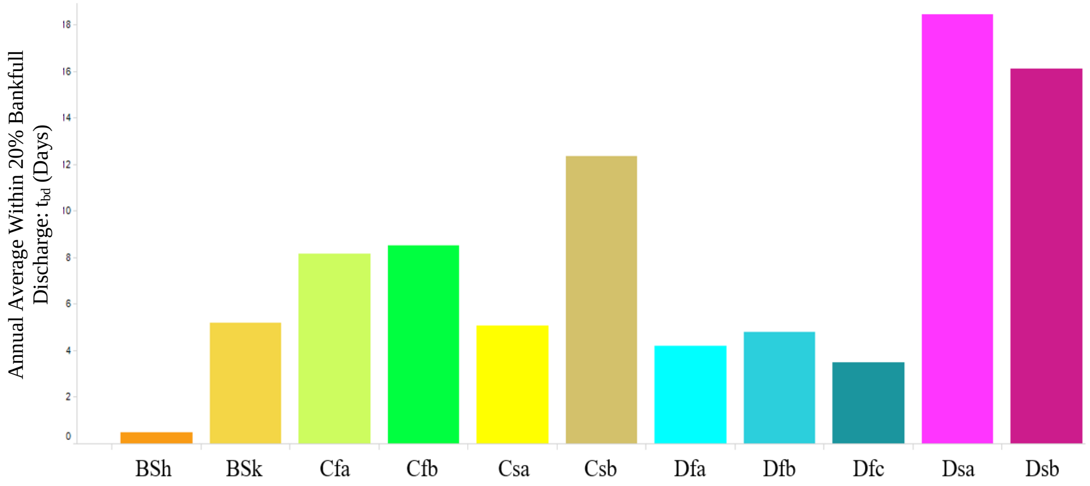
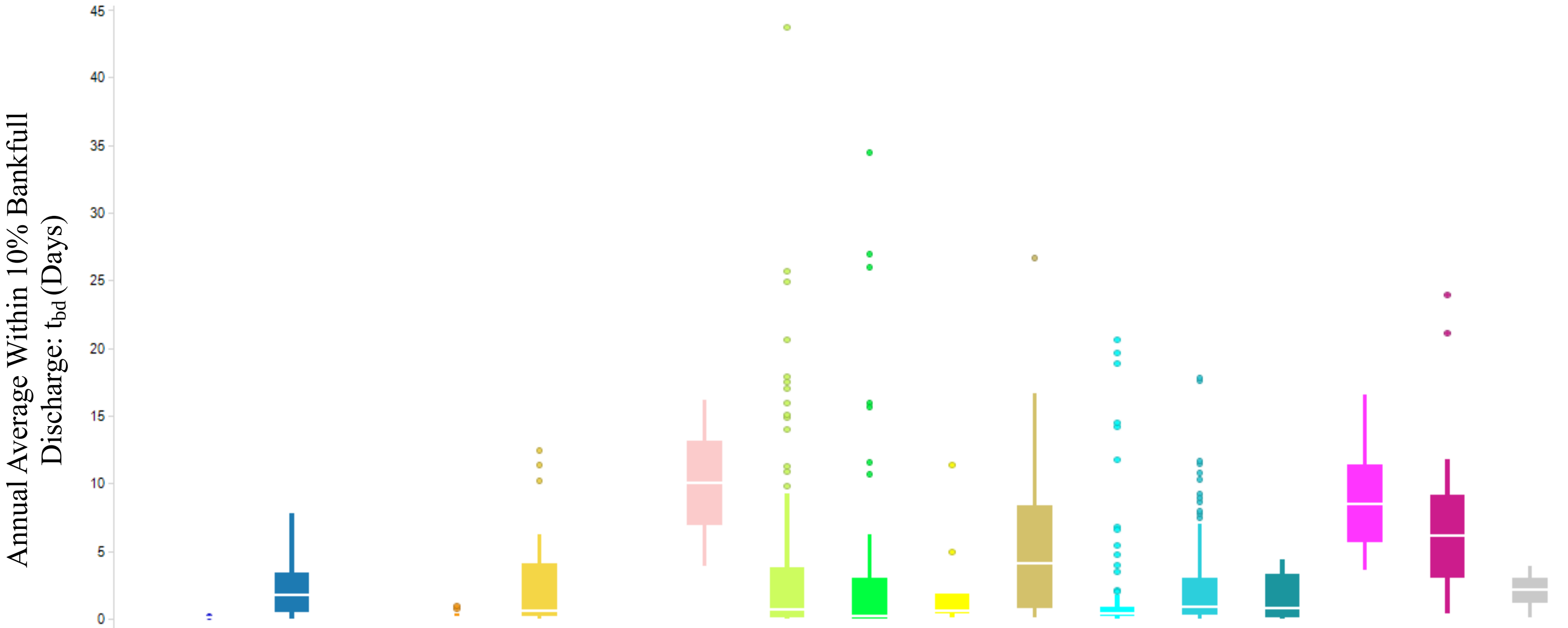


Figure 25: Averages days annually a stream runs within 20% of bankfull flow when binned by Köppen climate classification, all streams with a drainage area less than 30,000 km² and a minimum of 5 sites in the sample set.

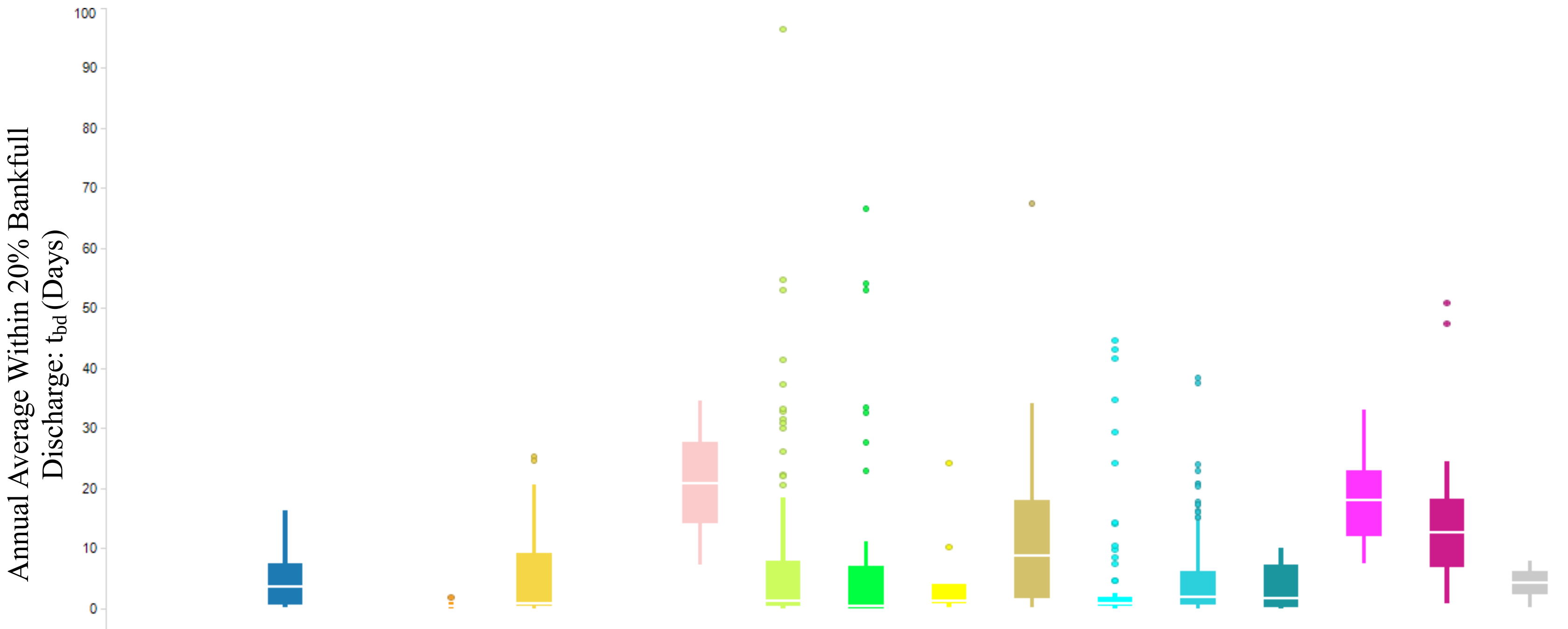
Category	Dependent	p-value	FStat	S2Btwn	S2Wthn	dfBtwn	dfWthn	n
Major Climate	t_{bd} (Days)	5.08E-03	3.7527	424.59	14510.4	4	513	518
Köppen Climate		3.94E-06	3.56222	1525.52	13409.5	16	501	518

Table 9: ANOVA results comparing t_{bd} when binned by Major and Köppen climate for all streams with a drainage area less than 30,000 km². [t_{bd}, average annual days within 10% of bankfull flow; FStat, F- statistic; S2Btwn, the sum of squares between groups; S2Wthn, the sum of squares within groups; dfBtwn, degrees of freedom between groups; dfWthn, degrees of freedom within groups; n, number]



	Af	Am	Aw	BSh	BSk	BWh	BWk	Cfa	Cfb	Csa	Csb	Dfa	Dfb	Dfc	Dsa	Dsb	ET
Count	5	5	1	17	35	4	2	90	41	8	36	83	152	12	7	17	3
Avg	0.09	2.70	1.62	0.22	2.43	0.04	10.04	3.96	4.15	2.40	5.69	1.95	2.26	1.57	8.94	7.59	2.07
Median	0.09	1.72	1.62	0.14	0.55	0.03	10.04	0.66	0.23	0.62	4.09	0.37	0.91	0.76	8.44	6.17	2.14
Outliers	1	0	0	2	3	0	0	14	7	2	1	14	12	0	0	2	0
StdDev	0.07	3.16	(Empty)	0.26	3.43	0.05	8.72	7.35	8.27	3.96	6.05	4.43	3.17	1.75	4.52	6.49	1.90
U95	0.14	5.47	1.62	0.34	3.56	0.09	22.12	5.47	6.68	5.14	7.66	2.90	2.76	2.56	12.29	10.67	4.22
L95	0.03	-0.07	1.62	0.10	1.29	-0.01	-2.04	2.44	1.62	-0.35	3.71	0.99	1.76	0.58	5.60	4.50	-0.08

Figure 26: Box-and-whisker plots comparing t_{bd} when binned by Köppen climate category for all streams that met data availability requirements with a drainage area less than 30,000 km². [t_{bd}, average annual days within 10% of bankfull flow; Avg, Average; StdDev, Standard deviation; U95, upper endpoint of 95% confidence interval; L95, lower endpoint of 95% confidence interval]



	Af	Am	Aw	BSh	BSk	BWh	BWk	Cfa	Cfb	Csa	Csb	Dfa	Dfb	Dfc	Dsa	Dsb	ET
Count	5	5	1	17	35	4	2	90	41	8	36	83	152	12	7	17	3
Avg	0.21	5.64	3.98	0.47	5.18	0.07	20.94	8.16	8.53	5.07	12.36	4.20	4.79	3.47	18.44	16.12	4.17
Median	0.21	3.63	3.98	0.40	0.93	0.06	20.94	1.35	0.48	1.26	8.77	0.83	1.89	1.76	18.10	12.62	4.36
Outliers	0	0	0	1	2	0	0	14	7	2	1	14	14	0	0	2	0
StdDev	0.12	6.61	(Empty)	0.48	7.27	0.09	19.16	15.43	16.62	8.43	13.76	9.68	6.65	3.83	8.91	14.06	3.84
U95	0.31	11.44	3.98	0.70	7.59	0.16	47.49	11.35	13.61	10.91	16.86	6.28	5.85	5.64	25.04	22.81	8.52
L95	0.11	-0.15	3.98	0.24	2.77	-0.01	-5.61	4.98	3.44	-0.77	7.87	2.12	3.73	1.30	11.84	9.44	-0.17

Figure 27: Box-and-whisker plots comparing t_{bd} when binned by Köppen climate category for all streams that met data availability requirements with a drainage area less than 30,000 km². [t_{bd}, average annual days within 20% of bankfull flow; Avg, Average; StdDev, Standard deviation; U95, upper endpoint of 95% confidence interval; L95, lower endpoint of 95% confidence interval]

4.4 PROPORTION OF WATER DISCHARGED AT BANKFULL FLOW VS. DRAINAGE AREA AND CHANNEL SIZE

4.4.1 All Streams in Aggregate

The average annual proportion of water discharged during bankfull flow is determined here for each stream and this value is tested against drainage area, mean bankfull-channel depth, bankfull-channel cross-sectional area in aggregate and without regard to climate. Average annual water volume discharged during the duration of bankfull flow is calculated using the less stringent 20% range for t_{bd}. The total flow in this range is divided by total average annual flow to calculate the proportion of water discharged on average annually during the bankfull flow event (**Appendix VI**). Neither drainage area, mean bankfull-channel depth, nor bankfull-channel cross-sectional influence the proportion of water that is discharged during bankfull stage. In all these relationships, calculated p-values were less than .05, all F-statistic values over 1, and both R and R^2 were low, indicating the model to be statistically significant and yet no correlation between the tested variables **(Table 11)**. Much like the relationship between t_{bd}, there is no strong linear correlation between the proportion of annual discharge during bankfull flow and any spatial attribute tied to drainage area or channel size **(Appendix VII)**.

4.4.2 Binned by Major Climate and Köppen Climate

Relationship between bankfull proportion and drainage area improves in some cases when binned by 1st order climates. Polar and Tropical climates with R values of -0.78 and -0.86, respectively, show a very strong negative linear correlation between bankfull proportion and drainage area.The p-values and f-statistic values for Polar and

Tropical climates indicate statistical significance, but the sample sets for both of these major climates are small and so additional data would be preferred to further test this implied relationship **(Table 11)**. For major climates Arid, Temperate and Cold both the p-values and f-statistic values indicate the results are significant, but the low R values argue there continues to be no meaningful evidence of a linear correlation between drainage area and annual bankfull proportion.

Correlation between mean bankfull-channel depth or bankfull-channel cross-sectional area and the annual bankfull flow proportion was only marginally improved when binned by major climate and remains weak. The statistical summary completed to evaluate the relation of proportion of water discharged during bankfull flow and mean bankfull-channel depth resulting in statistically meaningful values only for the major climates of Temperate and Cold, with no evidence of correlation between these variables **(Table 11)**. Bankfull flow proportion and bankfull-channel cross-sectional area are statistically significant for major climates of Arid and Cold and still only show a weak correlation (R^2= 0.28, 0.02) **(All figures available in Appendix VIII)**.

Binning by specific Köppen climate classification does not generally show significant correlation between bankfull flow proportion and drainage area, mean bankfull-channel depth, or bankfull-channel cross-sectional area. Most Köppen climate bins show large calculated p-values, indicating the model to be insignificant **(Table 11)**. Only the climates of Cfa and Csa have p-values that indicate the values are non-random when binned by drainage area, and out of these only the climate of Csa shows a strong linear relationship based on the calculated R and R^2 values. Only climates of Dfb and Dfc show a statistically non-random relationship between bankfull flow proportion and mean bankfull-channel depth. In both Dfc and Dfb climates, R^2 values are negative indicating a weak negative linear relationship. Similarly only one Köppen climate, BSk, shows a p-value indicating a link between bankfull flow proportion and bankfull cross-sectional area. While the BSk correlation coefficient value of 0.60 shows a moderate positive relationship, the coefficient of determination is only 0.37, indicating the variation in bankfull flow is not well explained by cross sectional area **(Table 11)**. **(All figures available in Appendix IX)**.

4.5 PROPORTION OF WATER DISCHARGED AT BANKFULL FLOW BINNED BY MAJOR AND KÖPPEN CLIMATE

The variance in bankfull flow proportion is further evaluated here without considering any spatial features but rather by simple binning by climate. When binning by major climate alone, the climates of Arid, Temperate and Cold all had an average proportion of waters discharged at bankfull flow value between 6.3%-7.4%, with Tropical streams having an average of 3.7%. Polar streams showed the largest average percentage of water discharged during bankfull flow (10%), but included only three streams in this sample set and comparison with the other major climates is not equivalent **(Figure 28)**.

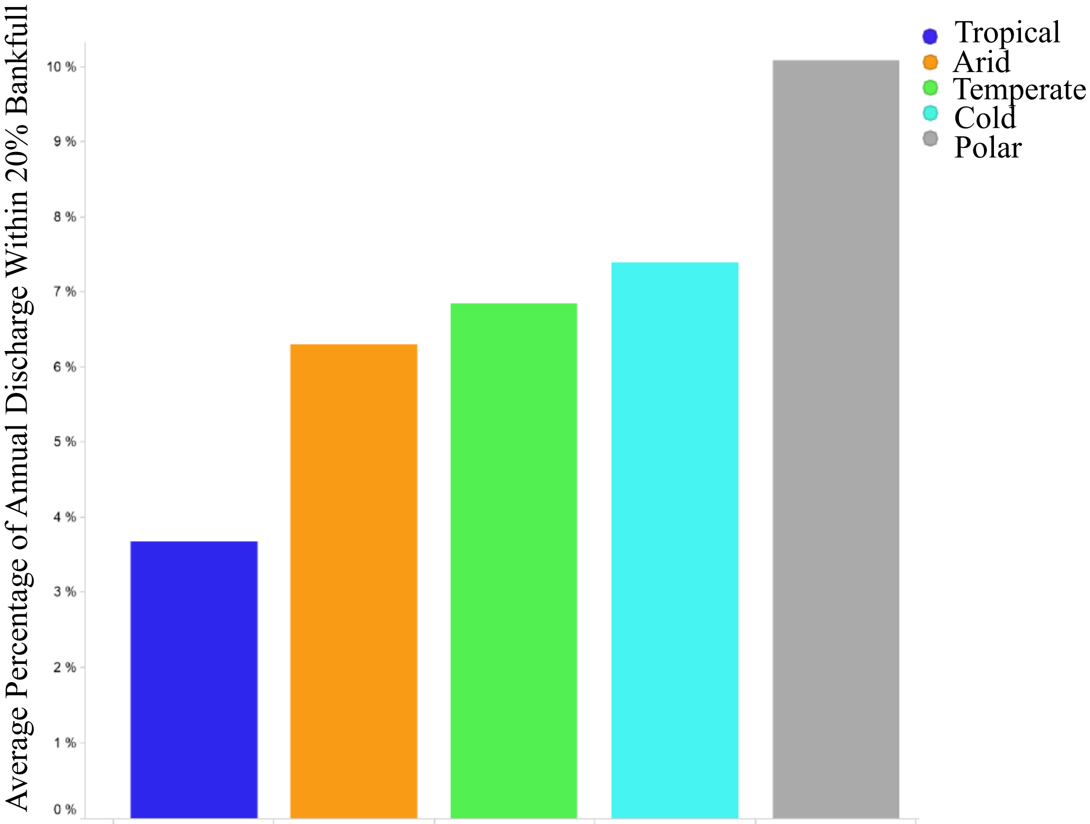


Figure 28: Average annual percentage of water discharged within 20% of the bankfull flow, binned by major climate classification including all streams that met data availability requirements with a drainage area less than 30,000 km².

Binning by 3rd-order Köppen climates with samples of five or more reveals additional trends in bankfull flow proportion. Tropical streams average from 1.7%-5.2%, with the higher average value in Am, the Tropical monsoon climate. The average percentage for the hot semi-arid climate of BSh was nearly half of the value for the cold semi-arid climate of BSk with averages of 4.2% and 7.3% respectively. Calculated average values for temperate climates of Cfb and Cfa ranged from 5%-6.6% with climates Csa and Csb both showing larger values for average proportion of water discharged during bankfull (ranging from 7.6%-9.4%). Similarly, the average values for cold climates of Dsa and Dsb where more than two times the values for climates Dfa, Dfb and Dfc, all of which showed lower average percentages of water discharged during bankfull flow (ranging from 5.5%-7.4%) **(Figure 29)**.

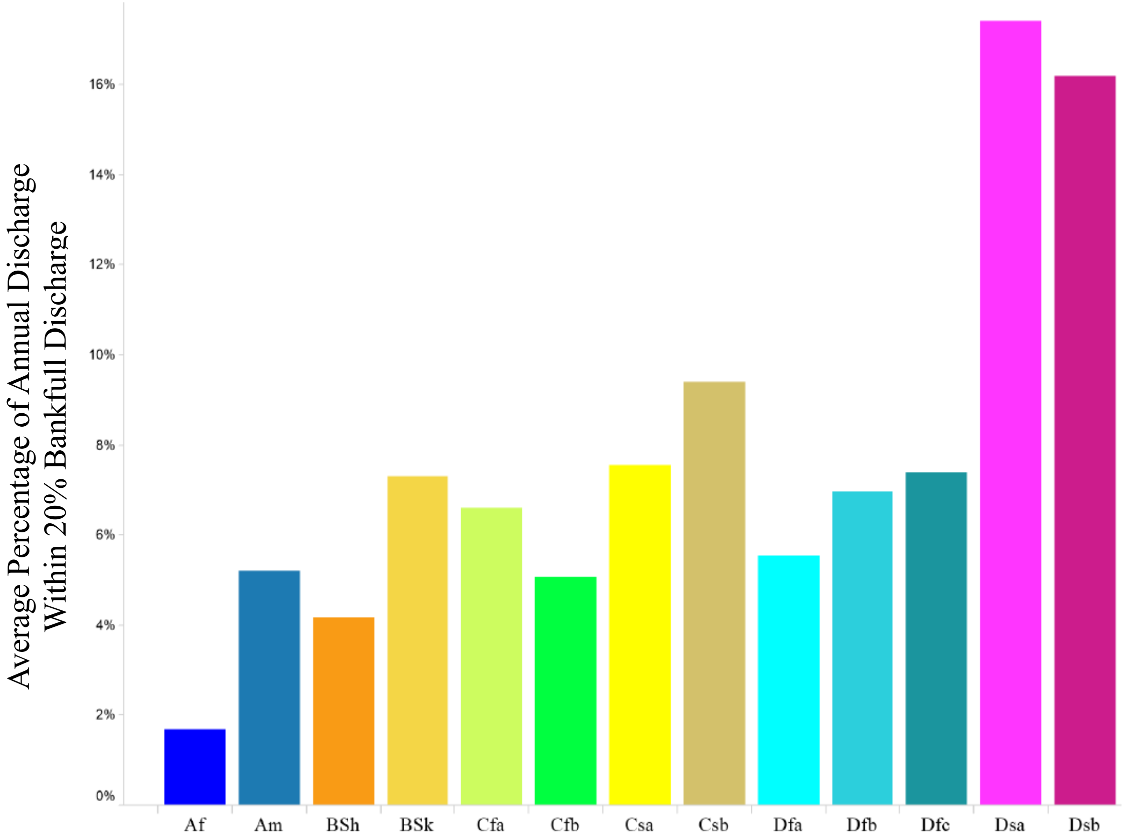


Figure 29: Average annual percentage of water discharged within 20% of the bankfull flow, binned by Köppen climate classification, including all streams that met data availability requirements with a drainage area less than 30,000 km² and a minimum of 5 sites in the sample set.

ANOVA testing and graphical analysis shows percentage of annual water discharge during bankfull flow is significantly different in full Köppen classification but not in major climate. The ANOVA test computed for major climate produced an F-statistic value of 1.55. This value does not exceed the calculated critical F value of 2.39 indicating there is not significant variance in annual water discharge during bankfull flow between major climates. Köppen climates bins however have significant variance in annual water discharge during bankfull flow as indicated by the ANOVA test. The F-statistic of 6.49 is much greater than the calculated critical F value of 1.66 **(Table 10)**. Both major and specific Köppen climates have minimal outliers that result in small standard deviation values calculated for all bins with most box and whisker plots showing minimum skewness **(Figure 30, Figure 31)**. Proportion of annual discharge during bankfull duration varies significantly when streams are binned by Köppen climate without distinct subpopulations for major climates.

Category	Dependent	p-value	FStat	S2Btwn	S2Wthn	dfBtwn	dfWthn	n
Major Climate	Percentage of Average Annual Water Volume Discharged During Bankfull Flow	1.86E-01	1.5524	0.0223	1.8459	4	513	518
Köppen Climate		2.29E-13	6.4857	0.3206	1.5477	16	501	518

Table 10: ANOVA results comparing proportion of annual water volume discharged during bankfull flow when binned by major climate and Köppen climate for all streams that met data availability requirements with a drainage area less than 30,000 km². [FStat, F- statistic; S2Btwn, the sum of squares between groups; S2Wthn, the sum of squares within groups; dfBtwn, degrees of freedom between groups; dfWthn, degrees of freedom within groups; n, number]

Table 11: Statistical summary of linear regression model for all streams that met data availability requirements binned. [P_{bf} , Percentage of Average Annual Water Volume Discharged within 20% of Bankfull Flow; DA, Drainage Area; D_{bf}, Mean Channel Depth at Bankfull; A_{bf}, Bankfull-channel Cross-sectional Area; FStat, F- statistic; R^2, coefficient of determination; R, correlation coefficient; Df, degrees of freedom; n, number; m^3/s, cubic meters per second; km^2, square kilometers; m, meters; m^2, square meters; †, p-value and F-statistic indicate no significant correlation between the tested variables; * Excluding outlier streams with drainage areas > 30,000 km^2]

Proportion of Average Annual Water Volume Discharged During Bankfull vs. Drainage Area and Channel Size: All Streams excluding outliers with drainage area > 30,000 km^2

Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
P_{bf}	DA (km^2)	1.72E-02	5.7147	0.0111	0.1055	508	510	$P_{bf} = 0.0682 + (0.0000 * DA)$
P_{bf} †	D_{bf} (m)	2.27E-01	1.4649	0.0034	-0.0585	426	428	$P_{bf} = 0.0772 + (-0.0033 * D_{bf})$
P_{bf}	A_{bf} (m^2)	3.84E-03	8.4543	0.0202	0.1420	411	413	$P_{bf} = 0.0705 + (0.0001 * A_{bf})$

Proportion of Average Annual Water Volume Discharged During Bankfull vs. Drainage Area and Channel Size: Binned by Major Climate

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Polar †	P_{bf}	DA (km^2)	4.27E-01	1.5914	0.6141	-0.7837	1	3	$P_{bf} = 0.1303 + (0.0000 * DA)$
Tropical †	P_{bf}	DA (km^2)	1.39E-01	5.7550	0.7421	-0.8615	2	4	$P_{bf} = 0.0455 + (-0.0010 * DA)$
Arid	P_{bf}	DA (km^2)	3.90E-03	9.0689	0.1394	0.3733	56	58	$P_{bf} = 0.0527 + (0.0000 * DA)$
Temperate	P_{bf}	DA (km^2)	2.95E-02	4.8210	0.0273	0.1651	172	174	$P_{bf} = 0.0639 + (0.0000 * DA)$
Cold* †	P_{bf}	DA (km^2)	2.55E-01	1.3009	0.0048	0.0694	269	271	$P_{bf} = 0.0723 + (0.0000 * DA)$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Tropical †	P_{bf}	D_{bf} (m)	2.75E-01	1.5011	0.2309	-0.4805	5	7	$P_{bf} = 0.1661 + (-0.0517 * D_{bf})$
Arid †	P_{bf}	D_{bf} (m)	1.71E-01	1.9382	0.0404	0.2011	46	48	$P_{bf} = 0.0546 + (0.0090 * D_{bf})$
Temperate †	P_{bf}	D_{bf} (m)	5.55E-02	3.7373	0.0297	0.1724	122	124	$P_{bf} = 0.0606 + (0.0101 * D_{bf})$
Cold*	P_{bf}	D_{bf} (m)	9.89E-04	11.1109	0.0427	-0.2067	249	251	$P_{bf} = 0.0865 + (-0.0099 * D_{bf})$

Major Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Tropical †	P_{bf}	A_{bf} (m^2)	3.78E-01	0.9344	0.1575	0.3968	5	7	$P_{bf} = 0.0077 + (0.0021 * A_{bf})$
Arid	P_{bf}	A_{bf} (m^2)	1.30E-04	17.5336	0.2804	0.5295	45	47	$P_{bf} = 0.0441 + (0.0006 * A_{bf})$
Temperate †	P_{bf}	A_{bf} (m^2)	7.74E-02	3.1711	0.0253	0.1592	122	124	$P_{bf} = 0.0698 + (0.0001 * A_{bf})$
Cold*	P_{bf}	A_{bf} (m^2)	4.43E-02	4.0898	0.0174	0.1319	231	233	$P_{bf} = 0.0716 + (0.0002 * A_{bf})$

Table 11 Continued

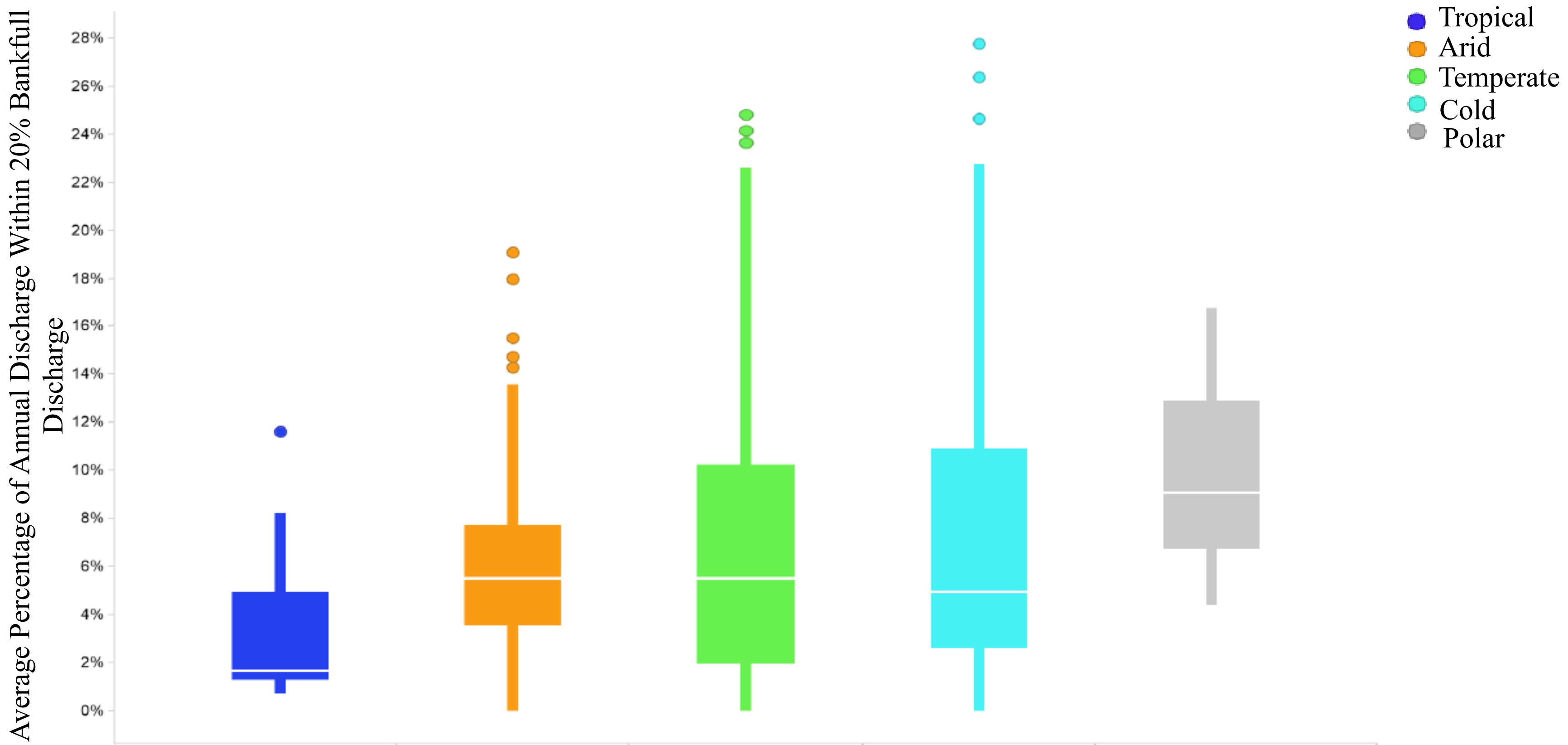
Proportion of Average Annual Water Volume Discharged During Bankfull vs. Drainage Area and Channel Size: Binned by Köppen Climate

Köppen Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Af †	P_{bf}	DA (km^2)	1.39E-01	5.755	0.7421	-0.8615	2	4	$P_{bf} = 0.0455 + (-0.0010 * DA)$
BSh †	P_{bf}	DA (km^2)	3.06E-01	1.1211	0.0695	0.2637	15	17	$P_{bf} = 0.0389 + (0.0000 * DA)$
BSk †	P_{bf}	DA (km^2)	1.62E-01	2.0457	0.0584	0.2416	33	35	$P_{bf} = 0.0653 + (0.0000 * DA)$
BWh †	P_{bf}	DA (km^2)	7.37E-01	0.149	0.0693	0.2633	2	4	$P_{bf} = 0.0221 + (0.0000 * DA)$
Cfa	P_{bf}	DA (km^2)	3.76E-02	4.456	0.0482	0.2195	88	90	$P_{bf} = 0.0559 + (0.0001 * DA)$
Cfb †	P_{bf}	DA (km^2)	5.41E-01	0.3798	0.0099	0.0995	38	40	$P_{bf} = 0.0455 + (0.0000 * DA)$
Csa	P_{bf}	DA (km^2)	1.13E-03	33.9025	0.8496	0.9218	6	8	$P_{bf} = 0.0498 + (0.0000 * DA)$
Csb †	P_{bf}	DA (km^2)	9.62E-01	0.0024	0.0001	0.0083	34	36	$P_{bf} = 0.0934 + (0.0000 * DA)$
Dfa †	P_{bf}	DA (km^2)	3.04E-01	1.0723	0.0131	0.1143	81	83	$P_{bf} = 0.0505 + (0.0000 * DA)$
Dfb* †	P_{bf}	DA (km^2)	5.64E-01	0.3339	0.0022	-0.0471	150	152	$P_{bf} = 0.0704 + (0.0000 * DA)$
Dfc †	P_{bf}	DA (km^2)	3.41E-01	1.0013	0.091	-0.3017	10	12	$P_{bf} = 0.0895 + (0.0000 * DA)$
Dsa †	P_{bf}	DA (km^2)	6.77E-01	0.1947	0.0375	-0.1936	5	7	$P_{bf} = 0.1833 + (0.0000 * DA)$
Dsb †	P_{bf}	DA (km^2)	4.37E-01	0.6384	0.0408	0.202	15	17	$P_{bf} = 0.1544 + (0.0000 * DA)$
ET †	P_{bf}	DA (km^2)	4.27E-01	1.5914	0.6141	-0.7837	1	3	$P_{bf} = 0.1303 + (0.0000 * DA)$

