University of Redlands

Mapping the Trans-Atlantic Slave Trade

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

by

Jeremiah J. Huggins

Mark Kumler, Ph.D., Committee Chair

Douglas Flewelling, Ph.D.

John Glover, Ph.D.

August 2021

Mapping the Trans-Atlantic Slave Trade

Copyright © 2021

by

Jeremiah J. Huggins

The report of Jeremiah J. Huggins is approved.

John Glover, Ph.D.

Douglas Flewelling, Ph.D.

Mark Kumler, Ph.D., Committee Chair

July 2021

Acknowledgements

Sincerest thanks to Dr. Glover for his constant assistance across various aspects of the project, truly it could not have been done without him and his expertise. The same is true of Dr. Kumler who has been a significant help throughout the year and has identified and helped to coordinate needed specialists and has further helped in terms of cartographic accuracy. Further, Nathan Strout deserves a “shout out” for calmly dealing with my many concerns during the server implementation attempts.

Abstract

Mapping the Trans-Atlantic Slave Trade

by

Jeremiah J. Huggins

The Trans-Atlantic Slave Trade and Intra-American Slave Trade displaced millions of people from Africa all over the globe. Many people throughout the Western Hemisphere who are descended from slaves that crossed “The Middle Passage” are now largely incapable of retracing their family origins. Many of these displaced people are located in the Caribbean. This is a major spatial and historical problem that could be addressed in a user-friendly way using Geographic Information Systems. To remedy this lack of retractability, this project aims to create an easy-to-navigate website, hosted by the University of Redlands, that will allow these descendants to better identify their ethnic and historical origins. The scope of this project will be limited to a few Caribbean islands, but the project will continue forward as an ongoing piece of work. In doing this, the intended result is a University of Redlands affiliated and managed website linked to a GIS map, incorporating public app and Field Map app. Also included will be an analysis of the problem, and an effective remedy to the problem via GIS. The hope is this project will contribute to a process of recovering these lost origins for millions in the Western Hemisphere.

Table of Contents

Chapter 1 – Introduction	1
1.1 Client.....	2
1.2 Problem Statement	2
1.3 Proposed Solution	3
1.3.1 Goals and Objectives	4
1.3.2 Scope.....	5
1.3.3 Methods.....	5
1.4 Audience	7
1.5 Overview of the Rest of this Report	8
Chapter 2 – Background and Literature Review	9
2.1 African History and the Trans-Atlantic Slave Trade	9
2.2 Genetic Influences of the Trans-Atlantic Slave Trade.....	12
2.3 Data Collection on the Trans-Atlantic Slave Trade	13
2.4 3-D Visualization and Mapping.....	14
2.5 Geographic Information System Opportunities Identified.....	16
2.6 Summary	17
Chapter 3 – Systems Analysis and Design.....	19
3.1 Problem Statement	19
3.2 Requirements Analysis	19
3.3 System Design	22
3.4 Project Plan	28
3.5 Summary	37

Chapter 4 – Database Design.....	39
4.1 Conceptual Data Model	39
4.2 Data Sources	41
4.3 Data Collection Methods	43
4.4 Logical Data Model	44
4.5 Data Scrubbing and Loading	49
4.6 Summary	53
Chapter 5 – Implementation.....	55
5.1 Logical Implementation	55
5.2 Web Application Creation and Organization.....	58
5.2.1 Challenges in Implementation	59
5.2.2 Successes in Implementation	65
5.3 Summary	67
Chapter 6 – Results and Analysis.....	69
6.1 Capabilities Employed	69
6.2 Analysis.....	72
6.3 Results.....	73
Chapter 7 – Conclusions and Future Work.....	85
7.1 In Conclusion	85
7.2 Future Work	86
7.2.1 Table Creation Automation.....	86
7.2.2 ArcGIS API for JavaScript	88
7.2.3 Microsoft SQL Server.....	89

7.2.4 Field Maps	89
Works Cited	91
Appendix A. User Manual.....	93
 Chapter 1 – User Manual	 94
1.1 2D by 25-Year App.....	94
1.2 2D by Year App	106
1.3 3D 25-Year Ports	118
1.4 3D 25-Year Regions	124
1.5 Experience Builder App.....	128

Table of Figures

Figure 3-1:	Suspected Slave voyages data org.	23
Figure 3-2:	Relationship Diagram 1.	24
Figure 3-3:	Relationship Diagram 2..	25
Figure 3-4:	Original Project Plan.....	29
Figure 4-1:	Conceptual Data Model.	40
Figure 4-2:	Logical Data Model.	45
Figure 4-3:	Data Reformatting for Time Properties.	50
Figure 5-1:	Exponential Size Features.....	62
Figure 5-2:	Nevis, largest known port value.....	63
Figure 5-3:	Antigua, largest known port value.....	63
Figure 5-4:	Jamaica, largest known port value.....	64
Figure 5-5:	Overlapping features example, improved.	67
Figure 6-1:	Embarked Slaves to Antigua by Year.....	76
Figure 6-2:	Disembarked Slaves on Antigua by Year.	76
Figure 6-3:	Embarked Slaves to Nevis by Year.....	77
Figure 6-4:	Disembarked Slaves on Nevis by Year.....	77
Figure 6-5:	Embarked Slaves to Jamaica by Year.....	78
Figure 6-6:	Disembarked Slaves on Jamaica by Year.	78
Figure 6-7:	Embarked Slaves to Antigua by Hist. African Region.	79
Figure 6-8:	Disembarked Slaves to Antigua by Hist. African Region.	79
Figure 6-9:	Embarked Slaves to Nevis by Hist. African Region.....	80
Figure 6-10:	Disembarked Slaves to Nevis by Hist. African Region.....	80
Figure 6-11:	Embarked Slaves to Jamaica by Hist. African Region.	81
Figure 6-12:	Disembarked Slaves to Jamaica by Hist. African Region.	81
Figure 6-13:	Embarked Slaves to Antigua by African Port.....	82
Figure 6-14:	Disembarked Slaves on Antigua by African Port.	82
Figure 6-15:	Embarked Slaves to Nevis by African Port.	83
Figure 6-16:	Disembarked Slaves on Nevis by African Port.....	83
Figure 6-17:	Embarked Slaves to Jamaica by African Port.....	84
Figure 6-18:	Disembarked Slaves on Jamaica by African Port.....	84
Figure 7-1:	Reformatting Example.	87

List of Tables

Table 3.1 Deliverables and Criteria.	20
Table 3.2 Contextual fields for Field Maps features.....	27
Table 3.3 Domains for “Slave Trade Activity” Field.	28
Table 3.4 Hist. African Regions - Number of Vertices.	31
Table 3.4 Qualitative Contextual Fields.	32
Table 3.4 Quantitative Contextual Fields.	33
Table 4.1 Fields included in the “Voyages Tables”.....	44
Table 4.2 Totals Feature Layer Fields by Alias.	46
Table 4.3 Organizational Inconsistencies in Jamaica Data.....	47
Table 4.4 Ulisses Ship Inconsistency.....	48
Table 4.5 Unique Identifier Creation Guide.	51
Table 4.6 Unique Identifier Tracking Format.....	52
Table 5.1 ArcGIS Pro Feature Datasets vs ArcGIS Online Web Feature Layers.....	58
Table 6.1 SlaveVoyages Regions & Ports Totals Data.....	74
Table 6.2 Mapping the Trans-Atlantic Slave Trade Project Totals	74

List of Acronyms and Definitions

API	Application Programming Interface
AQL	Acceptable Quality Level
“British Caribbean”	The Caribbean islands that became part of the British Empire
CSV	Comma Separated Values
DNA	Deoxyribonucleic acid
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
IDs	Identifiers
IMP	Imputed Results Calculated by an Algorithm
MIP	Masters Individual Project
QC	Quality Control
REST	Representational state transfer
SQL	Sequential Querying Language
3D	Three Dimensional
2D	Two Dimensional

Chapter 1 – Introduction

The project's inception was a result of Dr. John Glover, a Professor of History at the University of Redlands, and Dr. Alana Belcon, an adjunct professor at the University of Redlands from Trinidad. In 2018, Dr. Conroy Reynolds of the School of Education approached Dr. Glover in order to ask the question – could the origins of slaves brought over to Antigua (Dr. Reynold's home country) be deciphered through historical journals or other sources? For Dr. Glover, the idea sprouted to make use of SlaveVoyages; an international study, to get the information Dr. Reynolds was looking for, however, the problem on how was best to display that data remained. To identify the best method to do this, Dr. Glover contacted Dr. Alana Belcon. Dr. Belcon specializes in tropical aquatic environments and is also highly experienced in Geographic Information Systems. Having grown up in Trinidad, Dr. Belcon was aware that often the descendants of these displaced people cannot retrace their families' origins past the slave ship their ancestors arrived on (even this is extremely rare). The idea came about to use new data that is being compiled by SlaveVoyages, as well as the new DNA tests done by "23andMe," which result in a map of genetic origins, plus Geographic Information Systems to try and fill this historical gap in some way.

