University of Redlands

Assessment of Climate Change Scenarios on the Yukon River Basin

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

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The report of John Ngwembo Yembu is approved.

A handwritten signature in black ink, appearing to be 'Ruijin Ma', written over a horizontal line.

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Mark Kumler, Ph.D., Committee Chair

December 2012

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Abstract

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By

John Ngwembo Yembu

There are indications that the climate is going to experience drastic change in the future, as it has occurred in the past and is currently happening now. Climate simulations have shown some potential hydrologic effects of climate change in the Yukon River Basin due to changes in temperature and precipitation. The Yukon River Inter-Tribal Watershed Council currently does not utilize spatial software to manage, analyze, or produce maps of climate change scenarios in the Yukon River basin. It is important to create a geodatabase, determine differences in climate change scenarios, and calculate peak discharge rates in the different regions using geospatial techniques. Climate modeling is one of the best tools available to determine the trends in future climate. In this project, the temperature and precipitation differences for the 20th century (1980-1999) and mid-century (2040-2059), were determined with data from the National Center for Atmospheric Research (NCAR), Community Climate System Model (CCSM), indicating a future increase in temperature and precipitation. The U.S. Geological Survey regression equations, basin characteristics, and pythonWin were used to create a python script and tool to calculate peak discharge rates. The methods used in this project allow it to be easily adapted for future projects in the Yukon River Basin.

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List of Acronyms and Definitions

CCSM	Climate Community System Model
CFS	Cubic Feet per Second
GCM	General Circulation Model
GCM	Global Climate Model
GIS	Geographic Information Systems
GCM	Global Coupled Model
IDW	Inverse Distance Weighted interpolation
IPCC	Intergovernmental Panel on Climate Change
IPD	Information Product Definition
MIDL	Master Input Data List
NCAR	National Center for Atmospheric Research
NAD	North America Datum
Q2	Two-Year Returns Period
Q25	Twenty Five-Year Returns Period
Q50	Fifty -Year Returns Period
UML	Unified Modeling Language
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
YRB	Yukon River Basin
YRITWC	Yukon River Inter-Tribal Watershed Council

Chapter 1 – Introduction

Climate simulations have shown some potential hydrologic effects of climate change on the Yukon River Basin (YRB) in forms of changes in temperature and precipitation. Projected increases in temperature will likely lead to a rise in runoff which might be balanced by an increase in evaporation (Hay & Gregory, 2010). There had been great attention in climate change since early times revealing that climate change is not restricted only to the past but it is taking place on time scales with impact on human activities (Neelin, 2011).

The third longest river in North America, flowing through northern British Columbia and Alaska is the Yukon River; it has a length of 3185 kilometers and a watershed drainage area of 840,000 square kilometers (Services PR, 1997).

Figure 1-1: Location of the Yukon River Basin in Canada and Alaska

1.1 Client

Ryan Toohey was the client for this project. In that capacity, he was able to provide direct links to data sources, as well as data collected by the Yukon River Inter-Tribal Watershed Council (YRITWC). He specified requirements for a mapping application to analyze and visualize the climate data. He was also there to direct the research, clarify methodologies, and answer questions about the study area. He reviewed progress and suggested changes or corrections to deliverables.

YRITWC is an indigenous grass roots organization and collaborative partner of the United States Geological Survey (USGS). It is an international organization with 501(c)

(3) non-profit status in the United States and Societal Status in Canada. It is a coalition of sovereign tribal and First Nation governments, founded in 1997 by a group of 56 chiefs and elders who gathered in Galena, Alaska, to discuss their concerns about increased cancer and other health problems in human communities and game species within the Yukon River watershed. The long-term vision for the organization was articulated by the tribal leaders at the historic 1997 summit that birthed the Watershed Council: to once again drink clean water directly from the Yukon River as their ancestors had for thousands of years (YRITWC, 2005).

1.2 Problem Statement

The YRITWC currently does not utilize spatial software to manage, analyze, and produce maps of climate change scenarios in the Yukon River basin. Their data are currently stored in different file formats in an external hard drive, not in a geodatabase. The client needed to know how to determine climate change differences which will enable visualizing of climate change in Yukon River Basin, and also how to calculate peak discharges in the different regions of the Yukon River Basin. Therefore, the client needs a complementary analysis to help provide answers on: What are the climate change scenarios on the Yukon River Basin using geospatial techniques? How can peak discharge be determined in the Yukon River Basin? What will be the changes in climate in the Yukon River Basin in the future?

1.3 Proposed Solution

Three solutions were proposed in this study. The first solution was to create a geodatabase to make sure that the client data are stored in a spatial environment to enable analysis. The second solution was to calculate the peak discharge for the Yukon River basin. This will help to determine the rate of runoff in the different regions of Yukon River Basin. To address the third need of the client, climate change differences were calculated for periods of 1980-1999 and the 2040-2059 in ArcGIS with data from the National Center for Atmospheric Research (NCAR) Climate Community System Model (CCSM), designed to predict future climate forecast as well as provide further analysis on the open space climate change scenarios for the Yukon River Inter-Tribal Watershed Council.

The designed solution was to use Geographic Information Systems (GIS) to determine climate change differences for the 20th century (1980-1999) and mid-century (2040-2059), and to create a tool to calculate peak discharge rates. With this tool, the client was able to calculate peak discharge for the regions in the Yukon River Basin. The tool should be reusable in the future to calculate peak discharges on the Yukon River Basin for the mid-century (2040-2059) and end of century (2080-2099), with changes in basin characteristics. The code was written in pythonWin and a script tool was created from it in ArcGIS.

1.3.1 Goals and Objectives

The main goal for this project was to determine the differences between climate change scenarios in the Yukon River Basin.

The three main objectives were:

- To determine peak discharge in Yukon River Basin;
- To determine changes in peak discharge over time;
- To determine differences between climate change scenarios.

1.3.2 Scope

To be able to attain the client's goals, three major GIS components were developed and included in the project documentation, namely a GIS geodatabase, peak discharges, and a climate change difference. The GIS geodatabase was configured to store, organize, modify, and extract spatial data relevant to the Yukon River Basin and climate change analysis. The peak discharges were calculated using the USGS regression equations. The third GIS component, a climate change difference were calculated for 1980-1999 and 2040-2059. The project is limited to the Yukon River Basin.

1.3.3 Methods

To produce the major GIS components, several steps were involved. Geodatabase design involved extracting the main feature classes from the client's master data and data from NCAR, and normalizing the attribute tables. In addition, data manipulation and data conversion were performed from the feature classes to layer files. The user needs and requirements were considered in creating the geodatabase and calculating the peak discharge rates. Finally, the climate change anomaly was calculated in ArcGIS environment, using the NCAR Climate Community System Model (CCSM) to determine climate change difference for present, the 20th Century and the Mid-Century scenarios.

1.4 Audience

This document will be used by the 70 Alaska Native Tribes and Yukon First Nations that the YRITWC represents. It will be of interest to those who frequently work with climate data to assess climate change anomalies and prediction of future changes in climate. The science department manager for the YRITWC will use this document frequently to calculate peak discharge rates on the Yukon River Basin.

1.5 Overview of the Rest of this Report

The goal was to educate readers on the possibilities of GIS applications in climate change scenarios and discuss the methods applied. Chapter 2 will provide the background and literature review on climate change scenarios on the Yukon River Basin and climate change predictions. Chapters 3 and 4 will examine the system and database design for the GIS applications. These chapters will present information on the user needs and information products, as well as the data development methods used. Chapter 5 will deal with the implementation strategy applied. Chapter 6 will look at the results and analysis, and Chapter 7 will present conclusions.