Köppen Climate	Dependent	Independent	p-value	FStat	R^2	R	Df	n	Equation
Am †	P_{bf}	D_{bf} (m)	5.09E-01	0.5574	0.1567	-0.3959	3	5	$P_{bf} = 0.1316 + (-0.0681 * D_{bf})$
BSh †	P_{bf}	D_{bf} (m)	4.11E-01	0.715	0.0455	0.2133	15	17	$P_{bf} = 0.0383 + (0.0028 * D_{bf})$
BSk †	P_{bf}	D_{bf} (m)	1.53E-01	2.1812	0.0866	0.2943	23	25	$P_{bf} = 0.0596 + (0.0183 * D_{bf})$
BWh †	P_{bf}	D_{bf} (m)	4.30E-01	0.9635	0.3251	-0.5702	2	4	$P_{bf} = 0.1955 + (-0.2707 * D_{bf})$
Cfa †	P_{bf}	D_{bf} (m)	9.63E-01	0.0022	0	-0.005	88	90	$P_{bf} = 0.0663 + (-0.0005 * D_{bf})$
Csb †	P_{bf}	D_{bf} (m)	4.09E-01	0.7017	0.0236	0.1537	29	31	$P_{bf} = 0.0787 + (0.0068 * D_{bf})$
Dfa †	P_{bf}	D_{bf} (m)	6.78E-02	3.426	0.0406	-0.2014	81	83	$P_{bf} = 0.0756 + (-0.0205 * D_{bf})$
Dfb*	P_{bf}	D_{bf} (m)	1.37E-02	6.243	0.0469	-0.2165	127	129	$P_{bf} = 0.0831 + (-0.0106 * D_{bf})$
Dfc	P_{bf}	D_{bf} (m)	2.53E-03	17.1307	0.6556	-0.8097	9	11	$P_{bf} = 0.1296 + (-0.0231 * D_{bf})$
Dsa †	P_{bf}	D_{bf} (m)	5.23E-02	6.4192	0.5621	-0.7498	5	7	$P_{bf} = 0.2256 + (-0.0391 * D_{bf})$
Dsb †	P_{bf}	D_{bf} (m)	4.28E-01	0.665	0.0425	0.206	15	17	$P_{bf} = 0.1340 + (0.0192 * D_{bf})$

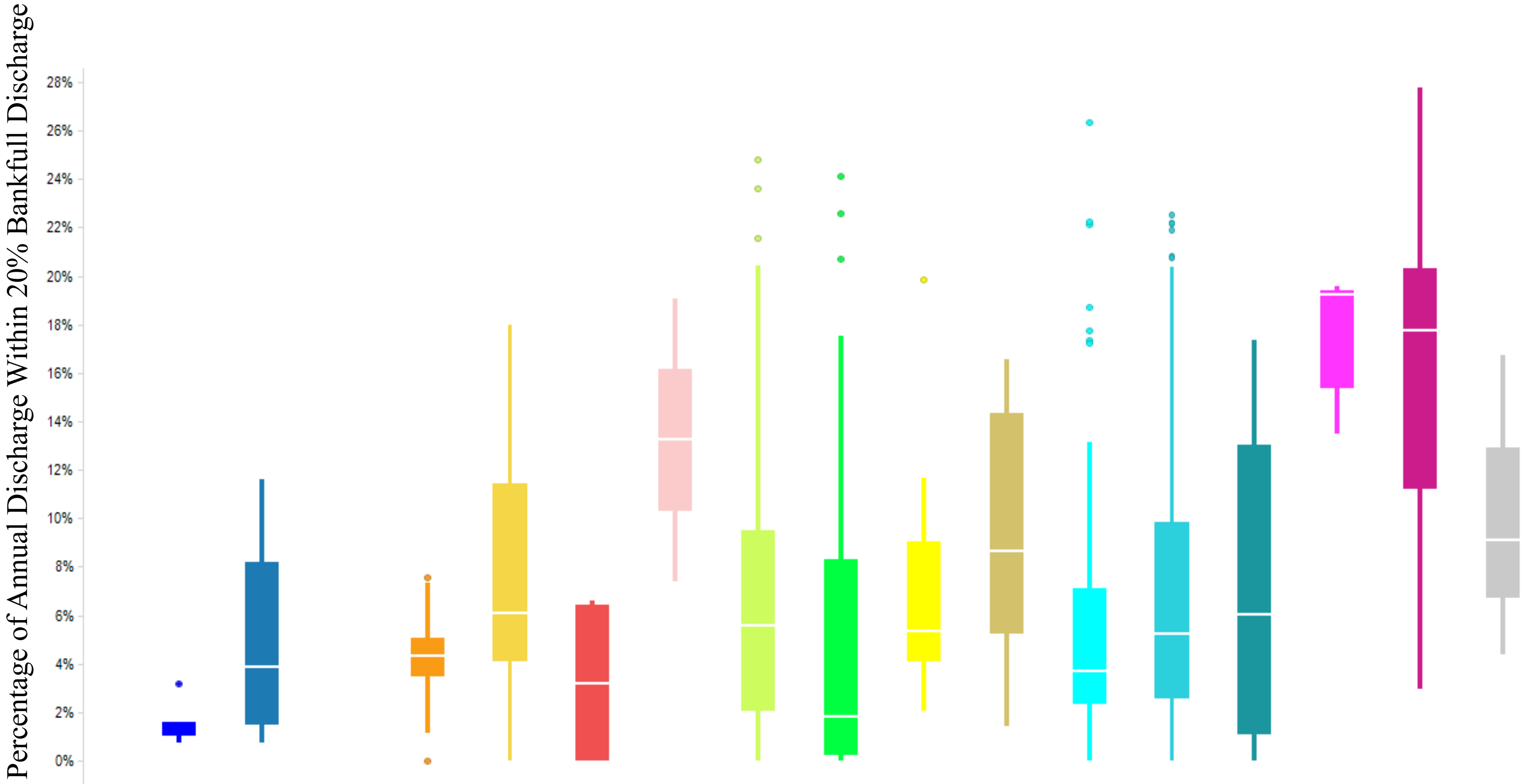
Table 11 Continued

Köppen Climate	**Dependent**	**Independent**	**p-value**	**FStat**	**R²**	**R**	**Df**	**n**	**Equation**
Am †	P_{bf}	A_{bf} (m²)	3.10E-01	1.4891	0.3317	0.5759	3	5	$P_{bf} = 0.0004 + (0.0029 * A_{bf})$
BSh †	P_{bf}	A_{bf} (m²)	1.99E-01	1.8066	0.1075	0.3279	15	17	$P_{bf} = 0.0360 + (0.0001 * A_{bf})$
BSk	P_{bf}	A_{bf} (m²)	1.67E-03	12.818	0.3681	0.6067	22	24	$P_{bf} = 0.0574 + (0.0006 * A_{bf})$
BWh †	P_{bf}	A_{bf} (m²)	9.22E-01	0.0122	0.0061	-0.078	2	4	$P_{bf} = 0.0395 + (-0.0004 * A_{bf})$
Cfa †	P_{bf}	A_{bf} (m²)	6.60E-01	0.1943	0.0022	-0.0469	88	90	$P_{bf} = 0.0678 + (-0.0001 * A_{bf})$
Csb †	P_{bf}	A_{bf} (m²)	4.96E-01	0.4758	0.0161	0.1271	29	31	$P_{bf} = 0.0885 + (0.0000 * A_{bf})$
Dfa †	P_{bf}	A_{bf} (m²)	2.74E-01	1.2152	0.0148	-0.1216	81	83	$P_{bf} = 0.0606 + (-0.0002 * A_{bf})$
Dfb* †	P_{bf}	A_{bf} (m²)	8.90E-01	0.0192	0.0002	-0.0127	118	120	$P_{bf} = 0.0753 + (0.0000 * A_{bf})$
Dfc †	P_{bf}	A_{bf} (m²)	3.56E-01	1.0851	0.2134	-0.4619	4	6	$P_{bf} = 0.1705 + (-0.0079 * A_{bf})$
Dsa †	P_{bf}	A_{bf} (m²)	9.90E-02	4.0923	0.4501	-0.6709	5	7	$P_{bf} = 0.1934 + (-0.0003 * A_{bf})$
Dsb †	P_{bf}	A_{bf} (m²)	3.05E-01	1.1266	0.0699	0.2643	15	17	$P_{bf} = 0.1432 + (0.0002 * A_{bf})$



	A	B	C	D	E
Count	11	58	175	271	3
Avg	3.66%	6.30%	6.84%	7.38%	10.08%
Median	1.69%	5.53%	5.49%	4.93%	9.09%
Outliers	1	5	3	3	0
StdDev	0.04	0.05	0.06	0.06	0.06
L95	0.02	0.05	0.06	0.07	0.03
U95	0.06	0.07	0.08	0.08	0.17

Figure 30: Box-and-whisker plots comparing annual average percentage of water discharged within 20% of bankfull flow when binned by major climate for all streams that met data availability requirements with a drainage area less than 30,000 km². [StdDev, Standard deviation; U95, upper endpoint of 95% confidence interval; L95, lower endpoint of 95% confidence interval]



	Af	Am	Aw	BSh	BSk	BWh	BWk	Cfa	Cfb	Csa	Csb	Dfa	Dfb	Dfc	Dsa	Dsb	ET
Count	5	5	1	17	35	4	2	90	41	8	36	83	152	12	7	17	3
Avg	1.67%	5.19%	6.00%	4.17%	7.28%	3.24%	13.23%	6.58%	5.05%	7.54%	9.37%	5.53%	6.95%	7.38%	17.40%	16.17%	10.08%
Median	1.64%	3.87%	6.00%	4.33%	6.11%	3.18%	13.23%	5.55%	1.80%	5.33%	8.64%	3.68%	5.22%	6.01%	19.23%	17.74%	9.09%
Outliers	1	0	0	2	0	0	0	3	3	1	0	7	6	0	0	0	0
StdDev	0.01	0.05	(Empty)	0.02	0.05	0.04	0.08	0.05	0.07	0.06	0.05	0.05	0.06	0.07	0.03	0.07	0.06
L95	0.01	0.01	0.06	0.03	0.06	0.00	0.02	0.05	0.03	0.04	0.08	0.04	0.06	0.04	0.15	0.13	0.03
U95	0.02	0.09	0.06	0.05	0.09	0.07	0.25	0.08	0.07	0.12	0.11	0.07	0.08	0.11	0.19	0.19	0.17

Figure 31: Box-and-whisker plots comparing annual average percentage of water discharged within 20% of bankfull flow when binned by Köppen climate for all streams that met data availability requirements with a drainage area less than 30,000 km². [StdDev, Standard deviation; U95, upper endpoint of 95% confidence interval; L95, lower endpoint of 95% confidence interval]

4.5 ERROR ANALYSIS

Some error sources in this analysis are tied to the way in which gaging data are intrinsically collected and results cannot be extended to attributes not included or considered in the final dataset. Findings of this study are applicable to single strand channels and are extended to braided systems with caution. This is because stream gauge data and bankfull survey data are preferentially collected at riffle locations along the reach of single strand channels where gaging is most practical (Cinotte, 2003; Lawlor, 2004; Mistak and Stille, 2008; Moody et al., 2003), and more rarely gage wide braided channels with anabranches **(Figure 32)**. Additional stream specific attributes (i.e. channel slope, channel elevation and stream bed lithology) not considered in this study may be sources of variability not accounted for in the derived results (Chaplin, 2005; Sherwood and Huitger, 2005; Sweet and Geratz, 2003). Acquisition and incorporation of additional stream specific attributes could potentially minimize error resulting in more accurate predictive ability regarding both spatial and temporal attributes**.** Further, channel gaging is biased against highly remote areas, streams that pose little hazard, and streams that rarely flow. Extreme arid rivers are particularly underrepresented. Accordingly, the study did not capture all Köppen climates, and focused on climates with more robust data sets.

Linear regression equations derived in this study can be used to predict relationships between drainage area vs. bankfull discharge, mean bankfull-channel depth and cross-sectional bankfull-channel area for several statistically significant sample sets with robust data. Due to limitations such as data availability and land area coverage the computed linear regression equations for some relationships can be used with greater confidence than others. A linear regression equation should be considered insignificant and is not recommended for use if the p-value is greater than 0.05. Equations for statistically significant relationships with moderate to strong correlations (R and R^2 are greater than 0.50) can be used with greater confidence.

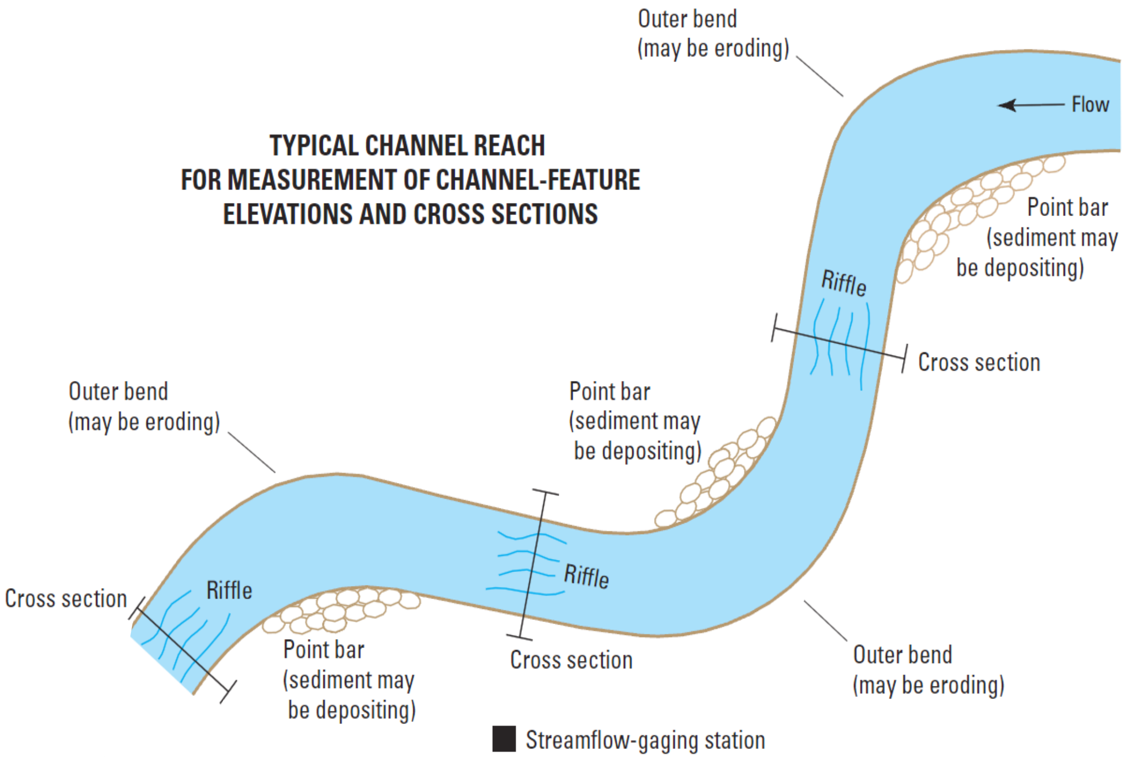


Figure 32: Illustration of typical location of gaging station and cross-sectional measurements along a typical channel reach (Lawlor, 2004).

CHAPTER 5

DISCUSSION

5.1 DRAINAGE AREA VS. BANKFULL DISCHARGE

Drainage area is a primary control on river discharge for small and medium drainages, albeit this relationship varies considerably between these drainages. Drainage area vs bankfull discharge showed weak to moderate correlation for all small and medium drainages in aggregate (R^2 value of 0.39 and R value of 0.62). Regional studies commonly compare this relationship using a log-log plot which improves resulting correlation (Bent and Waite, 2013; Cinotto, 2003; Lawlor, 2004). Using a log-log graph the correlation in the data set is significantly strengthened (R^2 value of 0 .55) **(Figure 33a)**.

Weaker correlation between drainage area and discharge improves when larger drainages are included. Including the 6 large outlier streams on the log-log plot further strengthened the correlation (R^2 value of 0.60) **(Figure 33b)**. Previous works addressing this aggregate relationship across the range from small to large drainages also show much stronger correlation than observed in small and medium drainages alone (see Syvitski, & Milliman, 2007; Blum et al., 2013). Most recently, Blum, et al. (2013) produced correlation between drainage area and discharge with R^2 value of 0.94, but included very large drainages with areas up to 10^7 square kilometers. Most of the variation in discharge between drainages appears to manifest in the smaller drainages. Larger drainages that integrate multiple smaller drainages tend to average out the local variations between small drainages and more effectively converge on a consistent discharge trend.

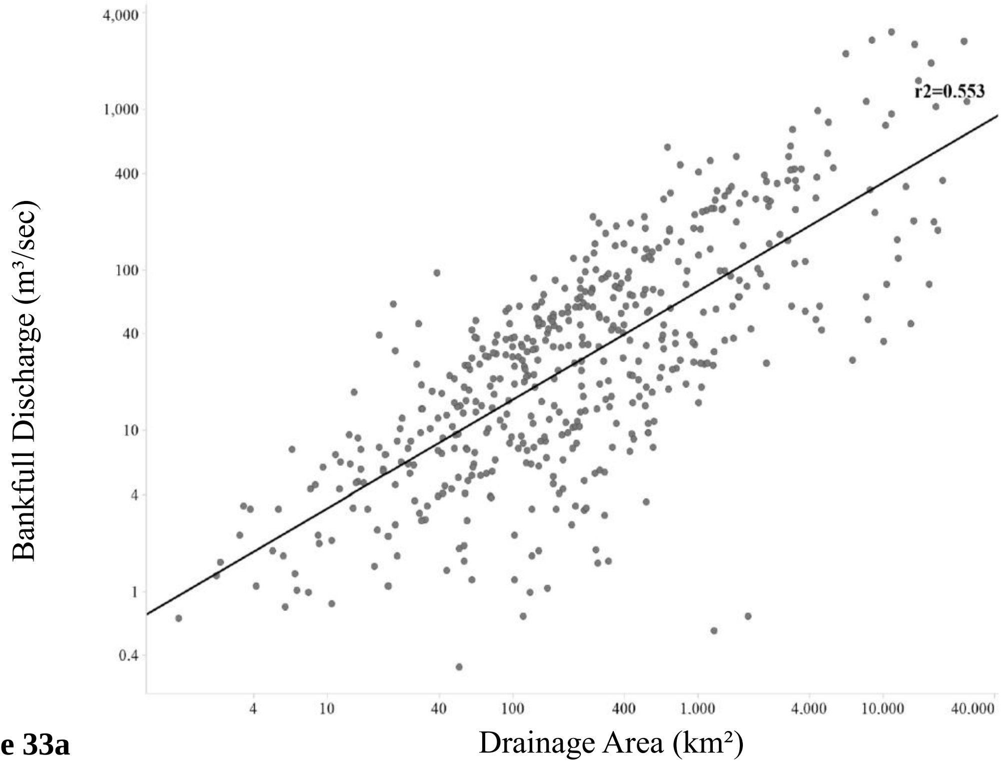


Figure 33a

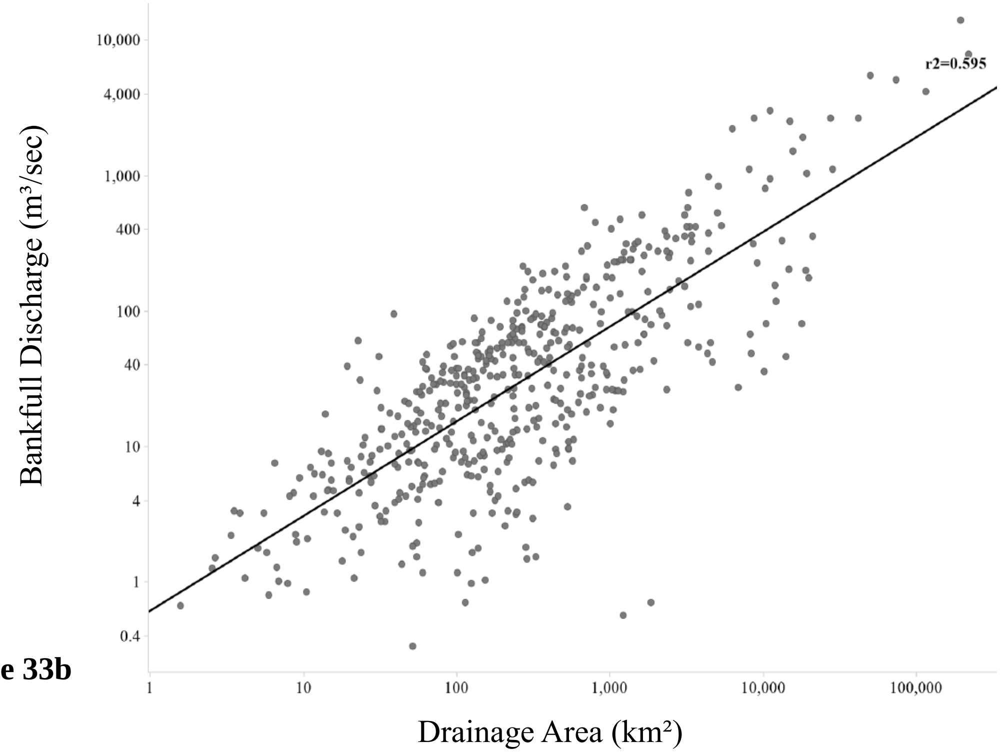


Figure 33b

Figure 33a, b: Relation between bankfull discharge and drainage area on a logarithmic scale. Fig. a: All streams with drainage areas less than 30,000 km². Fig. b: All streams. [m³/sec, cubic meters per second; km², square kilometers]

Binning by major climate improves correlation between drainage area and bankfull discharge. Drainage area and bankfull discharge have an overall strong correlation when binned by major climate (R^2 values ranging from 0.50 to 0.99) (**Table 6**). Cold climate streams show the weakest correlation between drainage area and bankfull discharge (R^2 value= 0.51, R= 0.71), with this correlation becoming significantly stronger when including the 6 large outlier streams (R^2 value= 0.83, R= 0.91). As seen in aggregate, correlation improves when larger drainages are incoroporated. This suggests that integration of smaller drainages into larger drainage systems also averages out variation between drainages within the same general climatic regime.

Correlation between drainage area and bankfull discharge is generally strong when binned by specific Köppen climate. Prior works most commonly do regional studies that correlate proximal drainages within a similar climate (e.g., Chaplin, 2005; Lawlor, 2004; Sweet and Geratz, 2003), rather than develop comparisons for dispersed drainages that share a similar climate category (e.g., Syvitski, & Milliman, 2007; Plink-Björklund, 2015). Similar to previous regional works, however, general binning by Köppen climate shows moderate to strong climate-specific correlation between drainage area and bankfull discharge. This is generally true of all climates tested and across a range of sample sizes with one notable exception. The humid subtropical climate of Cfa contains 90 streams and yet shows the weakest correlation with an R^2 and R value of 0.24 and 0.49 respectively (**Table 6**). The climate of Cfa covers a vast area of the Southeastern United States with a high concentration of diverse physiographic regions, which may factor into the weak correlation between drainage area and bankfull discharge in this climate. Whether binned by climate or in aggregate, bankfull discharge shows stronger correlation to drainage area than any other variable tested.

5.2 CHANNEL SIZE VS. DRAINAGE AREA: THE ROLE OF CLIMATE

Channel size correlates to drainage area for small and medium drainages, but the correlation is weak. Bankfull channel size is measured as both channel depth and channel cross-sectional area to capture the key dimensions of channel depth and to capture the relationship between channel depth and channel width. While both correlations are weak, there is stronger correlation between mean bankfull-channel depth and drainage area (R^2= 0.30, R= 0.55) than bankfull-channel cross-sectional area and drainage area (R^2= 0.19, R= 0.43) (**Table 12**). This contrasts regional studies where bankfull-channel cross-sectional area generally shows stronger correlation to drainage area (Cinotto, 2003; McCandless, 2003b). Factors that are captured in regional studies and are not accounting for in aggregate such as drainage bedrock and land use (Chaplin, 2005) may cause weak correlation between channel dimension and drainage area. While many regional works have addressed the relationship between channel dimensions and drainage area (Cinotto, 2003; McCandless, 2003b; Mulvihill et al., 2007; Blanton, 2008; Bent & Waite, 2013) paleohydrological application would benefit from additional work on the aggregate level.

Binning by major climate generally improves correlation between mean bankfull-channel depth and bankfull-channel cross-sectional area vs drainage area. Similar to regional studies (Cinotto, 2003; McCandless, 2003b) streams in both Arid and Temperate climates show stronger correlation between drainage area and bankfull-channel cross-sectional area than mean bankfull-channel depth **(Table 12)**. Contrastingly, Cold climate streams show stronger correlation between drainage area and mean bankfull-channel depth. Correlation further strengthens between drainage area and mean bankfull-channel depth when including the 6 large outlier streams **(Table 12)**. As with discharge, channel size appears to correlate better with drainage area as rivers with larger drainage areas are included and variations between local subdrainages are averaged. Studies of the Kuparuk River in Alaska found width proportionally increases less rapidly in channels with larger drainage areas, while depth continues to increase at a steady rate (McNamara et al., 2009; Best, 2002). Most large streams and most medium streams in this dataset are Cold climate streams. The improved correlation between depth and drainage area for these Cold climate streams may be an artifact of the data set and this scaling relationship could also occur in Arid and Temperate rivers if further tested in the future.

Drainage Area vs. Channel Size					
All Small and Medium Streams in Aggregate	**Dependent**	**Independent**	**R^2**	**R**	**n**
	D_{bf} (m)	DA (km^2)	0.3051	0.5523	421
	A_{bf} (m^2)	DA (km^2)	0.1888	0.4345	406
Major Climate	**Dependent**	**Independent**	**R^2**	**R**	**n**
Arid	D_{bf} (m)	DA (km^2)	0.2034	0.4510	48
Temperate	D_{bf} (m)	DA (km^2)	0.4891	0.6994	124
Cold	D_{bf} (m)	DA (km^2)	0.5805	0.7619	251
Cold*	D_{bf} (m)	DA (km^2)	0.4627	0.6802	247
Major Climate	**Dependent**	**Independent**	**R^2**	**R**	**n**
Arid	A_{bf} (m^2)	DA (km^2)	0.3994	0.6320	47
Temperate	A_{bf} (m^2)	DA (km^2)	0.6894	0.8303	124
Cold	A_{bf} (m^2)	DA (km^2)	0.2384	0.4883	233

Table 12: Statistical summary of linear regression model. [DA, Drainage Area; D_{bf}, Mean Channel Depth at Bankfull; A_{bf} , Bankfull-channel Cross-sectional Area; R^2, coefficient of determination; R, correlation coefficient; n, number; km^2, square kilometers; m, meters; m^2, square meters * Excluding outlier streams with drainage areas > 30,000 km^2]

Binning by Köppen climate further improves correlation between mean bankfull-channel depth and bankfull-channel cross-sectional area vs drainage area, better mirroring regional trends. The majority of statistically significant Köppen climate streams maintain moderate correlation in the relation between mean bankfull-channel depth and drainage area, and show moderate to strong correlation between bankfull-channel cross-sectional area and drainage area (**Table 6**). Climates BSk and Dfb show stronger correlation between mean bankfull-channel depth and drainage area. Stronger correlation between mean bankfull-channel depth and drainage area, vs channel cross-sectional area and drainage area, may again be a result of a generally improved correlation with channel depth over area as larger drainages are incorporated as BSk and Dfb contain the most medium size streams out of all Köppen climate bins **(Table 13)**. The scaling of depth to drainage area vs. width to drainage area with increasing catchment size within Köppen climate warrants further investigation (e.g. McNamara et al., 2009; Best, 2002). In most regional studies bankfull discharge and bankfull-channel cross-sectional area have the strongest correlation to drainage area and mean bankfull-channel depth has the weakest correlation (Brockman, 2010; Chaplin, 2005; Cinotto, 2003; McCandless, 2003b; Westergard et al., 2004). Binning by Köppen climate overall trends become more in line with previous regional studies.

Number of Medium Streams	Köppen climate	Major Climate
15	BSk	Arid
14	Dfb	Cold
12	Csb	Cold
6	Dfc	Temperate
6	Dsb	Cold
4	Cfb	Temperate
4	Dsa	Cold
2	BSh	Arid
2	BWk	Arid
1	Csa	Temperate
1	ET	Polar

Table 13 : Number of all medium streams with drainage areas ranging from 2,000 km² – 30,000 km² grouped by climate.

5.3 t_{bd}: AVERAGE ANNUAL DAYS OF BANKFULL FLOW

Paleohydrologic estimates largely evaluate bankfull discharge, thus knowing the duration of this discharge (t_{bd}) is a crtical variable for estimating total annual bankfull discharge. The recurrence interval for bankfull flow is a topic of extensive work (e.g., Dury et al, 1963; Leopold et al., 1964). Fewer studies focus directly on the specific annual days a stream maintains bankfull flow (Andrews, 1980; Andrews and Nankervis, 1995; Dudley, 2004; Powell et al., 2006; Wolman and Miller, 1960). Previous works on bankfull duration focus mostly on regional areas with significantly varying results. Example durations include one day in Northeastern Puerto Rico Tropical streams (Pike and Scatena, 2010), two days in England and Wales (Nixon, 1959), 1.5 to 11 days in Colorado and Wyoming (Andrews, 1980), and one to 24 days in large Ohio streams (Powell et al., 2006).

Predicting bankfull duration in paleochannels requires correlation of bankfull duration to a trait that can be extracted from the stratigraphic record. Channel size (i.e.

depth, cross-sectional area, and drainage area) and climatic conditions are both extractable from the stratigraphic record and are compared to bankfull duration in this section. Channel size appears to have no relationship to bankfull duration, but climate has a strong control on the duration of bankfull flow in small and medium drainages. Data from this study shows that recognition of paleoclimate for paleorivers permits prediction of t_{bd} to within standard deviations of two to four times the average value (**Figure 21)** (**Figure 26**). While still broad, this error is substantially less than the order of magnitude error imposed for t_{bd} when streams are considered in aggregate without a climatic distinction (after Holbrook and Wanas, 2014).

The duration of bankfull flow (t_{bd}) has no consistent linear relationship with any spatial attributes (i.e. drainage area, mean bankfull-channel depth, and/or bankfull-channel cross-sectional area) in small and medium drainages. The majority of calculated p-values for all simple linear regression models showed the model to be statistically insignificant, whether correlated in aggregate or binned by climate. Likewise, no evidence for correlation between t_{bd} and drainage area, mean bankfull-channel depth, and/or bankfull-channel cross-sectional area was found in the multiple regression model (**Figure 16**). In the few anomalous cases with statistically significant strong correlation (i.e. correlation between t_{bd} and drainage area in Tropical streams) the sample sets are small. These results should be reviewed as preliminary at best.

Climate has a statistically significant control on t_{bd}. Average days at bankfull varies distinctly between climates in data from this study, whether binned by Major or Köppen climate (see **Appendix X**). Previous works that have addressed average annual bankfull duration are often regional studies (Nixon, 1959; Andrews, 1980; Carson et al., 2007; Pike and Scatena, 2010), and/or base averages on small sample sets (e.g. Wolman and Miller, 1960). Streams are not compared across large areas by climate category for bankfull duration. Plink-Björklund (2015) more recently addresses impact of climate on variability on discharge with large non-regional data sets, but annual days of bankfull duration is not the concentration.

Average annual bankfull duration is shortest in Tropical streams (average t_{bd} 1.41 days per year within 10% of bankfull discharge) **(Figure 21).** Intense tropical rains cause flashy floods for streams in Tropical climates (Pike and Scatena, 2009; Plink-Björklund, 2015; Schellekens et al., 1999). Bankfull stage is surpassed so quickly during flash flood events that the duration at bankfull is commonly below the resolution of the collected mean daily discharge data. In Tropical Rainforest (Af) streams t_{bd} is the shortest (average t_{bd} = 0.09 day per year) due to most flooding events being flashy. As expected Monsoonal (Am) climate streams have longer flooding events and longer bankfull flow durations (average t_{bd} = 2.70 days per year) (**Figure 26**). Most recorded days at bankfull for Monsoonal (Am) streams occur during the falling stage of the river with no bankfull stage captured in the rising limb of the flood hydrograph.

Arid climate streams are within 10% of bankfull discharge less than 2 days a year on average (average t_{bd} = 1.88 days per year) **(Figure 21).** There is significant variance, however, in bankfull duration among Arid climate streams. Semi-Arid hot climate (BSh) streams show much shorter bankfull duration (t_{bd} value of 0.22 days per year) than Semi-Arid cold climate (BSk) streams (t_{bd} value of 2.43 days per year) (**Figure 26**). Flashy floods specifically dominate BSh streams resulting in short flood durations and even shorter bankfull flow durations. High intensity storms and poor vegetation cover are often the cause of flashy floods in arid regions (Lin, 1999; Farquharson et al., 1992). Flooding events in BSk climate streams generally have longer duration with longer bankfull flow discharge in studied streams, again more typically in the flood falling stage. Snow/ice meltwater are a potential factor in the longer flood durations observed in semi-arid cold climate (BSk) streams (Lin, 1999).

Temperate streams average 4.29 days annually within 10% of bankfull discharge. Average bankfull durations range from an average of 2.40 days in Csa climate streams to 5.69 days in Csb climate streams **(Figure 21) (Figure 27)**. Additional trends also emerge at the level of Köppen climate. Within the climate of Csa most streams run at bankfull less than one day a year with the average days at bankfull skewed in our data by 2 outlier streams running at bankfull an average of 4.92-11.38 days annually. All Csa streams with average bankfull duration of less than one day are mountainous streams in California where the 2 outlier streams are in a plateau physiographic region of Washington State. The 2 outlier streams are also within 30 miles of the Csb climate boundary where average t_{bd} values are similar to those seen in the two outliers streams. Differing physiographic regions and/or error in Köppen climate boundaries may be responsible for the 2 outlier streams identified in the Csa climate. In the climate of Cfa all outlier streams with long durations are from coastal plains regions (Blanton, 2008; McCandless, 2003a; Sweet and Geratz, 2003). High rainfall onto near level topography likely reduces flushing rates of channels (Sweet and Geratz, 2003) and may cause the increased duration of bankfull flow for streams in coastal plains regions. No abrupt regional trends in t_{bd} are observed for streams in the Köppen climate bins of Cfb (average t_{bd} value of 4.15 days) or Csb (average t_{bd} value of 5.69 days). This suggest that some climates are sensitive to regional factors with respect to bankfull duration and some are not as susceptible.

Cold streams run within 10% of bankfull discharge for an average of 2.64 days annually. The trend is bimodal with peaks driven, respectively, by Cold climates with a dry summer (Dsa, Dsb) and climates without a dry season (Dfa, Dfb, Dfc) (**Figure 24**) (**Figure 26**). The average bankfull duration in Cold summer-dry climate streams (average Dsa t_{bd} = 8.94, average Dsb t_{bd} = 7.59) is more than double the bankfull duration of Cold humid streams (average Dfa t_{bd} = 1.95, average Dfb t_{bd} = 2.26, average Dfc t_{bd} = 1.57). Snow-melt inducing longer periods of bankfull discharge in Cold dry summer climate streams (Dsa, Dsb) is the apparent driver behind this trend. Only the Köppen climate bin of Dfa shows a definable regional trend in t_{bd}. Out of the 14 outlier streams in climate Dfa (average t_{bd} > 2 days) 11 are in Southern Lower Michigan, the wettest ecoregion in Michigan (Rachol and Boley-Morse, 2009).