In researching possible alternatives that might exist, there were many articles about how Ancestry.com has failed African American customers worldwide (e.g. Green, 2019; Ross, 2019). This specifically revolves around the fact that most white Americans can easily trace their records, while the majority of black Americans cannot. So many records were lost due to the slave trade and purposeful mis-keeping of records or deceit, especially in America, where slaves' full names were often not recorded. The site has made efforts, such as creating an African America research guide, and partnering with Henry Louis Gates Jr. who has access to billions of historical records (Gates, 2019) – yet obviously these vast data records aren't "user friendly" (Green, 2019). Otherwise, the most prominent reclamation effort of data is SlaveVoyages. The rest are sources such as federal records, blogs, and articles, which are not interactive or helpful for determining one's individual origins.

Dr. John Glover has done significant research in this field, specifically on African History and the Trans-Atlantic Slave Trade. Dr. Glover has spent time in Senegal (Africa) doing field work on multiple occasions. Through this research he has gained access to numerous primary sources for data on the topic. Dr. Glover has created a class at the University of Redlands based on this topic and the ability to use GIS to solve historical issues (History 251). He further plans to create an abroad May term class specifically to go to Antigua and do field work.

Dr. John Glover and Prof. Alana Belcon's problem lies in needing a GIS expert to take this from an idea, turn it into a real operational product, and create a geodatabase that allows for easy manipulation and use of the data. There is a distinct lack of ancestral traceability for the descendants of those displaced, therefore, Dr. Glover needs a GIS analyst to compile relevant data specific to chosen islands throughout the "British Caribbean." Facilitating the plan to create an easily navigable database where the descendants of displaced peoples can retrace their origins, eventually turning into an

effective platform for presenting that data to a wide range of people. Once completed the intent is to expand this technology and platform to the rest of the Americas.

1.1 Client

The client is Dr. John Glover, a professor at the University of Redlands who teaches History and Spatial Studies. He is experienced in African history and has some experience in GIS. Dr. Glover has compiled data tables in .csv format for geocoding and has shared those. There is an ArcGIS Online map and a story map that Dr. Glover used in his History 251 course. Dr. Glover also has a large collection of historical sources on Africa and the Trans-Atlantic Slave Trade, in addition to the publicly accessible SlaveVoyages databases. He was the project's go-to source for primary source suggestions, organization preferences, project goals, and historically accurate information when implementing data in pop ups and/or other significant data that might require oversight in terms of authenticity. Prof. Alana Belcon was the co-originator of this project. The primary idea was originally inspired by Dr. Reynolds question, however, Dr. Belcon came up with the idea to link with DNA results and create a website. The hope is that she will be able to have some sort of administrative role through the project's creation.

1.2 Problem Statement

The Trans-Atlantic Slave Trade was purposefully kept secret to a large degree from its inception due to two primary reasons: 1.) withholding information from enemies and allies and 2.) its eventual illegality after 1808. Therefore, there are very poor records overall on slaving activities (especially with land slave routes). This holds true for most of the slaving activity of many European powers like the Portuguese, Dutch, French, and other nations. The poor records mean many of the slaves who were displaced permanently were left with no way to retrieve their lost origins. They were transported to places where they had no understanding of the language, along-side Africans from all over the continent who all spoke different languages themselves. For those whose ancestors left by slaving caravans on land, there is little hope of later retrieving their initial origins. This is because it was extremely rare that African slave merchants ever kept records. Many of these slaves would be brought to the coasts from hundreds of miles inland, either by caravan or by river, and would be sold onto slaving vessels operated by Europeans. For those whose ancestors were transported on ships, there is more chance of retrieving their lost origins because many ships' journeys were logged and maintained over the years. Importantly, this does not mean that an exact origin point can be identified for where these displaced people were born in Africa. Instead, it would be more feasible to identify possible origin ports along the African coasts that one's ancestor could have been embarked from. Further, new abilities in genetic testing have resulted in the new 23andMe genetic maps, which are received as a result of doing the test. The problem lies in the fact that this genetic information is largely useless without historical and spatial context, which the project hopes to remedy. The dark shadow slavery has left across

history – preventing millions of descendants from retracing their ancestry and heritage – could finally start to be put back together through spatial analysis and mapping.

By no means would this project accomplish this entire feat. Simply, this project focuses solely on the slaves who were transported to Antigua, Nevis and Jamaica – in the future other islands in the “British Caribbean” will be added. The model created is effective for approaching other islands and countries throughout the Americas because of the reality that the same dispersion of slaves and warring between European powers occurred across the Americas as well. The project required analysis of Trans-Atlantic Slave Trade Database’s records as well as many other components. As raw data, this information is hard to discover, hard to decipher, and remains largely inaccessible to most people. Geographic Information Systems provide an opportunity to visually present the data in a more easily understood format. This project is simply a humble start to a long process of repairing this information island by island.

1.3 Proposed Solution

The identified solution is to use Geographic Information Systems, specifically 3D visualizations and 3D scenes, to provide an improved visualization of data related to the Trans-Atlantic Slave Trade. The project employs a simplified database organization which promotes use by the average person. In visualizing data, 3D visualizations provide the unique capability of displaying significantly more information at first glance. It is the client and project team’s belief that the use of ArcGIS Pro’s 3D capabilities will improve the average person’s ability to glean information from this visualization. Further, other visualizations fail to make use of this technology.

Optionally, our project might be used in tandem with 23andMe test results. Today, 23andMe tests result in an online account and map, which identifies what the percentages for one’s genetic origins are through a color-coded world countries map. These results could be helpful – unless users already have other methods for identifying their origins, such as the year their ancestor was transported, or where their ancestor landed, or various other supporting contextual information like family histories. Importantly, the project product is only meant to supply historical and spatial context related to the slave trade generally, not to specific case scenarios. Without the ability to extract 23andMe data, the best assistance our project can provide is through supplying historical and spatial context which might assist someone who is trying to identify their origins. Therefore, in no way is our project linked to 23andMe; simply, 23andMe provides another resource to help the user identify personal contextual information that might assist them in their searches. That specific information may be useful in conjunction with our project product depending on the user’s intent.

Importantly, even with SlaveVoyages and DNA results, making use of historical databases in order to identify contextual information relevant to your own ancestor would be extremely difficult. Simply put, although the database was not at all made for such a purpose, SlaveVoyages does provide a significant amount of important contextual data that could be used to identify a range of ships that a descendant’s ancestor might have been on. The contextual information provided includes everything from the types of ships, to their names, owners, captains, ports of landing, and more; however, doing this in

the current database is very difficult. In Conroy Reynolds' case, he was provided a range of 600 ships from thirty-three ports that could have transported his ancestors. Of course, the hope is to narrow this further, however, that will likely be dependent upon the amount of contextual information the user comes in with. It's important to recognize that once slaves were disembarked at a destination, they reproduced and intermixed. As a result, the various genetics would become mixed together over time, which does impact retractability for the descendants of those displaced. In many cases these descendants DNA may point to origin regions in multiple locations of the African continent.

Through using ArcGIS Pro and its relational database capabilities, it was possible to identify how to coordinate and relate the data so that everything "pulls" from the original dataset of the voyages, which contain the contextual information used for all layers. In creating this, the project team identified inconsistencies in the SlaveVoyages database which would have been extremely confusing for the average user. By clarifying this, and identifying where further simplicity and consistency could be achieved, the data was reformatted accordingly so as to be most clear, and include all the contextual information related to the people being transported on those vessels.

1.3.1 Goals and Objectives

The goal of this project was to create a process or model by mapping Antigua and the significant geographic origins of the descendants of slaves brought over from Africa. Additionally, it was Dr. John Glover's hope that this project demonstrates it is possible to pull back the veil and provide historical and spatial context for the millions of living descendants who have been seeking these answers their entire lives. The project created a model which can be applied by future classes for learning, as well as editors and professionals to create accurate, interactive, informative, and visual layers. It will eventually include all the islands of the Caribbean. The objective is to create a process and an operational model for three Caribbean islands to inform the further dissemination of data pertaining to the Trans-Atlantic Slave Trade and the Caribbean Islands in the future by Dr. Glover and future graduate students. This project focuses solely on the slaves who were transported to Antigua, Nevis, and Jamaica from Africa. This should be expanded in the future to include all the Americas. Therefore, the primary objective in this project is to create a geodatabase which contains 3D visualizations of data related to the specified islands, and has the ability to provide contextually significant historical and spatial information to the viewer that relates to those records. The goal is to ensure it is more easily navigable, informative, and descriptive allowing the more average person to view graphic visual representations of data, instead of hard data.