Chapter 2 – Background and Literature Review

In order to effectively predict climate change at global, regional, and local levels, precise methods are imperative that will clearly assess its impacts by developing appropriate adaptation and mitigation guidelines (Giorgi, 2005). A lot has been done in handling the challenges of climate change by scientists and economists taking into account risks, costs, and also how future changes will look like (Nordhaus, 1994). Knox (2012) states “... one sees climate change as an urgent problem that threatens our planet; one does not. I want our president to place scientific evidence and risk management above electoral politics.” (Bloomberg, 2012) referenced Knox and added “... our climate is changing, and while the increase in extreme weather we have experienced in New York and around the world may or may not be the result of it, the risk that it might be-given this week’s devastation-should compel all elected leaders to take immediate action.”

2.1 Climate Change Prediction

Climate change will have a significant effect on water resources in many parts of the world, and in the future may lead to extreme weather conditions. Population increase has been identified as a significant barrier to sustainable use of water resources due to constant demand, which is posing challenges to climate in the present century. This effect is going to be more prominent in the developing countries which are always prone to water shortages (Jones J. , 1999). Determining the state of the atmosphere is essential in predicting how specific weather patterns evolve at different times of the day. There are many uncertainties and shortcomings, especially when it comes to predicting current climate. It will be a good idea that the end users should be aware of what is happening (Giorgi, 2005).

Climate change prediction requires effort to predict anthropogenic impacts on the environment, as well as natural phenomena that affect daily activities. A lot still has to be done at the level of mitigation strategies, government policy, international protocols, and conventions when making decisions in predicting climate change caused by human impact. The human dimension of climate science focuses on how the public interprets predictions, natural climate variations, and the usefulness of the information to countries or interest groups (Neelin, 2011).

2.2 Science and Climate Change

There are indications that the climate is going to experience drastic change in the future, as it has occurred in the past and is currently happening. Changes in environmental quality and climate will exact enormous effects on the quality of life especially with the rise in urbanization, industrialization, and pollution (Dangermond & Artz, 2010).

Considering anticipated changes in global climate and ecology, there are great indications that the effects will be very visible on human activities in the nearest future. Therefore, it is important to independently examine the consequences brought by anthropogenic activities (Dale, 1997). There have been variations in winter precipitation in western North America from projected climate warming, resulting from slight changes

in snow conditions which are influenced by changes in climate at macro and micro scales (Lapp, Bryne, Townshend, & Kienzle, 2005).

Studies have been carried out and indicated a steady rise of average surface temperatures, shifts in precipitation ranges, and other climatic happenings are the most significant means to confirmed changes in climate (The Intergovernmental Panel on Climate Change (IPCC, 2007). Lin, Hong, Wu, Wu, & Verburg (2007) indicated that "...land use change can be characterized by the complex interaction of behavioral and structural factors associated with demand, technological capacity, and social relations, which in turn affect demand and environmental capacity, as well as the nature of the environment in question" (p.111).

2.3 Modeling Climate Change

It is advisable to use climate models to predict future trends in climate, even though they have a high degree of uncertainty. There are a lot of uncertainties to determining future emissions, as changes will probably happen in technological development before the end of this century. To predict future occurrences in climate, the IPCC developed a set of scenarios that indicate future emissions ranging from changes in demographics to technology. The range of possible future scenarios can provide us with the best understanding of how the future climate will look (Boehnert, 2012).

In order to acquire data for weather forecasting, computer models are used that have sufficient speed with automatic techniques for data input, quality control, interpolation, and mining data points in sparsely covered regions. It is not possible for a climate model to precisely reproduce every detail of the real climate. For example different runs of the General Circulation Model may produce different temperature and rainfall values. Due to the complexity of models, it is difficult to determine the difference in performance; therefore it is important to get a close and realistic climate change result with little adjustments to an understanding showing why the system behaves as it does (Edwards, 2010).

2.4 USGS Regression Equation

Different statistical methods have been established. Regression analysis conducted on basin climate, physical characteristics, and peak flows in conterminous basins of Canada and Alaska helped determine the magnitude of floods on stream sites (Jones & Fahl, 1994).

Standardized statistical procedures have been used to collect data for surface water stations that provide information on peak stream flow magnitude estimates, for 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals. The physical characteristics, climate, and statistics of the drainage basins are necessary to develop equations that determine the peak stream flows at sites where little or no data have been collected (Curran, Meyer, & Tasker, 2003).

2.5 Community Climate Simulation System Models

In order to simulate climate scenarios, the community climate system model (CCSM) has four components, the atmosphere, ocean, sea ice, and land surface, is greatly utilized. It has been used by students, researchers, and scientists to study inter annual and decadal

inconsistency in the simulation of past climate systems, and to estimate changes in future anthropogenic climate. There are three versions of the CCSM, with version three presented to the climate community through the National Center for Atmospheric Research (NCAR) on June 23, 2004. It is good at producing realistic simulations over a wide range of spatial resolutions, climate change, variability, and supporting simulations lasting several millennia (Collins, et al., 2005).

For studies involving the natural variability of the climate system and its response to changes, general circulation models are usually used. To include chemical and biogeochemical processes in the future, the climate system model version one was developed as a comprehensive model of the climate system. The modeling system is made freely available to the general community by NCAR (Boville & Gent, 1998).

The second version of the CCSM was described as a 1000- control simulation of present climate accomplished without modifications of flux. Whenever the control simulation is above 150 years it provides or indicates small trends in the upper-ocean, sea ice, atmosphere, and land surfaces. Even though the deep ocean has meaningful and small trends, this cannot permit the control simulation to continue much further (Kiehl & Gent, 2004).

Edwards (2010) argued that “... Simulation models are based on physical theory, even though after atmospheric physics became adequate to the task early in the twentieth century, computational friction prevented serious attempts to simulate weather or climate mathematically. Weather forecasters built numerical models to calculate the atmosphere’s large scale motions and predict the weather. Climate scientists then used similar techniques to simulate the global climate for long periods. By changing the simulated forces and conditions, they also used models to predict how climate will change as human activity alters the composition of the atmosphere and other climate-related systems” (Edwards, 2010).

2.6 Climate Change and Water Resources

Watershed hydrology could be affected by vegetation types, soil properties, geology, terrain, climate, land use practices, and spatial patterns of interactions among these factors (Tomer & Schilling, 2009). There are indications of future warmer climate from a baseline dataset of water quality which served as an important frame of reference to assess future changes on the Yukon River Basin (Schuster, Bryan, & Nicole, 2010).

Hydrological models and GIS techniques are becoming more useful in determining rainfall and run off simulations and are able to predict floods, climate changes, and land use impacts on flooding. GIS techniques are more capable of determining hydrological parameters of terrain and digital elevation model (Bahremand & Smedt, 2008).

2.7 Summary

Climate change is the single largest environmental and humanitarian crisis of this century. Accurate climate change predictions are needed at the global and, more importantly, at regional and local scales. The United States Geological Survey has used

regression equations to estimate the magnitude of flood on streams in Alaska. Coming up with appropriate methods to determine how changes in climate would affect Yukon River peak discharge would be of great interest to the Yukon River Inter-Tribal Watershed Council.

Chapter 3 – Systems Analysis and Design

3.1 Problem Statement

The Yukon River Inter-Tribal Watershed Council currently does not utilize spatial software to manage, analyze, or produce maps of climate change scenarios on the Yukon River Basin. The client data are currently stored in different file formats in an external hard drive, rather than in a geodatabase. The client cannot determine difference in climate change to aid in visualizing climate change scenarios in the Yukon River Basin, and cannot determine the peak discharge rates in the different regions of the Yukon River Basin.