5.4 RELATIONSHIP BETWEEN BANKFULL AND ANNUAL DISCHARGE

The proportion of annual water discharged by a river during bankfull flow varies significantly by climate and does not show strong correlation to drainage area, mean bankfull-channel depth or bankfull-channel cross-sectional area. Simiarly to t_{bd} climate has more significant impact than river size on the percentage of annual water discharged during bankfull duration. In aggregate the average annual proportion of discharge during bankfull is 7.03%. Binning by major climate significant variation in annual percentage of water discharged during bankfull flow is not supported (**Table 10**) (**Figure 28**). Binning by Köppen climate results in distinct populations in proportion of water discharged during bankfull flow (**Table 10**) (**Figure 29**).

Binning by Köppen climate reveals significant variance in the proportion of annual discharge occurring during bankfull duration. Climates with highly seasonal rainfall (i.e. Am, Csa, Csb, Dsa, Dsb) show higher percentages of annual discharge during bankfull flow. Conversely, more humid climates with perennial rainfall (i.e. Cfa, Cfb, Dfa, Dfb, Dfc) show smaller percentages of annual discharge occurring during bankfull duration (**Figure 29**). These findings are in line with previous work that found high discharge variability between annual discharge range and mean discharge in seasonal climate streams (i.e. tropical monsoonal streams (Am)) and less variability in perennial rainfall climate streams (i.e. equatorial tropic streams (Af) and temperate streams) (Latrubesse et al., 2005; Plink-Björklund, 2015). Annual percentage of water discharged during bankfull flow is impacted not just by total precipitation but also the seasonality of precipitation. This difference in frequency patterns of precipitation explains why binning by Köppen climate reveals significant variations in annual bankfull proportion not seen when binning only by major climate. Regardless of major climate, streams with highly seasonal rainfall move a higher percentage of annual water discharge during bankfull flow than streams in climates with perennial precipitation.

5.5 APPLICATION TO THE ROCK RECORD

Previous workers have addressed the importance of paleohydrologic reconstructions for predictive purposes in the rock record (Miall, 2006; Fielding, 2008) and yet there is significant work remaining to further available analysis (Davidson and North, 2009; Holbrook and Wanas, 2014). Drainage area vs. channel size vs. discharge has been addressed regionally with few attempts to break these relationships out by climate in aggregate. The findings of this study facilitate an approach to calculate drainage area, discharge and/or channel size by leveraging basic knowledge of the climate and drainage area of the stream, this is an improvement as it minimizes error in water discharge estimates and bankfull duration. An order of magnitude in error remains in sediment flux esimates as proportion of sediment moved during bankfull has yet to be improved upon.

Paleohydrologic reconstructions depend on knowledge of temporal (i.e., discharge, t_{bd}) and spatial (i.e., channel size, drainage area) aspects of stratigraphic channels. Channel size and representative bedload, and sometimes drainage area, can be measured directly from the rock record, but temporal aspects like bedload and annual discharge must be estimated using modern analogues. The accuracy of these estimates depends on the applicability of the analogues. Climate significantly controls the temporal attribute of t_{bd} and impacts relationships between spatial attributes of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area. Paleoclimate of the stratigraphic channel must be determined to find the best analogue relationships to estimate drainage area and discharge from measured channel dimensions (Davidson and North, 2009; Holbrook and Wanas, 2014).

Using climate-based estimates of t_{bd} improves the accuracy of discharge estimates. Previously using a default value for t_{bd} of 7.3 days to estimate yearly average sediment discharge of Bahariya rivers an annual average suspended load of 112,000-561,000 m^3/yr and an average annual bedload of 48,000 m^3/yr for a total sediment discharge of 160,000-609,000 m^3/yr was computed (Holbrook and Wanas, 2014). Using the climate of the U.S. Great Plains as an analogue to the paleoclimate of the Bahariya channels catchment area (Holbrook and Wanas, 2014) a warm semi-arid climate (BSh) would be the most fitting proxy. Applying the less restrictive average t_{bd} value for the Köppen climate of BSh (0.47 average annual days within 20% of bankfull discharge) estimated sediment discharge of Bahariya rivers are lessened by an order of magnitude with average annual bedload of 3,100 m^3/yr and suspended sediment load of 3,400-32,000 m^3/yr, for a total sediment discharge estimate of 6,500-35,100 m^3/yr. Sediment volumes derived using climate specific t_{bd} do not account for the volume of sediment in the Bahariya channels catchment area sink (i.e. accumulation rate of 72,000-144,000 m^3/yr (Holbrook and Wanas, 2014)), indicating another major stream must be contributing to this sink or that the proportion of sediment transported during bankfull flow is less in hot semi-arid streams.

Using climate specific values for proportion of water discharged during bankfull further improves water discharge estimates (**Table 11**). Prior approaches used velocity and cross-sectional area to calculate bankfull water discharge, then assumed bankfull made up 1%-2% (Meybeck et al., 2003; Kiel, 2015) of the annual flow to develop a scaling relationship accordingly. Now with knowledge of the actual proportion of bankfull water discharge vs the annual flow a modified version of the existing fulcrum approach equation (**Eq.1**) can be used to estimate discharge specific to climate (**Figure 29**) (**Figure 31**).

CHAPTER 6

CONCLUSION

- Between the spatial attributes of bankfull discharge, drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area correlation is weak to moderate in aggregate with improved relationships when adding the parameter of climate.
- Overall the strongest correlation between spatial attributes is between drainage area and bankfull discharge whether binned or unbinned by climate.
- Mean-bankfull channel depth, rather than bankfull-channel cross-sectional area, shows a closer relationship to drainage area only in bins with larger streams indicating this is a result of a scaling relationship.
- Correlation between the temporal attribute of days at bankfull (t_{bd}) and the spatial attributes of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area is not supported in this study. Average annual days at bankfull flow (t_{bd}) is not significantly impacted by any tested spatial characteristic.
- Climate significantly impacts average annual bankfull duration (t_{bd}) of a stream whether binning by major or Köppen climate. Average t_{bd} values between climates significantly vary with outliers within climate bins resulting from additional parameters not accounted for in this study such as physiographic region.
- Whether using major or Köppen climate specific t_{bd} values error in discharge estimates are minimized when applied in the Fulcrum approach.

- Spatial attributes of drainage area, mean bankfull-channel depth or bankfull-channel cross-sectional do not significantly impact proportion of water discharged during bankfull.
- Only when binning by Köppen climate does significant variance in proportion of water discharged during bankfull occur due to streams with highly seasonal rainfall moving a higher percentage of annual water discharge regardless of major climate. Seasonality of precipitation significantly impacts the proportion of water discharge during bankfull flow.
- To estimate the most accurate average proportion of water discharged during bankfull specific Köppen climate for the stream's drainage area is required.

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APPENDIX

APPENDIX I: Data load governance and business rules for all reference tables, primary tables and derived data.

Data Sources Overview

- The BANKFULL_DISCHARGE_LIT table will be populated with raw table Bankfull_Literature_values.
- The REF_LITERATURE_SOURCE table will be populated with raw table Data_Source.
- STREAM_DESC_DATA, STREAM_DISCHARGE_DATA and REF_CLIMATE_LOCATION will be populated by multiple data sources with each raw data source having specific data mapping and business rules to populate the appropriate processed database columns and tables.
- REF_CLIMATE will be populated with raw table Climate Description.
- The REF_COUNTY, REF_STATE and REF_COUNTRY tables will be populated with multiple data sources with each raw data source having specific data mapping and business rules to populate the appropriate processed database columns and tables.

Business Rules

General Business Rules

- For each unique value of BANKFULL_DISCHARGE_LIT. [SITE_ID] an associated record must be populated in STREAM_DESC_DATA and STREAM_DISCHARGE_DATA joining on [SITE_ID].
- For each unique value of BANKFULL_DISCHARGE_LIT. [SITE_ID] an associated record must be populated in REF_LITERATURE_SOURCE joining on [SITE_ID].
- For each value of STREAM_DESC_DATA. [SITE_ID] a REF_CLIMATE_LOCATION record must exist joining on [CLIMATE_ID], [COUNTY_ID], [STATE_ID] and [COUNTRY_ID].

Raw Source Specific Business Rules for Data Load- Reference Tables

Climate by County

- For each unique combination of [FIPS] and [CLS] in raw table Climate by County a record will need to be created in REF_CLIMATE_LOCATION showing the relationship between location and climate.
- For each unique value of [FIPS] a record must be inserted into REF_COUNTY with the [FIPS] value populated in [COUNTY_ID] and the associated [COUNTY] value from raw table Climate by County populated in REF_COUNTY. [COUNTY_NAME].

- If [FIPS] is a four-digit value take left most digit and concatenate with '0'. If [FIPS] is a five-digit value take 2 left most digit value to populate [STATE_ID]. (I.e. if [FIPS]='48325', [STATE_ID] ='48' and [COUNTY_ID] ='48325' or if [FIPS]='1001', [STATE_ID]='01' and [COUNTY_ID]='01001'). For each unique value of [STATE_ID] a record must be inserted into REF_STATE with the parsed [FIPS] value populated in [STATE_ID] and the associated [STATE] value from raw table Climate by County populated in REF_STATE.[STATE_NAME].
- All records populated from raw table Climate by County must be populated with a value of ‘1’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID]=’1’ will be populated with the value ‘United States’ for REF_COUNTRY.[COUNTRY_NAME].
- ADDITIONAL LOGIC: In the event there are multiple streams within a single county that truly have unique values for [CLIMATE_ID], meaning these streams are not within 5 miles of the existing [CLIMATE_ID] values polygon when reviewed on the Koppen Climate World map, a new record will need to be inserted into REF_COUNTY and REF_CLIMATE_LOCATION to account for this additional climate.
    - REF_COUNTY. [COUNTY_ID] and REF_CLIMATE_LOCATION. [COUNTY_ID] of the inserted records will add a ‘1’ to the end of the value of [COUNTY_ID] so that a second [CLIMATE_ID] can be associated to the location. (Ex: If a record already exist for [COUNTY_ID] = ‘08049’ but we need to account for a second climate in this county a new record of [COUNTY_ID] = ‘080491’ will be inserted into REF_COUNTY, and new record in REF_CLIMATE_LOCATION will also be inserted with [COUNTY_ID] = ‘080491’ being tied to the additional [CLIMATE_ID]).
    - In the event a stream needs to be associated with this additional climate the value for STREAM_DESC_DATA.[CLIMATE_ID] will also need to be updated with the concatenated ‘1’ on the end so that it will join to the newly created record in REF_CLIMATE_LOCATION.
        - After quality assurance review of all assigned climates for USGS sites the below records were inserted into but REF_COUNTY and REF_CLIMATE_LOCATION to accommodate for multiple climates in a single county:

EXISTING_COUNTY_ID	STATE_ID	INSERTED_COUNTY_ID	COUNTY_NAME	CLIMATE_ID
08049	8	080491	Grand	30
16015	16	160151	Boise	21
16049	16	160491	Idaho	18
24023	24	240231	Garrett	17
25021	25	250211	Norfolk	18
30061	30	300611	Mineral	22
53047	53	530471	Okanogan	5
53037	53	530371	Kittitas	5

▪ he value for [COUNTY_ID] were updated for the following STREAM_DESC_DATA records so that they may be joined to appropriate climate in REF_CLIMATE_LOCATION.

SITE_ID	EXISTING_COUNTY_ID	UPDATED_COUNTY_ID
09010500	08049	080491
13185000	16015	160151
13200000	16015	160151
13316500	16049	160491
13336500	16049	160491
01596005	24023	240231
03078000	24023	240231
01103500	25021	250211
12353850	30061	300611
12445000	53047	530471
12484500	53037	530371

USGS Sourced: Description Data Records and Scraped Discharge Data Records

- While the majority of records sourced from the USGS will leverage the raw Climate by County table to determine location and climate for each record, records sourced from USGS for Puerto Rico streams must be addressed differently.
- For records populated from raw table Description Data Records_Puerto Rico two records must be inserted into REF_COUNTY with the [FIPS] value populated in [COUNTY_ID] and the associated [COUNTY] value populated in REF_COUNTY. [COUNTY_NAME] as follows:
  - COUNTY_ID = ‘72119’ COUNTY_NAME= ‘Rio Grande’
  - COUNTY_ID = ‘72053’ COUNTY_NAME= ‘Fajardo’
- All records populated from raw table Description Data Records_Puerto Rico must be populated with a value of ‘9999’ for [STATE_ID]. In REF_STATE,

[STATE_ID] =’9999’ will be populated with the value ‘N/A’ for REF_ STATE. [STATE _NAME].

- If the record is populated from raw table Description Data Records_Puerto Rico, general mapping will be the same as any other USGS sourced record but [COUNTRY_ID] must be populated with ‘5’. REF_COUNTRY, [COUNTRY_ID] =’5’ will be populated with the value ‘Puerto Rico’ for REF_COUNTRY. [COUNTRY_NAME].
- Due to all Puerto Rico streams in this study having the same climate (‘Af’) only one distinct record will need to be created in REF_CLIMATE_LOCATION showing the relationship between location and climate for all Puerto Rican streams.

STATIONS

- For each unique combination of [PROV_TERR_STATE_LOC] and [CLIMATE_ID] in raw table STATIONS a record will need to be created in REF_CLIMATE_LOCATION showing the relationship between location and climate.
- All records populated from raw table STATIONS must be populated with a value of ‘9999’ for [COUNTY_ID]. In REF_COUNTY, [COUNTY_ID] =’9999’ will be populated with the value ‘N/A’ for REF_COUNTRY. [COUNTY_NAME].
- For each unique value of [PROV_TERR_STATE_LOC] in raw tables STATIONS a record must be inserted into REF_STATE with the [STATE_ID] being assigned as follows and [STATE_NAME] being populated as follows:

[PROV_TERR_STATE_LOC]	[STATE_NAME]	[STATE_ID]
NB	New Brunswick	57
PE	Prince Edward Island	58
AB	Alberta	59
NT	Northwest Territories	60
BC	British Columbia	61
MI	Michigan	62
ME	Maine	63
AK	Alaska	64
WA	Washington	65
NL	Newfoundland and Labrador	66
NU	Nunavut	67
YT	Yukon	68
MN	Minnesota	69
MT	Montana	70
MB	Manitoba	71
ON	Ontario	72
NS	Nova Scotia	73
ND	North Dakota	74
ID	Idaho	75
SK	Saskatchewan	76
QC	Quebec	77

- All records populated from raw table STATIONS must be populated with a value of ‘2’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID] =’2’ will be populated with the value ‘Canada’ for REF_COUNTRY. [COUNTRY_NAME].

OPW- Ireland sourced data

- Due to Ireland only having one climate for the entire country (‘Cfb’) only one distinct record will need to be created in REF_CLIMATE_LOCATION showing the relationship between location and climate for this data source.
- All records populated from raw table(s) Irish_River_Desc and Irish River Daily Discharge must be populated with a value of ‘9999’ for [COUNTY_ID]. In REF_COUNTY, [COUNTY_ID] =’9999’ will be populated with the value ‘N/A’ for REF_COUNTRY. [COUNTY_NAME].
- All records populated from raw table(s) Irish_River_Desc and Irish River Daily Discharge must be populated with a value of ‘9999’ for [STATE_ID]. In REF_STATE, [STATE_ID] =’9999’ will be populated with the value ‘N/A’ for REF_ STATE. [STATE _NAME].

- All records populated from raw table(s) Irish_River_Desc and Irish River Daily Discharge must be populated with a value of ‘3’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID] =’3’ will be populated with the value ‘Ireland’ for REF_COUNTRY. [COUNTRY_NAME].

Colombia_Desc

- For each unique value of [CLIMATE_ID] in raw table Colombia_Desc a record will need to be created in REF_CLIMATE_LOCATION showing the relationship between location and climate.
- All records populated from raw table Colombia_Desc must be populated with a value of ‘9999’ for [COUNTY_ID]. In REF_COUNTY, [COUNTY_ID] =’9999’ will be populated with the value ‘N/A’ for REF_COUNTRY. [COUNTY_NAME].
- All records populated from raw table Colombia_Desc must be populated with a value of ‘78’ for [STATE_ID]. In REF_STATE, [STATE_ID] =’78’ will be populated with the value ‘Cauca’ for REF_ STATE. [STATE _NAME].
- All records populated from raw table Colombia_Desc must be populated with a value of ‘4’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID] =’4’ will be populated with the value ‘Colombia’ for REF_COUNTRY. [COUNTRY_NAME].

Data_Source

- For each unique value of [SOURCE_ID] in raw table Data_Source a new record must be inserted into REF_LITERATURE_SOURCE with attribute specific mapping and business rules.

Raw Source Specific Business Rules for Data Load – Non-Reference Tables

USGS Sourced: Description Data Records and Scraped Discharge Data Records

- For each unique value of [site_no] in raw table Description Data Records a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules.
- For each unique combination of [site_no] and [datetime] in raw table Scraped Discharge Data Records a new record must be inserted into STREAM_DISCHARGE_DATA with attribute specific mapping and business rules.
- STREAM_DESC_DATA.[CLIMATE_ID] will need to be populated for all records populated from Description Data Records (excluding Puerto Rico streams) by joining to the REF_CLIMATE_LOCATION table on STREAM_DESC_DATA.[STATE_ID]=

REF_CLIMATE_LOCATION.[STATE_ID] and STREAM_DESC_DATA.[COUNTY_ID]= REF_CLIMATE_LOCATION.[COUNTY_ID] ad STREAM_DESC_DATA.[COUTNRY_ID]= REF_CLIMATE_LOCATION.[COUNTRY_ID], populating the appropriate REFL_CLIMATE_LOCATION.[CLIMATE_ID] in STREAM_DESC_DATA. [CLIMATE_ID].

HYDAT Canada Sourced: STATIONS, DLY_FLOWS & SED_DLY_SUSCON

- For each unique value of [STATION_NUMBER] in raw table STATIONS a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules.
- For each unique combination of [STATION_NUMBER] and [FLOW#] in raw table DLY_FLOWS where [FLOW#] is not NULL and [FLOW_SYMBOL#] <>'E' a new record must be inserted into STREAM_DISCHARGE_DATA with attribute specific mapping and business rules. This daily value must be populated with the correct date value in STREAM_DISCHARGE_DATA. [DATE] based on the values of [YEAR], [MONTH] and the numeric value within [FLOW#] of the record in raw table DLY_FLOWS. (I.e. if [FLOW#] = [FLOW1] this is the daily discharge data for the first day of the month. If the value for [YEAR] in the same raw record =’1986’ and the value for [MONTH] =’9’, STREAM_DISCHARGE_DATA. [DATE]=’09/01/1986’)
- For each unique combination of [STATION_NUMBER] and [SUSCON#] in raw table SED_DLY_SUSCON where [SUSCON#] is not NULL and [SUSCON_SYMBOL#] <>'E' a new value must be inserted into STREAM_DISCHARGE_DATA. [SUSPENDED_SED_DISCHARGE]. [SUSPENDED_SED_DISCHARGE] will need to be populated with the appropriate value for each day for the specific site by joining on SED_DLY_SUSCON. [STATION_NUMBER] = STREAM_DISCHARGE_DATA= [SITE_ID] and joining on the concatenated value of SED_DLY_SUSCON. [MONTH]+ Numeric value within SED_DLY_SUSCON. [SUSCON#] + SED_DLY_SUSCON. [YEAR] = STREAM_DISCHARGE_DATA. [DATE].

OPW- Ireland sourced data

- For each unique value of [Site ID] in raw table Irish_River_Desc a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules.
- For each unique combination of [Station_number] and [Date] in raw table Irish River Daily Discharge a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules.

IDEAM- Colombia source data

- For each unique value of [SITE_ID] in raw table Colombia_Desc a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules.
- For each unique combination of [station_id], [year], [day] and [month] where [value] is not NULL in raw table Colombia_Discharge a new record must be inserted into STREAM_DESC_DATA with attribute specific mapping and business rules. In the event there are duplicate records take the record where the source is ‘IDEAM’ as first priority in order to ensure the most accurate data is being used to populate the database.

Bankfull Literature Values

- For each unique value of [SITE_ID] in raw table Bankfull Literature Values a new record must be inserted into BANKFULL_DISCHARGE_LIT with attribute specific mapping and business rules.

Derived Results Data

- To leverage the acquired data in the processed database, comparison needs to be made between the daily discharge volumes and the bankfull volume of each stream. The average days in a year that the stream runs within 10% and 20% of bankfull flow, respectively, must be derived. Streams can then be binned based on parameters such as climate, drainage area and channel size to calculate the most accurate tbd value (average days at bankfull flow) to be leveraged in the fulcrum approach.
- In order for a stream to be included in the derived results set the stream must have at least 5 complete years of daily discharge data, these years do not need to be consecutive.
- In order for a year to be included into the average for a specific stream a non-NULL daily discharge value must be populated for each day of that year (keeping in mind special scenarios such as leap year and records with ‘-1’ discharge values indicating ICE conditions).
- Join BANKFULL_DISCHARGE_LIT to STREAM_DESC_DATA and STREAM_DISCHARGE_DATA on [SITE_ID]. Grouping by [SITE_ID] and YEAR of STREAM_DISCHARGE_DATA.[DATE] compute how many days within each year each stream runs within 10% and separately within 20% of bankfull flow (i.e. BANKFULL_DISCHARGE_LIT.[BK_DISCHARGE_CUBIC_M_PER_SEC]) then take the total average days within bankfull flow for each stream.
- For each stream that meets the criteria, the calculated values for days on average each stream runs within 10% and 20% of bankfull will need to be populated in STREAM_DESC_DATA. [AVG_WITHIN_10] and STREAM_DESC_DATA. [AVG_WITHIN_20] respectively.

- EX: The bankfull discharge of a stream ‘ABC123’ is 100 cubic meters per sec. For the stream to be within 10% of this bankfull flow the daily discharge value would need to fall in the range of 90-110 cubic meters per sec and to be within 20% of bankfull flow the daily discharge value would need to be within the range of 80-120 cubic meters per sec. The following data was derived in the processed database to determine how many days stream ‘ABC123’ is within 10% and 20% of bankfull flow:

Year	**Days Within10% BK Annually**	**Days Within 20% BK Annually**
1973	2	3
1974	2	4
1975	0	1
1980	3	3
1981	3	3
1982	1	2
1983	1	2
1984	4	5
1985	3	4
[AVG_WITHIN_##%]	**2.11**	**3**

Now that Tbd has been determined for this stream, other streams with similar attributes (within the same climate, similar in channel size etc.) can be grouped together to take an overall average based on specified parameters to be used for Tbd).

APPENDIX II: All data mapping from each raw data source into the defined database structure, including all attribute specific business rules. Raw Source of 'NOW' indicates this was a manually created table, as these are my initials.

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
USGS	Description Data Records	agency_cd	STREAM_DESC_DATA	DESC_SOURCE	
USGS	Description Data Records	site_no	STREAM_DESC_DATA	SITE_ID	
USGS	Description Data Records	station_nm	STREAM_DESC_DATA	SITE_NAME	
USGS	Description Data Records	dec_lat_va	STREAM_DESC_DATA	LATITUDE	
USGS	Description Data Records	dec_long_va	STREAM_DESC_DATA	LONGITUDE	
USGS	Description Data Records	dec_coord_datum_cd	STREAM_DESC_DATA	LAT_LONG_DATUM	
USGS	Description Data Records	state_cd	STREAM_DESC_DATA	STATE_ID	
USGS	Description Data Records	county_cd	STREAM_DESC_DATA	COUNTY_ID	Concatenate the values of [state_cd]+ [county_cd] to populate [COUNTY_ID], adding leading zeroes as necessary to ensure a 5 digit value in [COUNTY_ID] when populated from this data source.
USGS	Description Data Records	country_cd	STREAM_DESC_DATA	COUNTRY_ID	
USGS	Description Data Records	alt_va	STREAM_DESC_DATA	ALTITUDE	
USGS	Description Data Records	drain_area_va	STREAM_DESC_DATA	DRAINAGE_AREA_MI	2nd priority mapping, only populated with [drain_area_va] if [contrib_drain_area_va] is NULL
USGS	Description Data Records		STREAM_DESC_DATA	DRAINAGE_AREA_KM	If drainage area is populated from this source drainage area must also be populated in square kilometers by multiplying the value of [DRAINAGE_AREA_MI] * '2.58999' to populated the value for [DRAINAGE_AREA_KM).

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
USGS	Description Data Records	contrib_drain_area_va	STREAM_DESC_DATA	DRAINAGE_AREA_MI	1st priority mapping
USGS	Description Data Records		STREAM_DESC_DATA	DRAINAGE_AREA_KM	If drainage area is populated from this source drainage area must also be populated in square kilometers by multiplying the value of [DRAINAGE_AREA_MI] * '2.58999' to populated the value for [DRAINAGE_AREA_KM).
NOW	Climate by County	STATE	REF_STATE	STATE_NAME	State name must be associated to the appropriate [STATE_ID] based on the value of the [FIPS] code.
NOW	Climate by County	COUNTY	REF_COUNTY	COUNTY_NAME	County name must be associated to the appropriate [COUNTY_ID] based on the value of the [FIPS] code.
NOW	Climate by County	FIPS	REF_STATE	STATE_ID	If [FIPS] is a four digit value take left most digit and concatanate with '0'. If [FIPS] is a five digit value take 2 left most digit value to populate [STATE_ID]. (I.e. if [FIPS]='48325', [STATE_ID]='48' and [COUNTY_ID]='48325' or if [FIPS]='1001', [STATE_ID]='01' and [COUNTY_ID]='01001'
NOW	Climate by County		REF_COUNTY	COUNTY_ID	Pad the value with leading zeroes to ensure a 5 digit value is populated into [COUNTY_ID] if necessary, when populating from Climate by County

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
NOW	Climate by County		REF_COUNTRY	COUNTRY_ID	If record populated from Climate by County [COUNTRY_ID]='1'
NOW	Climate by County		REF_COUNTRY	COUNTRY_NAME	If record populated from Climate by County [COUNTRY_NAME] =' United States'
NOW	Climate by County		REF_CLIMATE_LOCATION	STATE_ID	
NOW	Climate by County		REF_CLIMATE_LOCATION	COUNTY_ID	
NOW	Climate by County		REF_CLIMATE_LOCATION	COUNTRY_ID	
NOW	Climate by County	CLS	REF_CLIMATE_LOCATION	CLIMATE_ID	The value for [CLIMATE_ID] will be determined based on joining Climate by County. [CLS]=REF_CLIMATE. [SYMBOL] and populating REF_CLIMATE_LOCATION. [CLIMATE_ID] with the correct value. REF_CLIMATE_LOCATION. [CLIMATE_ID] must be populated in the appropriate record in REF_CLIMATE_LOCATION dependent on the values of [COUNTY_ID], [STATE_ID] and [COUNTRY_ID].
NOW	Data_Source	Source_ID	REF_LITERATURE_SOURCE	REF_SOURCE_ID	
NOW	Data_Source	Source_Name	REF_LITERATURE_SOURCE	REF_SOURCE	
NOW	Bankfull_Literature_values	Site_ID	BANKFULL_DISCHARGE_LIT	SITE_ID	
NOW	Bankfull_Literature_values	Site_Name	BANKFULL_DISCHARGE_LIT	SITE_NAME	
NOW	Bankfull_Literature_values	Bankfull_estimate m^3/sec	BANKFULL_DISCHARGE_LIT	BK_DISCHARGE_CUBIC_M_PER_SEC	
NOW	Bankfull_Literature_values	Bankfull_estimate f^3/sec	BANKFULL_DISCHARGE_LIT	BK_DISCHARGE_CUBIC_FT_PER_SEC	
NOW	Bankfull_Literature_values	Bankfull_Est_Type	BANKFULL_DISCHARGE_LIT	BANKFULL_TYPE	
NOW	Bankfull_Literature_values	Estimate_Confidence	BANKFULL_DISCHARGE_LIT	SOURCE_CONFIDENCE	

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
NOW	Bankfull_Literature_values	CHANNEL_DEPTH_Ft	BANKFULL_DISCHARGE_LIT	CHANNEL_DEPTH_FT	
NOW	Bankfull_Literature_values	Channel_Width_Ft	BANKFULL_DISCHARGE_LIT	CHANNEL_WIDTH_FT	
NOW	Bankfull_Literature_values	CHANNEL_DEPTH_m	BANKFULL_DISCHARGE_LIT	CHANNEL_DEPTH_M	
NOW	Bankfull_Literature_values	Channel_Width_m	BANKFULL_DISCHARGE_LIT	CHANNEL_WIDTH_M	
NOW	Bankfull_Literature_values	Channel_H_Ref	BANKFULL_DISCHARGE_LIT	CHANNEL_H_REF	
NOW	Bankfull_Literature_values	Channel_W_Ref	BANKFULL_DISCHARGE_LIT	CHANNEL_W_REF	
NOW	Bankfull_Literature_values	Source_ID	BANKFULL_DISCHARGE_LIT	REF_SOURCE_ID	
NOW	Climate Description	SYMBOL	REF_CLIMATE	SYMBOL	
NOW	Climate Description		REF_CLIMATE	CLIMATE_ID	Auto generated key for each distinct value of [SYMBOL].
NOW	Climate Description	MAIN_CLIMATE	REF_CLIMATE	1ST_ORDER	
NOW	Climate Description	PRECIPITATION	REF_CLIMATE	2ND_ORDER	
NOW	Climate Description	TEMPERATURE	REF_CLIMATE	3RD_ORDER	
USGS	Scraped Discharge Data Records	agency_cd	STREAM_DISCHARGE_DATA	DIS_SOURCE	
USGS	Scraped Discharge Data Records	site_no	STREAM_DISCHARGE_DATA	SITE_ID	
USGS	Scraped Discharge Data Records	datetime	STREAM_DISCHARGE_DATA	DATE	
USGS	Scraped Discharge Data Records		STREAM_DESC_DATA	DATA_BEGIN_DATE	Populated for each unique record as determined by unique value of Scraped Discharge Data Records [site_no]. Populated with the minimum value for scraped discharge data record [datetime] where [Discharge cubic feet per second] is not NULL.
USGS	Scraped Discharge Data Records		STREAM_DESC_DATA	DATA_END_DATE	Populated for each unique record as determined by unique value of Scraped Discharge Data Records [site_no]. Populated with the maximum value for scraped discharge data record [datetime]

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
					where [Discharge cubic feet per second] is not NULL.
USGS	Scraped Discharge Data Records	Discharge cubic feet per second	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_FT_PER_SEC	If value populated with 'ICE' or 'Bkw' flag record with a value of '-1', if value of any other VARCHAR value NULL out.
USGS	Scraped Discharge Data Records		STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	If STREAM_DISCHARGE_DATA record populated by raw table Scraped Discharge Data Records, STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_M_PER_SEC] will have to be populated by taking the value of STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_FT_PER_SEC] and multiplying that value by '0.0283168466' to convert to meters per second and populate[DISCHARGE_CUBIC_M_PER_SEC].
USGS	Scraped Discharge Data Records	Suspended sediment concentration milligrams per liter	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	STATIONS	STATION_NUMBER	STREAM_DESC_DATA	SITE_ID	
HYDAT	STATIONS	STATION_NAME	STREAM_DESC_DATA	SITE_NAME	
HYDAT	STATIONS	PROV_TERR_STATE_LOC	STREAM_DESC_DATA	STATE_ID	State ID as provided in business rules document
HYDAT	STATIONS		REF_STATE	STATE_ID	State ID populated as provided in business rules document
HYDAT	STATIONS		REF_STATE	STATE_NAME	State name as provided in business rules

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
					document
HYDAT	STATIONS	CLIMATE_ID	STREAM_DESC_DATA	CLIMATE_ID	Column added by NOW to provide site specific climate values for Canadian streams.
HYDAT	STATIONS		STREAM_DESC_DATA	STATE_ID	State ID as provided in business rules document
HYDAT	STATIONS		STREAM_DESC_DATA	COUNTRY_ID	If the STREAM_DESC_DATA record is populated from the raw source table STATIONS populate COUNTRY_ID= '2'
HYDAT	STATIONS		STREAM_DESC_DATA	COUNTY_ID	If the STREAM_DESC_DATA record is populated from the raw source table STATIONS populate COUNTY_ID= '9999' (The COUNTY_ID ='9999' is a default value for [COUNTY_NAME] ='N/A'
HYDAT	STATIONS	LATITUDE	STREAM_DESC_DATA	LATITUDE	
HYDAT	STATIONS	LONGITUDE	STREAM_DESC_DATA	LONGITUDE	
HYDAT	STATIONS		STREAM_DESC_DATA	LAT_LONG_DATUM	Populate for 'NAD 83' for all records populated from STATIONS.
HYDAT	STATIONS	DRAINAGE_AREA_GROSS	STREAM_DESC_DATA	DRAINAGE_AREA_KM	2nd priority mapping, only populated with [DRAINAGE_AREA_GROSS] if [DRAINAGE_AREA_EFFECT] is NULL
HYDAT	STATIONS		STREAM_DESC_DATA	DRAINAGE_AREA_MI	If drainage area is populated from this source drainage area must also be populated in square miles by multiplying the value of [DRAINAGE_AREA_

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
					KM] * '0.386102' to populated the value for [DRAINAGE_AREA_MI).
HYDAT	STATIONS	DRAINAGE_AREA_EFFECT	STREAM_DESC_DATA	DRAINAGE_AREA_KM	1st priority mapping
HYDAT	STATIONS		STREAM_DESC_DATA	DRAINAGE_AREA_MI	If drainage area is populated from this source drainage area must also be populated in square miles by multiplying the value of [DRAINAGE_AREA_KM] * '0.386102' to populated the value for [DRAINAGE_AREA_MI).
HYDAT	STATIONS		STREAM_DESC_DATA	DESC_SOURCE	When STREAM_DESC_DATA record is populated from raw table STATIONS populate STREAM_DESC_DATA.[SOURCE]= 'HYDAT'
HYDAT	STATIONS		STREAM_DESC_DATA	DATA_BEGIN_DATE	Populate for each unique record populated from raw table STATIONS (as determined by unique STREAM_DESC_DATA. [SITE_ID]). Populate with the minimum value for STREAM_DISCHARGE_DATA. [DATE] joining on [SITE_ID].
HYDAT	STATIONS		STREAM_DESC_DATA	DATA_END_DATE	Populate for each unique record populated from raw table STATIONS (as determined by unique STREAM_DESC_DATA. [SITE_ID]). Populate with the maximum value for