This required analysis of the Trans-Atlantic Slave Trade database's records. Optionally, users that have received 23andMe results in advance of using the map, can provide greater historical and spatial context for themselves with that supporting information. Geographic Information Systems are particularly suited to remedying this lack of comprehensibility present in the spatially vast data surrounding the Trans-Atlantic Slave Trade and Intra-American Slave Trades. Therefore, the final objective of this project is the use of Geographic Information Systems to create a more effective visual representation of new data being collected by SlaveVoyages, and to use historical and

spatial context to assist people in possibly delineating their origins. This will further allow the more average person to better decipher this data as well as the related spatial and historical context associated.

1.3.2 Scope

The scope of this project is limited to locating the origins (historically and spatially) for people living on Antigua and two other Caribbean Islands. The current scope is the creation of a map, housed in a geodatabase which will be managed by Dr. Glover and posted through the University of Redlands site. The final products include:

- 1.) The original geodatabase that contains all the project feature layers housed in 3 feature datasets called Antigua, Nevis, and Jamaica. Further, a toolbox including any ModelBuilder tools created is included.

- 2.) A map that is editable and also managed by Dr. Glover – primarily to be used in classes. Further, this map should be connected to a Field Maps app, include domains, and be capable of in the field edits. This version allows field work to be done during Dr. Glover’s May term course.

- 3.) A map, presented publicly, which is displayed in a finalized Web Application including all finalized data for Antigua, Nevis, and Jamaica. This is only editable by Dr. Glover. This specifically includes the feature class data for the feature datasets in the original geodatabase and any capabilities implemented or created during analysis.

Future additions will only be done by Dr. John Glover. The original version is owned and operated by Dr. Glover, along with the original geodatabase and toolbox. The maps and data have privileges set by the organization account to make it so that Dr. Glover can assign editors or viewers (managed by University of Redlands Enterprise Account – Nathan Strout). The final portion of the scope is documentation on the process of creation and lesson plans for the creation of various steps in the project.

1.3.3 Methods

The project is oriented to serve as an effective tool in deciphering the spatial and historical context for the descendants of those displaced by the Trans-Atlantic Slave Trade. The map itself should effectively organize the layers of data and tools used so they can be accessed and viewed by the average person, manipulated and learned from by students, as well as studied and added to by professionals such as Dr. Glover. The project is database management oriented. The methodology employed is scientific, analyzing the spatial and historic components, implementing GIS tools, 3-D symbol visualizations, organizing and setting up an effective enterprise geodatabase and implementing it. Instead of creating a single “Map,” a model for the dissemination of this data was created and a geodatabase that was applied in various capacities:

First, was the creation of the original map, which holds all layers used. These layers include the origins of slaves who were brought to Antigua, Nevis and Jamaica as well as these destinations themselves. The main components that must be mapped are the port locations identified by Dr. Glover through historical research, as well as the regions

and three island destinations, historical sources, and further quantitative and qualitative data fields, provided by SlaveVoyages. The layers include origin-to-destination lines to identify the distances from locations of ports and regions to the island destination for embarked slaves. Further, the general boundaries for kingdoms (to the best degree historical accuracy will allow) are included along with major rivers. These layers include symbology to assist in directing the viewer's attention, or orient viewers better to their specific inquiry. Further supporting information could cover, but is not limited to, an ethnic and linguistic map of Africa, land routes used for slave trading, displaying regions where borders for African kingdoms were unclear, child mortality, disease, and possibly other variables that could be helpful supporting information for those retracing their historical and spatial origins. Contextual information is provided by the information available on SlaveVoyages: there is extensive voyages data, which was used to create a relational table; this table provides data which allows for the facilitation of various new contextual information. For example, for African regions and ports, there is the average tonnage (size) of the ships which embarked slaves at any specified port or region, and the average Middle Passage time for ships which traveled from the port or region. The other variable, is the lack of automatability. Due to the nature of this historical data there is no good way to identify the inconsistencies or issues which might arise in the future, therefore, automation is likely to become more work than it is worth. In order to automate this process, a significant amount of custom code would need to be written and used in tandem with Esri tools, which presents significant challenges and ultimately, due to the wish for some work to be included into an undergraduate curriculum, it was decided this was far too complicated for the project's application.

Once this first version has been drafted, and the hypothesis confirmed that Geographic Information Systems are an apt technology capable of simplifying this complex information, the second step can be undertaken: creating and finalizing the manual for furthering this research to other islands in the Caribbean. The process to accomplish this requires documenting the physical creation of every aspect of the project and eventually compiling all this information into a manual. The documentation includes the data set up, the Unique ID creation, the ArcGIS Pro work, and the ArcGIS Online work. This documented model is going to be provided separately and used by Dr. Glover to dictate the creation of further islands in the future.

Once completed and finalized, a survey was created, which helps to determine whether the applied methodology is useful and to get feedback on what type of information can be useful to someone trying to unveil their origins and which apps are being used most. All results are shared with the "Atlantic Slave Trade Dashboard" group. In time, this will hopefully prove our methodology works and show that it does hold value to the "viewer."

The final steps were creating a copy of the original map for use by the general public and a copy for class-use. The best way to ensure the data is not edited or corrupted by others is to have the original version only be accessible by the client himself. Therefore, it was decided the best route is likely to have multiple versions. The first was a version of the original that will be used by students in classes in the future. Layer editability is manageable through either turning layer editing off on specific layers or keeping them as is. Editor tracking is only enabled on the Field Map version of the project for the reason that no edits should ever take place on the "Public Version." Only

full features that are entirely finalized should ever be added to the public facing version. Methods to prevent errors from occurring were implemented in order to reduce the amount of possible future mistakes. The class version is linked to the Esri Field Maps App so that edits may be done in the field. The second, and final map product, is a version presented in a Web Application for purely public use.

1.4 Audience

The intended audience are the descendants of the people transported across the Atlantic during the Trans-Atlantic Slave Trade to the islands of Antigua, Nevis, or Jamaica specifically. Optionally, people might have identified supporting information through taking 23andMe DNA tests, which would help them to identify that their ancestors did indeed originate in various African regions and that their haplogroup doesn't follow the normal distribution (possibly). In this case, the user should have their 23andMe map which identifies the countries that make up their "ancestry composition" and use that as an assistive tool in identifying where their ancestors might be from. Using this contextual information, it is still unlikely that specific origins would be identifiable. By identifying what ships came from that region a user might possibly identify information related to ships their ancestor might have been transported on. Importantly, the project is intended to provide contextually significant historical information, not find a person's ancestor—specifically, the project is catered towards identifying information relevant to finding the origin locations of African ports used by European slave ships and supportive information on the ships themselves. That information is intended to be the pertinent information for the descendants of those displaced, not case specific information. The intent is to help identify further contextual information related to the possible origins of their ancestors (very generally). The success of users is largely dependent on if they have key pieces of supporting information, such as knowing the location and year from which their family line originates in the Americas (extremely rare).

The general audiences are the public and academics interested in the material. Therefore, the Web App must be catered to the average person's understanding of the Trans-Atlantic Slave Trade and use of mapping technology. Further audiences we might hope to reach could include: the people living in the countries specified as the project topic (Antigua, Nevis, Jamaica) and the people who live in the African regions where so many people were displaced. Ideally, this project could eventually provide contextual information which would allow people in Africa to identify which Caribbean islands, countries in the Americas, or US States, slaves from regions in Africa were transported too. Further, the project could provide the ability for those living in the country destinations to retrace where the many slaves that were disembarked there possibly originated from. To simplify; the product, just as it can be used to identify possible voyages which disembarked slaves on Antigua, Nevis, or Jamaica, could also be used to identify how many slaves were embarked from a region in Africa to each destination included. The primary goal being to improve people's knowledge on the number of people who were forcibly removed from their home continent and displaced thousands of miles away and the effects that it had.

1.5 Overview of the Rest of this Report

The report will discuss the various complications related to the collection of data and mapping of the Trans-Atlantic Slave Trade and specifically will provide some simplified visualization of the data relevant to the project topic. The report will be split into seven chapters detailing important aspects of the project. The first few sections will detail the historical background to the project, and how the various complications related to collecting data from the slave trade have affected research and the capability to retrace the genetics of those displaced. The third and fourth chapters will explain the system design and how the analysis will be conducted. Then the geodatabase, its design, and functionality will be discussed, along with the processes of implementation and analysis. Lastly, there will be the conclusion and implications for further stud

Chapter 2 – Background and Literature Review

In this chapter, the primary topics which will be covered are: First, a brief overview of the history related to the West African Slave Trade, detailing misconceptions about the slave trade and various reasons for the lack of reliable data. Second, the chapter will delve into current studies on the genetic impact of the Trans-Atlantic Slave Trade and further analyze the impacts of sex bias. Third, the chapter will then move into the realities surrounding the secretive nature of the slave trade, various reasons for missing data, and the monumental opportunities provided by mapping technology and 3D mapping capabilities. At the end, a summary will identify how this information specifically relates to the project and what aspects of the project are intended to help solve various mentioned issues.