3.2 Requirements Analysis

The focus of this project was to create three major components: a geodatabase, peak discharge rates, and difference in climate change scenarios. The deliverables were created to allow the client or any other knowledgeable ArcGIS user to easily analyze, visualize, and edit data, calculate peak discharge rates, and predict climate change in the Yukon River Basin. The waterfall methodology was used in the original project plan, where requirements were gathered, reviewed, and implemented.

A requirements analysis was conducted to evaluate whether the proposed tool would meet the client's specific needs. It involved documenting use cases and information product descriptions, as well as creating a sample questionnaire. This was to identify and evaluate the functional and non-functional requirements of the project, which were specified by the client and incorporated into the project.

3.2.1 Functional Requirements

The functional requirements described the functions that the script tool had to do, specifically to calculate the peak discharges and to determine the differences between the two climate change scenarios. The client needed a geodatabase to store spatial data, determine differences between climate change scenarios, and predict peak discharges. This new information was presented in maps, charts and tabular format. The requirements for the tools are presented in Table 1.

Table 1. Functional Requirements

Requirement	Comments
File geodatabase storage	Created by the researcher
Current and future climate scenarios for Yukon River Basin	Climate Anomaly calculated in ArcGIS
Use two climate range years to determine current and future climate change	Choice of years: 20 th century or historic climate simulations (1980-1999) and high A2 scenario (2040-2059) Mid-Century average
Use existing climate data	NCAR CCSM
Climate difference	Determined by the researcher
Peak discharge rates	Calculated
Ability to print the map display	When needed

The client wanted a tool that could be easily used by a knowledgeable Arc GIS user to calculate peak discharge rates. The tool was designed to be modifiable and repeatable so that a user could update the data and the differences in climate change scenarios as needed.

3.2.2 Non-functional Requirements

The primary non-functional requirement was that the tool would work with new model output. The climate parameters had to be updateable because information in the Yukon River Basin is always changing. It is also possible that the client will need to determine peak discharges in other geographic areas. To accommodate the updated information, the tool should be automated and easy to operate. Therefore, the tool needed to handle different basin characteristics to meet these non-functional requirements. In addition, a geodatabase was necessary for data storage and organization to assist in the calculations and data maintenance.

Non-functional requirements focus on how the tool will perform these tasks. These included the usability, technical, operational, transitional, and legislative requirements that were developed from the use cases are presents in Table 2.

Table 2. Non-functional Requirements for the System

Type	Requirement	Description
Usability	Easy to use	Simple design
	Effectiveness	Users should be able to perform tasks accurately
	Efficiency	Users should be able to complete the tasks within a given time
Technical	ArcGIS Desktop 10. 0	The climate anomaly and python script applications were created using ArcGIS Desktop 10.0
	Data Storage	File geodatabase storage for climate difference, script and peak discharges
Operational	Script tool	Calculate peak discharges and display the results
Transitional	Data Conversion	Data were projected to NAD _1927 Alaska_Albers_Meters
	Testing	Peak discharge rates calculated and script run
	Demonstration	Information on how to run the script tool
	System Documentations	This includes a help document for the climate difference and script, metadata for the script tool, an instruction manual, and a project report
Legislative	Privacy Protection	Removing owner names associated with climate difference

Usability requirements focused on ease of use, effectiveness, and efficiency. There was the need for the geodatabase and script tool to efficiently generate the climate difference datasets, and peak discharge rates. It was also important to maximize user effectiveness in accomplishing these tasks.

Technical requirements focused on the layout and minimum software specifications. To be able to determine climate differences or create maps for display, the client needs ArcGIS Desktop 10.0. A geodatabase was necessary to organize and store the data, as well as to calculate climate differences and peak discharge. Since the geodatabase needed to have a flexible storage capacity without the need for multiple editors, a file geodatabase was used.

The main operational requirement of the system was the script tool. It allowed the client to set the initial basin characteristics, calculate peak discharge rates, and retrieve the results.

Transitional requirements focused on data conversion, testing, system demonstration and documentation. These were included in the requirements to ensure that the client would know how to use and maintain the tool. New data layers created were transformed into the Nad_1927_Alaska_Albers_Meters to stay in compliance with the client's projection standards. There were multiple climate difference datasets calculated and

scripts developed to ensure that the functional and non-functional requirements were met. A brief demonstration of the tool was also provided to the client, along with accompanying documentation. These documents included a DVD with all the necessary data, a help document for the climate anomaly and script, and a complete project report.

To comply with legislative requirements, all owner names that were associated with the climate data were removed from the geodatabase to maintain anonymity.

3.3 System Design

System design took the client's functional and non-functional requirements into consideration. The script tool was designed to be accessed from a computer with ArcGIS 10.0 having a geodatabase configured for data storage. The geodatabase and the script tool are the primary elements of the system design as shown in Figure 3-1.

Figure 3-1: System Architecture

PythonWin needs to be installed to develop the Python scripts that are necessary for the calculation of peak discharges. The data that were required to meet the goals of the Yukon River Inter-Tribal Watershed Council were temperature, precipitation, drainage areas, areas of lakes and ponds, basin elevations, linkage design component, and area of forest. Within the geodatabase the data were divided into four feature datasets; namely climate, hydrology, natural features, and physical features. The design of the geodatabase allows the client to insert other datasets that may be useful in future work. The calculation of climate differences was done solely with ArcGIS; the tool to calculate the peak discharge values was created in Python script.

3.4 Project Plan

The client needed a geodatabase and climate change datasets at the beginning of the project. It was during the course of the project that the need for a tool to calculate peak discharge values was added.

3.4.1 Original Plan

The project phases include project define, project plan, project execute, project control, and project close. The phases were comprised of tasks “T” and milestones “M”. The original plan involved the development of two deliverables a geodatabase and a climate difference. The geodatabase was designed for the storage of all relevant climate datasets for the YRITWC, and also provided information on climate change difference presented in Table 3.

Table 3. Initial Project Plan

Phase	Task	Start	End	Duration (days)
1	Define	2/7/2012	3/3/2012	26
T	Project Selection	2/7/2012	2/11/2012	4
T	Project Approval	2/7/2012	2/10/2012	4
T	Develop a Project Proposal	3/2/2012	3/25/2012	22
M	Present Project Proposal to Client	3/19/2012	3/19/2012	-
2	Plan	4/3/2012	5/16/2012	45
T	Data Collection	4/3/2012	4/22/2012	20
T	Assess User Needs	4/4/2012	4/9/2012	6
T	Develop Information Products	4/10/2012	4/25/2012	16
T	Assess User Requirements	5/1/2012	5/16/2010	16
3	Execute	5/17/2012	9/30/2012	107
T	Develop Geodatabase	5/17/2012	5/26/2012	10
T	Create/Update Metadata	5/17/2012	6/27/2012	11
M	Submit Database Design for Review	6/4/2012	6/4/2012	-
T	Calculate Climate Anomalies	6/24/2012	7/24/2012	30
T	Calculate Discharge	7/25/12	9/30/12	68
T	Create Script	7/25/12	9/30/12	68
4	Monitor	10/1/2010	11/22/12	51
T	Test Design/ Functions	10/2/2012	10/10/2012	9
M	Design Release to Client	10/15/2012	10/15/2012	-
T	Revisions	10/15/2012	10/25/2012	11
T	Test Design/ Functions	10/25/2012	10/3/2012	6
M	Design Release to Client	11/5/2012	11/3/2012	-
T	Revisions	11/5/2012	11/10/2012	5
T	Finalize Model Deliverables	11/10/2012	11/22/2012	13
T	Finalize Project Documentation	10/2/2012	11/22/2012	51
5	Close	12/3/2012	12/11/2012	10
M	Present Project	11/30/2012	11/30/2012	-
T	Deliver Project Solution to Client	12/3/2012	12/11/2012	10

3.4.2 Revised Plan

The revised scope included the calculation of peak discharge values. This change affected the starting time for each phase. To complete the planning phase, new information products, user needs, and system requirements were developed. The researcher had to search for new data for the calculation of peak discharge values, which were then preprocessed. The execution phase experienced some delay, as the feature classes within the geodatabase needed to be reprocessed, peak discharge values to be calculated, a script was written and climate differences calculated. Due to the addition of the requirement to calculate peak discharge values, the monitor phase was also extended. Despite all the time delays in many of the phases, the overall project completion date was not significantly changed.