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
					STREAM_DISCHARGE_DATA.[DATE] joining on [SITE_ID].
HYDAT	DLY_FLOWS	STATION_NUMBER	STREAM_DISCHARGE_DATA	SITE_ID	
HYDAT	DLY_FLOWS	YEAR	STREAM_DISCHARGE_DATA	DATE	Where [FLOW#] is not NULL, Concatenate [YEAR]+[MONTH] and the numeric value within [FLOW#] to populate STREAM_DISCHARGE_DATA.[DATE] (i.e. if [YEAR]='1914', [MONTH]='9' and [FLOW1] is not NULL, STREAM_DISCHARGE_DATA.[DATE]='09-01-1914'
HYDAT	DLY_FLOWS	MONTH	STREAM_DISCHARGE_DATA	DATE	Where [FLOW#] is not NULL, Concatenate [YEAR]+[MONTH] and the numeric value within [FLOW#] to populate STREAM_DISCHARGE_DATA.[DATE] (i.e. if [YEAR]='1914', [MONTH]='9' and [FLOW1] is not NULL, STREAM_DISCHARGE_DATA.[DATE]='09-01-1914'
HYDAT	DLY_FLOWS		STREAM_DISCHARGE_DATA	DIS_SOURCE	When STREAM_DISCHARGE_DATA record is populated from raw table DLY_FLOWS populate STREAM_DISCHARGE_DATA.[SOURCE]= 'HYDAT'

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
HYDAT	DLY_FLOWS	FLOW1	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	For each record where [FLOW#] is not NULL and [FLOW_SYMBOL#] <>'E' populate STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_M_PER_SEC] with the value for [FLOW#] . This daily value must be populated for the correct date based on the values of [YEAR], [MONTH] and the numeric value within [FLOW#] of the record. (I.e. if [FLOW#] = [FLOW1] this is the daily discharge data for the first day of the month.
HYDAT	DLY_FLOWS		STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_FT_PER_SEC	If STREAM_DISCHARGE_DATA record populated by raw table DLY_FLOWS, STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_FT_PER_SEC] will have to be populated by taking the value of STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_M_PER_SEC] and multiplying that value by '35.3147' to convert to feet per second and populate[DISCHARGE_CUBIC_FT_PER_SEC]. For each unique record populated from DLY_FLOWS into STREAM_DISCHARGE_DATA (Unique defined as a unique

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
					combination of [SITE_ID] + [DATE]) a value for STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_FT_PER_SEC] will need to be derived from STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_M_PER_SEC].
HYDAT	DLY_FLOWS	FLOW2	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW3	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW4	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW5	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW6	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW7	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW8	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW9	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW10	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW11	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW12	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW13	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW14	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW15	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW16	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW17	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW18	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW19	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW20	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW21	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW22	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW23	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW24	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
HYDAT	DLY_FLOWS	FLOW25	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW26	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW27	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW28	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW29	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW30	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	DLY_FLOWS	FLOW31	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	
HYDAT	SED_DLY_SUSCON	SUSCON1	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	Where [SUSCON#] is not NULL and [SUSCON_SYMBOL#]<>'E' Join on SED_DLY_SUSCON.[STATION_NUMBER] = STREAM_DISCHARGE_DATA=[SITE_ID] and join on the Concatenated value of SED_DLY_SUSCON.[YEAR]+SED_DLY_SUSCON.[MONTH] + the numeric value within SED_DLY_SUSCON.[SUSCON#] = STREAM_DISCHARGE_DATA.[DATE] to populate STREAM_DISCHARGE_DATA.[SUSPENDED_SED_DISCHARGE] with the appropriate value for each day for the specific site.
HYDAT	SED_DLY_SUSCON	SUSCON2	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON3	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON4	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON5	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON6	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON7	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON8	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
HYDAT	SED_DLY_SUSCON	SUSCON9	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON10	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON11	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON12	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON13	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON14	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON15	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON16	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON17	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON18	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON19	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON20	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON21	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON22	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON23	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON24	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON25	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON26	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON27	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON28	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON29	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON30	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
HYDAT	SED_DLY_SUSCON	SUSCON31	STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	
OPW	Irish River Daily Discharge	Station_number	STREAM_DISCHARGE_DATA	SITE_ID	
OPW	Irish River Daily Discharge	Date	STREAM_DISCHARGE_DATA	DATE	
OPW	Irish River Daily Discharge	Discharge_Daily_Mean_ cubic_meter_per_second	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
OPW	Irish River Daily Discharge		STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_FT_PER_SEC	If STREAM_DISCHARGE_DATA record populated by raw table Irish River Daily Discharge Data, STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_FT_PER_SEC] will have to be populated by taking the value of STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_M_PER_SEC] and multiplying that value by '35.3147' to convert to feet per second and populate[DISCHARGE_CUBIC_FT_PER_SEC]. For each unique record populated from Irish River Daily Discharge Data into STREAM_DISCHARGE_DATA (Unique defined as a unique combination of [SITE_ID] + [DATE]) a value for STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_FT_PER_SEC] will need to be derived from STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_M_PER_SEC].
OPW	Irish River Daily Discharge		STREAM_DISCHARGE_DATA	DIS_SOURCE	When STREAM_DISCHARGE_DATA record is populated from raw table Irish River Daily Discharge populate STREAM_DISCHAR

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
					GE_DATA.[DIS_SOURCE]= 'OPW'
OPW	Irish_River_Desc	Site Name	STREAM_DESC_DATA	SITE_NAME	
OPW	Irish_River_Desc	Latitude	STREAM_DESC_DATA	LATITUDE	
OPW	Irish_River_Desc	Longitude	STREAM_DESC_DATA	LONGITUDE	
OPW	Irish_River_Desc		STREAM_DESC_DATA	LAT_LONG_DATUM	When populating a STREAM_DESC_DATA record from Irish_River_Desc [LAT_LONG_DATUM] must be populated with 'WGS 84' as this is the datum of the data per the data source.
OPW	Irish_River_Desc	Catchment Size (km^2)	STREAM_DESC_DATA	DRAINAGE_AREA_KM	
OPW	Irish_River_Desc		STREAM_DESC_DATA	DRAINAGE_AREA_MI	If drainage area is populated from this source drainage area must also be populated in square miles by multiplying the value of [DRAINAGE_AREA_KM] * '0.386102' to populate the value for [DRAINAGE_AREA_MI).
OPW	Irish_River_Desc	Site ID	STREAM_DESC_DATA	SITE_ID	
OPW	Irish_River_Desc		REF_COUNTRY	COUNTRY_NAME	Where STREAM_DESC_DATA record populated from Irish_River_Desc populate STREAM_DESC_DATA.[COUNTRY_NAME] with 'Ireland'.
OPW	Irish_River_Desc		REF_COUNTRY	COUNTRY_ID	When STREAM_DESC_DATA record populated from raw table Irish_River_Desc [COUNTRY_ID]='3'

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
OPW	Irish_River_Desc		STREAM_DESC_DATA	COUNTRY_ID	When STREAM_DESC_DATA record populated from raw table Irish_River_Desc [COUNTRY_ID]='3'
OPW	Irish_River_Desc		STREAM_DESC_DATA	SOURCE	When STREAM_DESC_DATA record is populated from raw table Irish_River_Desc populate STREAM_DESC_DATA.[SOURCE]= 'OPW'
OPW	Irish_River_Desc		STREAM_DESC_DATA	DATA_BEGIN_DATE	Populate for each unique record populated from raw table Irish_River_Desc (as determined by unique STREAM_DESC_DATA. [SITE_ID]). Populate with the minimum value for STREAM_DISCHARGE_DATA. [DATE] joining on [SITE_ID].
OPW	Irish_River_Desc		STREAM_DESC_DATA	DATA_END_DATE	Populate for each unique record populated from raw table Irish_River_Desc (as determined by unique STREAM_DESC_DATA. [SITE_ID]). Populate with the maximum value for STREAM_DISCHARGE_DATA. [DATE] joining on [SITE_ID].
OPW	Irish_River_Desc		STREAM_DESC_DATA	DESC_SOURCE	When STREAM_DESC_DATA record is populated from raw table Irish_River_Desc populate STREAM_DESC_DA

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
					TA.[DESC_SOURCE] = 'OPW'
IDEAM	Colombia_Desc	SITE_ID	STREAM_DESC_DATA	SITE_ID	
IDEAM	Colombia_Desc	SITE_NAME	STREAM_DESC_DATA	SITE_NAME	
IDEAM	Colombia_Desc	LATITUDE	STREAM_DESC_DATA	LATITUDE	
IDEAM	Colombia_Desc	LONGITUDE	STREAM_DESC_DATA	LONGITUDE	
IDEAM	Colombia_Desc		STREAM_DESC_DATA	LAT_LONG_DATUM	Always populated with 'NAD 83' for this data source
IDEAM	Colombia_Desc	ALTITUDE	STREAM_DESC_DATA	ALTITUDE	
IDEAM	Colombia_Desc	STATE	REF_STATE	STATE_NAME	When STREAM_DESC_DATA record populated from raw table Colombia_Desc must be populated with a value of ‘78’ for [STATE_ID]. In REF_STATE, [STATE_ID] =’78’ will be populated with the value ‘Cauca’ for REF_ STATE. [STATE _NAME].
IDEAM	Colombia_Desc		STREAM_DESC_DATA	STATE_ID	When STREAM_DESC_DATA record populated from raw table Colombia_Desc must be populated with a value of ‘78’ for [STATE_ID]. In REF_STATE, [STATE_ID] =’78’ will be populated with the value ‘Cauca’ for REF_ STATE. [STATE _NAME].
IDEAM	Colombia_Desc	COUNTRY	REF_COUNTRY	COUNTRY_NAME	When STREAM_DESC_DATA record populated from raw table Colombia_Desc must be populated with a

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
					value of ‘4’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID] =’4’ will be populated with the value ‘Colombia’ for REF_COUNTRY. [COUNTRY_NAME]
IDEAM	Colombia_Desc		STREAM_DESC_DATA	COUNTRY_ID	When STREAM_DESC_DATA record populated from raw table Colombia_Desc must be populated with a value of ‘4’ for [COUNTRY_ID]. In REF_COUNTRY, [COUNTRY_ID] =’4’ will be populated with the value ‘Colombia’ for REF_COUNTRY. [COUNTRY_NAME]
IDEAM	Colombia_Desc		STREAM_DESC_DATA	COUNTY_ID	When STREAM_DESC_DATA record populated from raw table Colombia_Desc must be populated with a value of ‘9999’ for [COUNTY_ID]. In REF_COUNTY, [COUNTY_ID] =’9999’ will be populated with the value ‘N/A’ for REF_COUNTRY. [COUNTY_NAME].
IDEAM	Colombia_Desc	CLIMATE_ID	STREAM_DESC_DATA	CLIMATE_ID	
IDEAM	Colombia Discharge	station_id	STREAM_DISCHARGE_DATA	SITE_ID	Populating with only the numeric portion of [station_id] (i.e. if [station_id]='26027200 PTE CARRETERA' parse out the numeric portion of the attribute and populate [SITE_ID]='26027200'

Raw Source	**Raw Table**	**Raw Column**	**Processed Table**	**Processed Column**	**Attribute Specific Business Rule**
IDEAM	Colombia Discharge	year	STREAM_DISCHARGE_DATA	DATE	Where [value] is not NULL, Concatenate [Month] + [day] + [year] to populate STREAM_DISCHARGE_DATA.[DATE] (i.e. if [YEAR]='1970', [day]='01' and [month]= '4', STREAM_DISCHARGE_DATA.[DATE]='04/01/1970'
IDEAM	Colombia Discharge	day	STREAM_DISCHARGE_DATA	DATE	Where [value] is not NULL, Concatenate [Month] + [day] + [year] to populate STREAM_DISCHARGE_DATA.[DATE] (i.e. if [YEAR]='1970', [day]='01' and [month]= '4', STREAM_DISCHARGE_DATA.[DATE]='04/01/1970'
IDEAM	Colombia Discharge		STREAM_DISCHARGE_DATA	DIS_SOURCE	When STREAM_DISCHARGE_DATA record is populated from raw table Colombia Discharge populate STREAM_DISCHARGE_DATA.[SOURCE]= 'IDEAM'
IDEAM	Colombia Discharge	value	STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	This daily value must be populated for the correct date based on the values of [year], [day] and [month] for the record.

Raw Source	Raw Table	Raw Column	Processed Table	Processed Column	Attribute Specific Business Rule
IDEAM	Colombia Discharge		STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_FT_PER_SEC	If STREAM_DISCHARGE_DATA record populated by raw table Colombia Discharge, [DISCHARGE_CUBIC_FT_PER_SEC] will have to be populated by taking the value of STREAM_DISCHARGE_DATA.[DISCHARGE_CUBIC_M_PER_SEC] and multiplying that value by '35.3147' to convert to feet per second and populate[DISCHARGE_CUBIC_FT_PER_SEC]. For each unique record populated from Colombia Discharge into STREAM_DISCHARGE_DATA (Unique defined as a unique combination of [SITE_ID] + [DATE]) a value for STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_FT_PER_SEC] will need to be derived from STREAM_DISCHARGE_DATA. [DISCHARGE_CUBIC_M_PER_SEC].

APPENDIX III: User stories and user interface screen mock-up documentation provided to developers to define functional requirements and conceptual first pass for the user interface.

User Interface User Stories: High Level

- As a user, I want to input data so that sediment volume discharges, slope, mean flow velocity, bankfull discharge, bedload discharge and bedload sediment volume discharge can be calculated using a variety to equations.

- As a user, I want to determine year averaged bankfull flow duration (tbd) binned on a combination of attributes including climate, river size and drainage basin to get a more accurate value for days at bankfull flow based on my specific river's attributes.

- As a user, I want the option to determine year averaged bankfull flow duration (tbd) based on a very specific climate or a more general climate by being able to select 1st, 2nd and 3rd order Köppen classifications.

- As a user, I want to determine year averaged bankfull flow duration (tbd) binned on a combination of attributes including climate, river size and drainage basin and use this specified variable with data I input to calculate sediment volume discharge using the Fulcrum Approach to calculate a more accurate sediment discharge estimate.

- As a user, I want to see what specific streams' data contributed to the value of tbd so that I can feel confident in the calculation and look for a specific analogue stream.
- As a user, I want to be able to search for analogue rivers based on a combination of attributes including climate, river size and drainage basin.

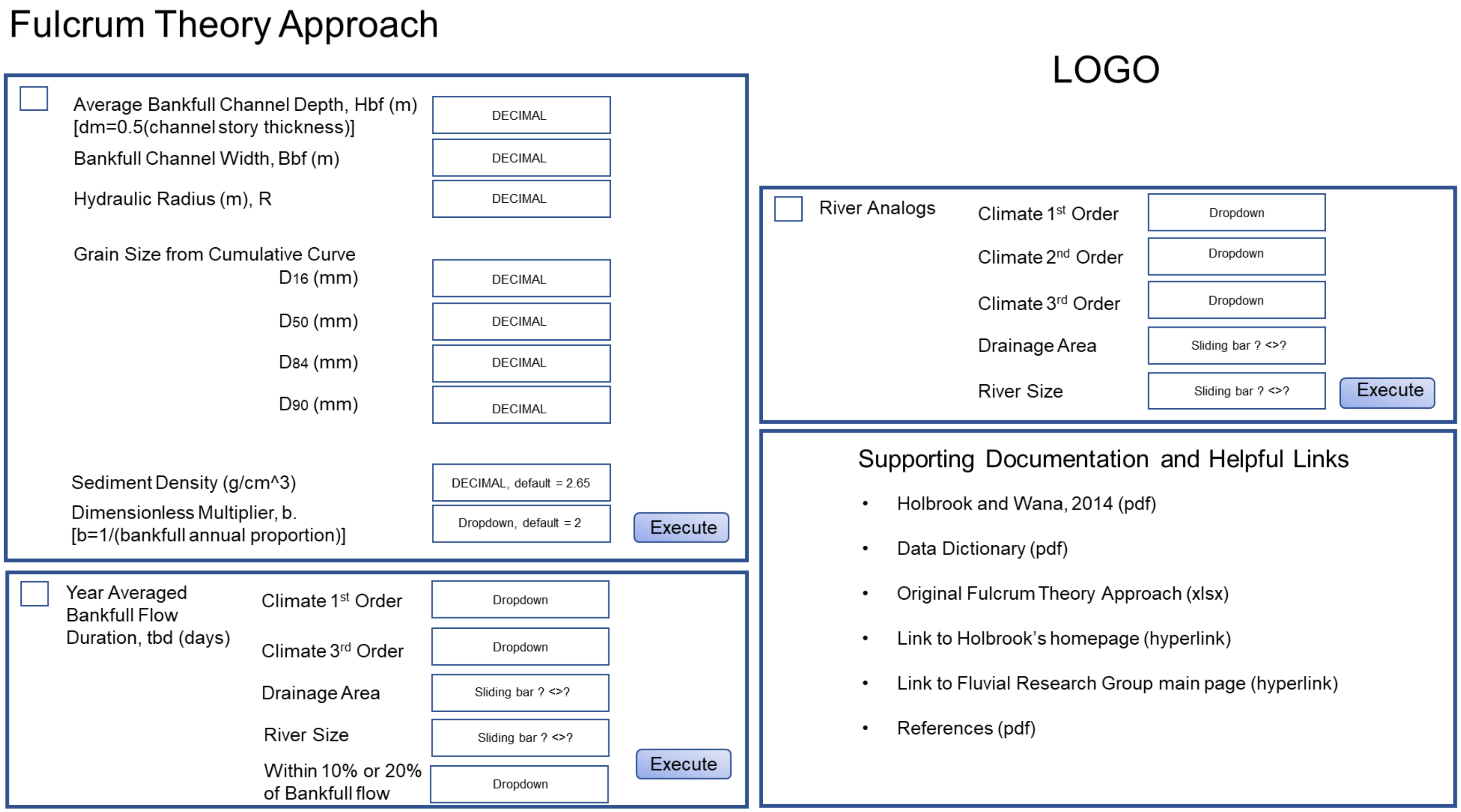
- As a user, I want to be able to look at stream specific data and an aerial map of that stream so that I can see what type of river this is (i.e. braided, meandering etc.) and further confirm it as a possible analogue.

- As a user, I want to know the reference source of the estimated bankfull discharge volume for each specific stream so that I can look at the original data source if desired.

- As a user, I want access to supporting documentation regarding the Fulcrum Approach for a more detailed understanding of the methodology.

- As a user, I want to be able to choose my level of precision by being able to select whether tbd is calculated based on being within 10% or 20% of the literature bankfull discharge value.

- As a user, I want to be able to access all daily discharge volumes for each stream.



Fulcrum Theory Approach

LOGO

☐ Average Bankfull Channel Depth, Hbf (m) [dm=0.5(channel story thickness)]	DECIMAL
Bankfull Channel Width, Bbf (m)	DECIMAL
Hydraulic Radius (m), R	DECIMAL
Grain Size from Cumulative Curve D16 (mm)	DECIMAL
D50 (mm)	DECIMAL
D84 (mm)	DECIMAL
D90 (mm)	DECIMAL
Sediment Density (g/cm^3)	DECIMAL, default = 2.65
Dimensionless Multiplier, b. [b=1/(bankfull annual proportion)]	Dropdown, default = 2

Execute

☐ Year Averaged Bankfull Flow Duration, tbd (days)	Climate 1st Order	Dropdown
	Climate 3rd Order	Dropdown
	Drainage Area	Sliding bar ? <>?
	River Size	Sliding bar ? <>?
	Within 10% or 20% of Bankfull flow	Dropdown

Execute

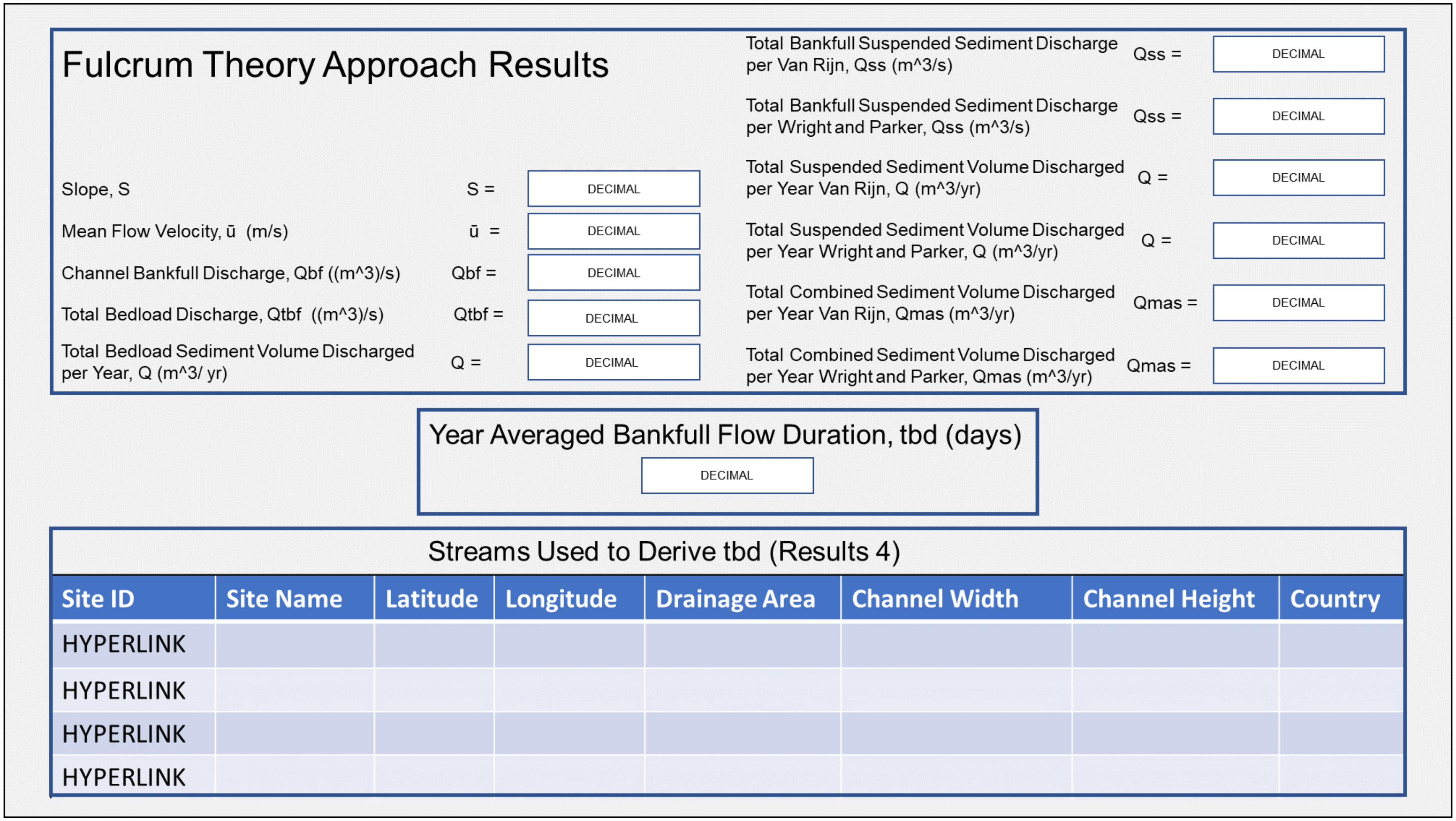
☐ River Analogs	Climate 1st Order	Dropdown
	Climate 2nd Order	Dropdown
	Climate 3rd Order	Dropdown
	Drainage Area	Sliding bar ? <>?
	River Size	Sliding bar ? <>?

Execute

Supporting Documentation and Helpful Links

- Holbrook and Wana, 2014 (pdf)
- Data Dictionary (pdf)
- Original Fulcrum Theory Approach (xlsx)
- Link to Holbrook's homepage (hyperlink)
- Link to Fluvial Research Group main page (hyperlink)
- References (pdf)

Screen Mockup 1: Illustrating conceptually the multiple modules user will need to be able to run within UI.



Fulcrum Theory Approach Results

Slope, S S = DECIMAL

Mean Flow Velocity, ū (m/s) ū = DECIMAL

Channel Bankfull Discharge, Qbf ((m^3)/s) Qbf = DECIMAL

Total Bedload Discharge, Qtbf ((m^3)/s) Qtbf = DECIMAL

Total Bedload Sediment Volume Discharged per Year, Q (m^3/ yr) Q = DECIMAL

Total Bankfull Suspended Sediment Discharge per Van Rijn, Qss (m^3/s) Qss = DECIMAL

Total Bankfull Suspended Sediment Discharge per Wright and Parker, Qss (m^3/s) Qss = DECIMAL

Total Suspended Sediment Volume Discharged per Year Van Rijn, Q (m^3/yr) Q = DECIMAL

Total Suspended Sediment Volume Discharged per Year Wright and Parker, Q (m^3/yr) Q = DECIMAL

Total Combined Sediment Volume Discharged per Year Van Rijn, Qmas (m^3/yr) Qmas = DECIMAL

Total Combined Sediment Volume Discharged per Year Wright and Parker, Qmas (m^3/yr) Qmas = DECIMAL

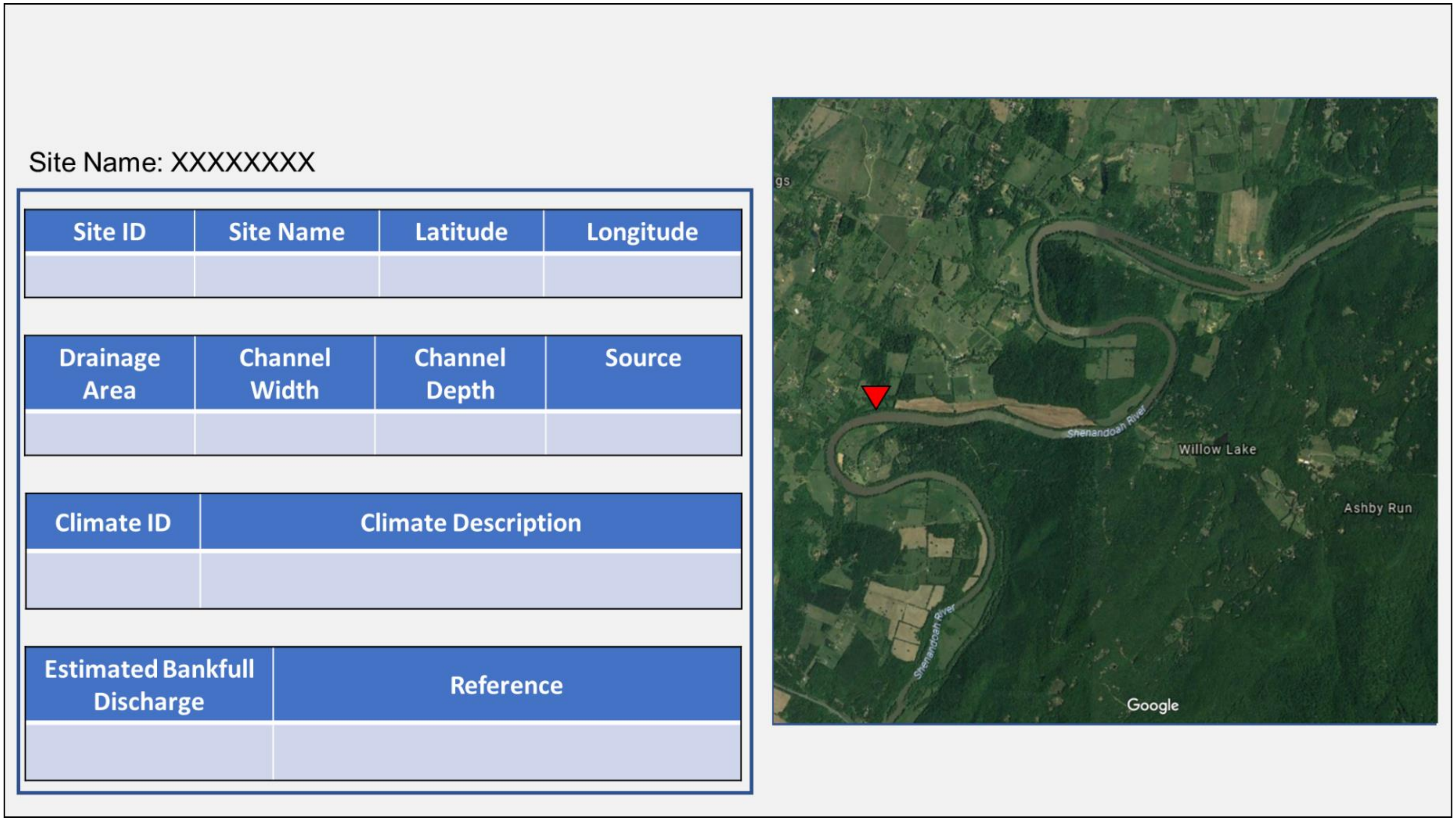
Year Averaged Bankfull Flow Duration, tbd (days)

DECIMAL

Streams Used to Derive tbd (Results 4)

Site ID	Site Name	Latitude	Longitude	Drainage Area	Channel Width	Channel Height	Country
HYPERLINK							
HYPERLINK							
HYPERLINK							
HYPERLINK							

Screen Mockup 2: Results screen illustrating how streams used to derive tbd value will need to be displayed for user review.



Site Name: XXXXXXXX

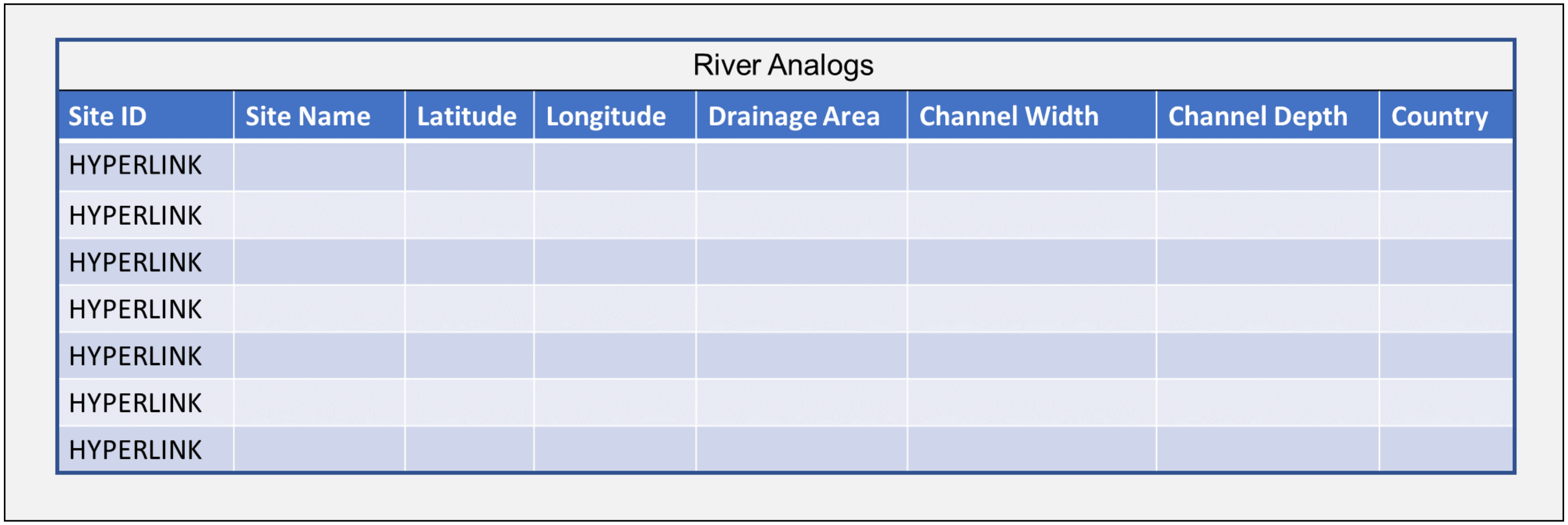
Site ID	Site Name	Latitude	Longitude

Drainage Area	Channel Width	Channel Depth	Source

Climate ID	Climate Description

Estimated Bankfull Discharge	Reference

Screen Mockup 3: Illustrating how user will need the ability to drill down on specific streams for additional data.



River Analogs

Site ID	Site Name	Latitude	Longitude	Drainage Area	Channel Width	Channel Depth	Country
HYPERLINK							
HYPERLINK							
HYPERLINK							
HYPERLINK							
HYPERLINK							
HYPERLINK							
HYPERLINK							

Screen Mockup 4: Illustrating how similarly to tbd results, analogue stream results will need to be displayed in a grid format from which a user can select and review specific stream

APPENDIX IV: Full data dictionary for all attributes within the database.