2.1 African History and the Trans-Atlantic Slave Trade

Since the Trans-Atlantic Slave Trade's origins, the voyages of slaving ships were largely mysterious, especially for the slaves on board. This left millions of people displaced without any information on their origins or homelands across the Atlantic. This is an issue that until now has been left largely unsolved. Yet, two decades ago for the first time, an international research project by the name of SlaveVoyages began compiling the necessary documents to retrieve some portion of these scattered records on the slave trade through the Americas, and across the Atlantic. There is an opportunity here to do real good for millions of people. Yet, to understand the nature of the issue, one must first have an in-depth knowledge of African History to see how and why it is a spatial issue.

Africa has been influenced by global actors throughout history. However, in the last four hundred or so years, there has been significantly more European incursion and interaction than there was previously. This is largely due to the military competition of naval empires in Europe, the ever-persistent conflict between these empires, as well as between Christianity and Islam. This is evidenced by the stark differences in religious belief between different areas of Africa. The dominantly Islamic areas of Africa are the Swahili Coast of East Africa, and north of the rainforest in West Africa – specifically, in the more arid regions like the Sahel and Sahara. Alternatively, the coastal regions south of Senegal are dominantly Christian and so too are the rainforest regions (after western influences reached there). These African kingdoms and nations only became impacted by Islamic or Christian influences after the fall of the Roman and Persian Empires. Specifically, the interaction largely insinuated as a result of the vast wealth in gold accumulating in the Ghana Empire in the tenth and eleventh centuries C.E. The Ghana Empire would decline during the mid-eleventh century C.E. and would be succeeded by the Mali empire which is where the influence of this great wealth started to branch out of Africa. For example, Mansa Musa's pilgrimage to Mecca (1324 C.E.) during his reign (c.1312 - c.1337 C.E.) (Graft-Johnson, 2021). Famously, Mansa Musa traded so much gold during his time in Egypt (on his way to Mecca) that he completely destabilized the country's economy by tanking the price of gold. Estimates state that it would take over a

decade for Egypt to recover from this. Paintings and stories of his wealth would reach Europe in short order after this. What's important to note, is that religious conflict (forceful conversion), in many senses, was considered "justified" by European military powers due to the church's influence. Further, the geopolitical context of the time was such that the European powers were at a disadvantage in terms of trade and were having to pay vast amounts of money in order to provide for their populations and armies. This was a result of the reality that these European powers were dependent upon Muslim traders (the middlemen) when it came to purchasing products from the Eastern powers like China or India. This was also true when it came to the gold trade coming from Sub-Saharan West Africa. As the Portuguese gained in military might, they also changed attitudes about this trade situation, and decided to take on an attitude similar to that during The Reconquista. Simply stated, the goal being to find the source of the gold and open up new trade routes to India and China, which were the sources for the spices and other luxury trade goods from the East. Eventually, the Portuguese would become interested in sugar as they moved south, requiring the need for labor and contributing to the start of the Trans-Atlantic Slave Trade.

Initially, when the Portuguese first traveled the coasts of West Africa in the 15th – 16th centuries C.E., they raided the coastline primarily. However, their raids were short-lived and often ended in disaster due to African resistance, malaria, and rain – which largely rendered matchlock muskets useless. The Portuguese were more successful than the Spanish in West Africa and dominated the slave trade from c.1444 to c. 1600 C.E. Eventually, due to conflict between these two empires and disputes over ownership of territories, the Treaty of Tordesillas was signed in 1494 and Spain was confined to North Africa. As a result, the Spanish were largely denied the ability to obtain slaves by themselves. The Spanish then created the *Asiento* contract: a lucrative contract where the slave trade was largely contracted out to various European powers for specified time periods. Wars between European powers would only become more frequent in the following centuries. Due to conflicts such as the Seven Year's War, African territories, ports, and forts on the coasts would become constant battlegrounds for European powers vying over control of the slave trade. Simultaneously, due to the constant changing of hands, African slaves were frequently sent to different countries and each nation would send slaves to their own territories. As a result, slaves could end up all over the world.

Successful European incursion into the African interior did not really begin until quinine was discovered in the bark of the Cinchona trees between c. 1750-1820. Europeans from c. 1444-1820 settled for renting forts on the coast and settling on uninhabited islands. Sometimes European nations would war with one another for each other's resources. During this era, there were plenty of enticing reasons for Europeans to come to Africa beyond religious conquest (often framed as charitable acts of saving "heathen" souls). There was gold, and there were valuable resources like spices, sugar, and sorghum. There is the misperception that Europeans had better natural resources than Africans. This is woefully untrue. Europeans struggled greatly to find attractive items and technology they could trade with African merchants who had significantly better iron, better copper, precious metals, gems, unique spices as well as many other high quality natural resources. Eventually, Europeans developed trading relations which were significantly more lucrative than the raiding had been. One of the primary reasons European powers "set up shop" was to grow sugar, since it requires a humid equatorial

climate to flourish. Harvesting these resources propagated the European need for slaves due to sugar's intensive labor requirements. The damage of the sugar trade would be significant for people across the African continent. In the late 16th century, the Portuguese dominance came to a close and Holland took over a significant portion of the Portuguese forts, ports, and trade posts. France and Britain become involved in the 17th century as well. From the 18th century to the 19th, the British largely dominated the slave trade, even though many other nations contributed, including the French, Dutch, Portuguese, Danes, Swedes, and Prussians.

It should be noted some forms of slavery did exist before Europeans arrived in Africa. Among the indigenous people, however, "slavery" was much more similar to indentured servitude or assimilation until it was overtaken by European influences. The slave trade could not have occurred without the warring of African kingdoms and enslaving of their enemies. Yet just as true is the fact it could have never become a global, Trans-Atlantic scourge without European influences. One of the most famous slave forts was El Mina, a fort prison on the coast which was often a captured slave's last view of his or her home continent. There are various theories on what perpetuated the slave trade but some of the most prominent are the "gun slave cycle" theory and the "horse slave cycle" theory, both of which have been debated at length. One of the more famous revisionists of the "gun slave cycle" theory is John Thornton. Thornton argued that the matchlock musket was not an effective enough weapon that it would have replaced African arms completely (if at all). Instead, he has proposed that the true influence of the "gun slave cycle" could not be felt until matchlocks were replaced by flintlocks in the 1690's. This is supported by an extreme uptick in slaves being exported from the 1700's on; in some places like the Gold Coast numbers as much as tripled. This theory is often complimentary to the "horse-slave cycle" theory, proposed because many empires such as the Oyo Empire and Songhai empires had horse-based militaries that were extremely successful. However, there is a significant amount of evidence that horses were far preferred over muskets, and a horse could sell for as much as 12 slaves, whereas a gun might sell for four or five. Simultaneously the lands where horse-based militaries thrived often promoted the use of guns. This is illustrated by the existence of the Oyo Empire, which ruled far into the 18th century. This remains a highly debated topic today.

The combined influence of European powers and trade, plus the ensuing warfare between powerful African kingdoms, scarred the African continent even up to today. This scarring has left large historical wounds and countless lost records which have prevented many descendants of the survivors from ever reclaiming their origins and lineage. Therefore, for descendants of slaves, identifying one's lineage is an issue which requires a level of spatial analysis that would be difficult to do without a Geographic Information System.

In order to properly identify the pertinent information for the descendants retracing their origins, we must identify the historical and spatial components. First of all, there are many ethnic groups across Africa. Second, there are many different languages which might better indicate people's origins. Third, descendants can further assist their own ability to decipher spatial context and origin based off of their own personal genetics detected through DNA tests done by 23andMe. Fourth, there is also the ability to analyze the routes of ships and what ports they stopped at, which are often documented. This could help those with more-difficult-to-identify origins, granting the ability to identify

possible contextual information related to routes their ancestor might have taken. This would be highly dependent on if users are aware of their family's origin in the Americas (which is highly rare). There is data from SlaveVoyages giving the number of slaves who came through African and Caribbean ports, but it is very difficult to interpret. One of the primary aspects of the problem is the complexity of the data which makes it largely inaccessible to the general public. Many of these data variables could be cross analyzed (Ex: DNA & Region) and significantly improved through spatial analysis, especially in terms of making the data more interpretable.