Chapter 4 – Database Design

The project database design is discussed in this chapter which also explains the conceptual and logical data models. There follows a description of the data sources and data preparation procedures. The chapter concludes with an overall summary.

4.1 Conceptual Data Model

The conceptual model looks at an abstraction of real world entities and identifies the features, their attributes, and the relationships between them. The Unified Modeling Language (UML) was used to create the structure of the conceptual model for the project (Figure 4-1).

Figure 4-1: The Conceptual Data Model

The client needed climate change scenarios, peak discharges, and a geodatabase for the Yukon River Basin. These are divided into the following themes: temperature, precipitation, river basin, river, soils, vegetation and forest.

4.2 Logical Data Model

This step in the design process was to develop a logical data model, which describes the actual structure of the database. A file geodatabase was chosen for this project because of its capacity to store large amounts of data, multiple feature classes, and tables. The logical data model of this project contained two datasets: climate change and discharge. It

also included the associated feature datasets, feature classes, and tables. The logical data model (Figure 4-2) was created with the Unified Modeling Language.

Figure 4-2: Logical Data Model

4.3 Data Sources

The data for this project came from a variety of sources. The datasets were cleaned and organized in a geodatabase. The required datasets were enumerated and described in the Master Input Data List (MIDL) before the geodatabase was developed see Table 4.

Table 4. YRITWC Climate Change and Discharge MIDL

Data Set Name	Description	Data Type	Data Source	Data Processing (if available)
Yukon Boundary	Polygon feature class of the Yukon River Basin Boundary	Shape File	Provided by the client originally compiled by USGS	
Yukon Lakes	Polygon feature class of the Yukon River Basin	Shape File	Provided by the client originally compiled by USGS	
Sample Sites	Point feature class of the Yukon River Basin	Shape File	Provided by the client originally compiled by USGS	Projected to NAD_1927_Alaska_Albers_Meters
Sub	Polygon	Shape	Provided by the	Projected to

Data Set Name	Description	Data Type	Data Source	Data Processing (if available)
Watershed	feature class of the Yukon River Basin	File	client originally compiled by USGS	NAD_1927_Alaska_Albers_Meters
Yukon River	Line feature class that shows the river flowing across the Yukon Basin	Shape File	Provided by the client originally compiled by USGS	
Soils	Polygon feature class of the Yukon River Basin	Shape File	Provided by the client originally compiled by USGS	Projected to NAD_1927_Alaska_Albers_Meters
Towns	Point feature class of the towns in and around the Yukon River Basin	Shape File	Provided by the client originally compiled by USGS	
Forest	Polygon feature class of the Yukon River Basin	Shape File	http://www.cec.org/Page.asp .	Down load, project, interpolate, clipped to the study area, converted to polygon, and aggregate polygon
USGS Discharge Regions	Polygon feature class of Alaska and Conterminous Basins of Canada	Paper Hard Copy	USGS Water Resources Investigations Reports 93-4197	Scanned, georeference, digitized and Projected to NAD_1927_Alaska_Albers_Meters
Temperature	Polygon feature class of Yukon River Basin	Shape File	UCAR Website http://gisclimatechange.ucar.edu/	Down load, project, interpolate, clipped to the study area, and zonal statistics
Precipitation	Polygon feature class of Yukon River Basin	Shape File	UCAR Website http://gisclimatechange.ucar.edu/	Down load, project, interpolate, clipped to the study area, and zonal statistics

The client provided seven feature classes for the project area, which were originally compiled by the USGS from various sources and had varying degrees of documentation. The remaining four feature classes -temperature, precipitation, USGS discharge regions, and forest- needed to be collected and compiled.

4.4 Data Scrubbing and Loading

The datasets for this project covered a range of geographic areas with different projections. They needed to be cleaned before loaded into the database. The projection for this geodatabase was determined to be the NAD_1927_Alaska_Albers_Meters. This was chosen because the Yukon River Basin data were provided on this projection. For the purposes of this project, three feature classes – temperature, precipitation, and forest – were clipped to the Yukon boundary. Once the data preparation process was completed, the feature classes were loaded into the ArcGIS file geodatabase. In addition to feature classes clipped to the project area, the original feature classes were also loaded into the geodatabase for use in future projects as presented in Figure 4-3.

Figure 4-3: Final Geodatabase

4.5 Summary

The file geodatabase used for the project was discussed in this chapter. The conceptual model was used to identify the features and their attributes, and the relationships among them. The logical data model showed that the data used in this project were feature classes. This determined the schema type to be used in the geodatabase. The essential feature classes were compiled and loaded into a geodatabase. The client provided most of the feature classes which needed little processing before they were loaded into the geodatabase. The other feature classes were produced after being scanned, georeferenced, digitized, projected, interpolated, clipped to the project area, and processed.

Chapter 5 – Implementation

The Yukon River Basin climate change scenarios project tried to make spatial information more interpretable and the calculation of peak discharges straightforward for the client. The project utilized the ArcGIS software and PythonWin. The first process had to determine the changes in temperature and precipitation between the 1980-1999 period, known in the climate change community as the 20th Century, and the 2040-2059 period, known in the climate change community as the Mid-Century. The script tool was created, and the peak discharges were calculated. The peak discharge was determined for the Mid-Century period based on projected changes in minimum mean January temperature and mean annual precipitation.

5.1 Data Processing

This section describes the process of obtaining and processing the data for use in this project.

Figure 5-1: Project Implementation Work Flow

Figure 5-1 shows the general workflow of the implementation, and the rest of the chapter explains the workflow in detail.

5.1.1 Data Download and Projection

The datasets were derived from NCAR Community Climate System Model (CCSM), which is one of the most widely used global climate models. The CCSM was used with the 1980-1999 time period known in the climate community as the 20th Century, and the

High A2 scenario for the 2040-2059 time period known in the climate community as Mid-Century. The mean January temperature for both time periods was downloaded with specifications as illustrated in Figures 5-2 and 5-3 respectively.

Download NCAR Community Climate System Model (CCSM) projections in GIS formats

Step 1: Select Data Collection

☒ Global (1.4 degrees) [?](#)

☐ Continental U.S. (4.5 km) [?](#)

* Statistically Downscaled

Step 2: Select Climate Variable [?](#)

Air Temperature | TAS

Step 3: Select Model Simulation [Help Me Choose](#)

☒ 20th Century or Historical Climate Simulations (1870–1999) [?](#)

☐ IPCC Climate Change Commitment Scenario (2000–2099) [?](#)

☐ Medium A1B Scenario (2000–2099) [?](#)

☐ Low B1 Scenario (2000–2099) [?](#)

☐ High A2 Scenario (2000–2099) [?](#)

Step 4: Select Ensemble Member [Help Me Choose](#)

Ensemble Average

Step 5: Select Region of Interest

[SELECT REGION](#) [GLOBAL EXTENT](#)

Global dataset is the default. To extract data for a smaller region, please click Select Region box and draw a bounding box on the map.