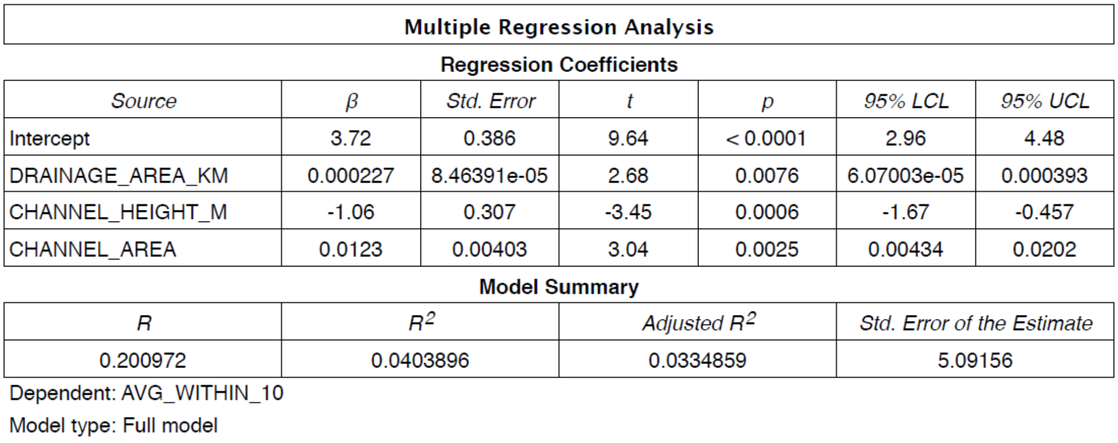
Processed Table	**Processed Column**	**Data Type**	**Key**	**Description**
BANKFULL_DISCHARGE_LIT	SITE_ID	INT	PK	The identification number of the water gauge site, either assigned by the authority maintaining the water gauging site (i.e. the USGS).
BANKFULL_DISCHARGE_LIT	SITE_NAME	VARCHAR(255)		The name of the water gauge site, either assigned by the authority maintaining the water gauging site (i.e. the USGS).
BANKFULL_DISCHARGE_LIT	BK_DISCHARGE_CUBIC_M_PER_SEC	DECIMAL		Estimated water discharge at bankfull flow, measured in cubic meter per second.
BANKFULL_DISCHARGE_LIT	BK_DISCHARGE_CUBIC_FT_PER_SEC	DECIMAL		Estimated water discharge at bankfull flow, measured in cubic feet per second.
BANKFULL_DISCHARGE_LIT	BANKFULL_TYPE	VARCHAR(255)		Method the bankfull discharge was determined by the worker.
BANKFULL_DISCHARGE_LIT	SOURCE_CONFIDENCE	INT		Assigned by (NOW) Confidence in the source for the bankfull discharge estimate.
BANKFULL_DISCHARGE_LIT	CHANNEL_DEPTH_FT	DECIMAL		Channel depth measured in feet. This value may be an averaged channel depth measured in the field by workers or determined based on scaling relationship and measured channel width.
BANKFULL_DISCHARGE_LIT	CHANNEL_WIDTH_FT	DECIMAL		Channel width measured in feet. This value often measured in the field by workers.
BANKFULL_DISCHARGE_LIT	CHANNEL_DEPTH_M	DECIMAL		Channel depth measured in meter. This value may be an averaged channel depth measured in the field by workers or determined based on scaling relationship and measured channel width.
BANKFULL_DISCHARGE_LIT	CHANNEL_WIDTH_M	DECIMAL		Channel width measured in meter. This value often measured in the field by workers.
BANKFULL_DISCHARGE_LIT	CHANNEL_D_REF	VARCHAR(255)		Provides a brief description about the channel height measurement (i.e. ‘Depth at Bankfull

				Stage')
BANKFULL_DISCHARGE_LIT	CHANNEL_W_REF	VARCHAR(255)		Provides a brief description about the channel width measurement (i.e. Depth at Bankfull Stage')
REF_LITERATURE_SOURCE	REF_SOURCE	VARCHAR (600)		Full literature source including author(s), title etc. in APA format.
REF_STATE	STATE_NAME	VARCHAR(64)		Name of the state the water gauge site is located.
REF_STATE	STATE_ID	INT	PK	State ID as assigned by the FIPS code of the location of the water gauge site.
REF_COUNTY	COUNTY_NAME	VARCHAR(64)		Name of the county the water gauge site is located.
REF_COUNTY	COUNTY_ID	INT	PK	County ID as assigned by the FIPS code of the location of the water gauge site.
REF_COUNTRY	COUNTRY_ID	INT	FK	Country_ID auto assigned
REF_COUNTRY	COUNTRY_NAME	VARCHAR(64)		Name of the country the water gauge site is located.
REF_CLIMATE	CLIMATE_ID	INT	PK	Climate ID as determined by the Köppen climate classification (i.e. Dnb).
REF_CLIMATE	CLIMATE_DESC	VARCHAR(64)		Full climate description as defined by Köppen classification.
REF_CLIMATE_LOCATION	CLIMATE_ID	INT	PK/FK	Climate ID as determined by the Köppen climate classification (i.e. Dnb).
REF_CLIMATE_LOCATION	COUNTY_ID	INT	PK/FK	County ID as assigned by the FIPS code of the location of the water gauge site.
REF_CLIMATE_LOCATION	STATE_ID	INT	PK/FK	State ID as assigned by the FIPS code of the location of the water gauge site.
REF_CLIMATE_LOCATION	COUNTRY_ID	INT	PK/FK	Country_ID auto assigned
REF_LITERATURE_SOURCE	REF_SOURCE_ID	INT	PK	Assigned by (NOW)
REF_LITERATURE_SOURCE	REF_SOURCE	VARCHAR(600)		Full title and author (s) of literature source used to populate stream specific bankfull discharge estimate.
STREAM_DESC_DATA	DESC_SOURCE	VARCHAR(64)		The source of the data (i.e. USGS or an international stream gauge data source)
STREAM_DESC_DATA	SITE_ID	INT	PK	The identification number of the water gauge site, either assigned by the

				authority maintaining the water gauging site (i.e. the USGS).
STREAM_DESC_DATA	SITE_NAME	VARCHAR(255)		The name of the water gauge site, either assigned by the authority maintaining the water gauging site (i.e. the USGS).
STREAM_DESC_DATA	LATITUDE	DECIMAL		Latitude value for the location of the water gauge site.
STREAM_DESC_DATA	LONGITUDE	DECIMAL		Longitude value for the location of the water gauge site.
STREAM_DESC_DATA	LAT_LONG_DATUM	VARCHAR(16)		Datum for the latitude/longitude values (i.e. NAD 27, NAD 83)
STREAM_DESC_DATA	STATE_ID	INT	FK	State ID as assigned by the FIPS code of the location of the water gauge site.
STREAM_DESC_DATA	COUNTY_ID	INT	FK	County ID as assigned by the FIPS code of the location of the water gauge site.
STREAM_DESC_DATA	COUNTRY_ID	INT	FK	Country_ID auto assigned
STREAM_DESC_DATA	CLIMATE_ID	INT	FK	Climate ID as determined by the Köppen climate classification (i.e. Dnb) .
STREAM_DESC_DATA	ALTITUDE	DECIMAL		Altitude for the water gauge site.
STREAM_DESC_DATA	DRAINAGE_AREA	DECIMAL		Determined drainage area that contribute to the stream being gauged.
STREAM_DESC_DATA	DATA_BEGIN_DATE	DATE		Earliest date daily discharge data is available.
STREAM_DESC_DATA	DATA_END_DATE	DATE		Latest date daily discharge data is available.
STREAM_DISCHARGE_DATA	DESC_SOURCE	VARCHAR(64)		The source of the data (i.e. USGS or an international stream gauge data source)
STREAM_DISCHARGE_DATA	SITE_ID	INT	PK	The identification number of the water gauge site, either assigned by the authority maintaining the water gauging site (i.e. the USGS).
STREAM_DISCHARGE_DATA	DATE	DATE		Date when discharge volume was gauged at water gauging site, measured in cubic feet per second.
STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_FT_PER_SEC	DECIMAL		Actual water discharge, measured in cubic feet per second.

STREAM_DISCHARGE_DATA	DISCHARGE_CUBIC_M_PER_SEC	DECIMAL		Actual water discharge, measured in cubic meter per second.
STREAM_DISCHARGE_DATA	SUSPENDED_SED_DISCHARGE	DECIMAL		Actual suspended sediment discharged, measured in milligrams per liter.
STREAM_DISCHARGE_DATA	DIS_SOURCE	VARCHAR(64)		The source of the data (i.e. USGS or an international stream gauge data source)

APPENDIX V: All ANOVA tables and multiple regression analysis data for all streams, computed by Aabel statistical software



Multiple Regression Analysis

Regression Coefficients

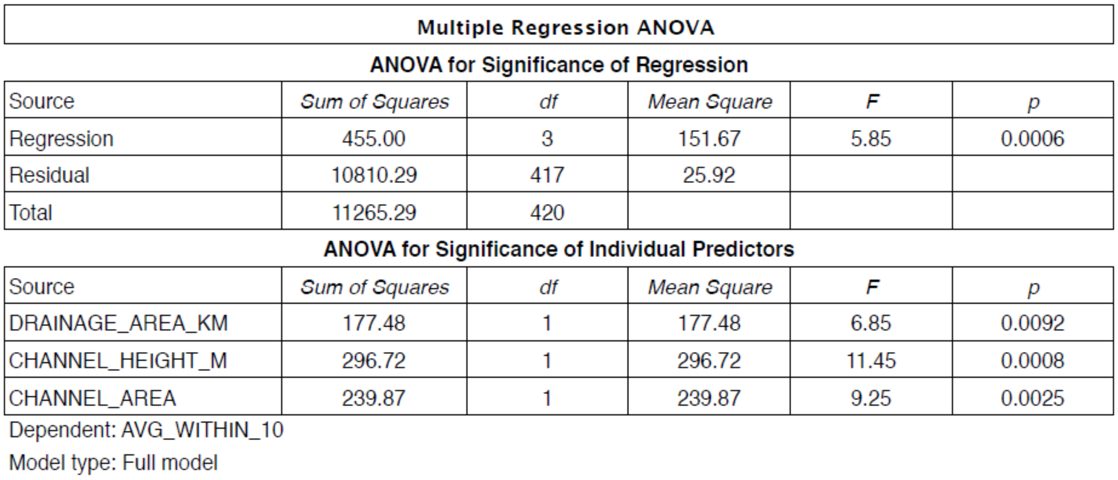
Source	*β*	*Std. Error*	*t*	*p*	*95% LCL*	*95% UCL*
Intercept	3.72	0.386	9.64	< 0.0001	2.96	4.48
DRAINAGE_AREA_KM	0.000227	8.46391e-05	2.68	0.0076	6.07003e-05	0.000393
CHANNEL_HEIGHT_M	-1.06	0.307	-3.45	0.0006	-1.67	-0.457
CHANNEL_AREA	0.0123	0.00403	3.04	0.0025	0.00434	0.0202

Model Summary

R	R^2	Adjusted R^2	*Std. Error of the Estimate*
0.200972	0.0403896	0.0334859	5.09156

Dependent: AVG_WITHIN_10

Model type: Full model



Multiple Regression ANOVA

ANOVA for Significance of Regression

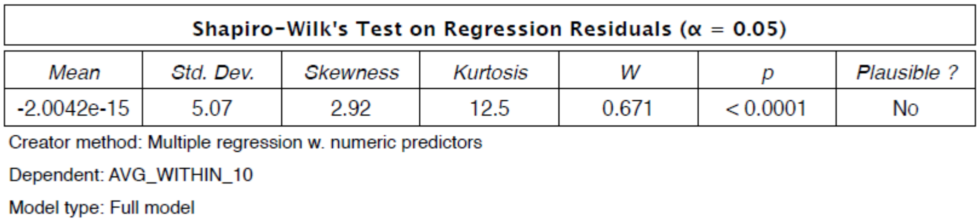
Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Regression	455.00	3	151.67	5.85	0.0006
Residual	10810.29	417	25.92		
Total	11265.29	420			

ANOVA for Significance of Individual Predictors

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
DRAINAGE_AREA_KM	177.48	1	177.48	6.85	0.0092
CHANNEL_HEIGHT_M	296.72	1	296.72	11.45	0.0008
CHANNEL_AREA	239.87	1	239.87	9.25	0.0025

Dependent: AVG_WITHIN_10

Model type: Full model



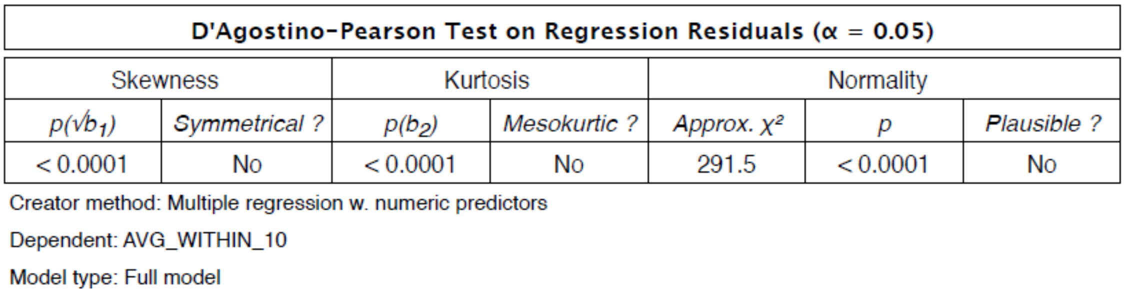
Shapiro-Wilk's Test on Regression Residuals ($\alpha = 0.05$)

Mean	*Std. Dev.*	*Skewness*	*Kurtosis*	*W*	*p*	*Plausible ?*
-2.0042e-15	5.07	2.92	12.5	0.671	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Full model



D'Agostino-Pearson Test on Regression Residuals ($\alpha = 0.05$)

Skewness		Kurtosis		Normality		
$p(\sqrt{b_1})$	*Symmetrical ?*	$p(b_2)$	*Mesokurtic ?*	Approx. χ^2	*p*	*Plausible ?*
< 0.0001	No	< 0.0001	No	291.5	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Full model

Multiple Regression Analysis

Regression Coefficients

Source	*β*	*Std. Error*	*t*	*p*	*95% LCL*	*95% UCL*
Intercept	3.51	0.378	9.3	< 0.0001	2.77	4.26
CHANNEL_HEIGHT_M	-0.669	0.268	-2.5	0.0128	-1.2	-0.143
CHANNEL_AREA	0.0125	0.00403	3.1	0.0021	0.00457	0.0204

Model Summary

R	R^2	*Adjusted* R^2	*Std. Error of the Estimate*
0.156586	0.0245191	0.0199286	5.09692

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: DRAINAGE_AREA_KM

Multiple Regression ANOVA

ANOVA for Significance of Regression

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Regression	277.52	2	138.76	5.34	0.0051
Residual	11040.91	425	25.98		
Total	11318.42	427			

ANOVA for Significance of Individual Predictors

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
CHANNEL_HEIGHT_M	150.26	1	150.26	5.78	0.0166
CHANNEL_AREA	249.82	1	249.82	9.62	0.0021

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: DRAINAGE_AREA_KM

Shapiro-Wilk's Test on Regression Residuals ($\alpha = 0.05$)

Mean	*Std. Dev.*	*Skewness*	*Kurtosis*	*W*	*p*	*Plausible ?*
2.35533e-16	5.08	2.88	12.2	0.664	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: DRAINAGE_AREA_KM

D'Agostino-Pearson Test on Regression Residuals ($\alpha = 0.05$)

Skewness		Kurtosis		Normality		
$p(\sqrt{b_1})$	*Symmetrical ?*	*$p(b_2)$*	*Mesokurtic ?*	*Approx. χ^2*	*p*	*Plausible ?*
< 0.0001	No	< 0.0001	No	292.5	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: DRAINAGE_AREA_KM

Multiple Regression Analysis

Regression Coefficients

Source	*β*	*Std. Error*	*t*	*p*	*95% LCL*	*95% UCL*
Intercept	2.78	0.277	10	< 0.0001	2.23	3.32
DRAINAGE_AREA_KM	8.11532e-05	7.35635e-05	1.1	0.2705	-6.33727e-05	0.000226
CHANNEL_AREA	0.00625	0.00375	1.67	0.0960	-0.00111	0.0136

Model Summary

R	*R^2*	*Adjusted R^2*	*Std. Error of the Estimate*
0.103189	0.010648	0.00673756	5.39108

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_HEIGHT_M

Multiple Regression ANOVA

ANOVA for Significance of Regression

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Regression	158.28	2	79.14	2.72	0.0666
Residual	14706.27	506	29.06		
Total	14864.55	508			

ANOVA for Significance of Individual Predictors

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
DRAINAGE_AREA_KM	31.02	1	31.02	1.07	0.3020
CHANNEL_AREA	80.85	1	80.85	2.78	0.0960

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_HEIGHT_M

Shapiro-Wilk's Test on Regression Residuals ($\alpha = 0.05$)

Mean	*Std. Dev.*	*Skewness*	*Kurtosis*	*W*	*p*	*Plausible ?*
-2.94896e-16	5.38	3.09	12.5	0.618	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_HEIGHT_M

D'Agostino-Pearson Test on Regression Residuals ($\alpha = 0.05$)

Skewness		Kurtosis		Normality		
$p(\sqrt{b_1})$	*Symmetrical ?*	*$p(b_2)$*	*Mesokurtic ?*	*Approx. χ^2*	*p*	*Plausible ?*
< 0.0001	No	< 0.0001	No	360.8	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_HEIGHT_M

Multiple Regression Analysis

Regression Coefficients

Source	*β*	*Std. Error*	*t*	*p*	*95% LCL*	*95% UCL*
Intercept	3.69	0.390	9.45	< 0.0001	2.92	4.45
DRAINAGE_AREA_KM	0.000229	8.54691e-05	2.67	0.0078	6.05626e-05	0.000397
CHANNEL_HEIGHT_M	-0.638	0.277	-2.31	0.0217	-1.18	-0.0939

Model Summary

R	*R^2*	*Adjusted R^2*	*Std. Error of the Estimate*
0.138192	0.019097	0.0144037	5.14157

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_AREA

Multiple Regression ANOVA

ANOVA for Significance of Regression

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Regression	215.13	2	107.57	4.07	0.0178
Residual	11050.16	418	26.44		
Total	11265.29	420			

ANOVA for Significance of Individual Predictors

Source	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
DRAINAGE_AREA_KM	187.44	1	187.44	7.09	0.0080
CHANNEL_HEIGHT_M	137.70	1	137.70	5.21	0.0230

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_AREA

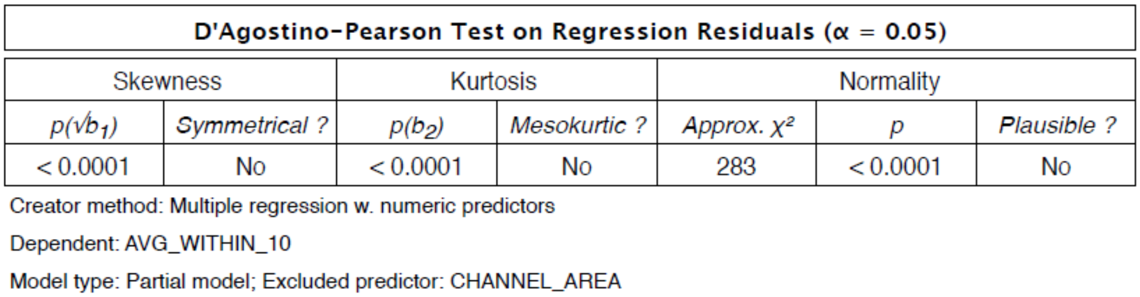
Shapiro-Wilk's Test on Regression Residuals ($\alpha = 0.05$)

Mean	*Std. Dev.*	*Skewness*	*Kurtosis*	*W*	*p*	*Plausible ?*
-1.41349e-15	5.13	2.83	11.8	0.678	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_AREA



D'Agostino-Pearson Test on Regression Residuals ($\alpha = 0.05$)

Skewness		Kurtosis		Normality		
$p(\sqrt{b_1})$	*Symmetrical ?*	*$p(b_2)$*	*Mesokurtic ?*	*Approx. χ^2*	*p*	*Plausible ?*
< 0.0001	No	< 0.0001	No	283	< 0.0001	No

Creator method: Multiple regression w. numeric predictors

Dependent: AVG_WITHIN_10

Model type: Partial model; Excluded predictor: CHANNEL_AREA

APPENDIX VI: All streams that met the data requirements to populate Tbd, average annual days within 20% of the bankfull flow, and the derived data from the available dataset used to calculate the average percentage of annual water discharged during the bankfull flow. All attributes with a grey heading are calculated from the available data with all other attributes directly sourced from the database.

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
26027210	Af	4,651,111,152.00	33	140,942,762.18	0.21212121	80.35	6,942,240.00	1,472,596.36	1.04%
50063800	Af	2,592,456,812.02	49	52,907,281.88	0.16326531	61.5	5,313,600.00	867,526.53	1.64%
50064200	Af	1,503,522,569.78	39	38,551,860.76	0.35897436	39.7	3,430,080.00	1,231,310.77	3.19%
50065700	Af	1,177,950,202.56	18	65,441,677.92	0.27777778	46.2	3,991,680.00	1,108,800.00	1.69%
50071000	Af	3,299,950,149.88	55	59,999,093.63	0.05454545	96.9	8,372,160.00	456,663.27	0.76%
26017020	Am	21,077,494,617.60	30	702,583,153.92	16.2333333	58.22	5,030,208.00	81,657,043.20	11.62%
26017040	Am	3,073,554,892.80	41	74,964,753.48	7.53658537	9.46	817,344.00	6,159,982.83	8.22%
26027080	Am	1,668,623,760.00	43	38,805,203.72	0.20930233	15.86	1,370,304.00	286,807.81	0.74%
26027200	Am	6,945,005,145.60	32	217,031,410.80	3.625	26.82	2,317,248.00	8,400,024.00	3.87%
26027220	Am	759,953,577.60	31	24,514,631.54	0.61290323	6.96	601,344.00	368,565.68	1.50%
26027090	Aw	5,803,598,332.80	42	138,180,912.69	3.97619048	24.13	2,084,832.00	8,289,689.14	6.00%
09473000	BSh	1,641,925,634.45	57	28,805,712.89	0.31578947	36.81	3,180,384.00	1,004,331.79	3.49%
09480000	BSh	195,151,731.46	64	3,049,245.80	0.046875	26.53	2,292,192.00	107,446.50	3.52%
09480500	BSh	1,823,544,204.47	88	20,722,093.23	0.09090909	99.59	8,604,576.00	782,234.18	3.77%
09481500	BSh	283,564,073.65	39	7,270,873.68	0.02564103	56.63	4,892,832.00	125,457.23	1.73%
09486100	BSh	22,314,469.33	6	3,719,078.22	0	9.34	806,976.00	0.00	0.00%
09497980	BSh	1,372,828,529.65	50	27,456,570.59	0.44	33.98	2,935,872.00	1,291,783.68	4.70%
09498870	BSh	446,367,383.26	19	23,493,020.17	0.15789474	49.21	4,251,744.00	671,328.00	2.86%
09499000	BSh	10,064,299,690.24	76	132,424,995.92	0.60526316	141.58	12,232,512.00	7,403,888.84	5.59%

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
09504000	BSh	7,570,832,385.21	52	145,592,930.48	1.15384615	67.96	5,871,744.00	6,775,089.23	4.65%
09505200	BSh	1,271,999,445.53	47	27,063,817.99	0.40425532	33.56	2,899,584.00	1,172,172.26	4.33%
09505350	BSh	2,000,933,288.45	56	35,730,951.58	0.71428571	42.48	3,670,272.00	2,621,622.86	7.34%
09505800	BSh	2,687,255,684.51	52	51,677,993.93	0.40384615	72.94	6,302,016.00	2,545,044.92	4.92%
09506000	BSh	12,758,048,428.77	38	335,738,116.55	1.94736842	119.64	10,336,896.00	20,129,744.84	6.00%
09507600	BSh	98,431,419.56	9	10,936,824.40	0.44444444	3.26	281,664.00	125,184.00	1.14%
09510200	BSh	1,255,507,424.97	56	22,419,775.45	0.35714286	36.81	3,180,384.00	1,135,851.43	5.07%
09512500	BSh	1,463,909,347.40	77	19,011,809.71	0.15584416	59.47	5,138,208.00	800,759.69	4.21%
09513780	BSh	505,070,028.86	50	10,101,400.58	0.68	13.03	1,125,792.00	765,538.56	7.58%
05CK004	BSk	60,933,493,728.00	32	1,904,171,679.00	0.0625	1132.67	97,862,688.00	6,116,418.00	0.32%
06306300	BSk	21,675,149,314.27	55	394,093,623.90	12.1818182	55.22	4,771,008.00	58,119,552.00	14.75%
06307500	BSk	29,644,946,857.41	77	384,999,309.84	11.8181818	42.48	3,670,272.00	43,375,941.82	11.27%
06307528	BSk	731,231.30	5	146,246.26	0.2	0.34	29,376.00	5,875.20	4.02%
06307600	BSk	93,471,460.65	31	3,015,208.41	2.58064516	0.57	49,248.00	127,091.61	4.22%
06307616	BSk	12,696,625,538.16	36	352,684,042.73	12.8055556	27.61	2,385,504.00	30,547,704.00	8.66%
06307740	BSk	147,630,333.62	31	4,762,268.83	4.74193548	0.71	61,344.00	290,889.29	6.11%
06307830	BSk	6,532,415,685.69	18	362,911,982.54	13.5555556	35.96	3,106,944.00	42,116,352.00	11.61%
06308500	BSk	21,735,237,820.31	58	374,745,479.66	11.4827586	46.44	4,012,416.00	46,073,604.41	12.29%
07207500	BSk	771,047,138.84	75	10,280,628.52	0.34666667	8.95	773,280.00	268,070.40	2.61%
08341500	BSk	127,409,371.08	22	5,791,335.05	0	3.65	315,360.00	0.00	0.00%
08380500	BSk	1,556,756,953.85	90	17,297,299.49	1.14444444	8.41	726,624.00	831,580.80	4.81%
08477110	BSk	565,938,355.11	36	15,720,509.86	0.30555556	16.48	1,423,872.00	435,072.00	2.77%
09432000	BSk	3,882,819,269.22	18	215,712,181.62	3.11111111	49.21	4,251,744.00	13,227,648.00	6.13%
09442000	BSk	1,817,354,916.77	8	227,169,364.60	2.875	82.12	7,095,168.00	20,398,608.00	8.98%

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
09460150	BSk	29,106,885.84	20	1,455,344.29	0.3	0.85	73,440.00	22,032.00	1.51%
09471000	BSk	4,399,936,240.71	98	44,897,308.58	0.60204082	59.47	5,138,208.00	3,093,410.94	6.89%
09471550	BSk	1,410,954,285.48	37	38,133,899.61	0.40540541	59.47	5,138,208.00	2,083,057.30	5.46%
10255810	BSk	40,664,024.85	51	797,333.82	0.03921569	4.9	423,360.00	16,602.35	2.08%
10259200	BSk	93,578,131.17	54	1,732,928.35	0.14814815	6.6	570,240.00	84,480.00	4.87%
11012500	BSk	220,607,525.22	79	2,792,500.32	0.10126582	11.4	984,960.00	99,742.78	3.57%
11015000	BSk	724,387,672.64	81	8,943,057.69	0.81481481	7.5	648,000.00	528,000.00	5.90%
11022200	BSk	50,089,172.51	32	1,565,286.64	0.46875	2.8	241,920.00	113,400.00	7.24%
11028500	BSk	425,860,587.77	77	5,530,656.98	0.62337662	8.6	743,040.00	463,193.77	8.38%
11042400	BSk	372,944,989.05	57	6,542,894.54	0.26315789	16.4	1,416,960.00	372,884.21	5.70%
11044350	BSk	204,143,738.09	27	7,560,879.19	0.92592593	4.1	354,240.00	328,000.00	4.34%
11046530	BSk	506,275,503.58	31	16,331,467.86	0.83870968	13.7	1,183,680.00	992,763.87	6.08%
11047300	BSk	440,984,485.54	30	14,699,482.85	1.53333333	8.6	743,040.00	1,139,328.00	7.75%
12445000	BSk	229,325,136,625.61	87	2,635,921,110.64	20.7241379	200.25	17,301,600.00	358,560,744.83	13.60%
12500450	BSk	161,293,454,483.83	50	3,225,869,089.68	25.44	227.61	19,665,504.00	500,290,421.76	15.51%
13334700	BSk	1,803,499,982.25	28	64,410,713.65	0.5	14.95	1,291,680.00	645,840.00	1.00%
14021000	BSk	24,187,491,576.06	54	447,916,510.67	10.8518519	68.22	5,894,208.00	63,963,072.00	14.28%
14026000	BSk	52,457,476,493.45	87	602,959,499.92	7.62068966	109.6	9,469,440.00	72,163,663.45	11.97%
14038530	BSk	8,019,907,707.23	45	178,220,171.27	24.7333333	15.01	1,296,864.00	32,075,769.60	18.00%
14046500	BSk	149,558,419,874.27	87	1,719,062,297.41	7.2183908	333.33	28,799,712.00	207,887,576.28	12.09%
09484560	BWh	14,205,650.55	6	2,367,608.42	0	35.11	3,033,504.00	0.00	0.00%
09484590	BWh	3,915,175.01	6	652,529.17	0	18.83	1,626,912.00	0.00	0.00%
09485000	BWh	236,445,528.28	46	5,140,120.18	0.17391304	21.75	1,879,200.00	326,817.39	6.36%
09486800	BWh	133,203,513.01	32	4,162,609.78	0.125	25.49	2,202,336.00	275,292.00	6.61%

SITE_ID	**Köppen Climate**	**Total Discharge (m³)**	**Total Years of Discharge**	**Annual Average Discharge (m³)**	**20% tbd (Days)**	**Qbf (m³/s)**	**Average Daily Bankfull Discharge (m³)**	**Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)**	**Average % Annual Water Volume Discharged at Bankfull Flow**
12510500	BWk	287,015,789,721.23	90	3,189,064,330.24	34.4888889	204.3	17,651,520.00	608,781,312.00	19.09%
13305000	BWk	12,797,058,205.63	56	228,518,896.53	7.39285714	26.39	2,280,096.00	16,856,424.00	7.38%
01484000	Cfa	457,128,187.71	28	16,326,006.70	5.25	2.83	244,512.00	1,283,688.00	7.86%
01484100	Cfa	189,610,051.24	58	3,269,138.81	1.22413793	0.99	85,536.00	104,707.86	3.20%
01485500	Cfa	3,206,272,883.64	67	47,854,819.16	11.0597015	6.28	542,592.00	6,000,905.55	12.54%
01487000	Cfa	6,146,294,832.52	73	84,195,819.62	8.30136986	9.65	833,760.00	6,921,350.14	8.22%
01489000	Cfa	331,614,004.33	41	8,088,146.45	1.3902439	2.43	209,952.00	291,884.49	3.61%
01491000	Cfa	8,680,111,166.32	69	125,798,712.56	7.43478261	19.52	1,686,528.00	12,538,969.04	9.97%
01492500	Cfa	177,981,472.34	20	8,899,073.62	3.4	2.21	190,944.00	649,209.60	7.30%
01580000	Cfa	10,216,943,342.49	90	113,521,592.69	0.23333333	74.02	6,395,328.00	1,492,243.20	1.31%
01581700	Cfa	2,288,950,782.84	49	46,713,281.28	0.14285714	55.53	4,797,792.00	685,398.86	1.47%
01582000	Cfa	4,491,279,477.73	72	62,378,881.64	0.05555556	47.4	4,095,360.00	227,520.00	0.36%
01583000	Cfa	73,665,534.50	34	2,166,633.37	0.02941176	3.26	281,664.00	8,284.24	0.38%
01583100	Cfa	342,668,911.14	25	13,706,756.45	0.08	13.62	1,176,768.00	94,141.44	0.69%
01583500	Cfa	4,559,661,420.83	72	63,328,630.84	0.15277778	43.35	3,745,440.00	572,220.00	0.90%
01583580	Cfa	29,819,082.81	21	1,419,956.32	0	3.26	281,664.00	0.00	0.00%
01583600	Cfa	937,798,754.53	34	27,582,316.31	0.32352941	18.77	1,621,728.00	524,676.71	1.90%
01584050	Cfa	424,830,214.17	41	10,361,712.54	0.14634146	10.34	893,376.00	130,737.95	1.26%
01589440	Cfa	1,185,042,911.26	41	28,903,485.64	0.09756098	25.91	2,238,624.00	218,402.34	0.76%
01591000	Cfa	2,588,812,863.93	72	35,955,734.22	0.19444444	29.59	2,556,576.00	497,112.00	1.38%
01591400	Cfa	884,505,282.84	38	23,276,454.81	0.02631579	42.45	3,667,680.00	96,517.89	0.41%
01591700	Cfa	1,029,967,342.45	38	27,104,403.75	0.10526316	29.17	2,520,288.00	265,293.47	0.98%
01593500	Cfa	3,375,676,749.62	84	40,186,627.97	0.46428571	29	2,505,600.00	1,163,314.29	2.89%
01594526	Cfa	2,489,600,107.29	27	92,207,411.38	5.22222222	19.06	1,646,784.00	8,599,872.00	9.33%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
01645000	Cfa	9,010,183,439.14	86	104,769,574.87	0.30232558	72.55	6,268,320.00	1,895,073.49	1.81%
01650500	Cfa	1,600,333,331.43	78	20,517,093.99	0.17948718	25.68	2,218,752.00	398,237.54	1.94%
01658000	Cfa	1,842,337,372.34	37	49,792,901.96	3.89189189	15.29	1,321,056.00	5,141,407.14	10.33%
01658500	Cfa	408,980,956.88	65	6,292,014.72	0.70769231	5.81	501,984.00	355,250.22	5.65%
01660000	Cfa	27,989,243.04	11	2,544,476.64	0	7.7	665,280.00	0.00	0.00%
01660400	Cfa	1,308,366,556.83	42	31,151,584.69	0.4047619	37.1	3,205,440.00	1,297,440.00	4.16%
01661050	Cfa	799,106,138.13	46	17,371,872.57	1.26086957	7.74	668,736.00	843,188.87	4.85%
01661500	Cfa	1,565,241,079.63	68	23,018,251.17	0.79411765	13.16	1,137,024.00	902,930.82	3.92%
01670300	Cfa	49,525,531.36	11	4,502,321.03	0.45454545	4.84	418,176.00	190,080.00	4.22%
02031000	Cfa	4,186,253,075.61	45	93,027,846.12	0.17777778	117.53	10,154,592.00	1,805,260.80	1.94%
02032640	Cfa	2,582,575,598.96	23	112,285,895.61	0.26086957	100.54	8,686,656.00	2,266,084.17	2.02%
02036500	Cfa	1,259,053,314.47	72	17,486,851.59	0.09722222	24.16	2,087,424.00	202,944.00	1.16%
02039000	Cfa	4,098,172,782.10	70	58,545,325.46	0.55714286	32.85	2,838,240.00	1,581,305.14	2.70%
02050500	Cfa	96,553,455.72	12	8,046,121.31	0.08333333	8.58	741,312.00	61,776.00	0.77%
02053500	Cfa	3,922,531,088.43	66	59,432,289.22	14.0151515	4.7	406,080.00	5,691,272.73	9.58%
02071530	Cfa	893,340,904.62	22	40,606,404.76	0.04545455	32.28	2,788,992.00	126,772.36	0.31%
02074500	Cfa	8,370,493,503.62	87	96,212,569.01	0.11494253	197.67	17,078,688.00	1,963,067.59	2.04%
0208111310	Cfa	3,160,933,827.60	29	108,997,718.19	32.8275862	1.82	157,248.00	5,162,072.28	4.74%
02084557	Cfa	833,381,822.22	36	23,149,495.06	31.5555556	1.19	102,816.00	3,244,416.00	14.02%
0208925200	Cfa	1,823,576,572.61	27	67,539,873.06	13.4814815	6.82	589,248.00	7,943,936.00	11.76%
02091000	Cfa	3,956,419,235.60	54	73,267,022.88	8.09259259	10.51	908,064.00	7,348,592.00	10.03%
02092000	Cfa	6,832,189,176.43	38	179,794,452.01	13.9473684	20.9	1,805,760.00	25,185,600.00	14.01%
02092500	Cfa	9,801,689,571.96	58	168,994,647.79	30	9.63	832,032.00	24,960,960.00	14.77%
02093000	Cfa	4,892,298,043.13	49	99,842,817.21	8.73469388	13.3	1,149,120.00	10,037,211.43	10.05%