2.2 Genetic Influences of the Slave Trade

There are new databases being produced now, and further well-known ones worth mentioning that include the new ground-breaking scientific analyses of the genetic fallout associated with the Trans-Atlantic & Intra-American Slave Trades. For the first time, genetic data can help us map the world distribution of those descendent from slaves. This study was completed in August 2020 and could significantly improve the analysis done in this project by providing genetic context to historical occurrences, and possibly provide data that is more extensive and in-depth, aiding the project's analysis. In "Genetic Consequences of the Transatlantic Slave Trade in the Americas" Micheletti, et al. (2020) developed a study of the various issues that caused genetic variation to decrease in populations impacted by the slave trade. "According to historical records of transatlantic slavery, traders forcibly deported an estimated 12.5 million people from ports along the Atlantic coastline of Africa between the 16th and 19th centuries with global impacts reaching to the present day, more than a century and a half after slavery's abolition" (Micheletti et al., 2020, p. 265). This analysis was done by cross-analyzing many variables with genetic data from 23andMe, including over a million people. Specifically, the analysis included 180,000 people of African descent. This was paired down to data on living individuals with genetics that can be traced back to Africa including 37,000 individuals from Africa, 30,000 representing the Americas, and about 21,000 representing Europe (Micheletti et al., 2020). The team employed various genetic calculations including an identity by descent calculation, a calculation on the time between descendent and the most common ancestor of African descent, and ancestral sex bias. Their study shows that a significant connection exists between the embarkation counts from ports and regions along the West African coast and the genetic variation of subsequent regions where those slaves were sent. However, this correlation fades when disembarkation numbers for areas in North and South America are analyzed. The example given states, "The study cohorts representing the United States ($p = 0.66$) and northern South America ($p = 0.09$) have very little m_{IBD} with Senegambia, compared to the proportion of captives from Senegambia disembarking in those two regions" (Micheletti et al., 2020, p. 269). This could mean a few things: slaves disembarked in these regions were likely moved to other locations or perished at an abnormally high rate possibly due to disease. Further, they could have simply escaped and joined the indigenous territories in outlying areas (which was common in South American Countries like Brazil).

The disproportionate number of males taken (especially young males), who largely perished due to the slave trade, severely impacted genetic variation heavily all over the world. Ultimately, slaves who were men were considered “work mules.” They were less valuable compared to women due to the inability to reproduce, particularly in Africa, and therefore more expendable. However, in America, men were more valued. Therefore, male slaves were disproportionately targeted for labor and were subsequently recruited and killed at a significantly higher rate due to exhaustion and brutality from slave owners (in terms of punishment and labor). The impact this had was immense worldwide. In America the genetic variation is very difficult to decipher simply because there is a large amount of opportunity for data corruption as well as purposeful manipulation of records. This is specified by Micheletti et al., “the extent of this sex bias in gene pool contributions may vary across the Americas due to the regional differences in mortality of enslaved men, rape of enslaved African women, forced segregation, and practices of reducing African representation by promoting reproduction with Europeans” (Micheletti et al., 2020, p. 266). However, in Africa it did cause there to be a significantly disproportionate number of women to men.

Micheletti and his supporting authors cross-analyzed “Ancestral Sex Bias,” “Time to Most Recent Common Ancestor,” “Identity by Descent,” “Ancestry Inference,” “SlaveVoyages.org,” “Population Structure,” and “Genotyping” through 23andMe data and the Human Genome Diversity Project. By doing this they “determined ancestral connections using identity by descent, local ancestry inference, and Bayesian dating techniques. In addition, we used ancestral admixture models to estimate the bias in gene pool contributions of African, European, and indigenous American men and women to current populations of the Americas. We used data from this large, diverse cohort of individuals to obtain unprecedented insights into the genetic impact of the Transatlantic slave trade” (Micheletti et al, 2020, p.266). The study’s analytical depth is far superior to the planned analysis for this project largely because it includes high level genetic analysis of many thousands of individuals, as well as their genetic lines. The data also covers an extremely wide range of variables and resources beyond simply using “23andme” and SlaveVoyages. The focus, however, is technically on genetics, and the result allowed them to identify regions across the world and show what the largest genetic percentage of African descent is in each region as a result of the slave trade. They also were able to analyze the effects the loss of these generations of people had on Africa.

2.3 Data Collection on the Trans-Atlantic Slave Trade

Surprisingly, from a data perspective, there have been few attempts to create a dataset to better decipher the realities of the slave trade. Even in 1989 no database had ever been created on the Trans-Atlantic and Intra-American Slave Trades. However, luckily in 1990 David Eltis and others created SlaveVoyages (SlaveVoyages, 2018a). For the first time data was gathered and the actual information necessary for analyses was organized because of this effort. Alphonse Fletcher of Harvard was quoted as saying “If there were a Pulitzer Prize given for historical databases, the Transatlantic Slave Trade Database would win it, hands down” (Emory, n.d.). This database contains millions of files on the Atlantic and Trans-Atlantic Slave Trades containing data from embarkation

numbers, to disembarkation, to ports, to ships from many different countries, in the form of tables, graphs, maps, and timelapses (SlaveVoyages, 2018b). It further includes data on the slaves themselves, the captains, the businesses' profitability, and further uncommon incidents like lost ships. Because of the 30,000+ voyage records collected, further studies can now be created on the Trans-Atlantic Slave Trade and Intra-American Slave Trade. This work was revolutionary for the study of African history as a whole. The current website is the result of further work over three years by a diverse team of specialists, historians, cartographers, programmers, web designers as well as further consulting from universities across four continents. The fundamental funding for this work was the National Endowment for the Humanities; the work was carried out at Emory Center for Digital Scholarship, University of California at Irvine, University of California at Santa Cruz, and Hutchins Center of Harvard University all of which contributed immensely to the creation of the SlaveVoyages database (SlaveVoyages, 2018a, par. 1).

Due to the growing body of data presented by the efforts of SlaveVogages.org, and the aptitude GIS has demonstrated for solving spatially related problems such as this, it is essential work that should be done. It will serve millions of people with African ancestry, whose family histories have been ignored and hidden for far too long.

There is a significant amount of research that has been done surrounding the Trans-Atlantic Slave Trade, especially in historical literature, journals, and cartography. This includes historical sources from multiple countries, across hundreds of years, including primary to secondary sources. One of the most well-known would be "The Journal of African History," established in 1960 at the University of Cambridge. This journal is one of the most highly cited and well-known sources on African history. It is a peer reviewed academic journal, and new issues are released three times a year. Other available academic sources include historians who have published notable books on the slave trade in West Africa such as John Thornton of Boston University writer of *Africa and Africans in the Making of the Atlantic World 1400-1800* (1992), and Malyn Newitt of Kings College London who wrote *The Portuguese in West Africa, 1415-1670: A Documentary History* (2010). A significant cartographic source worth mentioning would be the "David Rumsey Map Collection," which is an enormous collection of historical maps spanning locations across the entire world, from many cultures, covering everything from navigation, to topography, to cities, and more. This site is incredibly extensive and employs GIS so that users can search by location and find maps which correlate to specific areas of study. Another cartographic source is the *Atlas of the Transatlantic Slave Trade*, written by David Eltis in 2010. This source is a more specific collection of maps on the slave trade from 1500-1867, and specifically covers many of the regions that will be included in this project (Eltis, 2010).

2.4 3-D Visualization and Mapping

Spatial analysis has also gone through major evolutions in the last decade. For time immemorial maps have been made in 2D, largely on paper. It should be noted 3D depictions of information have existed for centuries, but were largely in the form of printed aerial images. For many years geographic analysis was confronted by the issue

that no matter what map was made, it was “static.” With modern Geographic Information Systems, today there is the ability to completely circumvent the “static” nature of 2D maps, and instead create 3D world and local scenes for mapping which are entirely variable (ESRI, 2017). There are many clear advantages to 3D analysis as stated by Esri: 1.) There is the ability to view objects from a vertical view, meaning objects contain vertical information by the value Z (ESRI, 2017). 2.) In 3D there is a greater ability to symbolize objects. Specifically, it makes objects significantly more recognizable due to the fact they are viewed in the dimension we are most used to. Every symbol and feature (object) also has the dimension Z to allow for symbolizing object height (ESRI, 2017). 3.) With 3D you (as the user) also view objects from a “birds-eye view,” this allows for a much greater ability to perceive landscapes at initial glance (ESRI, 2017). 4.) Unlike with 2D maps, the more recognizable 3D nature of the scene often allows the more average viewer to achieve a greater level of depth in understanding (ESRI, 2017).

A great example of disorganization that could be largely prevented through 3D mapping would be the map created by The Harvard World Map project, viewable through the link in the references (Neblier, 2008). The advantages attributable to Geographic Information Systems allow for a dramatic improvement of the cartographic view offered in Eltis’ *Atlas of the Transatlantic Slave Trade* (2010). What required 336 pages and 100+ maps to show in 2D form can be presented in a single, interactive map through GIS using 3D. This would make the data and the insights offered in Eltis’ extensive research far more accessible to far more people.