West -178.9284

East -126.1941

South 45.661772

North 73.259052

Step 6: Select Temporal Resolution [Help Me Choose](#)

☒ Monthly Mean ☐ Annual Mean ☐ Long Term Average

Step 7: Select Time Period

Please select a month, start year and end year. You may select:

- One month and a range of years between 1870 to 1999.
- All months for a range of years between 1870 to 1999.*

* Interval may not exceed 80 years.

Month	Start Year	End Year
January	1980	1999

Step 8: Select File Type and Download [Help Me Choose](#)

☒ Shapefile ☐ Text File

Figure 5-2: Mean January Temperature for the 20th Century

Download NCAR Community Climate System Model (CCSM) projections in GIS formats

Step 1: Select Data Collection

☒ Global (1.4 degrees) [?](#)

☐ Continental U.S. (4.5 km) [?](#)

* Statistically Downscaled

Step 2: Select Climate Variable [?](#)

Air Temperature | TAS

Step 3: Select Model Simulation [Help Me Choose](#)

☐ 20th Century or Historical Climate Simulations (1870–1999) [?](#)

☐ IPCC Climate Change Commitment Scenario (2000–2099) [?](#)

☐ Medium A1B Scenario (2000–2099) [?](#)

☐ Low B1 Scenario (2000–2099) [?](#)

☒ High A2 Scenario (2000–2099) [?](#)

Step 4: Select Ensemble Member [Help Me Choose](#)

Ensemble Average

Step 5: Select Region of Interest

[SELECT REGION](#) [GLOBAL EXTENT](#)

Global dataset is the default. To extract data for a smaller region, please click Select Region box and draw a bounding box on the map.

West -178.9284

East -126.1941

South 45.661772

North 73.259052

Step 6: Select Temporal Resolution [Help Me Choose](#)

☒ Monthly Mean ☐ Annual Mean ☐ Long Term Average ☐ Climate Anomaly

Step 7: Select Time Period

Please select a month, start year and end year. You may select:

- One month and a range of years between 2000 to 2099.
- All months for a range of years between 2000 to 2099.*

* Interval may not exceed 80 years.

Month	Start Year	End Year
January	2040	2059

Step 8: Select File Type and Download [Help Me Choose](#)

☒ Shapefile ☐ Text File

Figure 5-3: Mean January Temperature for the Mid-Century

The mean annual precipitation for both time periods was downloaded with specifications as shown in Figures 5-4 and 5-5 respectively.

Download NCAR Community Climate System Model (CCSM) projections in GIS formats

Step 1: Select Data Collection

- ☒ Global (1.4 degrees) [?](#)
- ☐ Continental U.S. (4.5 km) [?](#)
- * Statistically Downscaled

Step 2: Select Climate Variable [?](#)

Total Precipitation | PPT ▼

Step 3: Select Model Simulation [Help Me Choose](#)

- ☒ 20th Century or Historical Climate Simulations (1870–1999) [?](#)
- ☐ IPCC Climate Change Commitment Scenario (2000–2099) [?](#)
- ☐ Medium A1B Scenario (2000–2099) [?](#)
- ☐ Low B1 Scenario (2000–2099) [?](#)
- ☐ High A2 Scenario (2000–2099) [?](#)

Step 4: Select Ensemble Member [Help Me Choose](#)

Ensemble Average ▼

Step 5: Select Region of Interest

SELECT REGION GLOBAL EXTENT

Global dataset is the default. To extract data for a smaller region, please click Select Region box and draw a bounding box on the map.

West

East

South

North

Step 6: Select Temporal Resolution [Help Me Choose](#)

☐ Monthly Mean ☒ Annual Mean ☐ Long Term Average

Step 7: Select Time Period

Please select a start year and end year between 1870 to 1999.

Start Year End Year

Step 8: Select File Type and Download [Help Me Choose](#)

☒ Shapefile ☐ Text File

[Download File](#)

Figure 5-4: Mean Annual Precipitation for the 20th Century

Download NCAR Community Climate System Model (CCSM) projections in GIS formats

Step 1: Select Data Collection

- ☒ Global (1.4 degrees) [?](#)
- ☐ Continental U.S. (4.5 km) [?](#)
- * Statistically Downscaled

Step 2: Select Climate Variable [?](#)

Total Precipitation | PPT ▼

Step 3: Select Model Simulation [Help Me Choose](#)

- ☐ 20th Century or Historical Climate Simulations (1870–1999) [?](#)
- ☐ IPCC Climate Change Commitment Scenario (2000–2099) [?](#)
- ☐ Medium A1B Scenario (2000–2099) [?](#)
- ☐ Low B1 Scenario (2000–2099) [?](#)
- ☒ High A2 Scenario (2000–2099) [?](#)

Step 4: Select Ensemble Member [Help Me Choose](#)

Ensemble Average ▼

Step 5: Select Region of Interest

SELECT REGION GLOBAL EXTENT

Global dataset is the default. To extract data for a smaller region, please click Select Region box and draw a bounding box on the map.

West

East

South

North

Step 6: Select Temporal Resolution [Help Me Choose](#)

☐ Monthly Mean ☒ Annual Mean ☐ Long Term Average ☐ Climate Anomaly

Step 7: Select Time Period

Please select a start year and end year between 2000 to 2099.

Start Year End Year

Step 8: Select File Type and Download [Help Me Choose](#)

☒ Shapefile ☐ Text File

[Download File](#)

Figure 5-5: Mean Annual Precipitation for the Mid-Century

The CCSM outputs contained information for each point about change in mean annual precipitation and mean January temperature for the 20th Century and the Mid-Century periods. The point data were re-projected into NAD_1927_Alaska_Albers_Meters, the coordinate system used in the Yukon River boundary dataset provided by the client.

5.1.2 Climate Data Conversion

This section describes the methods used in the data conversion to make it ready for use in this project. The attribute tables for the mean monthly temperature for the 20th Century and Mid-Century periods were joined and the differences were calculated using the field calculator. These were averaged into 20 yearly forecast grids. The differences in temperature were converted from degrees Kelvin to degrees Fahrenheit as shown in Figure 5-6.

Figure 5-6: Join Tables and Field Calculator on Temperature

The final step was to establish a baseline from the data. Baselines are historical norms or standards, based on a reference series of years. The prediction data were expressed as offsets of the NCAR Community Climate System Model (CCSM). Baselines are used in most climate change research; forecast values were often specified as offsets above or below a specified baseline.

The attribute tables for the mean annual monthly precipitation for the 20th Century and Mid-Century periods were joined and the differences calculated using the field calculator as illustrated in Figure 5-7.

Figure 5-7: Join Tables and Field Calculator on Precipitation

The mean monthly temperature and mean annual precipitation for the data points for the 20th Century and Mid-Century were transformed into a continuous grid (Figure 5-8) with the Inverse Distance Weighted (IDW) interpolation routine, as recommended by experts from NCAR.

Figure 5-8: Inverse Distance Weighted (IDW) for Temperature Difference

The mean monthly temperature and the mean annual monthly precipitation gridded datasets for the 20th Century and Mid-Century periods were clipped to the boundary of the Yukon River Basin as shown on Figure 5-9.