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
02104220	Cfa	2,571,003,902.85	26	98,884,765.49	54.8461538	4.93	425,952.00	23,361,828.92	23.63%
02105900	Cfa	971,849,818.89	30	32,394,993.96	16.1666667	2.76	238,464.00	3,855,168.00	11.90%
0210783230	Cfa	12,461,807.76	7	1,780,258.25	1.14285714	0.81	69,984.00	79,981.71	4.49%
0210783276	Cfa	57,668,333.02	7	8,238,333.29	4.57142857	1.67	144,288.00	659,602.29	8.01%
02235200	Cfa	1,596,215,604.77	32	49,881,737.65	33.25	1.56	134,784.00	4,481,568.00	8.98%
02244420	Cfa	3,665,744,348.62	51	71,877,340.17	26.2352941	3.23	279,072.00	7,321,536.00	10.19%
02244473	Cfa	1,145,234,207.81	30	38,174,473.59	30.9	0.71	61,344.00	1,895,529.60	4.97%
02267000	Cfa	2,220,796,688.94	63	35,250,741.09	96.4603175	1.05	90,720.00	8,750,880.00	24.82%
02268390	Cfa	962,132,183.61	25	38,485,287.34	53.04	1.81	156,384.00	8,294,607.36	21.55%
02269520	Cfa	1,373,843,440.91	25	54,953,737.64	37.44	3	259,200.00	9,704,448.00	17.66%
02270000	Cfa	750,020,231.20	36	20,833,895.31	41.3888889	1.19	102,816.00	4,255,440.00	20.43%
02295013	Cfa	739,919,780.87	27	27,404,436.33	22.4074074	0.99	85,536.00	1,916,640.00	6.99%
02297310	Cfa	10,486,906,386.82	64	163,857,912.29	22.234375	7.93	685,152.00	15,233,926.50	9.30%
02299950	Cfa	3,355,976,123.91	50	67,119,522.48	18.46	3.28	283,392.00	5,231,416.32	7.79%
02320700	Cfa	2,022,105,649.26	47	43,023,524.45	20.6595745	3.34	288,576.00	5,961,857.36	13.86%
02322016	Cfa	28,565,043.64	9	3,173,893.74	2.55555556	1.02	88,128.00	225,216.00	7.10%
03149500	Cfa	2,107,756,888.70	27	78,065,069.95	0.92592593	59.19	5,114,016.00	4,735,200.00	6.07%
03159540	Cfa	7,745,244,016.11	50	154,904,880.32	3.78	59.47	5,138,208.00	19,422,426.24	12.54%
03235500	Cfa	34,669,019.40	31	1,118,355.46	0	3.4	293,760.00	0.00	0.00%
03284520	Cfa	33,662,255.22	14	2,404,446.80	1.71428571	1.08	93,312.00	159,963.43	6.65%
03284525	Cfa	23,423,818.25	14	1,673,129.88	0.42857143	1.27	109,728.00	47,026.29	2.81%
03284530	Cfa	246,209,159.11	14	17,586,368.51	1.92857143	7.5	648,000.00	1,249,714.29	7.11%
03284555	Cfa	889,689,616.82	14	63,549,258.34	3.21428571	12.86	1,111,104.00	3,571,405.71	5.62%
03287580	Cfa	34,787,604.72	12	2,898,967.06	1.66666667	1.67	144,288.00	240,480.00	8.30%

SITE_ID	**Köppen Climate**	**Total Discharge (m^3)**	**Total Years of Discharge**	**Annual Average Discharge (m^3)**	**20% tbd (Days)**	**Qbf (m^3/s)**	**Average Daily Bankfull Discharge (m^3)**	**Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)**	**Average % Annual Water Volume Discharged at Bankfull Flow**
03287590	Cfa	100,633,089.27	15	6,708,872.62	3.66666667	2.1	181,440.00	665,280.00	9.92%
03287600	Cfa	565,142,583.25	18	31,396,810.18	4.27777778	7.62	658,368.00	2,816,352.00	8.97%
03288100	Cfa	4,987,895,427.63	24	207,828,976.15	4.04166667	54.09	4,673,376.00	18,888,228.00	9.09%
03288500	Cfa	48,088,659.91	19	2,530,982.10	0.52631579	1.8	155,520.00	81,852.63	3.23%
03289000	Cfa	1,810,697,110.63	57	31,766,615.98	1.45614035	15.4	1,330,560.00	1,937,482.11	6.10%
03289193	Cfa	292,174,268.34	18	16,231,903.80	0.5	11.89	1,027,296.00	513,648.00	3.16%
03289200	Cfa	1,572,165,635.47	19	82,745,559.76	0.68421053	30.58	2,642,112.00	1,807,760.84	2.18%
03291000	Cfa	1,877,538,692.30	37	50,744,288.98	1.94594595	33.42	2,887,488.00	5,618,895.57	11.07%
03292474	Cfa	168,404,441.52	19	8,863,391.66	1.31578947	4.73	408,672.00	537,726.32	6.07%
03292480	Cfa	202,894,298.48	18	11,271,905.47	0.88888889	7.7	665,280.00	591,360.00	5.25%
03293000	Cfa	1,679,549,892.05	70	23,993,569.89	0.97142857	14.98	1,294,272.00	1,257,292.80	5.24%
03297800	Cfa	260,306,793.52	14	18,593,342.39	2.35714286	9.71	838,944.00	1,977,510.86	10.64%
03298000	Cfa	11,905,654,641.79	69	172,545,719.45	2.31884058	92.6	8,000,640.00	18,552,208.70	10.75%
03298135	Cfa	103,413,886.92	10	10,341,388.69	1.9	4.73	408,672.00	776,476.80	7.51%
03409500	Cfa	31,635,272,912.70	73	433,359,902.91	0.90410959	304.41	26,301,024.00	23,779,008.00	5.49%
03414500	Cfa	22,527,539,871.78	61	369,303,932.32	1.08196721	215.77	18,642,528.00	20,170,604.07	5.46%
03415000	Cfa	5,717,760,582.46	40	142,944,014.56	0.65	119.21	10,299,744.00	6,694,833.60	4.68%
03416000	Cfa	8,822,946,880.33	53	166,470,695.86	0.35849057	146.68	12,673,152.00	4,543,205.43	2.73%
03539600	Cfa	6,313,481,297.34	27	233,832,640.64	0.7037037	189.44	16,367,616.00	11,517,952.00	4.93%
08324000	Cfa	4,180,450,982.32	65	64,314,630.50	1.41538462	31.15	2,691,360.00	3,809,309.54	5.92%
08387600	Cfb	72,761,868.84	37	1,966,537.00	1.10810811	1.08	93,312.00	103,399.78	5.26%
08MH001	Cfb	88,399,036,800.00	41	2,156,074,068.29	5.2195122	275	23,760,000.00	124,015,609.76	5.75%
11001	Cfb	2,233,479,052.80	31	72,047,711.38	0.48387097	36.54	3,157,056.00	1,527,607.74	2.12%
14007	Cfb	659,585,462.40	13	50,737,343.26	0	24.08	2,080,512.00	0.00	0.00%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
14011	Cfb	305,609,068.80	5	61,121,813.76	0	33.59	2,902,176.00	0.00	0.00%
14018	Cfb	28,738,228,550.40	27	1,064,378,835.20	7	146.47	12,655,008.00	88,585,056.00	8.32%
14029	Cfb	10,717,358,745.60	8	1,339,669,843.20	11.125	167.18	14,444,352.00	160,693,416.00	12.00%
15002	Cfb	25,029,593,481.60	28	893,914,052.91	0	513.84	44,395,776.00	0.00	0.00%
15003	Cfb	5,041,763,913.60	27	186,731,996.80	0	170.57	14,737,248.00	0.00	0.00%
15006	Cfb	44,262,187,171.20	35	1,264,633,919.18	2.71428571	250.92	21,679,488.00	58,844,324.57	4.65%
16002	Cfb	11,627,080,588.80	41	283,587,331.43	0.7804878	75.54	6,526,656.00	5,093,975.41	1.80%
16009	Cfb	43,856,965,987.20	44	996,749,226.98	1.06818182	199.17	17,208,288.00	18,381,580.36	1.84%
18002	Cfb	64,792,439,913.60	34	1,905,659,997.46	6.70588235	279.1	24,114,240.00	161,707,256.47	8.49%
18003	Cfb	26,749,891,526.40	24	1,114,578,813.60	0.45833333	314.97	27,213,408.00	12,472,812.00	1.12%
19001	Cfb	1,643,499,590.40	20	82,174,979.52	0.45	28.87	2,494,368.00	1,122,465.60	1.37%
20002	Cfb	15,347,558,419.20	32	479,611,200.60	0.09375	196.55	16,981,920.00	1,592,055.00	0.33%
23002	Cfb	21,236,099,011.20	30	707,869,967.04	0.2	277.6	23,984,640.00	4,796,928.00	0.68%
25003	Cfb	3,923,430,220.80	15	261,562,014.72	7.26666667	46.08	3,981,312.00	28,930,867.20	11.06%
25020	Cfb	1,608,331,593.60	13	123,717,814.89	0.30769231	86.72	7,492,608.00	2,305,417.85	1.86%
25027	Cfb	1,703,069,712.00	26	65,502,681.23	0	37.83	3,268,512.00	0.00	0.00%
26004	Cfb	439,704,979.20	5	87,940,995.84	27.8	6.02	520,128.00	14,459,558.40	16.44%
26005	Cfb	28,695,312,547.20	42	683,221,727.31	0	231.21	19,976,544.00	0.00	0.00%
26008	Cfb	3,065,855,011.20	16	191,615,938.20	0	50.53	4,365,792.00	0.00	0.00%
26009	Cfb	287,781,897.60	6	47,963,649.60	7.5	9.11	787,104.00	5,903,280.00	12.31%
26021	Cfb	18,661,886,784.00	31	601,996,347.87	0.16129032	110.22	9,523,008.00	1,535,969.03	0.26%
26108	Cfb	2,889,355,017.60	8	361,169,377.20	66.5	11.03	952,992.00	63,373,968.00	17.55%
27001	Cfb	521,698,579.20	10	52,169,857.92	0.3	20.94	1,809,216.00	542,764.80	1.04%
30004	Cfb	7,438,533,696.00	17	437,560,805.65	0	180.67	15,609,888.00	0.00	0.00%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
30005	Cfb	8,182,674,604.80	46	177,884,230.54	0.15217391	59.47	5,138,208.00	781,901.22	0.44%
30007	Cfb	8,366,629,449.60	26	321,793,440.37	1.88461538	61.17	5,285,088.00	9,960,358.15	3.10%
34001	Cfb	60,710,418,259.20	35	1,734,583,378.83	53	43.3	3,741,120.00	198,279,360.00	11.43%
35005	Cfb	12,700,896,681.60	25	508,035,867.26	33.56	39.54	3,416,256.00	114,649,551.36	22.57%
36010	Cfb	13,787,301,340.80	30	459,576,711.36	0.33333333	113.18	9,778,752.00	3,259,584.00	0.71%
36018	Cfb	2,439,805,276.80	18	135,544,737.60	0.66666667	27.19	2,349,216.00	1,566,144.00	1.16%
36021	Cfb	744,723,763.20	22	33,851,080.15	0	31.42	2,714,688.00	0.00	0.00%
6011	Cfb	2,239,440,134.40	18	124,413,340.80	22.9444444	13	1,123,200.00	25,771,200.00	20.71%
6012	Cfb	2,922,532,099.20	29	100,776,968.94	54.137931	5.2	449,280.00	24,323,089.66	24.14%
6013	Cfb	4,035,938,140.80	30	134,531,271.36	3.06666667	27.05	2,337,120.00	7,167,168.00	5.33%
7002	Cfb	3,187,125,532.80	23	138,570,675.34	32.6086957	1.5	129,600.00	4,226,086.96	3.05%
7033	Cfb	1,434,676,924.80	17	84,392,760.28	0	89.19	7,706,016.00	0.00	0.00%
9001	Cfb	2,305,916,726.40	31	74,384,410.53	0.03225806	59.36	5,128,704.00	165,442.06	0.22%
10263500	Csa	1,415,579,259.81	93	15,221,282.36	1.38709677	5.3	457,920.00	635,179.35	4.17%
11058500	Csa	431,493,451.71	95	4,542,036.33	1.04210526	2.6	224,640.00	234,098.53	5.15%
11063500	Csa	125,561,573.47	76	1,652,125.97	0.18421053	3.9	336,960.00	62,071.58	3.76%
11063510	Csa	345,786,234.71	38	9,099,637.76	0.23684211	9.1	786,240.00	186,214.74	2.05%
11098000	Csa	878,099,155.50	101	8,694,051.04	2	4.1	354,240.00	708,480.00	8.15%
11111500	Csa	879,808,379.30	63	13,965,212.37	1.12698413	7.9	682,560.00	769,234.29	5.51%
14017000	Csa	8,348,392,938.04	41	203,619,339.95	10.3170732	26.62	2,299,968.00	23,728,938.15	11.65%
14018500	Csa	33,617,522,810.94	65	517,192,658.63	24.2461538	49.02	4,235,328.00	102,690,414.28	19.86%
11119500	Csb	261,411,567.36	74	3,532,588.75	0.82432432	3.4	293,760.00	242,153.51	6.85%
11124500	Csb	1,294,481,431.61	75	17,259,752.42	1.45333333	11.3	976,320.00	1,418,918.40	8.22%
11128250	Csb	68,364,009.74	38	1,799,052.89	0.28947368	5.6	483,840.00	140,058.95	7.79%

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
12010000	Csb	33,416,843,051.13	87	384,101,644.27	8.89655172	63.66	5,500,224.00	48,933,027.31	12.74%
12013500	Csb	34,601,025,321.48	60	576,683,755.36	25.3333333	42.73	3,691,872.00	93,527,424.00	16.22%
12027500	Csb	223,442,401,890.63	88	2,539,118,203.30	12.8863636	358.81	31,001,184.00	399,492,530.18	15.73%
12031000	Csb	216,048,361,210.03	59	3,661,836,630.68	28.8305085	239.11	20,659,104.00	595,612,472.95	16.27%
12164500	Csb	11,238,923,240.57	7	1,605,560,462.94	67.4285714	45.59	3,938,976.00	265,599,524.57	16.54%
12167000	Csb	150,105,233,991.44	88	1,705,741,295.36	0.89772727	584.24	50,478,336.00	45,315,778.91	2.66%
12178000	Csb	398,278,116,605.40	100	3,982,781,166.05	12.15	361.65	31,246,560.00	379,645,704.00	9.53%
12179000	Csb	209,886,159,503.46	44	4,770,139,988.72	8.63636364	424.8	36,702,720.00	316,978,036.36	6.65%
12181000	Csb	234,323,910,390.99	43	5,449,393,264.91	11.0465116	425.93	36,800,352.00	406,515,516.28	7.46%
12186000	Csb	91,882,992,527.19	91	1,009,703,214.58	4.12087912	145.55	12,575,520.00	51,822,197.80	5.13%
12200500	Csb	1,130,230,852,619.67	76	14,871,458,587.10	17.7105263	1122.6	96,992,640.00	1,717,790,703.16	11.55%
12205000	Csb	56,383,312,924.48	79	713,712,821.83	1.51898734	128.2	11,076,480.00	16,825,032.91	2.36%
12209000	Csb	36,030,310,627.91	54	667,227,974.59	0.51851852	215.4	18,610,560.00	9,649,920.00	1.45%
12210500	Csb	183,146,025,788.47	61	3,002,393,865.38	7.01639344	330.49	28,554,336.00	200,348,455.87	6.67%
12213100	Csb	169,139,098,015.03	49	3,451,818,326.84	16.5714286	277.45	23,971,680.00	397,244,982.86	11.51%
13346800	Csb	249,135,307.58	38	6,556,192.30	0.92105263	4.36	376,704.00	346,964.21	5.29%
14157500	Csb	97,661,363,616.18	71	1,375,512,163.61	23.5211268	87.08	7,523,712.00	176,966,183.66	12.87%
14202000	Csb	56,553,926,913.67	51	1,108,900,527.72	34.0588235	56.87	4,913,568.00	167,350,345.41	15.09%
14203500	Csb	26,800,391,597.18	77	348,057,033.73	29.2077922	20.39	1,761,696.00	51,455,250.70	14.78%
14207500	Csb	114,262,502,246.63	87	1,313,362,094.79	27.2643678	79.47	6,866,208.00	187,202,820.41	14.25%
14222500	Csb	57,535,071,698.15	87	661,322,663.20	9.85057471	95.24	8,228,736.00	81,057,778.76	12.26%
14305500	Csb	131,627,214,625.18	97	1,356,981,594.07	18.8762887	135.06	11,669,184.00	220,270,885.61	16.23%
14306500	Csb	100,666,331,322.94	77	1,307,354,952.25	23.5454545	99.74	8,617,536.00	202,903,802.18	15.52%
14308000	Csb	71,714,514,813.83	78	919,416,856.59	3.08974359	241.99	20,907,936.00	64,600,161.23	7.03%

SITE_ID	**Köppen Climate**	**Total Discharge (m^3)**	**Total Years of Discharge**	**Annual Average Discharge (m^3)**	**20% tbd (Days)**	**Qbf (m^3/s)**	**Average Daily Bankfull Discharge (m^3)**	**Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)**	**Average % Annual Water Volume Discharged at Bankfull Flow**
14308600	Csb	14,230,007,387.92	14	1,016,429,099.14	3.28571429	261.51	22,594,464.00	74,238,953.14	7.30%
14312000	Csb	202,875,854,268.80	83	2,444,287,400.83	13.3975904	281.02	24,280,128.00	325,295,208.87	13.31%
14325000	Csb	67,481,031,996.18	97	695,680,742.23	16.8865979	69.3	5,987,520.00	101,108,842.89	14.53%
14328000	Csb	57,978,122,802.65	79	733,900,288.64	0.86075949	150.49	13,002,336.00	11,191,884.15	1.52%
14337600	Csb	63,738,614,591.63	34	1,874,665,135.05	1.82352941	268.96	23,238,144.00	42,375,439.06	2.26%
14339000	Csb	175,308,211,286.14	78	2,247,541,170.34	1.76923077	419.99	36,287,136.00	64,200,317.54	2.86%
14357500	Csb	9,537,364,309.18	93	102,552,304.40	1.16129032	40.61	3,508,704.00	4,074,624.00	3.97%
14359000	Csb	287,649,605,878.92	110	2,614,996,417.08	2.79090909	431.88	37,314,432.00	104,141,187.49	3.98%
14372300	Csb	279,392,370,727.77	55	5,079,861,285.96	6.61818182	805.42	69,588,288.00	460,547,942.40	9.07%
01101000	Dfa	2,410,519,331.40	71	33,950,976.50	2.6056338	7.73	667,872.00	1,740,229.86	5.13%
01105600	Dfa	404,455,215.49	50	8,089,104.31	0.36	6.4	552,960.00	199,065.60	2.46%
01184100	Dfa	624,256,473.06	35	17,835,899.23	1.28571429	7.76	670,464.00	862,025.14	4.83%
01187300	Dfa	2,781,190,183.28	76	36,594,607.67	1.86842105	14.36	1,240,704.00	2,318,157.47	6.33%
01449360	Dfa	4,696,482,679.15	50	93,929,653.58	1.5	22.23	1,920,672.00	2,881,008.00	3.07%
01450500	Dfa	10,578,063,904.59	77	137,377,453.31	0.94805195	48.71	4,208,544.00	3,989,918.34	2.90%
01451800	Dfa	4,284,931,231.90	50	85,698,624.64	0.62	49.64	4,288,896.00	2,659,115.52	3.10%
01452000	Dfa	7,673,222,112.83	72	106,572,529.34	0.84722222	54.94	4,746,816.00	4,021,608.00	3.77%
01468500	Dfa	12,395,548,489.65	49	252,970,377.34	1.20408163	67.71	5,850,144.00	7,044,050.94	2.78%
01469500	Dfa	7,508,515,272.71	97	77,407,373.95	1.19587629	27.75	2,397,600.00	2,867,232.99	3.70%
01470756	Dfa	4,986,318,269.77	21	237,443,727.13	1.52380952	89.12	7,699,968.00	11,733,284.57	4.94%
01471980	Dfa	3,380,524,019.44	29	116,569,793.77	0.44827586	66.27	5,725,728.00	2,566,705.66	2.20%
01472157	Dfa	3,928,229,496.02	48	81,838,114.50	0.85416667	40.78	3,523,392.00	3,009,564.00	3.68%
01472198	Dfa	1,975,900,262.24	35	56,454,293.21	0.6	33.7	2,911,680.00	1,747,008.00	3.09%
01472199	Dfa	1,241,066,536.58	35	35,459,043.90	0.28571429	28.32	2,446,848.00	699,099.43	1.97%

SITE_ID	**Köppen Climate**	**Total Discharge (m³)**	**Total Years of Discharge**	**Annual Average Discharge (m³)**	**20% tbd (Days)**	**Qbf (m³/s)**	**Average Daily Bankfull Discharge (m³)**	**Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)**	**Average % Annual Water Volume Discharged at Bankfull Flow**
01475850	Dfa	755,265,166.76	35	21,579,004.76	0.42857143	17.02	1,470,528.00	630,226.29	2.92%
01477000	Dfa	7,155,325,614.72	85	84,180,301.35	0.44705882	50.18	4,335,552.00	1,938,246.78	2.30%
01480300	Dfa	1,364,343,183.51	56	24,363,271.13	2	9.43	814,752.00	1,629,504.00	6.69%
01480500	Dfa	3,083,379,369.81	54	57,099,617.96	0.64814815	31.07	2,684,448.00	1,739,920.00	3.05%
01480617	Dfa	3,600,283,660.84	47	76,601,780.02	0.38297872	46.53	4,020,192.00	1,539,648.00	2.01%
01495000	Dfa	5,320,855,609.01	84	63,343,519.15	0.17857143	59.44	5,135,616.00	917,074.29	1.45%
01496000	Dfa	1,123,458,546.93	35	32,098,815.63	0.28571429	37.83	3,268,512.00	933,860.57	2.91%
01555500	Dfa	18,031,274,941.87	87	207,256,033.81	0.82758621	97.73	8,443,872.00	6,988,032.00	3.37%
01565000	Dfa	8,971,833,675.22	46	195,039,862.50	0.76086957	70.52	6,092,928.00	4,635,923.48	2.38%
01566000	Dfa	14,332,551,738.86	61	234,959,864.57	0.98360656	116.96	10,105,344.00	9,939,682.62	4.23%
01567500	Dfa	1,092,111,971.66	62	17,614,709.22	0.58064516	12.01	1,037,664.00	602,514.58	3.42%
01568000	Dfa	22,926,790,471.20	87	263,526,327.26	0.90804598	123.05	10,631,520.00	9,653,908.97	3.66%
01579000	Dfa	50,820,183.61	9	5,646,687.07	0	17.39	1,502,496.00	0.00	0.00%
01585500	Dfa	191,189,044.03	67	2,853,567.82	0.02985075	4.59	396,576.00	11,838.09	0.41%
01586210	Dfa	525,184,932.53	34	15,446,615.66	0.05882353	17.75	1,533,600.00	90,211.76	0.58%
01586610	Dfa	1,060,321,465.98	34	31,185,925.47	0.11764706	29	2,505,600.00	294,776.47	0.95%
01603500	Dfa	1,415,619,065.53	49	28,890,185.01	0.75510204	16.93	1,462,752.00	1,104,527.02	3.82%
01609500	Dfa	37,724,909.55	10	3,772,490.96	0	6.23	538,272.00	0.00	0.00%
01610155	Dfa	2,521,250,351.02	26	96,971,167.35	0.76923077	77.19	6,669,216.00	5,130,166.15	5.29%
01613050	Dfa	577,002,020.64	49	11,775,551.44	0.32653061	8.64	746,496.00	243,753.80	2.07%
01639140	Dfa	365,114,369.91	11	33,192,215.45	0.09090909	39.33	3,398,112.00	308,919.27	0.93%
01639500	Dfa	7,184,157,701.64	69	104,118,227.56	0.24637681	75.27	6,503,328.00	1,602,269.22	1.54%
01643500	Dfa	3,753,004,355.63	59	63,610,243.32	0.25423729	52.87	4,567,968.00	1,161,347.80	1.83%
03021410	Dfa	2,116,670,678.44	18	117,592,815.47	4.66666667	27.75	2,397,600.00	11,188,800.00	9.51%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
03034500	Dfa	10,251,885,815.19	75	136,691,810.87	1.02666667	59.27	5,120,928.00	5,257,486.08	3.85%
03039925	Dfa	69,836,772.40	10	6,983,677.24	1.9	2.01	173,664.00	329,961.60	4.72%
03049000	Dfa	13,144,277,809.72	76	172,951,023.81	0.73684211	79.86	6,899,904.00	5,084,139.79	2.94%
03049800	Dfa	313,694,091.23	54	5,809,149.84	0.12962963	5.75	496,800.00	64,400.00	1.11%
03078000	Dfa	7,477,665,180.20	69	108,371,959.13	0.71014493	47.83	4,132,512.00	2,934,682.43	2.71%
03080000	Dfa	23,480,333,907.81	98	239,595,243.96	1.05102041	91.33	7,890,912.00	8,293,509.55	3.46%
03087000	Dfa	108,545,570.68	7	15,506,510.10	0.28571429	21.95	1,896,480.00	541,851.43	3.49%
03146500	Dfa	43,489,238,789.05	77	564,795,308.95	0.96103896	291.7	25,202,880.00	24,220,949.61	4.29%
03157000	Dfa	6,290,136,038.49	77	81,690,078.42	0.16883117	77.31	6,679,584.00	1,127,721.97	1.38%
03201700	Dfa	12,193,369.94	12	1,016,114.16	0	1.53	132,192.00	0.00	0.00%
03201800	Dfa	101,925,246.01	20	5,096,262.30	0.2	9.37	809,568.00	161,913.60	3.18%
03235000	Dfa	126,712,587.51	14	9,050,899.11	0	26.05	2,250,720.00	0.00	0.00%
03237500	Dfa	34,406,987,671.28	84	409,606,996.09	0.6547619	410.64	35,479,296.00	23,230,491.43	5.67%
03238745	Dfa	769,930,797.22	15	51,328,719.81	1.46666667	38.23	3,303,072.00	4,844,505.60	9.44%
03238772	Dfa	51,128,843.08	13	3,932,987.93	0.30769231	4.36	376,704.00	115,908.92	2.95%
03240500	Dfa	305,998,694.11	13	23,538,361.09	7.53846154	3.94	340,416.00	2,566,212.92	10.90%
03254400	Dfa	155,823,510.19	10	15,582,351.02	1.3	10.28	888,192.00	1,154,649.60	7.41%
03254480	Dfa	330,633,296.14	13	25,433,330.47	2.61538462	10.62	917,568.00	2,399,793.23	9.44%
03254550	Dfa	667,709,589.44	17	39,277,034.67	2.17647059	21.21	1,832,544.00	3,988,478.12	10.15%
03260700	Dfa	997,249,708.50	33	30,219,688.14	0.87878788	15.35	1,326,240.00	1,165,483.64	3.86%
03262001	Dfa	495,382,217.29	16	30,961,388.58	2.25	15.29	1,321,056.00	2,972,376.00	9.60%
03264000	Dfa	13,995,550,702.09	83	168,621,092.80	2.15662651	70.52	6,092,928.00	13,140,170.02	7.79%
03266500	Dfa	220,852,891.88	32	6,901,652.87	0.125	7.93	685,152.00	85,644.00	1.24%
03268500	Dfa	640,867,666.12	18	35,603,759.23	0.55555556	19.51	1,685,664.00	936,480.00	2.63%

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03277075	Dfa	895,391,523.01	17	52,670,089.59	0.64705882	46.44	4,012,416.00	2,596,269.18	4.93%
03277130	Dfa	705,985,724.47	14	50,427,551.75	1	57.77	4,991,328.00	4,991,328.00	9.90%
03292470	Dfa	1,953,963,225.50	17	114,939,013.26	2.23529412	54.09	4,673,376.00	10,446,369.88	9.09%
04096015	Dfa	1,341,807,715.37	17	78,929,865.61	9.94117647	7.76	670,464.00	6,665,200.94	8.44%
04096400	Dfa	4,467,422,469.52	28	159,550,802.48	8.60714286	18.72	1,617,408.00	13,921,261.71	8.73%
04096405	Dfa	8,733,619,324.66	54	161,733,691.20	43.1296296	9.66	834,624.00	35,997,024.00	22.26%
04096515	Dfa	1,828,646,896.36	47	38,907,380.77	24.3617021	3.28	283,392.00	6,903,911.49	17.74%
04096600	Dfa	5,907,306,631.39	26	227,204,101.21	14.2307692	24.32	2,101,248.00	29,902,375.38	13.16%
04097170	Dfa	1,053,992,797.10	19	55,473,305.11	29.4736842	4.08	352,512.00	10,389,827.37	18.73%
04097540	Dfa	4,806,001,544.91	54	89,000,028.61	41.7222222	5.47	472,608.00	19,718,256.00	22.16%
04103010	Dfa	5,190,191,074.53	24	216,257,961.44	10.625	18.09	1,562,976.00	16,606,620.00	7.68%
04104945	Dfa	823,062,134.62	22	37,411,915.21	44.7272727	1.67	144,288.00	6,453,608.73	17.25%
04105700	Dfa	2,041,752,010.01	52	39,264,461.73	34.7307692	2.27	196,128.00	6,811,676.31	17.35%
04117500	Dfa	21,801,998,224.74	72	302,805,530.90	0.36111111	125.02	10,801,728.00	3,900,624.00	1.29%
04160800	Dfa	578,257,650.08	49	11,801,176.53	4.79591837	1.95	168,480.00	808,016.33	6.85%
04161580	Dfa	748,426,583.44	49	15,274,011.91	0.51020408	5.3	457,920.00	233,632.65	1.53%
04185440	Dfa	91,934,695.68	25	3,677,387.83	0.24	7.08	611,712.00	146,810.88	3.99%
04199155	Dfa	560,096,333.77	27	20,744,308.66	0.85185185	17.84	1,541,376.00	1,313,024.00	6.33%
04213075	Dfa	194,852,735.95	30	6,495,091.20	0.66666667	4.33	374,112.00	249,408.00	3.84%
09060500	Dfa	794,550,524.09	27	29,427,797.19	14.4814815	6.2	535,680.00	7,757,440.00	26.36%
01093800	Dfb	257,053,293.78	40	6,426,332.34	0.15	5.98	516,672.00	77,500.80	1.21%
01096000	Dfb	6,832,881,753.24	67	101,983,309.75	4.02985075	21.01	1,815,264.00	7,315,242.99	7.17%
0010965852	Dfb	2,061,207,782.85	30	68,706,926.10	5.03333333	12.26	1,059,264.00	5,331,628.80	7.76%
01100600	Dfb	2,826,115,573.01	53	53,322,935.34	5.64150943	8.35	721,440.00	4,070,010.57	7.63%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
01103500	Dfb	21,780,333,418.02	79	275,700,423.01	20.7594937	27.02	2,334,528.00	48,463,619.24	17.58%
01105870	Dfb	1,546,791,752.92	50	30,935,835.06	1.04	7.16	618,624.00	643,368.96	2.08%
01109000	Dfb	6,023,834,630.97	91	66,195,984.96	11.8241758	8.35	721,440.00	8,530,433.41	12.89%
01109070	Dfb	965,255,036.43	48	20,109,479.93	2.64583333	5.47	472,608.00	1,250,442.00	6.22%
01111300	Dfb	1,332,486,644.87	49	27,193,605.00	1.28571429	9.01	778,464.00	1,000,882.29	3.68%
01111500	Dfb	11,876,225,151.03	76	156,266,120.41	2.52631579	34.27	2,960,928.00	7,480,239.16	4.79%
01162500	Dfb	2,905,408,797.62	96	30,264,674.98	7.94791667	5.15	444,960.00	3,536,505.00	11.69%
01163200	Dfb	2,934,192,027.86	52	56,426,769.77	3.55769231	10.59	914,976.00	3,255,203.08	5.77%
01169000	Dfb	13,400,209,866.38	77	174,028,699.56	0.61038961	86.94	7,511,616.00	4,585,012.36	2.63%
01169900	Dfb	2,445,521,867.42	50	48,910,437.35	0.04	48.43	4,184,352.00	167,374.08	0.34%
01170100	Dfb	4,021,229,453.41	48	83,775,613.61	0.125	59.76	5,163,264.00	645,408.00	0.77%
01171500	Dfb	6,970,795,404.39	77	90,529,810.45	0.58441558	45.31	3,914,784.00	2,287,860.78	2.53%
01174000	Dfb	186,032,380.77	34	5,471,540.61	0.76470588	2.27	196,128.00	149,980.24	2.74%
01174600	Dfb	33,065,218.37	32	1,033,288.07	0.46875	0.68	58,752.00	27,540.00	2.67%
01174900	Dfb	162,562,297.85	35	4,644,637.08	3.2	1.3	112,320.00	359,424.00	7.74%
01175670	Dfb	761,073,694.53	56	13,590,601.69	1.17857143	4.62	399,168.00	470,448.00	3.46%
01176000	Dfb	23,519,159,065.04	104	226,145,760.24	9.78846154	28.6	2,471,040.00	24,187,680.00	10.70%
01181000	Dfb	14,152,379,312.79	80	176,904,741.41	0.6	98.27	8,490,528.00	5,094,316.80	2.88%
01198000	Dfb	2,122,748,280.15	28	75,812,438.58	0.75	32.57	2,814,048.00	2,110,536.00	2.78%
01199050	Dfb	2,476,499,181.65	54	45,861,095.96	1.07407407	13.88	1,199,232.00	1,288,064.00	2.81%
01329490	Dfb	41,237,323,838.90	63	654,560,695.86	0.96825397	178.98	15,463,872.00	14,972,955.43	2.29%
01330000	Dfb	1,376,660,398.89	40	34,416,509.97	0.925	14.36	1,240,704.00	1,147,651.20	3.33%
01333000	Dfb	5,141,314,178.21	67	76,736,032.51	0.41791045	34.55	2,985,120.00	1,247,512.84	1.63%
01333500	Dfb	3,680,200,283.43	44	83,640,915.53	0.04545455	70.8	6,117,120.00	278,050.91	0.33%

SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
01334000	Dfb	17,137,756,660.81	85	201,620,666.60	1.63529412	53.21	4,597,344.00	7,518,009.60	3.73%
01360640	Dfb	318,263,650.72	25	12,730,546.03	1.12	6.43	555,552.00	622,218.24	4.89%
01361000	Dfb	18,444,041,381.00	47	392,426,412.36	37.6595745	19.54	1,688,256.00	63,579,002.55	16.20%
01516500	Dfb	702,818,747.06	62	11,335,786.24	0.12903226	19.4	1,676,160.00	216,278.71	1.91%
01537000	Dfb	1,869,482,548.21	51	36,656,520.55	0.39215686	21.01	1,815,264.00	711,868.24	1.94%
01538000	Dfb	5,688,261,388.88	97	58,641,869.99	1.04123711	20.19	1,744,416.00	1,816,350.68	3.10%
01542810	Dfb	406,436,106.58	52	7,816,078.97	1.88461538	3.31	285,984.00	538,969.85	6.90%
01544500	Dfb	15,501,839,316.70	76	203,971,569.96	1.36842105	79.58	6,875,712.00	9,408,869.05	4.61%
01545600	Dfb	3,424,709,810.60	52	65,859,804.05	1.38461538	22.09	1,908,576.00	2,642,643.69	4.01%
01547700	Dfb	3,229,159,801.77	61	52,937,045.93	1.08196721	25.15	2,172,960.00	2,351,071.48	4.44%
01549500	Dfb	3,981,706,460.58	76	52,390,874.48	0.46052632	37.89	3,273,696.00	1,507,623.16	2.88%
01550000	Dfb	26,647,999,550.34	103	258,718,442.24	0.66990291	133.95	11,573,280.00	7,752,973.98	3.00%
01552500	Dfb	3,278,909,439.08	76	43,143,545.25	0.25	38.52	3,328,128.00	832,032.00	1.93%
01553700	Dfb	2,247,181,543.77	35	64,205,186.96	0.65714286	49.81	4,303,584.00	2,828,069.49	4.40%
01595000	Dfb	9,279,311,933.45	60	154,655,198.89	0.31666667	76.85	6,639,840.00	2,102,616.00	1.36%
01596500	Dfb	4,622,110,061.02	68	67,972,206.78	0.61764706	36.13	3,121,632.00	1,928,066.82	2.84%
01597000	Dfb	867,803,811.29	34	25,523,641.51	0.70588235	12.54	1,083,456.00	764,792.47	3.00%
01AD002	Dfb	595,428,598,080.00	67	8,886,994,001.19	3.46268657	2550	220,320,000.00	762,899,104.49	8.58%
01AD003	Dfb	28,962,056,736.00	36	804,501,576.00	3.27777778	243	20,995,200.00	68,817,600.00	8.55%
01AG002	Dfb	2,398,071,657.60	21	114,193,888.46	2.85714286	34	2,937,600.00	8,393,142.86	7.35%
01AJ003	Dfb	19,321,977,513.60	26	743,152,981.29	2.23076923	243	20,995,200.00	46,835,446.15	6.30%
01AK001	Dfb	11,156,517,158.40	70	159,378,816.55	4.74285714	38	3,283,200.00	15,571,748.57	9.77%
01AK005	Dfb	244,138,233.60	14	17,438,445.26	1.5	6.2	535,680.00	803,520.00	4.61%
01AL002	Dfb	38,136,277,440.00	34	1,121,655,218.82	2.38235294	315	27,216,000.00	64,838,117.65	5.78%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
01AM001	Dfb	11,343,395,260.80	30	378,113,175.36	1.36666667	130	11,232,000.00	15,350,400.00	4.06%
01AP002	Dfb	20,931,004,713.60	50	418,620,094.27	1.72	151	13,046,400.00	22,439,808.00	5.36%
01AP004	Dfb	27,847,792,224.00	35	795,651,206.40	1.48571429	234	20,217,600.00	30,037,577.14	3.78%
01AQ001	Dfb	16,626,405,427.20	73	227,758,978.45	1.78082192	63	5,443,200.00	9,693,369.86	4.26%
01BC001	Dfb	66,297,658,464.00	31	2,138,634,144.00	4	591	51,062,400.00	204,249,600.00	9.55%
01BE001	Dfb	86,598,638,784.00	66	1,312,100,587.64	2.71212121	394	34,041,600.00	92,324,945.45	7.04%
01BJ001	Dfb	7,777,763,942.40	31	250,895,611.05	3.4516129	78	6,739,200.00	23,261,109.68	9.27%
01BJ003	Dfb	8,450,493,609.60	26	325,018,984.98	2.5	119	10,281,600.00	25,704,000.00	7.91%
01BL001	Dfb	1,910,506,608.00	19	100,552,979.37	1.89473684	43	3,715,200.00	7,039,326.32	7.00%
01BO001	Dfb	164,383,762,176.00	44	3,735,994,594.91	5.13636364	841	72,662,400.00	373,220,509.09	9.99%
01BO002	Dfb	5,970,911,673.60	14	426,493,690.97	2	137	11,836,800.00	23,673,600.00	5.55%
01BP001	Dfb	31,257,712,512.00	31	1,008,313,306.84	3.4516129	241	20,822,400.00	71,870,864.52	7.13%
01BP002	Dfb	252,564,480.00	11	22,960,407.27	3.54545455	6.1	527,040.00	1,868,596.36	8.14%
01BQ001	Dfb	18,500,473,440.00	28	660,731,194.29	1.25	221	19,094,400.00	23,868,000.00	3.61%
01BS001	Dfb	3,897,736,070.40	34	114,639,296.19	1.52941176	45	3,888,000.00	5,946,352.94	5.19%
01BV006	Dfb	3,632,557,363.20	24	151,356,556.80	0.95833333	59	5,097,600.00	4,885,200.00	3.23%
03011800	Dfb	3,579,499,570.93	51	70,186,266.10	0.76470588	25.2	2,177,280.00	1,664,978.82	2.37%
03022540	Dfb	1,141,211,408.12	23	49,617,887.31	0.47826087	30.02	2,593,728.00	1,240,478.61	2.50%
03026500	Dfb	845,051,723.71	65	13,000,795.75	0.53846154	7.08	611,712.00	329,383.38	2.53%
03028000	Dfb	7,178,706,250.98	63	113,947,718.27	0.50793651	50.69	4,379,616.00	2,224,566.86	1.95%
03076600	Dfb	4,222,923,855.35	52	81,210,074.14	0.94230769	32.05	2,769,120.00	2,609,363.08	3.21%
03089500	Dfb	431,644,894.48	29	14,884,306.71	0.62068966	14.16	1,223,424.00	759,366.62	5.10%
03092090	Dfb	682,304,465.05	27	25,270,535.74	0.18518519	25.77	2,226,528.00	412,320.00	1.63%
03093000	Dfb	9,067,641,513.81	86	105,437,692.02	3.22093023	34.55	2,985,120.00	9,614,863.26	9.12%

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03102500	Dfb	12,955,064,447.72	99	130,859,236.85	1.22222222	58.91	5,089,824.00	6,220,896.00	4.75%
03110000	Dfb	11,067,685,620.30	76	145,627,442.37	0.44736842	82.69	7,144,416.00	3,196,186.11	2.19%
04033000	Dfb	9,886,519,668.60	68	145,389,995.13	4.45588235	22.4	1,935,360.00	8,623,736.47	5.93%
04046000	Dfb	1,137,777,840.72	48	23,703,705.01	0.33333333	10.34	893,376.00	297,792.00	1.26%
04060500	Dfb	3,048,702,129.93	42	72,588,145.95	1.76190476	16.28	1,406,592.00	2,478,281.14	3.41%
04060993	Dfb	21,942,541,525.71	73	300,582,760.63	5.56164384	34.43	2,974,752.00	16,544,511.12	5.50%
04062200	Dfb	4,627,829,019.81	26	177,993,423.84	5.73076923	45.28	3,912,192.00	22,419,869.54	12.60%
04065500	Dfb	4,151,354,787.99	25	166,054,191.52	9.76	21.52	1,859,328.00	18,147,041.28	10.93%
04065600	Dfb	138,216,880.57	9	15,357,431.17	11.2222222	1.36	117,504.00	1,318,656.00	8.59%
04102776	Dfb	1,433,211,382.70	16	89,575,711.42	8.1875	10.7	924,480.00	7,569,180.00	8.45%
04108600	Dfb	2,890,301,303.44	51	56,672,574.58	9.19607843	6.6	570,240.00	5,243,971.76	9.25%
04111379	Dfb	2,534,312,914.42	26	97,473,573.63	22.9230769	7.39	638,496.00	14,636,292.92	15.02%
04111500	Dfb	590,677,597.00	56	10,547,814.23	1.92857143	4.56	393,984.00	759,826.29	7.20%
04114498	Dfb	11,130,527,938.87	66	168,644,362.71	10.3939394	23.96	2,070,144.00	21,516,951.27	12.76%
04123000	Dfb	3,861,255,016.58	31	124,556,613.44	1.19354839	14.1	1,218,240.00	1,454,028.39	1.17%
04124500	Dfb	1,050,999,416.85	35	30,028,554.77	0.77142857	11.75	1,015,200.00	783,154.29	2.61%
04125460	Dfb	12,651,806,060.51	49	258,200,123.68	4.36734694	24.95	2,155,680.00	9,414,602.45	3.65%
04128000	Dfb	9,950,597,823.28	51	195,109,761.24	8.68627451	14.22	1,228,608.00	10,672,026.35	5.47%
04129500	Dfb	4,758,204,834.39	38	125,215,916.69	9.71052632	11.13	961,632.00	9,337,952.84	7.46%
04135700	Dfb	9,295,249,389.65	48	193,651,028.95	6.29166667	18.72	1,617,408.00	10,176,192.00	5.25%
04146063	Dfb	5,508,646,609.86	36	153,017,961.38	23.9722222	11.41	985,824.00	23,632,392.00	15.44%
04150500	Dfb	11,554,792,015.83	57	202,715,649.40	7.92982456	35.28	3,048,192.00	24,171,627.79	11.92%
04159900	Dfb	3,554,001,353.61	40	88,850,033.84	6.225	22.06	1,905,984.00	11,864,750.40	13.35%
04160600	Dfb	4,711,905,317.55	54	87,257,505.88	1.90740741	40.72	3,518,208.00	6,710,656.00	7.69%

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04172500	Dfb	1,135,583,730.91	26	43,676,297.34	38.5	2.61	225,504.00	8,681,904.00	19.88%
04185000	Dfb	25,286,815,135.32	82	308,375,794.33	10.195122	54.66	4,722,624.00	48,147,727.61	15.61%
04196000	Dfb	5,032,971,966.55	59	85,304,609.60	2.3559322	45.6	3,939,840.00	9,281,995.93	10.88%
04206212	Dfb	69,065,025.88	12	5,755,418.82	0.08333333	9.06	782,784.00	65,232.00	1.13%
04206220	Dfb	331,524,117.29	11	30,138,556.12	0	35.4	3,058,560.00	0.00	0.00%
04212100	Dfb	521,207,076.36	12	43,433,923.03	0	300.19	25,936,416.00	0.00	0.00%
04250750	Dfb	12,813,556,306.60	51	251,246,202.09	0.33333333	142.45	12,307,680.00	4,102,560.00	1.63%
04253296	Dfb	37,769,168.03	16	2,360,573.00	0	2.24	193,536.00	0.00	0.00%
04254500	Dfb	43,138,340,492.08	60	718,972,341.53	1.7	182.38	15,757,632.00	26,787,974.40	3.73%
04256000	Dfb	13,263,828,403.76	74	179,240,924.38	0.5	68.53	5,920,992.00	2,960,496.00	1.65%
04274000	Dfb	9,139,438,993.08	48	190,404,979.02	0.64583333	87.79	7,585,056.00	4,898,682.00	2.57%
04275000	Dfb	19,753,002,650.43	70	282,185,752.15	0.27142857	182.38	15,757,632.00	4,277,071.54	1.52%
04276500	Dfb	20,180,004,001.10	70	288,285,771.44	0.17142857	175.58	15,170,112.00	2,600,590.63	0.90%
05AA024	Dfb	37,845,334,944.00	33	1,146,828,331.64	0	991.09	85,630,176.00	0.00	0.00%
05AD007	Dfb	131,158,141,056.00	55	2,384,693,473.75	0.18181818	1529.11	132,115,104.00	24,020,928.00	1.01%
05AE002	Dfb	2,811,707,078.40	56	50,209,054.97	0.03571429	169.9	14,679,360.00	524,262.86	1.04%
05AE027	Dfb	42,648,669,331.20	72	592,342,629.60	0.02777778	481.39	41,592,096.00	1,155,336.00	0.20%
05AJ001	Dfb	254,202,079,680.00	45	5,648,935,104.00	0.17777778	2661.78	229,977,792.00	40,884,940.81	0.72%
05BJ004	Dfb	5,430,628,800.00	21	258,601,371.43	0	453.07	39,145,248.00	0.00	0.00%
05CE001	Dfb	58,718,822,400.00	37	1,586,995,200.00	0.02702703	1047.72	90,523,008.00	2,446,567.78	0.15%
05DF001	Dfb	417,245,706,144.00	63	6,622,947,716.57	0.22222222	2675.94	231,201,216.00	51,378,047.99	0.78%
05EA001	Dfb	647,914,550.40	8	80,989,318.80	0	79.29	6,850,656.00	0.00	0.00%
06AD006	Dfb	18,041,986,915.20	37	487,621,267.98	1.59459459	155.74	13,455,936.00	21,456,762.81	4.40%
07BE001	Dfb	795,589,689,600.00	60	13,259,828,160.00	0.06666667	5097.03	440,383,392.00	29,358,892.81	0.22%

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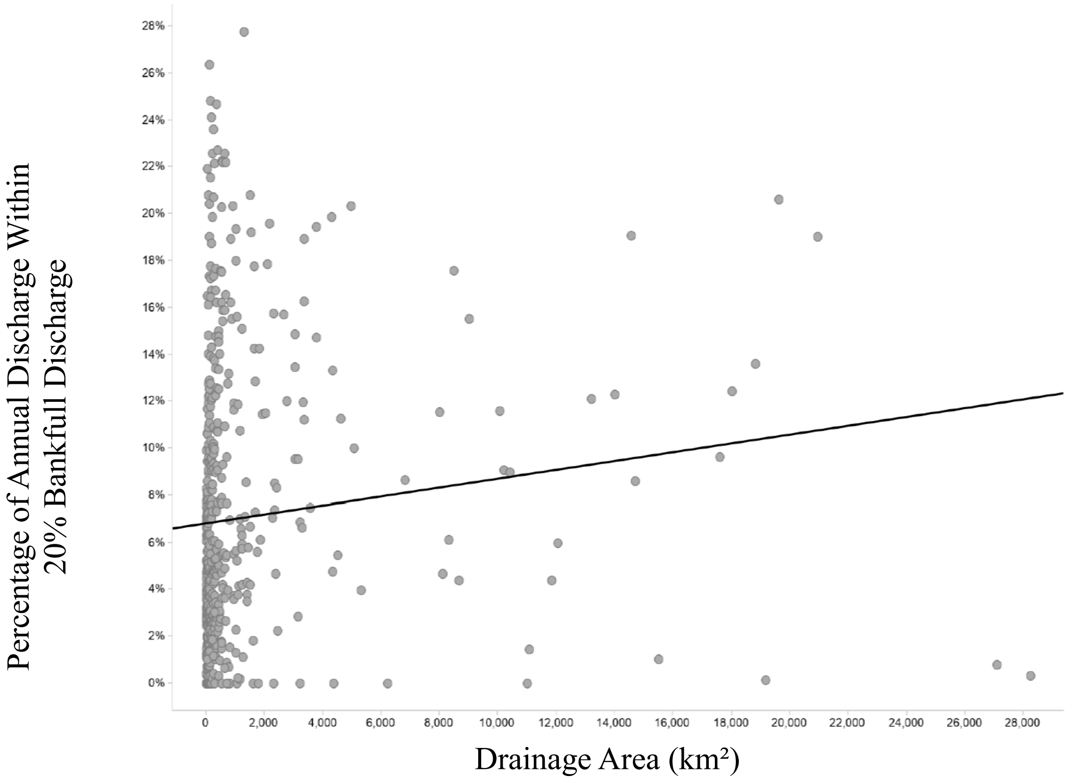
07GJ001	Dfb	301,328,605,440.00	29	10,390,641,566.90	0.10344828	5521.79	477,082,656.00	49,353,378.22	0.47%
07HA001	Dfb	1,787,039,107,200.00	31	57,646,422,812.90	0.09677419	14158.4	1,223,287,488.00	118,382,660.07	0.21%
08265000	Dfb	3,441,037,370.49	86	40,012,062.45	11.1162791	5.72	494,208.00	5,493,754.05	13.73%
08275500	Dfb	998,059,418.06	60	16,634,323.63	6.88333333	3.4	293,760.00	2,022,048.00	12.16%
08276500	Dfb	57,495,798,353.48	87	660,871,245.44	8.98850575	82.12	7,095,168.00	63,774,958.34	9.65%
08279000	Dfb	5,879,127,289.74	82	71,696,674.27	2.08536585	27.64	2,388,096.00	4,980,053.85	6.95%
08MC018	Dfb	1,262,824,128,000.00	28	45,100,861,714.29	28.8928571	4200	362,880,000.00	10,484,640,000.02	23.25%
08MF005	Dfb	4,811,008,089,600.00	57	84,403,650,694.74	29.5263158	8000	691,200,000.00	20,408,589,473.70	24.18%
12301999	Dfb	619,051,832.53	9	68,783,536.95	10.1111111	17.47	1,509,408.00	15,261,792.00	22.19%
12302500	Dfb	959,250,048.96	15	63,950,003.26	20.9333333	7.36	635,904.00	13,311,590.40	20.82%
12303100	Dfb	731,044,549.09	31	23,582,082.23	16.2580645	3.68	317,952.00	5,169,284.13	21.92%
12304040	Dfb	261,082,943.87	9	29,009,215.99	10	5.41	467,424.00	4,674,240.00	16.11%
12324100	Dfb	812,686,469.46	15	54,179,097.96	15.3333333	7.79	673,056.00	10,320,192.00	19.05%
12324590	Dfb	5,771,505,734.57	42	137,416,803.20	7.28571429	25.97	2,243,808.00	16,347,744.00	11.90%
12329500	Dfb	6,273,924,048.24	73	85,944,165.04	7.82191781	9.77	844,128.00	6,602,699.84	7.68%
12330000	Dfb	3,024,609,192.66	75	40,328,122.57	5.93333333	9.49	819,936.00	4,864,953.60	12.06%
12332000	Dfb	8,042,559,119.50	77	104,448,819.73	12.8961039	15.69	1,355,616.00	17,482,164.78	16.74%
12335500	Dfb	2,366,695,412.63	75	31,555,938.84	8.88	5.52	476,928.00	4,235,120.64	13.42%
12339450	Dfb	4,359,768,184.84	17	256,456,952.05	15.2352941	39.65	3,425,760.00	52,192,461.18	20.35%
12346500	Dfb	2,244,980,877.15	27	83,147,439.89	20.4444444	10.62	917,568.00	18,759,168.00	22.56%
12350500	Dfb	658,168,351.97	9	73,129,816.89	5.44444444	18.97	1,639,008.00	8,923,488.00	12.20%
12351400	Dfb	31,452,389.49	5	6,290,477.90	1.2	1.56	134,784.00	161,740.80	2.57%
12352000	Dfb	1,822,554,615.22	9	202,506,068.36	16.1111111	32.28	2,788,992.00	44,933,760.00	22.19%
12374250	Dfb	269,220,974.72	33	8,158,211.36	5.36363636	1.87	161,568.00	866,592.00	10.62%

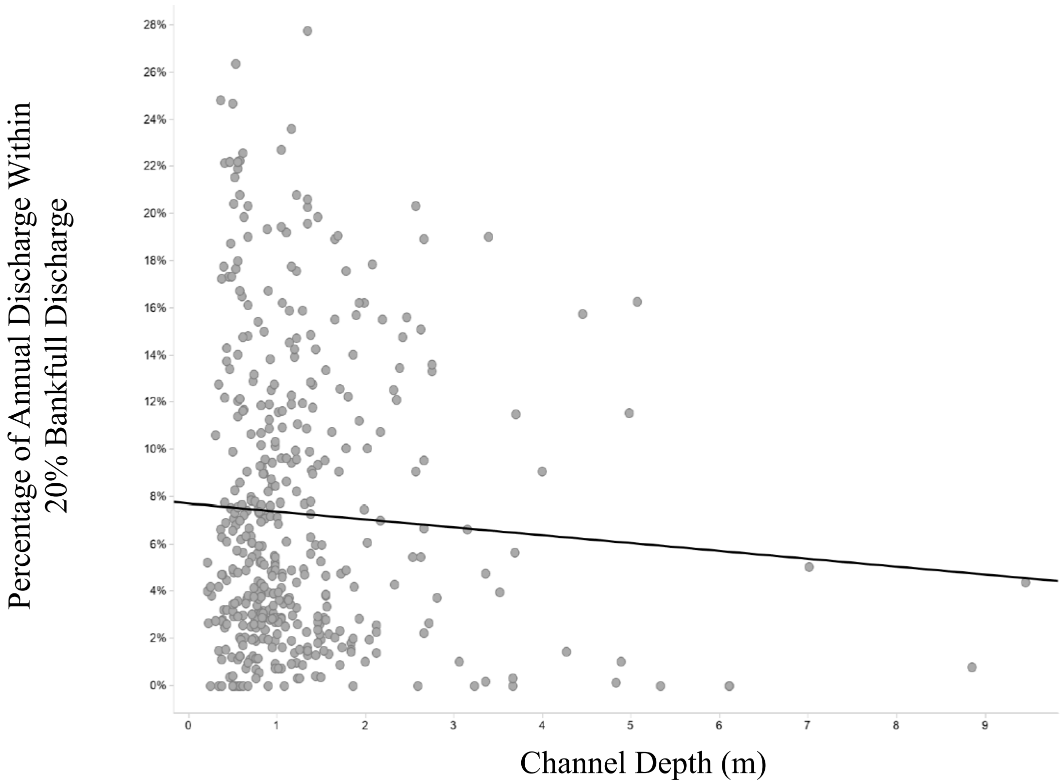
SITE_ID	**Köppen Climate**	**Total Discharge (m³)**	**Total Years of Discharge**	**Annual Average Discharge (m³)**	**20% tbd (Days)**	**Qbf (m³/s)**	**Average Daily Bankfull Discharge (m³)**	**Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)**	**Average % Annual Water Volume Discharged at Bankfull Flow**
12375900	Dfb	605,414,373.76	33	18,345,890.11	1.21212121	5.58	482,112.00	584,378.18	3.19%
12377150	Dfb	1,522,604,530.95	34	44,782,486.20	0.76470588	13.59	1,174,176.00	897,899.29	2.01%
12383500	Dfb	249,282,884.77	27	9,232,699.44	4.66666667	1.44	124,416.00	580,608.00	6.29%
12388400	Dfb	433,367,036.18	27	16,050,630.97	2.2962963	5.95	514,080.00	1,180,480.00	7.35%
13296500	Dfb	67,960,680,189.70	79	860,261,774.55	17.443038	101.95	8,808,480.00	153,646,651.14	17.86%
13297330	Dfb	650,890,122.44	44	14,792,957.33	5.63636364	3.88	335,232.00	1,889,489.45	12.77%
13297355	Dfb	1,292,709,906.55	44	29,379,770.60	11.1590909	4.36	376,704.00	4,203,674.18	14.31%
13316500	Dfb	42,586,851,466.05	62	686,884,701.07	17.8548387	92.58	7,998,912.00	142,819,283.61	20.79%
13333000	Dfb	193,806,276,146.84	72	2,691,753,835.37	17.3194444	316.05	27,306,720.00	472,937,220.00	17.57%
13336500	Dfb	289,015,805,667.69	87	3,322,020,754.80	14.6436782	534.12	46,147,968.00	675,775,991.17	20.34%
05CC002	Dfc	85,462,956,576.00	56	1,526,124,224.57	0.26785714	948.61	81,959,904.00	21,953,545.72	1.44%
05DB001	Dfc	19,668,064,896.00	24	819,502,704.00	0	750.4	64,834,560.00	0.00	0.00%
05DC001	Dfc	113,220,435,744.00	26	4,354,632,144.00	0	3058.22	264,230,208.00	0.00	0.00%
06714800	Dfc	68,230,965.18	5	13,646,193.04	8.4	3.1	267,840.00	2,249,856.00	16.49%
07083000	Dfc	1,830,822,803.68	70	26,154,611.48	7.24285714	6.2	535,680.00	3,879,853.71	14.83%
07086500	Dfc	2,899,843,177.02	48	60,413,399.52	0.77083333	23.6	2,039,040.00	1,571,760.00	2.60%
07AG001	Dfc	26,108,281,152.00	21	1,243,251,483.43	0	2222.87	192,055,968.00	0.00	0.00%
07BB002	Dfc	22,137,578,035.20	34	651,105,236.33	0.94117647	382.28	33,028,992.00	31,086,110.12	4.77%
08KA004	Dfc	207,005,466,240.00	15	13,800,364,416.00	10.2	1950	168,480,000.00	1,718,496,000.00	12.45%
09035700	Dfc	1,825,852,030.92	51	35,801,020.21	3.68627451	12.8	1,105,920.00	4,076,724.71	11.39%
09035900	Dfc	1,528,054,587.07	51	29,961,854.65	2.58823529	9.7	838,080.00	2,169,148.24	7.24%
09036000	Dfc	7,397,935,867.12	83	89,131,757.44	7.55421687	23.7	2,047,680.00	15,468,618.80	17.35%
13185000	Dsa	111,653,308,585.64	105	1,063,364,843.67	25.4571429	94.65	8,177,760.00	208,182,404.57	19.58%
13200000	Dsa	16,021,151,083.04	66	242,744,713.38	20.5909091	26.39	2,280,096.00	46,949,249.45	19.34%

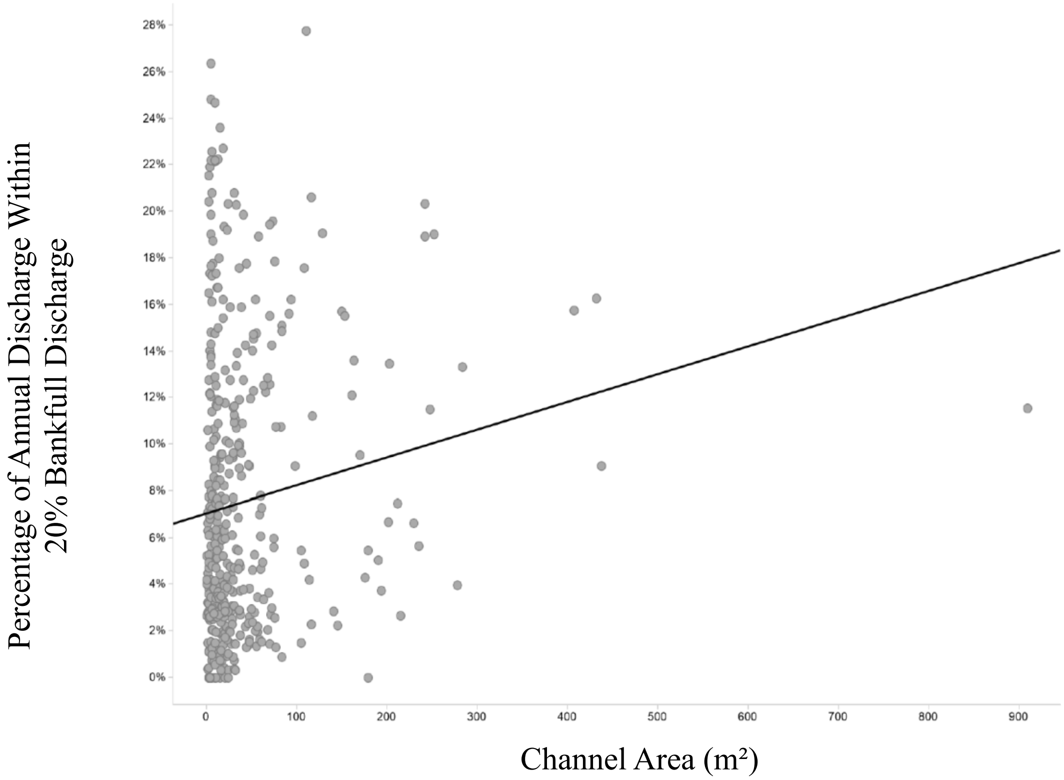
SITE_ID	Köppen Climate	Total Discharge (m³)	Total Years of Discharge	Annual Average Discharge (m³)	20% tbd (Days)	Qbf (m³/s)	Average Daily Bankfull Discharge (m³)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m³)	Average % Annual Water Volume Discharged at Bankfull Flow
13258500	Dsa	43,023,583,723.19	77	558,747,840.56	33.0909091	37.58	3,246,912.00	107,443,269.82	19.23%
13266000	Dsa	93,344,031,948.33	102	915,137,568.12	18.0980392	113.73	9,826,272.00	177,836,256.00	19.43%
13337000	Dsa	218,873,906,658.48	87	2,515,792,030.56	7.6091954	515.14	44,508,096.00	338,670,799.45	13.46%
13338500	Dsa	45,446,934,675.33	52	873,979,512.99	9.82692308	152.79	13,201,056.00	129,725,761.85	14.84%
13339500	Dsa	11,063,915,331.26	38	291,155,666.61	14.4210526	37.13	3,208,032.00	46,263,198.32	15.89%
12414500	Dsb	199,008,553,284.68	96	2,073,005,763.38	10.8125	348.34	30,096,576.00	325,419,228.00	15.70%
12414900	Dsb	15,744,232,338.02	50	314,884,646.76	6.08	57.8	4,993,920.00	30,363,033.60	9.64%
12447200	Dsb	135,440,163,799.70	50	2,708,803,275.99	16.46	362.5	31,320,000.00	515,527,200.00	19.03%
12449500	Dsb	77,960,494,562.00	62	1,257,427,331.65	4.98387097	327.66	28,309,824.00	141,092,509.93	11.22%
12452800	Dsb	19,934,992,585.54	59	337,881,230.26	14.5932203	54.37	4,697,568.00	68,552,644.88	20.29%
12479500	Dsb	115,451,317,281.85	73	1,581,524,894.27	50.9863014	99.69	8,613,216.00	439,156,026.74	27.77%
13186000	Dsb	46,956,411,319.42	71	661,357,905.91	19.9295775	68.14	5,887,296.00	117,331,321.69	17.74%
13235000	Dsb	56,663,469,829.23	75	755,512,931.06	6.96	134.89	11,654,496.00	81,115,292.16	10.74%
13239000	Dsb	33,765,653,688.63	105	321,577,654.18	11.0380952	76.66	6,623,424.00	73,109,984.91	22.73%
13240000	Dsb	8,890,607,402.89	71	125,219,822.58	18.084507	11.16	964,224.00	17,437,515.72	13.93%
13310700	Dsb	19,708,176,567.04	42	469,242,299.22	12.6190476	81.5	7,041,600.00	88,858,285.71	18.94%
13311000	Dsb	728,943,384.54	32	22,779,480.77	0.8125	9.57	826,848.00	671,814.00	2.95%
13313000	Dsb	27,026,991,045.17	88	307,124,898.24	7.44318182	75.9	6,557,760.00	48,810,600.00	15.89%
13340600	Dsb	149,821,040,243.68	49	3,057,572,249.87	18.3061224	365.61	31,588,704.00	578,266,683.43	18.91%
13344500	Dsb	8,373,423,811.26	55	152,244,069.30	2.8	26.31	2,273,184.00	6,364,915.20	4.18%
14048000	Dsb	200,693,410,564.95	110	1,824,485,550.59	24.5727273	177.2	15,310,080.00	376,210,420.36	20.62%
14050000	Dsb	7,002,689,546.83	53	132,126,217.86	47.5849057	7.93	685,152.00	32,602,893.28	24.68%
06721500	ET	672,873,714.75	14	48,062,408.20	4.35714286	11.6	1,002,240.00	4,366,902.86	9.09%
09010500	ET	3,679,198,926.17	63	58,399,982.96	7.92063492	14.3	1,235,520.00	9,786,102.86	16.76%

SITE_ID	Köppen Climate	Total Discharge (m^3)	Total Years of Discharge	Annual Average Discharge (m^3)	20% tbd (Days)	Qbf (m^3/s)	Average Daily Bankfull Discharge (m^3)	Average Annual Total Discharge Within 20% of Bankfull Discharge (m^3)	Average % Annual Water Volume Discharged at Bankfull Flow
15896000	ET	58,433,457,286.45	45	1,298,521,273.03	0.24444444	2704	233,625,600.00	57,108,479.99	4.40%

APPENDIX VII: Relationships between percentage of average annual water discharged within 20% of bankfull flow and the individual spatial attributes of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area for all streams, excluding 6 outliers streams with drainage areas > 28,000 km², based on data availability. [m³/sec, cubic meters per second; m, meters]

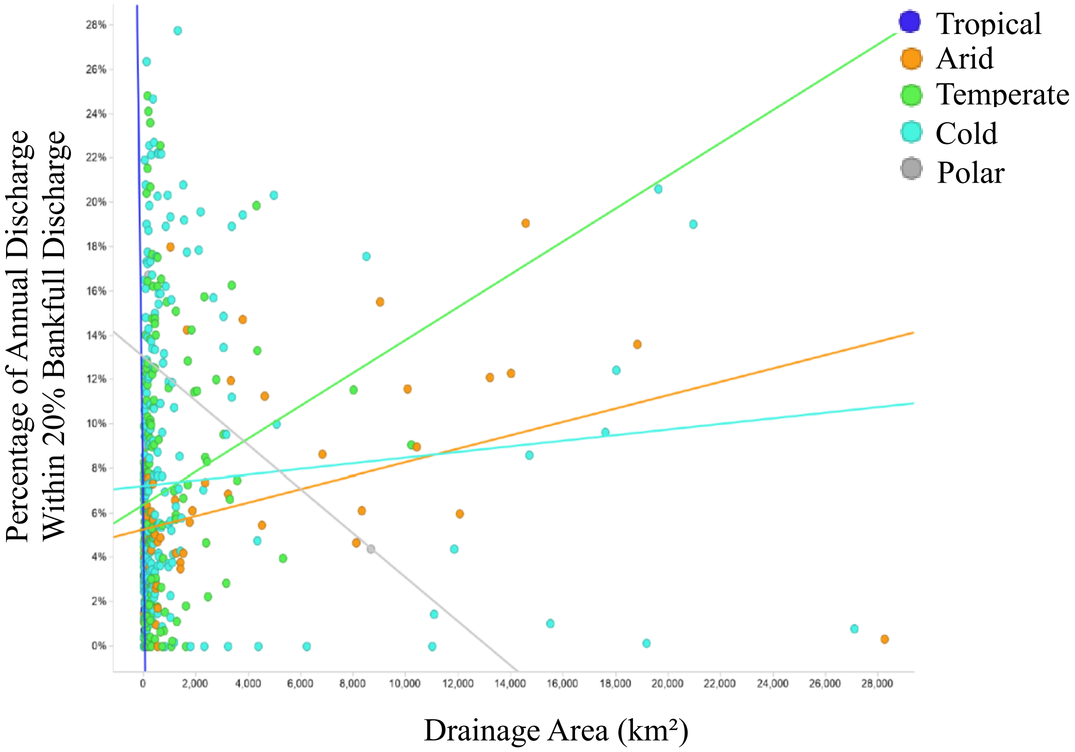


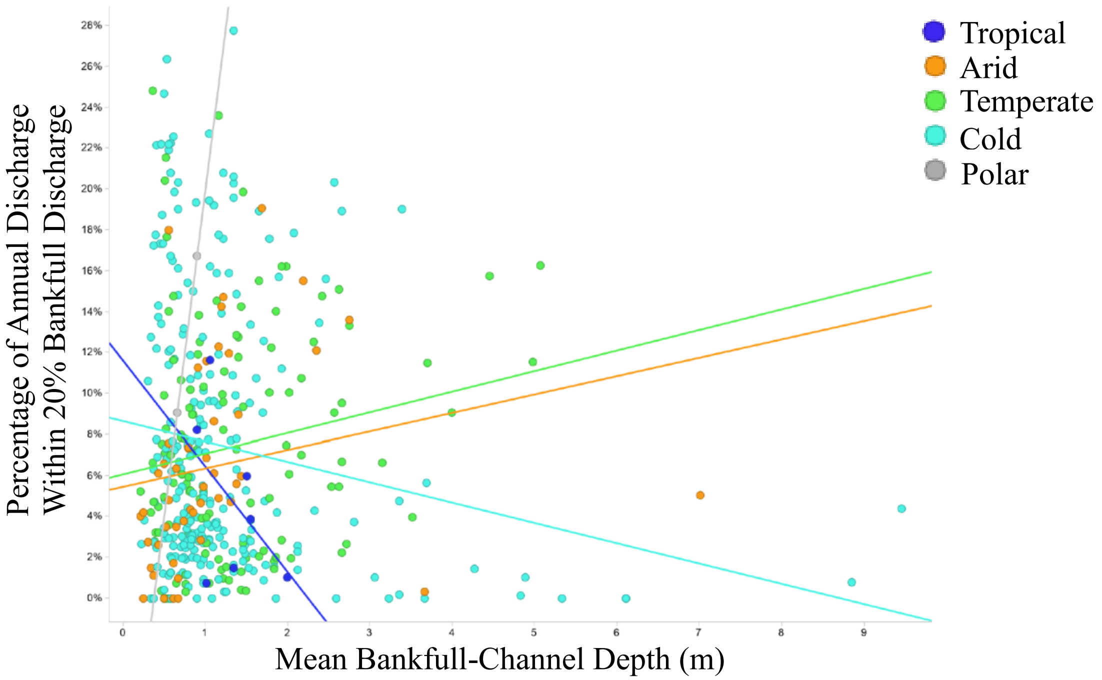


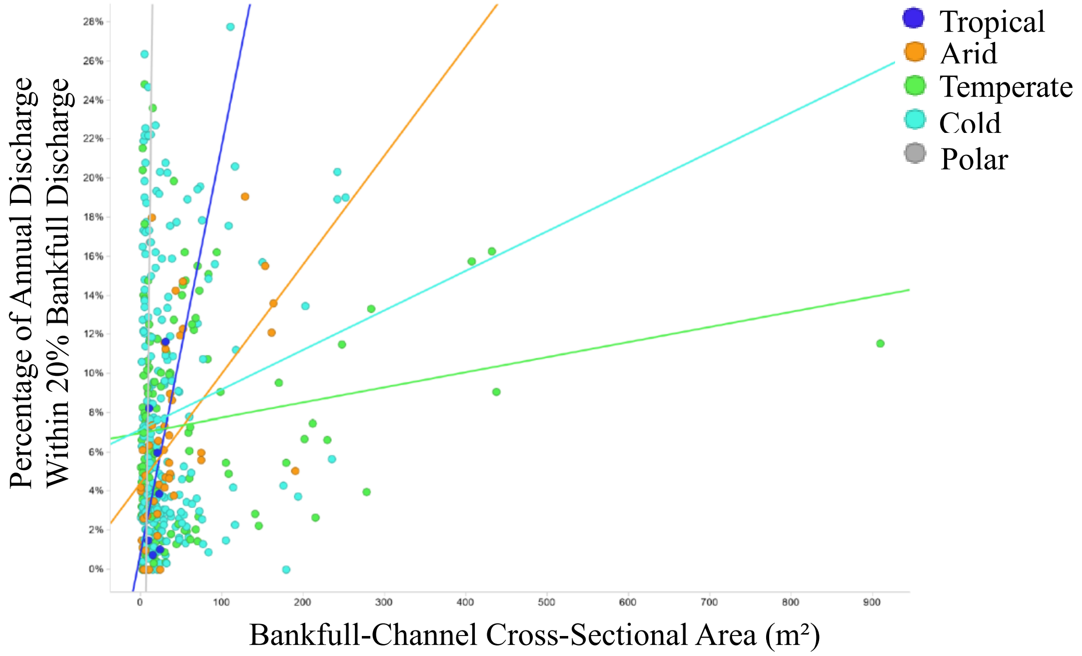


Channel Area (m²)