There are few examples of the use of 3D scenes or features for migration trend data; if one searches for “3D Migration maps using GIS” they will be confronted with a host of articles on topics ranging from migrating data across platforms to lessons on migrating personal knowledge of one GIS platform to another. It is safe to say; therefore, that 3D mapping is still relatively new. Some specific examples of using GIS 3D capabilities include the “Cool Maps” website which is the work of Sajit Thomas. This site includes maps across various topics, including migration trends, and uses matrixes of Origin Destination Links across various maps to coordinate these visualizations. As stated on their website these maps are simply for visualization purposes as well as displaying the capabilities of the ArcGIS API for JavaScript, but they are an example of some of the new capabilities included in 3D scenes and visualizations. The maps on “Cool Maps” use the Jet Stream effect to achieve the lines with the animated arrows flowing from origin point to destination. The “Cool Maps” gallery is one of a kind and even in targeted searches for alternate examples on ArcGIS Online’s Living Atlas I was not able to find another example where 3D scenes or features were used to display migration data (Thomas, 2021). One 2D example for the mapping of migration trends is the ArcGIS Blog post “Visualizing Population Migration by where people filed their taxes” detailing the use of the Distributive Flow Lines tool. In the article, the migrations discussed have to do with those trends specific to people leaving each state in the U.S. The maps display the varying migration numbers by width in a 2D map using tax data (Berry, 2019). This tool was something that was investigated for implementation in our own project, specifically to identify the various connections between the points. The issue that rendered this unviable was the fact that this tool requires a coordinate system in meters or feet. Our own coordinate system, because of the plan to implement 3D scenes, must be in WGS 1984 (auxiliary sphere), which isn’t in meters or feet.

2.5 Geographic Information System Opportunities

The study by Micheletti et al., “Genetic Consequences of the Transatlantic Slave Trade in the Americas,” did not sufficiently simplify the data presented so that it is easily understood. Instead, Micheletti et al. conducted an extensive and very broad genetic analysis which did little to present a more digestible explanation for those who donated their saliva for genetic results. Although the analysis done in the study is extremely expansive, the mapping/presentation of this data and its supporting information are very poor. Further, it does not appear to be done in any GIS system. It appears the study used Adobe Acrobat to create these “maps” and figures. Fatimah Jackson, a well-known biological anthropologist from Howard University, is quoted on *The Scientist* in *African American Genomes Yield Insight into Slavery Practices*, as saying: “This study suffers from a common issue: while the authors are to be commended for their contributions, geneticists often fail to include historians early in the planning of their studies, bringing them in only at the end to explain anomalies” (Heidt, 2020, para. 11-13). “Geneticists, like any scientist, believe if we have high quality data, the data will speak to us,” Instead, what’s required is for - “geneticists to work more intimately with scholars who have knowledge of the historical and social context of evolutionary processes” (Heidt, 2020, para. 11-13). There is an overall lack of historical context and background knowledge, as well as a total lack of Geographic Information System implementation. It could be substantially improved through various means by having a GIS analyst implement mapping practices.

One cannot accurately display geographically linked (largely spatial) information without any coordinate system, historical context, nor realistic geographical representation. The figures clearly have no forethought related to their projection, nor effort to simplify data, or give supporting information so the project could be more easily understood. In *How the Public Actually Uses Local Government Web Maps: Metrics from Denver* Brian Timothy details that the average visit time for maps is under two minutes. Further only 2% of people actually move past the default view presented by a map and less than a percent can open full screen view (Timothy, 2012). Likely due to these realities Brian Timothy shows statistics on how much greater the usage of “Single-Topic” maps (90,000 visits a month) is versus, multi-topic maps (25,000 visits a month) (Timothy, 2012). Every map is still incredibly difficult to decipher and could be vastly improved in the study by Micheletti et al. The figures on the map display genetic variation of regions as a result of the Trans-Atlantic Slave Trade through “silos.” Silos are a type of symbology that can be used in 3D on ArcGIS Pro through visualizing temporal data and creating a “time slider” but instead the study displays this data in 2D (without a GIS) using Adobe products (ESRI, 2019). The data is presented across massive scales when in reality it’s inevitably false at this scale and is at best an estimate. With the level of data analysis done they should have created more in-depth figures showing this down to local regions, inside countries. Further there is no time variable being taken into account on the figures which is a huge missed opportunity and inevitably results in less accurate results. If time is a factor, which it is, you have to create a map displaying these results with a time slider, as time is an important variable in this equation and all aspects of the mathematics done. Using 3D mapping would have improved the ability to account for time as a variable through space time analysis. This

would have improved the average person's ability to understand reducing the amount of data the viewer is confronted with at once, as well as improved the accuracy of the study. Had a GIS been used this could have been separated into seven different maps, or if it must be 2D, a multi scale map containing multiple layers of interlocking data which changes as one zooms in or out. That way it would be interactive and allows the user to browse through it.

2.6 Summary

To summarize, the primary conceptual issue is the lack of data presented by the majority of sources. This is largely a result of the complexity of genetic analysis, the overwhelming scale and historical complexity of solving the origins of slaves, which has rendered the topic largely inaccessible to the vast majority of people. Further attempts to remedy this have focused largely on the scientific analysis, or in-depth primary source analysis, and rarely have provided the necessary simple framework for the average individual to identify historical and spatial information of value. The products produced by most studies are highly complex, and to date none of them incorporated a GIS system to simplify that complexity. The simple use of Geographic Information Systems could advance the understanding of this topic significantly. Though investigating hundreds of years of data – which include spatial context – will never be simple, this project aims to simplify this to the extent a Geographic Information Systems application can simplify spatially complex and vast problems (or data). This will be accomplished by adding historical context provided through primary sources and prominent historical authors with works relating to the slave trade. Spatial context will be provided using GIS systems, customized symbology, and GIS tools, which will provide information that is more accessible and in depth to the average reader. By adding this spatial and historical context the intent is to provide information that is interesting to the viewer and context to their inquiries. With just genetic data alone, a person is left wondering what the value of this information is. For instance, now the user knows 60% of his DNA is Angolan, and 20% Congolese, but what does that mean? Where were his/her ancestors from? Or if genetic data results in him being largely Bantu, how does that assist someone when such a significant percentage of the population of Africa is Bantu? One would need historical context to assist in delineating what specific region their Bantu ancestors were from, or language would be useful too. By providing historical, lingual, bloodline, spatial and possibly more contexts, this project will start to provide extremely valuable supporting information to start filling in the historical gaps that currently exists. Specifically, this project aims to provide those types of answers for descendants of slaves who were brought from Africa to the Caribbean by creating two maps. One to be used to further research and work in the project through classes, and another for presentation to, and use by the public.

Furthermore, this map intends to prove and verify Geographic Information System's ability to simplify complex spatial data, while adding needed informative context to the viewer. Specifically, this will be done by going through the process of supplying spatial and historical context, applying Esri tools to analyze data in greater depth, and employing improved symbology, as well as permissions to manage user input.

The hope is to identify the best method for representing the critical information for the user. If proven successful, this will provide evidence that GIS systems are an apt technology for the dissemination and presentation of historical data related to the Trans-Atlantic Slave Trade and Intra-American Slave Trade. It will further prove GIS systems ability to manage multiple complex related data simultaneously. The map for this project is intended for the general public and those descended from slaves who were disembarked on Antigua, Nevis, and Jamaica, who are trying to decipher contextual information on their origins in Africa. Further efforts in the future will be focused on expanding the application of the method delineated from this project work to other islands in the Caribbean. In time, it will be a useful tool for researchers and descendants capable of providing context around origins locations, slave voyages, and providing context vital to understanding what this new data found by organizations like SlaveVoyages means.

Chapter 3 – Systems Analysis and Design

3.1 Problem Statement

The Trans-Atlantic Slave Trade was purposefully kept secret to a large degree from its inception due to two primary reasons: One, withholding information from enemies and allies and, two, its eventual illegality after 1808. Therefore, there is very little data overall on slaving activities (especially with land slave routes). This is consistent for most of the slaving activity of European powers like the Portuguese, Dutch, French and other nations. The poor records mean many of the slaves who were displaced permanently were left with no way to retrieve their lost origins. Of the millions transported, those transported by ship are some of the best recorded. Because of this, if descendants of those displaced people can identify that their ancestors were transported by ship then there is a greater possibility for identifying locations in Africa their ancestors might've originated. This provides spatial context that genetic analysis and Ancestry.com cannot provide as they do not incorporate mapping technology, spatial context, nor historical context. By providing this through Geographic Information Systems, it's possible to start to erase the dark shadow slavery has left across history which has prevented millions of descendants from retracing their origins.

3.2 Requirements Analysis

There were three stated primary requirements to the project originally. The first was the successful creation and deployment of the geodatabase. This initially included a server on which the data was going to be hosted. As will be discussed in the project plan, this server requirement was eventually dropped as a result of non-up-to-date servers (at the University of Redlands) and an inability to influence the update schedule. This would have required that the two primary variations of the geodatabase be housed on the enterprise geodatabase server and be separate, while remaining accessible for editing. This has changed for reasons explained in the next section, but as a result now the requirement is simply that the data be separate. The second primary project requirement is the geodatabase must fit the decided organizational format where each island destination is the name for the feature dataset. The datasets for these destinations are Antigua, Nevis, and Jamaica. Then there is the "Africa_Locations" feature dataset and the "Base_Layers" feature dataset, and the "Voyages Tables" (relationship data) included which correlate to the destinations. The third major requirement in the project is that the features displaying SlaveVoyages data all be visualized in 3D. The features do not need to be 3D objects, or multipatch features (type of feature class), they must simply display the attribute data as their Z value. Last but not least, the final major requirement is that the end application should not require any Esri credentials or University of Redlands credentials to access.