Figure 5-9: Clipped Temperature Difference

5.1.3 Temperature Range 20th Century and Mid-Century Scenarios

The temperature ranges for the 20th Century and the Mid-Century periods were determined. This was done using a field calculator, by subtracting the 20 year mean monthly temperature for the 20th Century from the mean monthly temperature for the Mid-Century. This produced raster datasets representing the climate differences between 20th Century and Mid-Century periods (Figure 5-10) shows the calculation using ArcGIS Field Calculator.

Figure 5-10: Calculating the Temperature Difference Dataset

5.1.3.1 Calculating the Temperature Change

The data to be symbolized are the differences between the most current climate values and the projected climate values downloaded from the Community Climate System

Model (CCSM). To reduce the year-to-year variability in climate, the averages were calculated for both 20 year periods as in Figure 5-11.

Figure 5-11: Calculating the Temperature Change Dataset

5.1.3.2 Temperature Difference for USGS Regions

Flood frequency region boundaries were compiled from a map in a USGS report on flood in the Alaska area as shown in 5-12.

Source: Jones and Fahl (1994)

Figure 5-12: Scanned Yukon River Basin regions from the USGS Alaska report

The regions were intersected with the river basin layer to divide the basin into three similar flood frequencies. Statistics for the temperature changes between the two periods

were calculated using the ArcGIS Zonal Statistics and Zonal Statistics as Table (see Figures 5-13 and 5-14).

Figure 5-13: Zonal Statistics tool used to calculate Temperature differences

Figure 5-14: Temperature Zonal Statistics as Table tool

5.2 Peak Discharge Calculation

Peak discharges were calculated for the Yukon River Basin for 2-, 25-, and 50- year return periods (Q2, Q2 and Q50), using the USGS equations and the script tool developed in this project.

5.2.1 USGS Regression Equations and Basin Characteristics

Estimated discharge values were calculated using complex regression equations developed by the USGS for each region. The equations required basin characteristics including: drainage area, mean annual precipitation, area of lakes and ponds, and elevation. Area of forest and mean minimum January temperature were added for region 5 as specified in the USGS report.

5.2.2 USGS Regression Equation and Basin Characteristics for Region

The complete equations used in calculating peak discharge for regions 3, 4, and 5 are presented in Equations 5-1 to 5-9.

Region 3:

$$Q2 = 16.2 A^{0.894} P^{0.949} (ST+1)^{-0.209} E^{-0.345} \quad (5-1)$$

$$Q25 = 112 A^{0.793} P^{0.588} (ST+1)^{-0.194} E^{-0.272} \quad (5-2)$$

$$Q50 = 147 A^{0.778} P^{0.544} (ST+1)^{-0.187} E^{-0.264} \quad (5-3)$$

Region 4:

$$Q2 = 3.58 A^{0.906} P^{0.891} (ST+1)^{-0.331} E^{-0.125} \quad (5-4)$$

$$Q25 = 1,699 A^{0.836} P^{0.917} (ST+1)^{-0.386} E^{-0.749} \quad (5-5)$$

$$Q50 = 4,323 A^{0.824} P^{0.936} (ST+1)^{-0.395} E^{-0.848} \quad (5-6)$$

Region 5:

$$Q2 = 418 A^{0.911} P^{1.342} (ST+1)^{-0.307} E^{-0.495} (F+1)^{-0.605} (J+32)^{-0.344} \quad (5-7)$$

$$Q25 = 46,460 A^{0.866} P^{1.083} (ST+1)^{-0.414} E^{-0.908} (F+1)^{-0.560} (J+32)^{-0.232} \quad (5-8)$$

$$Q50 = 90,720 A^{0.860} P^{1.031} (ST+1)^{-0.436} E^{-0.962} (F+1)^{-0.546} (J+32)^{-0.217} \quad (5-9)$$

Where:

A=Drainage Area in mi²

P= Mean Annual Precipitation in inches

ST = Area of Lakes and Ponds in percent

E = Mean Basin Elevation in feet

F=Area of Forest in mi²

J= Minimum Mean January Temperature in (°F)

5.2.3 Python Script Tools for Two Time Period

A Python script and a tool were developed for use in the calculation of peak discharges in the three flood frequency regions.

For each region, one Python script was created in PythonWin. These scripts were to execute the equations for two-year peak discharge (Q2), twenty five-year peak discharge (Q25), and fifty-year peak discharge (Q50), using the basin characteristics as inputs (see Figures 5-15, 5-16, and 5-17).

```
Region3
1 import arcpy
2 import math
3
4 # Create a function to calculate Discharge
5
6 def dischargeQ2(A, P, ST, E):
7     Q2=16.2*A**0.894*P**0.949*(ST+1)**-0.209*E**-0.345
8     return Q2
9
10 def dischargeQ25(A, P, ST, E):
11     Q25=112*A**0.793*P**0.588*(ST+1)**-0.194*E**-0.272
12     return Q25
13
14 def dischargeQ50(A, P, ST, E):
15     Q50=147*A**0.778*P**0.544*(ST+1)**-0.187*E**-0.264
16     return Q50
17
18 # Define Parameters/variables for Q2
19 area=float(arcpy.GetParameterAsText(0))
20 precipitation=float(arcpy.GetParameterAsText(1))
21 lakesArea=float(arcpy.GetParameterAsText(2))
22 elevation=float(arcpy.GetParameterAsText(3))
23
24 # Calculate discharge for Q2
25 discharge=dischargeQ2(area, precipitation, lakesArea,elevation)
26 arcpy.AddMessage("The discharge for Region 3 Q2 is: "+str(discharge))
27
28 # Calculate discharge for Q25
29 discharge=dischargeQ25(area, precipitation, lakesArea,elevation)
30 arcpy.AddMessage("The discharge for Region 3 Q25 is: "+str(discharge))
31
32 # Calculate discharge for Q50
33 discharge=dischargeQ50(area, precipitation, lakesArea,elevation)
34 arcpy.AddMessage("The discharge for Region 3 Q50 is: "+str(discharge))
35
```

Figure 5-15: Python Script for Region 3

```

Region4
1 import arcpy
2 import math
3
4 # Create a function to calculate Discharge
5
6 -def dischargeQ2(A, P, ST, E):
7     Q2=3.58*A**0.906*P**0.891*(ST+1)**-0.331*E**-0.125
8     return Q2
9
10 -def dischargeQ25(A, P, ST, E):
11     Q25=1699*A**0.836*P**0.917*(ST+1)**-0.386*E**-0.749
12     return Q25
13
14 -def dischargeQ50(A, P, ST, E):
15     Q50=4323*A**0.824*P**0.936*(ST+1)**-0.395*E**-0.848
16     return Q50
17
18 # Define Parameters/variables
19 area=float(arcpy.GetParameterAsText(0))
20 precipitation=float(arcpy.GetParameterAsText(1))
21 lakesArea=float(arcpy.GetParameterAsText(2))
22 elevation=float(arcpy.GetParameterAsText(3))
23
24 # Calculate discharge for Q2
25 discharge=dischargeQ2(area, precipitation, lakesArea,elevation)
26 arcpy.AddMessage("The discharge for Region 4 Q2 is: "+str(discharge))
27
28 # Calculate discharge for Q25
29 discharge=dischargeQ25(area, precipitation, lakesArea,elevation)
30 arcpy.AddMessage("The discharge for Region 4 Q25 is: "+str(discharge))
31
32 # Calculate discharge for Q50
33 discharge=dischargeQ50(area, precipitation, lakesArea,elevation)
34 arcpy.AddMessage("The discharge for Region 4 Q50 is: "+str(discharge))
35
36