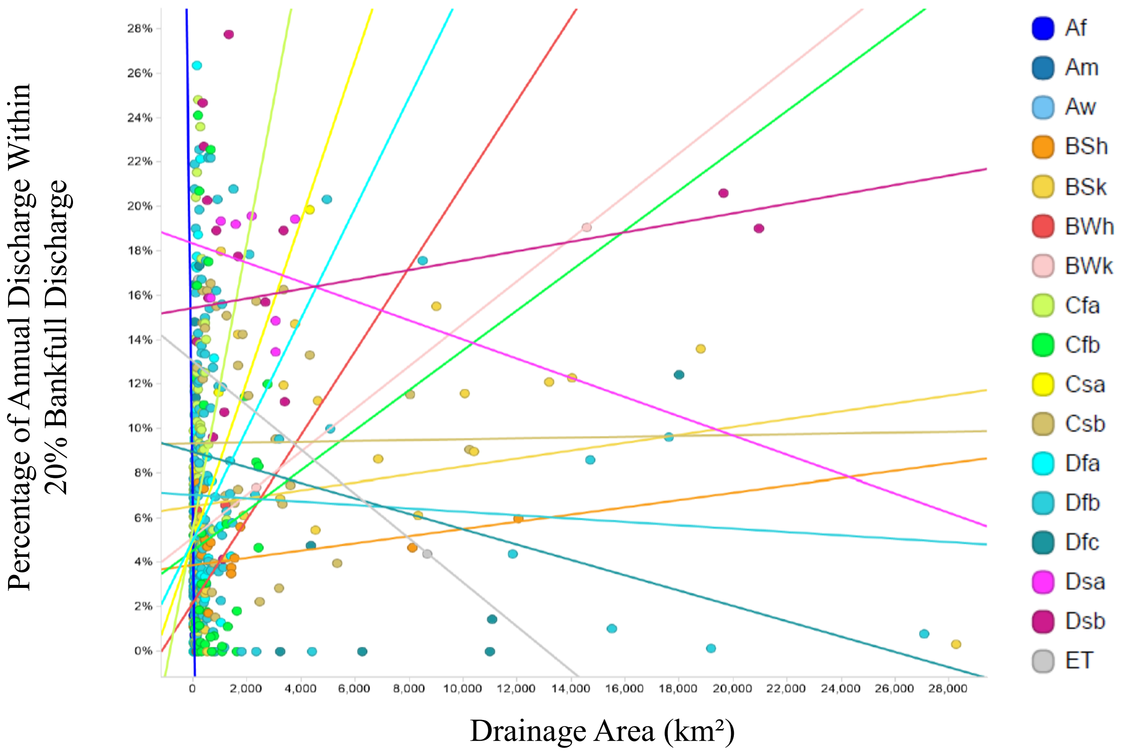
APPENDIX VIII: Relationships between percentage of average annual water discharged within 20% of bankfull flow and the individual spatial attributes of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area binned by major climate for all streams based on data availability. [m³/sec, cubic meters per second; m, meters * Excluding outlier streams with drainage areas > 28,000 km²]

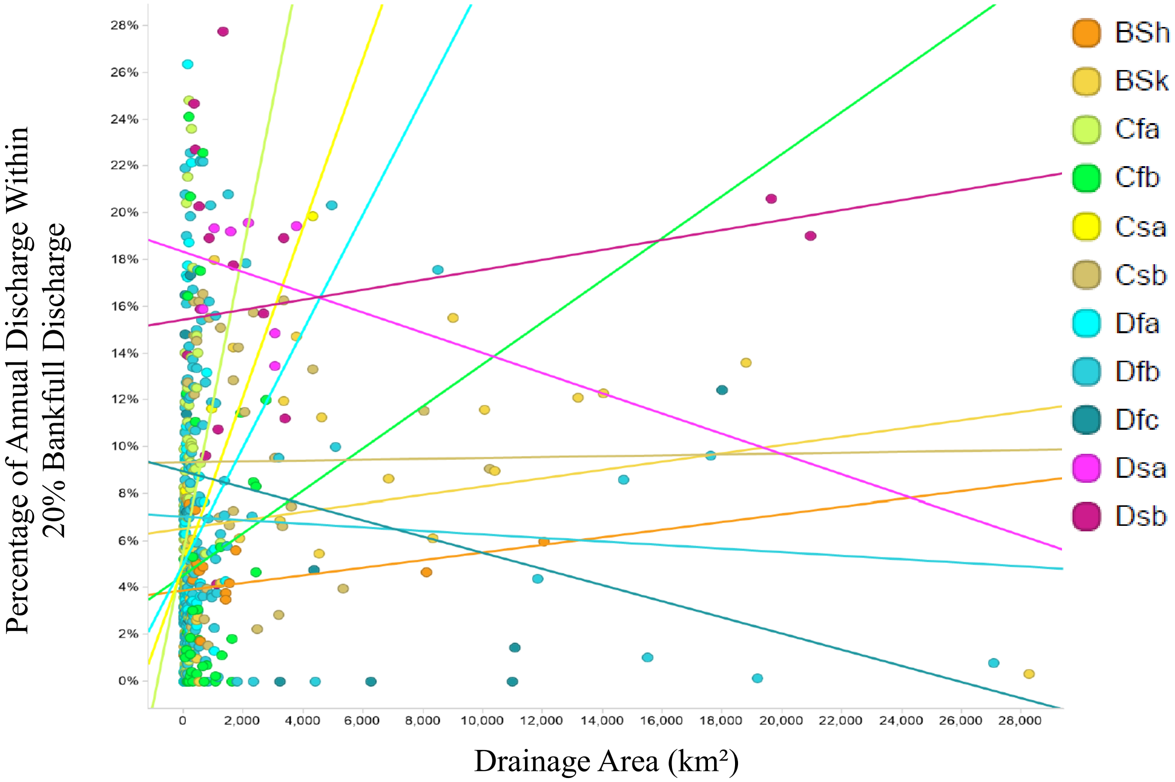


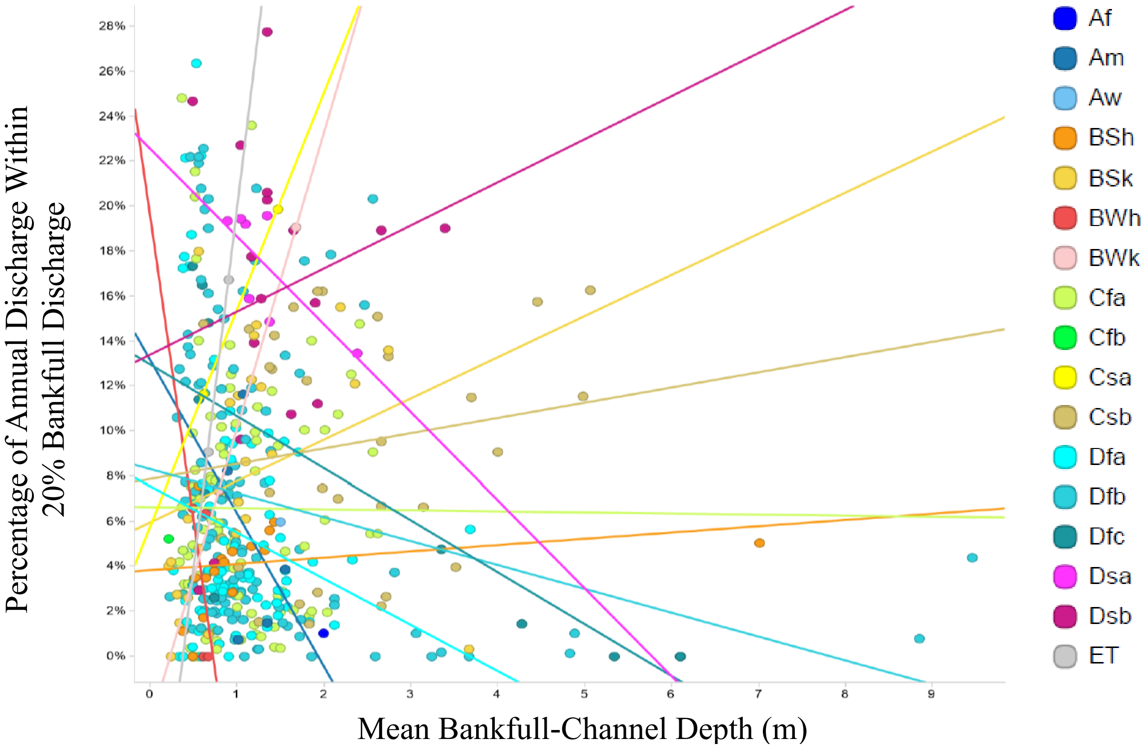

Tropical
Arid
Temperate
Cold
Polar
Percentage of Annual Discharge Within 20% Bankfull Discharge
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
7
8
9
Mean Bankfull-Channel Depth (m)


Tropical
Arid
Temperate
Cold
Polar
Percentage of Annual Discharge Within 20% Bankfull Discharge
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
100
200
300
400
500
600
700
800
900
Bankfull-Channel Cross-Sectional Area (m²)

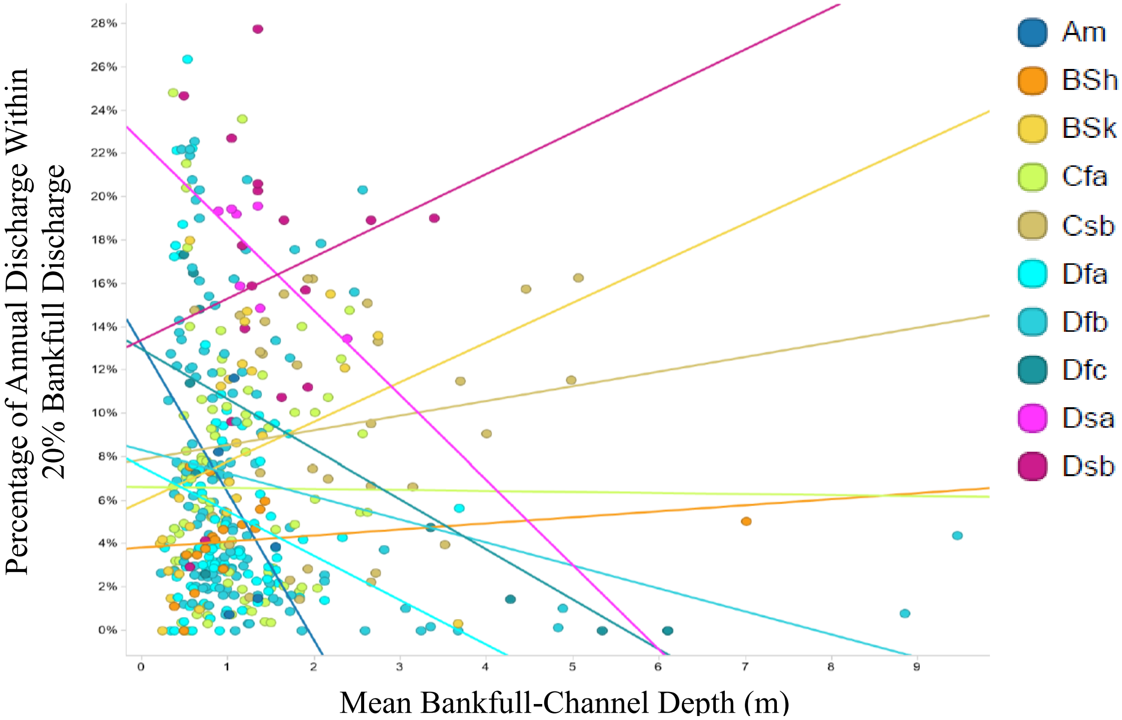
APPENDIX IX: Relationships between percentage of average annual water discharged within 20% of bankfull flow and the individual spatial attributes of drainage area, mean bankfull-channel depth and bankfull-channel cross-sectional area binned by Köppen climate for all streams based on data availability. [m^3/sec, cubic meters per second; m, meters * Excluding outlier streams with drainage areas > 28,000 km^2]



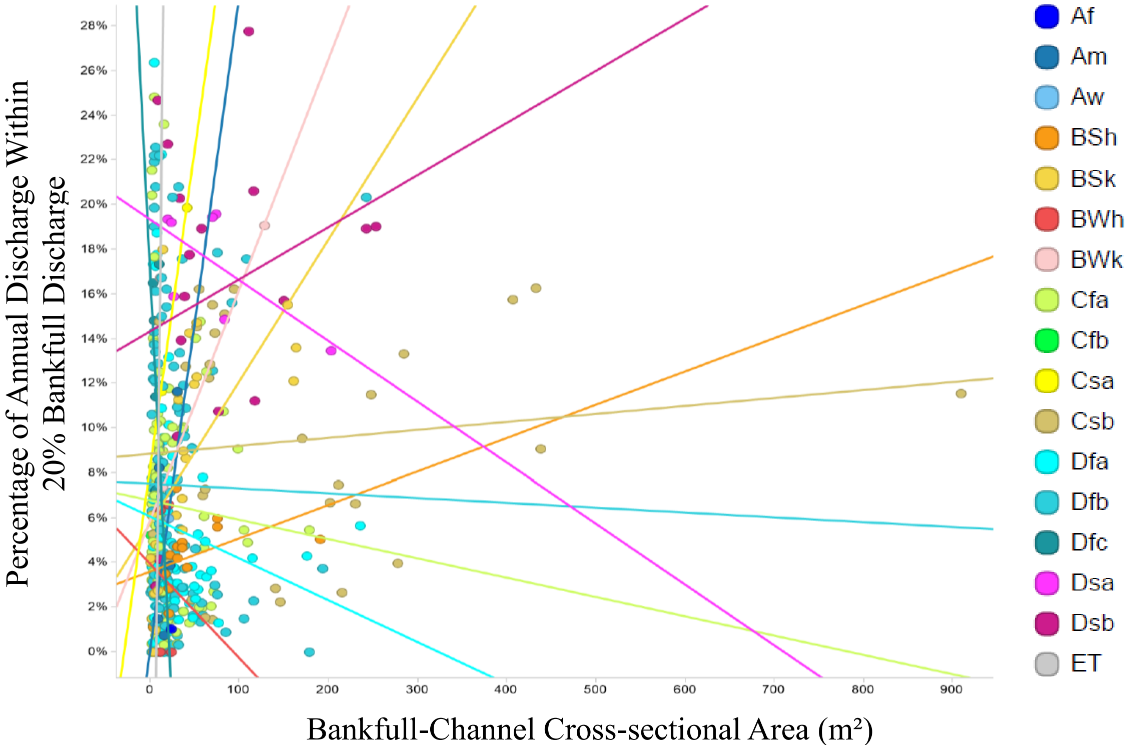


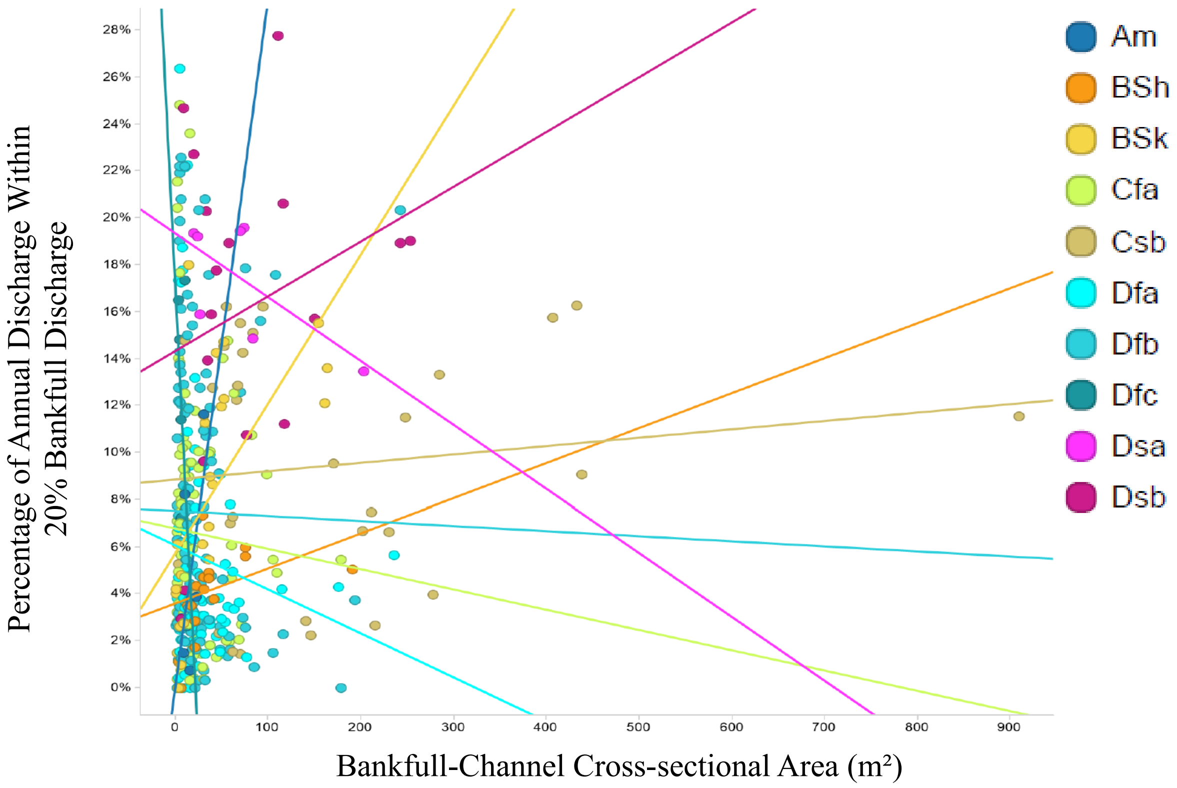


Only graphing climates with a minimum of 5 streams within the sample set.



Only graphing climates with a minimum of 5 streams within the sample set.





Only graphing climates with a minimum of 5 streams within the sample set.

APPENDIX X: Selected examples of daily discharge volumes by climate, discharges within 10% of bankfull indicated by grey coloration.

Climate: Tropical Monsoonal (Am)

Site ID: 26017040

Bankfull: 9.46 m^3/sec

Range Within 10% of Bankfull Discharge: 8.51-10.41 m^3/sec

Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
11/12/2004	3.07	12/18/2013	2.128
11/13/2004	28.3	12/19/2013	2.057
11/14/2004	10.62	12/20/2013	1.845
11/15/2004	8.51	12/21/2013	27.05
11/16/2004	23.37	12/22/2013	12.2
11/17/2004	10.32	12/23/2013	12.93
11/18/2004	9.56	12/24/2013	11.96
11/19/2004	9.56	12/25/2013	11.72
11/20/2004	5.79	12/26/2013	7.844
11/21/2004	4.53	12/27/2013	6.438
11/22/2004	3.84	12/28/2013	5.188

Climate: Tropical Rainforest (Af)

Site ID: 50064200

Bankfull: 39.70 m³/sec

Range Within 10% of Bankfull Discharge: 35.73-43.67 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
5/19/1969	1.36	9/13/1975	0.27
5/20/1969	20.42	9/14/1975	0.24
5/21/1969	98.26	9/15/1975	84.67
5/22/1969	2.86	9/16/1975	12.86
5/23/1969	2.12	9/17/1975	5.64
5/24/1969	2.29	9/18/1975	2.35

Site ID: 50063800

Bankfull: 61.50 m³/sec

Range Within 10% of Bankfull Discharge: 55.35-67.65 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
9/19/1998	2.75	11/10/2003	3.68
9/20/1998	1.98	11/11/2003	9.54
9/21/1998	67.39	11/12/2003	64.56
9/22/1998	47.57	11/13/2003	22.71
9/23/1998	4.28	11/14/2003	5.15
9/24/1998	2.27	11/15/2003	3.40

Climate: Semi-Arid hot (BSh)

Site ID: 09506000

Bankfull: 119.64 m^3/sec

Range Within 10% of Bankfull Discharge: 107.68- 131.60 m^3/sec

Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
4/9/1998	58.05	1/25/2013	5.38
4/10/1998	70.79	1/26/2013	5.92
4/11/1998	98.26	1/27/2013	143.28
4/12/1998	124.88	1/28/2013	294.49
4/13/1998	132.24	1/29/2013	80.42
4/14/1998	79.29	1/30/2013	27.21
4/15/1998	46.16	1/31/2013	18.26
4/16/1998	30.30	2/1/2013	14.92
4/17/1998	24.13	2/2/2013	13.39
4/18/1998	22.71	2/3/2013	12.63

Site ID: 09505350

Bankfull: 42.48 m^3/sec

Range Within 10% of Bankfull Discharge: 38.23- 46.73 m^3/sec

Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
9/28/1983	0.09	2/11/1995	1.76
9/29/1983	5.83	2/12/1995	1.42
9/30/1983	111.00	2/13/1995	13.25
10/1/1983	21.49	2/14/1995	142.15
10/2/1983	5.30	2/15/1995	111.57
10/3/1983	1.87	2/16/1995	20.13
10/4/1983	0.79	2/17/1995	10.05
10/5/1983	0.42	2/18/1995	6.23
10/6/1983	0.91	2/19/1995	5.10
10/7/1983	1.05	2/20/1995	4.73

Climate: Semi-Arid Cold (BSk)

Site ID: 09432000

Bankfull: 49.21 m³/sec

Range Within 10% of Bankfull Discharge: 44.29-54.1 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
8/18/1996	6.06	9/14/2013	40.78
8/19/1996	6.06	9/15/2013	122.61
8/20/1996	10.76	9/16/2013	317.15
8/21/1996	317.15	9/17/2013	190.86
8/22/1996	32.56	9/18/2013	134.50
8/23/1996	20.22	9/19/2013	70.79
8/24/1996	17.70	9/20/2013	52.39
8/25/1996	62.58	9/21/2013	46.44
8/26/1996	17.84	9/22/2013	43.89
8/27/1996	14.02	9/23/2013	38.51
8/28/1996	15.43	9/24/2013	32.85

Site ID: 06307600

Bankfull: 0.57 m³/sec

Range Within 10% of Bankfull Discharge: 0.51- 0.63 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
2/22/1990	0.14	3/3/2014	0.10
2/23/1990	0.57	3/4/2014	2.83
2/24/1990	1.42	3/5/2014	11.33
2/25/1990	3.96	3/6/2014	24.07
2/26/1990	8.47	3/7/2014	25.49
2/27/1990	6.12	3/8/2014	18.41
2/28/1990	2.46	3/9/2014	9.91
3/1/1990	1.33	3/10/2014	5.66
3/2/1990	0.91	3/11/2014	3.11
3/3/1990	0.65	3/12/2014	2.27
3/4/1990	0.51	3/13/2014	1.73
		3/14/2014	1.18
		3/15/2014	0.91
		3/16/2014	0.74
		3/17/2014	0.68
		3/18/2014	0.64
		3/19/2014	0.54
		3/20/2014	0.49

Climate: Temperate Without dry season Hot Summer (Cfa: Coastal)

Site ID: 02105900

Bankfull: 2.76 m^3/sec

Range Within 10% of Bankfull Discharge: 2.48- 3.04 m^3/sec

Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
10/20/1971	0.96	8/30/2006	0.15
10/21/1971	0.96	8/31/2006	7.76
10/22/1971	2.07	9/1/2006	58.05
10/23/1971	10.39	9/2/2006	21.86
10/24/1971	7.48	9/3/2006	8.61
10/25/1971	6.20	9/4/2006	4.76
10/26/1971	5.58	9/5/2006	2.97
10/27/1971	3.88	9/6/2006	4.96
10/28/1971	2.89	9/7/2006	4.56
10/29/1971	2.24	9/8/2006	2.46
10/30/1971	1.76	9/9/2006	1.47
10/31/1971	1.44	9/10/2006	0.96
11/1/1971	1.25	9/11/2006	0.67
11/2/1971	1.08		

Site ID: 01491000

Bankfull: 19.52 m^3/sec

Range Within 10% of Bankfull Discharge: 17.57-21.47 m^3/sec

Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
12/13/1996	10.14	4/2/2005	10.73
12/14/1996	92.03	4/3/2005	51.25
12/15/1996	106.47	4/4/2005	33.98
12/16/1996	38.79	4/5/2005	16.34
12/17/1996	21.21	4/6/2005	10.85
12/18/1996	17.36	4/7/2005	8.18
12/19/1996	16.34	4/8/2005	43.32
12/20/1996	17.50	4/9/2005	50.40
12/21/1996	14.16	4/10/2005	21.18
12/22/1996	10.76	4/11/2005	14.05

Climate: Temperate Without dry season Hot Summer (Cfa: Non-Coastal)

Site ID: 03293000

Bankfull: 14.98 m³/sec

Range Within 10% of Bankfull Discharge: 13.48- 16.48 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
2/16/2000	0.99	4/29/2010	0.42
2/17/2000	0.76	4/30/2010	0.29
2/18/2000	31.71	5/1/2010	3.85
2/19/2000	11.89	5/2/2010	30.58
2/20/2000	3.11	5/3/2010	6.97
2/21/2000	1.87	5/4/2010	2.60
2/22/2000	1.42	5/5/2010	1.52
2/23/2000	1.05	5/6/2010	1.02
2/24/2000	0.82	5/7/2010	0.77
2/25/2000	0.62	5/8/2010	1.11

Site ID: 03159540

Bankfull: 59.47 m³/sec

Range Within 10% of Bankfull Discharge: 53.52-65.42 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
4/9/1994	7.93	2/28/1997	4.02
4/10/1994	36.25	3/1/1997	58.62
4/11/1994	128.56	3/2/1997	291.66
4/12/1994	49.55	3/3/1997	187.46
4/13/1994	29.73	3/4/1997	99.11
4/14/1994	20.59	3/5/1997	33.13
4/15/1994	16.57	3/6/1997	17.92
4/16/1994	55.22	3/7/1997	10.62
4/17/1994	26.48	3/8/1997	7.25
4/18/1994	11.07	3/9/1997	5.75

Climate: Temperate Without dry season Warm Summer (Cfb)

Site ID: 14018

Bankfull: 146.47 m³/sec

Range Within 10% of Bankfull Discharge: 131.82-161.12 m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
1/21/1995	99.76	12/29/2013	73.51
1/22/1995	112.76	12/30/2013	102.08
1/23/1995	107.297	12/31/2013	136.329
1/24/1995	83.642	1/1/2014	156.12
1/25/1995	78.282	1/2/2014	155.066
1/26/1995	120.779	1/3/2014	148.489
1/27/1995	153.781	1/4/2014	142.97
1/28/1995	186.282	1/5/2014	130.109
1/29/1995	170.571	1/6/2014	115.26
1/30/1995	160.224	1/7/2014	107.63
1/31/1995	172.588	1/8/2014	96.898
2/1/1995	181.218	1/9/2014	96.403
2/2/1995	158.312	1/10/2014	91.185
2/3/1995	146.218	1/11/2014	78.51
2/4/1995	129.872	1/12/2014	69.366
2/5/1995	96.624	1/13/2014	67.086
2/6/1995	75.616	1/14/2014	63.985

Site ID: 08MH001

Bankfull: 275.00 m³/sec

Range Within 10% of Bankfull Discharge: 247.50-302.50m³/sec

Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
1/3/1914	25.5	12/25/1917	98.8
1/4/1914	52.4	12/26/1917	109
1/5/1914	207	12/27/1917	183
1/6/1914	566	12/28/1917	297
1/7/1914	453	12/29/1917	765
1/8/1914	368	12/30/1917	388
1/9/1914	309	12/31/1917	484
1/10/1914	235	1/1/1920	75.9
1/11/1914	130	1/2/1920	71.1
1/12/1914	109	1/3/1920	60.9

Climate: Cold Without dry season Warm Summer (Dfb)

Site ID: 01169900

Bankfull: 48.43 m³/sec

Range Within 10% of Bankfull Discharge: 43.59-53.27 m³/sec

Date	Mean Daily Discharge (m³/sec)
6/3/1982	1.19
6/4/1982	0.85
6/5/1982	4.73
6/6/1982	44.46
6/7/1982	12.88
6/8/1982	6.20
6/9/1982	3.79
6/10/1982	3.06
6/11/1982	2.61
6/12/1982	2.35

Site ID: 01AD003

Bankfull: 243.00 m³/sec

Range Within 10% of Bankfull Discharge: 218.70- 267.30 m³/sec

Date	Mean Daily Discharge (m³/sec)
4/23/2009	105.00
4/24/2009	157.00
4/25/2009	215.00
4/26/2009	260.00
4/27/2009	295.00
4/28/2009	288.00
4/29/2009	253.00
4/30/2009	223.00
5/1/2009	192.00

Climate: Cold Dry Summer Warm Summer (Dsb)

Site ID:12414500

Bankfull: 348.34 m³/sec

Range Within 10% of Bankfull Discharge: 313.51-383.17 m³/sec

Date	Mean Daily Discharge (m³/sec)
5/19/1999	191.14
5/20/1999	213.23
5/21/1999	212.66
5/22/1999	231.91
5/23/1999	262.78
5/24/1999	339.80
5/25/1999	436.08
5/26/1999	438.91
5/27/1999	353.96
5/28/1999	336.97
5/29/1999	339.80
5/30/1999	314.32
5/31/1999	278.35
6/1/1999	275.24
6/2/1999	276.37
6/3/1999	275.81
6/4/1999	251.45
6/5/1999	240.41
6/6/1999	233.90
6/7/1999	210.96
6/8/1999	194.25

Site ID:14048000

Bankfull: 177.20 m³/sec

Range Within 10% of Bankfull Discharge: 159.48-194.92 m³/sec

Date	Mean Daily Discharge (m³/sec)
4/3/2016	109.59
4/4/2016	122.05
4/5/2016	144.13
4/6/2016	162.54
4/7/2016	152.63
4/8/2016	144.70
4/9/2016	154.04
4/10/2016	176.98
4/11/2016	196.80
4/12/2016	202.18
4/13/2016	193.69
4/14/2016	189.44
4/15/2016	180.09
4/16/2016	168.48
4/17/2016	151.78
4/18/2016	134.50
4/19/2016	124.31
4/20/2016	124.59

VITA

Nicole Oma Wilson was born in the Blue Ridge Mountains of Virginia on August 18, 1985. She graduated from Spotswood High School in 2003 with honors. She earned her Bachelor of Science in Geology from University of Texas at Arlington, where she served as president of Sigma Gamma Epsilon and graduated summa cum laude in December 2012.

After completing her undergraduate degree Nicole began her career in geological data at TGS-NOPEC, first as a well header technician and later as supervisor over the TGS Longbow production product. In October 2014 she joined RigData in Fort Worth as their Data Acquisition Manager. Nicole returned to graduate school to accomplish her long held goal of becoming a geologist in August 2016. During her time at TCU she served as president of the TCU AAPG student chapter and was captain of the TCU IBA team placing 3rd in the Southwest Section Semi-finals.

Upon graduating from Texas Christian University, she will be joining Apache Corporation in Midland, Texas as a geologist. She is the wife of Brandon Wilson and the mother of two cats, Huckleberry and Mitch Wilson.

ABSTRACT

TUNING BANKFULL FLOW TO CLIMATE AS A PATH TO BETTER ESTIMATES OF SOURCE-TO-SINK MASS FLUX

By Nicole O. Wilson, M.S., 2018
Department of Geology
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Thesis Advisor: John Holbrook, Professor

Quantifying source-to-sink sediment flux for stratigraphic systems is critical for accurate basin models, but all available methods are hampered by low precision and most require data not readily attained. The Fulcrum approach uses commonly collected data but similarly yields only approximate flux estimates. In order to calculate a more precise source-to-sink estimate for long basin durations, the amount of time the fluvial systems runs at bankfull flow and the annual proportion of sediment discharged during this bankfull flow must be determined. By categorizing fluvial systems by attributes such as drainage area and paleoclimate at the time of discharge, a more specified and accurate bankfull flow duration and total bankfull discharge is estimated. We constructed a database that stores and categorizes these data and a user interface to query and display this data. The database can thus yield a more accurate value for duration and discharge at bankfull flow from modern rivers to be used as an analogue for stratigraphic rivers with interpreted climate and size parameters.