Deliverable	Type/Format	Requirement
Class Use Copy	File Geodatabase or Enterprise Geodatabase	<p>Class version must prevent public access and only allow organizational access.</p> <p>Map must be a 3D scene (global).</p> <p>All features must be in 3D except for rivers, region polygon layers, and labels.</p>
Public Use Copy	File Geodatabase or Enterprise Geodatabase	<p>Public App must not require Esri or AGOL credentials to access and view.</p> <p>University of Redlands hosted Web App must not require University of Redlands credentials.</p> <p>Map must be a 3D scene (global).</p> <p>All features must be in 3D except for rivers, region polygon layers, and labels.</p>
Field Maps Map	Mobile Geodatabase (SQLite)	<p>Functioning domains for the “Class Version” with proven functionality when offline (required). Domains must be made for existing layers (required).</p> <p>Optional: domains and empty layers for later contextual additions in the field (Port locations, illegal disembark locations, important locations, known slaving establishments...).</p>

Deliverable	Type/Format	Requirement
Webb App/Dashboard/Experience Builder	Application	Create an application for public viewing to the specifications of: 1.) Must be University affiliated and accessible via university website. 2.) Must provide user capability to play or pause a time slider. 3.) Relationship class connections must operate still so that user can click on a feature and identify all voyages related to that feature or vice versa. 4.) Must have layer list and legend, and should allow for filtering and querying in some form. 5.) Must allow table data viewing (not editing).
Website/Site Hub	Website	Provide a platform for the presentation of this data to the general public so that it may be hosted by the University of Redlands (client requested).
Documentation	Text or Excel files	Must be included in appendix Must provide lesson format

Table 3.1 Deliverables and Criteria

3.3 System Design

The project results in two end products: a primary set of web applications which display all complete and published layers of the project, and a secondary class version which will be the “in between” version where edits will be done and work accomplished, all of which requires reviewing before final publication. Both versions will contain the same data in separate ArcGIS Pro geodatabases at the end of the project. The only difference will be the Field Map features, which will only be present in the “Class Version.”

The project contains data on four primary physical entities: historical West African regions, ports in West Africa, voyages from West Africa, and the country destinations. The data for all features “pulls” from the voyages data. Due to this, the voyages data was chosen to be the basis for the relationship classes created. These relationships require the creation of unique identifiers; this process is a form of further quality control as every record must be double checked and their unique identifiers created. These unique identifiers act like a “key,” allowing the relationship to identify which records relate to the island destination, port, or region value in question. The project is coordinated so that the ports and regions data are summations of the voyages data, contained in the relational table. This means that for each port the value shown is equal to the sum of the voyage values related to that port for the chosen years. Likewise, if looking at a region value for a period of 25 years, that value shown is the sum of all voyage values for the 25-year period identified at that specific region.

Beyond this, the data within each feature class had to be entirely reformatted for the purpose of including time properties. All data in SlaveVoyages is formatted horizontally by column, row, and cell. To implement time properties, it was required that all these values be reformatted, so that for every year (or year increment) there is a feature (or port name) and set of values associated. This is discussed in greater depth in the “Data Scrubbing and Loading” section.

An important aspect of the projects system and its fundamental capabilities is the incorporated relationship classes. In advance of creating the relationship classes I identified that the best organization for the data would be to put most of the quantitative data within the feature classes attributes and include most of the qualitative data within the related “Voyages Table.” In creating the relationship classes I had to first come up with which type of relationship was most applicable. In doing this, every type (1:1, 1: Many, Many: Many) was tested to analyze how they changed the way the unique identifiers and data needed to be formatted. Eventually, the conclusion was that the most optimal method would be multiple one-to-many relationships. This was decided after coming to the realization that this was akin to how the database on Slavevoyage.org was facilitated. This was done to improve the ability for cross-analyzation and further provide consistency and accuracy to the data source. After determining that the SlaveVoyages database was being facilitated through some sort of relational database querying language, I was able to figure out how to appropriately organize our data to be most clear and accurate. The relationships would be connecting records within the entities present on the map, to records within the “Voyages Table.” These relationships will help keep the project consistent with the organization by which SlaveVoyages data is facilitated (shown below Figure 3-1).

Figure 3-1: Suspected SlaveVoyages data organization (SlaveVoyages, 2019)

Further, unique identifiers for over 4000 voyages had to be created, and not just unique identifiers for a single feature class, but for eight in each destination's dataset. Those would be the three ports features, the three regions features, and the two destination features. This required a significant amount of pre-planning and creating diagrams. After a while, it became clear that the best method would be to use a text field that would allow for the incorporation of symbols, so that there would be great variability present in the unique identifiers (allowing for likely hundreds of new additions in the future).

Figure 3-2: Relationship Diagram 1

The relationships correlate the data between the destinations (in the Caribbean) and the “Voyages_Table,” the origin ports in Africa and the “Voyages_Table,” as well as the origin regions in Africa and the “Voyages_Table.” Once these connections were created, they related the data between the destinations, voyages, and origin points. As shown in the diagram in Figure 3-2; pay close attention to the placement of the one and the many, not the fact there are many feature classes in each dataset, and one table for each dataset. This may at first glance appear to indicate that the relationship is backwards, however, inside the features and “Voyages_Table” the relationship as shown is correct. This is because the data in the “Voyages_Table” is the master key for all data facilitated through the database – meaning all the features connect to the “Voyages_Table” differently and it holds all the necessary information for the creation of the feature classes. What this also means is that the “Voyages_Table” holds more information or rows than any one of the features. Therefore, the relationship is connecting a single feature within the feature class to multiple rows in the “Voyages_Table” as shown in Figure 3.3. In this figure, there is a single port “Calabar” connecting to various voyages delineated by ship name (real data). This could be replicated for any of the features in the project. There are significantly more table rows the larger the year increments are, therefore in many ways this is acting like a filter – in yearly increments there will be the least table rows, 25-year increments will have more, while the totals will have the largest number of related rows.

Figure 3-3: Relationship Diagram 2

Through the implementation of the relationship classes, time properties, and the map format, which is visually displaying data, the project provides an extremely refined view of the SlaveVoyages data that is otherwise unobtainable without GIS. By seeing the data and interacting with it, instead of alternatively analyzing data and gleaning information from it, the project has improved the accessibility of this information. The intent is to provide a refined experience for the user which centers around reducing the amount of data the viewer is confronted with at one time. The time properties act as a filter ensuring that the data being presented is reduced to the time-period therein, while the relationships refine the data even further. By organizing the data in multiple feature classes, the project was able to provide a highly simplified “totals” layer, a refined 25-year increment layer, and an even further refined annual increment layer for region and port data. The destinations 25-year and annual increment data is provided, these values correlate to the 25-year port or region data previously mentioned. It is important to note that there is no total disembarked data for the destination because those values are held within the port’s data for the port’s totals and region totals values.

Logically, it is important at this point to make the connection that disembarkation values noted at the ports when summed are equal to the values for disembarked slaves on the island destination. To explain, if you were cross-checking within the Antigua dataset, investigating the disembarked slave values for a destination by 25-year increments between the years 1676-1800, and checking against the disembarked values in the African regions 25-year data for the same years – you would find the values for the African regions sum to be equal to the “Disembarked slaves by 25 yr period” field for the island destination data (during those same years). Through setting the data up in this way, the data is all connected in how it physically and logically would be connected. As the

viewer explores, they will start to see the patterns within the data which will lead to significantly greater understanding and ability to navigate this data. By being able to experience and see these patterns visually, the project immensely improves upon the lack of visual information present in historic data.

One more important aspect of the system is the domains and contingent values incorporated in the project which are methods used for reducing error in GIS. These functions reduce editing errors by preventing missteps during editing. Yet, domains also provide the basis for plotting map features while in the field, and in turn provide the basis for Field Maps. The domains, contingent values, and relationship classes work in tandem to provide a significant monitor that immediately identifies errors when they are made. In the future, as students edit this data, if a mistake is made they will immediately be able to identify that by simply checking the feature or row's attribute information. Additionally, if there is an error, this will prevent saving or committing these changes. This will need to be set up for new sets of data, however, only graduate students or the client himself should ever be doing that work.