```

Figure 5-16: Python Script for Region 4

```

Region5
1 import arcpy
2 import math
3
4 # Create a function to calculate Discharge
5
6 -def dischargeQ2(A, P, ST, E, F, J):
7     Q2=418*A**0.911*P**1.342*(ST+1)**-0.307*E**-0.495*(F+1)**-0.605*(J+32)**-0.344
8     return Q2
9
10 -def dischargeQ25(A, P, ST, E, F, J):
11     Q25=46460*A**0.866*P**1.083*(ST+1)**-0.414*E**-0.908*(F+1)**-0.560*(J+32)**-0.232
12     return Q25
13
14 -def dischargeQ50(A, P, ST, E, F, J):
15     Q50=90720*A**0.860*P**1.031*(ST+1)**-0.436*E**-0.962*(F+1)**-0.546*(J+32)**-0.217
16     return Q50
17
18 # Define Parameters/variables
19 area=float(arcpy.GetParameterAsText(0))
20 precipitation=float(arcpy.GetParameterAsText(1))
21 lakesArea=float(arcpy.GetParameterAsText(2))
22 elevation=float(arcpy.GetParameterAsText(3))
23 areaofforest=float(arcpy.GetParameterAsText(4))
24 janmintemp=float(arcpy.GetParameterAsText(5))
25
26 # Calculate discharge for Q2
27 discharge=dischargeQ2(area, precipitation, lakesArea,elevation, areaofforest, janmintemp)
28 arcpy.AddMessage("The discharge for Region 5 Q2 is: "+str(discharge))
29
30 # Calculate discharge for Q25
31 discharge=dischargeQ25(area, precipitation, lakesArea,elevation, areaofforest, janmintemp)
32 arcpy.AddMessage("The discharge for Region 5 Q25 is: "+str(discharge))
33
34 # Calculate discharge for Q50
35 discharge=dischargeQ50(area, precipitation, lakesArea,elevation, areaofforest, janmintemp)
36 arcpy.AddMessage("The discharge for Region 5 Q50 is: "+str(discharge))

```

Figure 5-17: Python Script for Region 5

5.3 Summary

This chapter detailed the data processing, calculation of climate differences, and calculation of peak discharge values for the 20th Century and Mid-Century scenarios.

Chapter 6 – Results and Analysis

6.1 Climate Change Scenarios Results

The differences in climate change scenarios were calculated by subtracting the values of the temperature and precipitation for the 20th Century from the values for the Mid-Century. This represented the changes between the two scenarios for the Yukon River Basin. The minimum mean temperature for the 20th Century and Mid-Century is shown in Table 5.

Table 5. Minimum Mean Temperature for the 20th and Mid-Century

Scenarios	Temperature Minimum (°F)
20 th Century	-6.75
Mid-Century	+3.13

6.2 Peak Discharge Calculation

Peak discharges for the three flood frequency return periods were calculated using the USGS equations and the script tool.

6.2.1 Basin Characteristics Output for USGS Regions

In order to calculate the total peak discharges for the two scenarios, the basin characteristics for the different regions were required. The values that remain constant are presented in Table 6.

Table 6. Region Characteristics that Remain Constant between Scenarios

Basin Characteristic	Region 3	Region 4	Region 5
Area of Basin	149,280 mi ²	11,212 mi ²	170,616 mi ²
Area of Lakes and Ponds as percentage of basin area	0	3.25%	0.42%
Main Basin Elevation	1,860 ft.	1,998 ft.	1,183 ft.
Area Forest	n/a	n/a	81,194 mi ²

Table 7 presents the climate changes between the two periods for precipitation and temperature. The changes are the same for all regions. The difference in precipitation between the two scenarios is 6.0 inches and for temperature it was 9.9 (°F). Therefore is an increase in the two climate parameters.

Table 7. Basin Characteristics for 20th and Mid-Century Periods

		Region 3	Region 4	Region 5
Precipitation	20 th Century	32.29 inches	32.29 inches	32.29 inches
	Mid-Century	38.06 inches	38 inches	38 inches
Temperature	20 th Century	-6.75 (°F)	-6.75 (°F)	-6.75 (°F)
	Mid-Century	3.13 (°F)	3.13 (°F)	3.13 (°F)

6.2.2 Peak discharge for the Two Time Periods

The peak discharge values for the Yukon River Basin for the 20th century were calculated with the aid of the script tool created in PythonWin using the basin characteristics and the climate change for the entire basin. The values are presented in tabular, map, and chart formats (Table 8 and Figures 6-1 to 6-4). This therefore indicates that USGS regression equation does not work with large basin area, other possible equations should be developed that will handle basin area for Alaska.

Table 8. Peak Discharge Table for the 20th Century

Discharge Years	Region 3 cfs	Region 4 cfs	Region 5 cfs
Q2	1,377,831	88,492	24,671
Q25	1,413,272	192,681	80,233
Q50	1,414,074	217,818	101,295

Figure 6-1: 2-Year Historic Peak Discharge

Figure 6-2: 25-Year Historic Peak Discharge

Figure 6-3: 50-Year Historic Peak Discharge

Figure 6-4: Historic Peak Discharge Rates

The peak discharge values for the Yukon River Basin for the Mid-century were calculated with the aid of the script tool created in PythonWin using the basin characteristics, and the climate change for the entire basin. The values are presented in tabular, map, and chart formats (Table 9 and Figures 6-5 to 6-8). The results show an unusual trend in the peak discharge values of region 3 of the Mid-Century period with the Q2 return period greater than the Q25, and the Q25 return period greater than the Q50 return period. It is possible that the USGS equations do not work well with very large basins such as those used in this study. These equations should be investigated before much weight is placed on the results.

Table 9. Peak Discharge for Mid-Century

Discharge Years	Region 3 cfs	Region 4 cfs	Region 5 cfs
Q2	1,610,480	102,552	27,459
Q25	1,556,716	224,034	88,798
Q50	1,546,373	254,053	111,707

Figure 6-5: 2-Year Project Peak Discharge

Figure 6-6: 25-Year Project Peak Discharge

Figure 6-7: 50-Year Project Peak Discharge

Figure 6-8: Projected Peak Discharge

6.3 Changes in Peak Discharge between the Two Scenarios

The peak discharge change over time was determined (see Tables 10 and 11).

Table 10. Change in Peak Discharge between the Two Time Periods

Flood Frequency Between Periods	Region 3 (cfs)	Region 4 (cfs)	Region 5 (cfs)
Q2	+232,649	+14,060	+2,788
Q25	+143,444	+31,353	+8,565
Q50	+132,299	+36,235	+10,412

Table 11. Change in Peak Discharge between the Two Time Periods (%)

Flood Frequency Between Periods	Region 3 (%)	Region 4 (%)	Region 5 (%)
Q2	16.9	15.9	11.3
Q25	10.1	16.3	10.6
Q50	9.3	16.6	11.3

For region 3, the two-year flood frequency return period (Q2) increased by 16.9% between the 20th Century and Mid-Century time periods. The twenty-five and fifty year returns increased by 10.1% and 9.3% respectively.

For regions 4 and 5, the return values changed significantly with a normal trend. For example, the volume for the Q2 returns period for region 4, increased by 15.9%, Q25 by 16.3% and Q50 by 16.6%. The Q2 return for region 5 increased by 11.3%, then Q25 by 10.6%, and Q50 by 11.3% respectively.

6.4 Summary

The variations in the flood frequency return periods result from differences in discharge values among the different regions of the basin. This indicates that there were changes in the peak discharges between the two scenarios.

Climate changes between the 20th Century and Mid-Century periods led to significant increase in the peak discharge values. These increases led to significant change in the return flood frequency values between the two time periods.

Chapter 7 – Conclusions and Future Work

This chapter provides the conclusion on the assessment of climate change scenarios in the Yukon River Basin. It summarizes the project, taking into consideration preceding chapters, major findings, the project deliverables, future works and suggestions, the conclusion, and summary.

7.1 Major Findings

In this project, the Inverse Distance Weighted (IDW) interpolation algorithm was used to create raster datasets from temperature and precipitation point data, as recommended by experts from National Center for Atmospheric Research. IDW created continuous surfaces by using only the geometric characteristics of the temperature and precipitation point observations. The differences in these two datasets indicate the climate change between the 20th Century and the projected Mid-Century periods for the Yukon River Basin. There are also some variations in the peak discharge values in the different regions due to changes in the basin characteristics. There are indications that changes in climate will lead to changes in peak discharge in the Yukon River Basin in the future. The client will use the method in this project and the tool created to closely monitor climate change scenarios and calculate peak discharges within the Yukon River Basin.

7.2 Project Deliverables

The project deliverables provided to the client according to the request were: Geodatabase, Python script tool, maps and project documentation, as well as U.S. Geological Survey regression equations and basin characteristics.

7.3 Future Works and Suggestions

The project will help the Yukon River Inter-Tribal Watershed Council protect and preserve the Yukon River Basin. It will enable them to visualize the projected climate change and also calculate the projected peak discharge. It would be great for this project to be repeated in five-year intervals. In a future project the differences between the 20th Century period and the end of the 21st Century (2080-2099) could be examined, as this will provide additional information to policy makers to effectively manage the basin in the long term. The soils, land use for all three regions, the area of forest for regions 3 and 4, should be considered in future projects. This project can be used to motivate future works on climate change and the calculation of peak discharges in the Yukon River Basin.

7.4 Conclusion

The main goal of this project was realized. Solutions were provided to the client's problems. The first solution was the creation of a geodatabase, to enable easy visualization and analysis. The second was the calculation of peak discharges, which will

help to determine flood frequency in the different regions of the Yukon River Basin. To address the third problem, projected climate changes were calculated for the 20th Century and the Mid-Century periods, using ArcGIS and data from the National Center for Atmospheric Research Climate Community System Model.

7.5 Summary

The project deliverables met the client requirements, which include: a geodatabase, a script tool, and methods to determine differences between climate change scenarios, maps and project documentation.

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Appendix A. Climate Change Maps and Charts

A: Precipitation Change for 20th Century and Mid-Century

B: Temperature Change for 20th Century and Mid-Century

C: Yukon Basin Outline

D: United States Geological Survey Regions

E: United States Geological Survey Regression Equations for Yukon River Basin.

Appendix B: Peak Discharge

Script Tool for the 20th Century and Mid-Century Periods

Historic Peak Discharge for Region 3

Historic Peak Discharge for Region 4

Historic Peak Discharge for Region 5

Projected Peak Discharge for Region 3

Projected Peak Discharge for Region 4

Projected Peak Discharge for Region 5

Appendix C: Forest Data preparation

1. Download

http://www.cec.org/Page.asp?PageID=924&ContentID=2819&AA_SiteLanguageID=1

2. Project: Layer properties-

Query Builder

Expression: class Name= Mixed Forest or class Name=deciduous or class Name =Taiga
or

3. Extract by mask

4. Convert raster to polygon
 5. Aggregate polygon on region 5 alone
- That select by attribute: Region 5.

Appendix D: Instruction Manual

- Download Temperature (TAS) and Precipitation data from National Center for Atmospheric Research (NCAR): <http://gisclimatechange.ucar.edu>. Contact the site administrator who will grant access to the website.
- The datasets was derived from a global climate model output. It contains information for each cell about change in annual mean temperature from the present day climate (1980-1999) to the Mid-Century (2040-2059) climate, as projected by High A2 scenario. The dataset came from the climate change scenario portal (<http://www.GISClimateChangeiucar.edu>).
- Project the data to area of interest projected coordinate system, for the Yukon River Basin project NAD_1927_Alaska_Albers_Meters was used.
- Join the temperature layers for the 20th Century and Mid-Century Scenarios in one attribute table, and do same with precipitation. This will provide access to find the differences in precipitation for the two difference scenarios using Field Calculator. Field Calculation – procedures
- Temp: Convert from Kelvin to Fahrenheit

$$(F1-273.15)*1.8+32$$
 Prep: mm to Inches

$$F1*0.0393701$$
- Interpolate the temperature and precipitation data to make sure that the data points are correct for the purpose of the project with exact representation. The Inverse Distance Weighted (IDW) interpolation is recommended.
- Clip the data to the study area, using extract by mask from the ArcGIS Toolbox.
- Find the range in temperature and precipitation between the two scenarios; this will give the actual change.

Tool Documenting

1. PythonWin should be downloaded online
2. To get access to the Python script created, On your PC go to start then type Python on display dialog, you will see PythonWin, IDLE Python and IDLE Python, click Python win then a Python dialog will open.
3. Go to file, then select open, navigate to your folder on c: MIP Final/MIP Scripts and click any one of the scripts: Region 3, Region 4, and Region 5. For example click and open Region 3 script, it will open showing the equations and Basin Characteristics for the two-year return period, twenty-five year return period, and fifty –year returns (Q2, Q25 and Q50).
4. These scripts are modifiable and can be used in the future to calculate the peak discharge for different return periods in the Yukon River Basin.

5. For example the peak discharge can be calculated for Q5, Q10, Q100, Q200, and Q500, by replacing, the values of the Basin Characteristics and equations in the Python script, as indicated in step 3 above.
6. To run the Tool, open ArcMap, then ArcCatalog, navigate to the Climate Change Discharge geodatabase. Open the Discharge Calculation Toolbox. Right click the Tool Calculated Discharge for Region 3 or 4 or 5. Then click to open to open the Tool dialog which will appear as shown below. Then you should manually enter the basin Characteristics values for the region for example here is region 4, dialog box, then click OK. It will run and a display message dialog with the discharge values for Q2, Q25 and Q50. See Appendix B.

7. To update or modify the Tool parameters, open ArcMap, then ArcCatalog, navigate to the Climate Change Discharge geodatabase. Open the Discharge Calculation Toolbox. Right click the Tool Calculated Discharge for Region 3 or 4 or 5. Then right click on one of the Tool, select Properties to open the Calculate Discharge Properties dialog for any of the region. The Properties dialog which will appear as shown below.

Calculate Discharge for Region 3 Properties

General Source **Parameters** Validation Help

Display Name	Data Type
Area for Q2	Double
Precipitation for Q2	Double
Area of Lakes for Q2	Double
Elevation for Q2	Double
2 Year Peak Discharge	Double
25 Year Peak Discha...	Double
50 Year Peak Discha...	Double

Click any parameter above to see its properties below.

Parameter Properties

Property	Value
Type	
Direction	
MultiValue	
Default	
Environment	
Filter	

To add a new parameter, type the name into an empty row in the name column, click in the Data Type column to choose a data type, then edit the Parameter Properties.

OK Cancel Apply

Then you should manually type the Basin Characteristics values for the region, after typing in the Basin Characteristics values, then click Source on the Calculate Discharge for Region3, then navigate to the script which will appears at once, then select one of the scripts, for example here is region 3, and then click OK, then the parameters will be updated automatically ready for use in the Tool.

8. The script and tool can always be modified to calculate peak discharge in the Yukon River Basin.