The client's May term class will make use of the created Field Maps product to add features and contextual information during the future trip to Antigua. This work will likely be done in the summer of 2022, or possibly later. The created offline areas for the Field Maps allow for edits to be done in the field across the entirety of Antigua and Nevis. These offline areas have a scale range which goes from "world scale" to "small building scale." The intent here being not to require too much of a load in terms of processing for phones or other mobile devices when interacting with the map in the field. In the future, more offline areas will need to be created for Jamaica if that becomes a planned May term trip. This is because Jamaica is significantly larger than Antigua or Nevis in terms of sheer land area. Due to this, Jamaica cannot be encapsulated by a single offline area, nor in two, or even three. This will require that the specific areas that the trip takes place be identified and created as offline areas in advance of the trip to Jamaica (if done in the future). Currently there are no planned trips to Nevis or Jamaica, however, they could be added May terms in the future. There are up to sixteen offline areas which can be made, only two have been created so far, therefore this leaves room for expansion.

The features added by students who are a part of the client's future May term course will improve the project and the contextual information it provides. The placement of these features provides further content to assist in the visualization of the project data; while the contextual information contained inside the attributes (facilitated by the domains) provides valuable information related to those locations that would otherwise be unobtainable. Providing spatial and historical contextual information is one of the primary purposes of the project. The other, is to improve the understanding of data relevant to the Trans-Atlantic Slave Trade through visualizations made possible by GIS. The attribute fields contained in these features detail various aspects of the locations themselves. These are included below in Table 3.2. These field names are taken from the ArcGIS Online version, as a result, they differ slightly in ArcGIS Pro. The primary difference is that instead of the alias "Windmill Physical Presence" used in ArcGIS Online for the domain – in ArcGIS Pro these domains are simply named "Windmill_Location" with "Location" replacing the forementioned "Physical Presence." This is a result of some of the finalization work related to the Field Maps version in ArcGIS Online. Specifically, this field was renamed in each domain to include "Physical

Presence” because a description is not immediately available in ArcGIS Online (as it is in ArcGIS Pro) for these domains. The intent being to make the name itself more descriptive for future student users.

Feature	Field1	Field2	Field3	Field4	Field5	Field6
Windmills	Plantation presence	Windmill Physical Presence	Windmill Count	Windmill Status	Slave Trade Activity	Source
Cattle Mills	Cattle Mill Physical Presence	Cattle Mill Status	Slave Trade Activity	Source		
Fort	Physical Presence	Fort Status	Slave Trade Activity	Source		
Town	Physical Presence	Town Status	Port Town Status	Slave Trade Activity	Source	
Road	Status	Type	Activity	Slave Trade Activity	Source	
Churches	Physical Presence	Church Status	Racial Accessibility	Source		

Table 3.2: Contextual fields for Field Maps features

The fields included have domains implemented which align to the field names in Table 3.2. These domains provide specific inputs for these fields which cannot be deviated from. This prevents error from being introduced and further ensures that the information provided is concise. The contextual information provided covers various topics: the physical presence fields identify whether the location is still physically present in real life using a range field from zero to two; zero being it does not exist, one being that it does, two being that it used to exist. The second field of importance is the status field, which identifies the condition of the location through five options which vary from pristine condition as well as being in use, to very poor condition meaning only the foundation is identifiable. The third and possibly most important field is the “Slave Trade Activity” field, which identifies what the specific slave trade related activity was at any given location. The domains (options) for this field are detailed in Table 3.3. The final field is the “Sources” field. This field identifies how the information was obtained, whether through a primary or secondary source, or firsthand experience. There are some outlier fields specific to individual features such as the “Plantation presence” field and the “Port Town Status” field. These identify different aspects of these specific features, however, they are of less importance compared to those detailed above.

Code	Desc.
Auctioning	The sale and purchase of slaves was done here
Cattle Work	Slaves were used to work cattle here
Field Working	Slaves harvested crops (sugar) here
Illegal Slave Activity	Slaves were bought, sold, or interacted with illegally here
Indentured Service	Slaves were sold into indentured servitude here
Land Transportation	Slaves were transported here
Other	Other slave trade related activities occurred
River Transportation	Slaves were transported by river here
Shipping	The slave trade was present at ports here
Slave Escape Route	Slaves escaped through this route
Slave Sanctuary	Slave escaped to here

Table 3.3: Domains for “Slave Trade Activity” Field

The project’s system, therefore, will combine all of these stated capabilities in order to provide an effective platform which accomplishes each of the client’s requirements. These will eventually be organized inside a Web Application as mentioned and a Field Maps Application which will incorporate the stated capabilities and system design. The intent in incorporating all of these aspects was different for each capability, the relationship classes and time properties are largely for the viewers and refining the data, while the domains and contingent values are primarily for editors and improving the editing process.

3.4 Project Plan

The client’s initial concept for this project was a Dashboard application that would allow the user to visualize the world as a 3D globe, employ 3D features, a time slider, and further provide the capability for a user to click on a feature and be presented with the information that relates to that point. The primary objective in employing these capabilities is to reduce the amount of information the user is confronted with as they select or narrow their search. The client’s concept was that there would be two primary end-deliverables: one, a Dashboard (changed to multiple Web Applications as discussed later in this section) which would be hosted on a university affiliated site that does not require Esri credentials. Then second, was a Field Maps application which would be connected to a second version of the project data and allow for in-the-field edits to be done on an abroad trip.

Figure 3-4: Original Project Plan

In order to achieve this result, the conceptual model for the project was initially laid out so that sufficient time could be given to perfecting each section. Initially, the client was under the impression that all the data needed had been extracted, as a result time resources were not correctly designated to extraction and formatting. As the project progressed challenges would arise in the GIS during creation. Due to this, more time would need to be allotted for addressing issues here.

The intent was to create two versions of the same geodatabase. Versions, as used here, is not referring to “versioning” (a capability of ArcGIS Pro), instead it is simply referring to creating two separate file geodatabases, or two sets of the data within an enterprise geodatabase. This was done to separate the data and ensure that edits done in the Field Maps version would not transfer to the public facing version. These versions of the geodatabase would be copied to the enterprise geodatabases server, which would allow for one to be connected to the Web Application and the second to be connected to the Field Maps application. This would create two separate versions so that the class version edits didn’t bleed into the public facing version. The server further allows for the seamless transfer of edits from Field Maps to ArcGIS Pro, and the publishing of the Web Application publicly so that viewers do not require Esri credentials. After these steps the final Web App and Field Maps application would be created, then tested, and once the client and project advisor were both satisfied, the project would be complete. As will be explained in greater detail in the logical model, there were various issues the project encountered that prevented us from carrying out the plan stated (shown in Figure 3-4).

Significant work was put into trying to achieve this result, however, the issues we encountered were beyond the project team's control and ability to change. These would result in changes to the final product, which would not be hosted on a server under the University of Redlands in the end, but would instead use ArcGIS Online, and would not be a Dashboard but instead four Web Applications and an Experience Builder App, which would include further changes to the planned 3D presentation of the data.

The original plan was accurate to the overall goals and deliverables the project would produce, yet very unrefined to the actual work which would need to be completed. There were also various realities which impacted the project schedule, for example, the client's GIS experience and complex data formatting procedures which resulted in the data for the map layers being insufficient for the intended purpose. Originally, it was understood that the client had all of the data formatted and ready for use. This turned out to be incorrect as only one third of the data was extracted at the start and none of it was in the necessary format for time properties to be implemented. The reality of the situation was that the client was not fully aware of the specific format for the data, which would be required for the project; and the original data extracted included only Antigua because the project scope was expanded later to encompass Nevis and Jamaica. Significant data extraction quality checks had to be done and all project data needed to be reformatted. The creation of these layers took significant time resources from the project.

There were various tasks which were identified as being crucial during the project planning and execution. The first being extracting data and creating features to visualize the totals. Once that was completed, next came extracting all 25-year and annual data required. These were compiled and organized into a folder named after the country destination (Caribbean Island) in question, then folders were created for "Totals," "25yr," and "Annual." In total, there would be ninety-six tables worth of data extracted for the features, ranging from 24 records to 3592 records, all of which would need reformatting in order to create the features. These would be consolidated into 24 feature classes across 3 feature datasets and would include 3 tables.

Some layers were provided; those included the "All_African_Ports" feature, the original region features, the Antigua land area feature, and "World_Continents_Vignette" feature. The port location layers, and the regions were provided by the client, while the Antigua shapefile was provided by the project team's cartographic advisor, as was the "World_Continents_Vignette." The Antigua feature is still highly detailed (even after a simplified version was found), and it contains 510 vertices. Importantly, this is not the only feature with this level of detail – the region layers provided by the client were highly detailed as well. The number of vertices for the original regions are shown in Table 3.4:

Region	Vertices
Senegambia	358
Sierra Leone	128
Windward Coast	138
Gold Coast	153
Bight of Benin	202
Bight of Biafra	254
West Central Africa	155
Southeast Africa	904
Africa Unspecified ("Other Africa")	35

Table 3.4: Hist. African Regions – Number of Vertices

This is worth mention due to the fact that the detailed nature of these polygons would impact processing throughout the project. This was an unforeseen variable, which affected processing at certain points during the creation process. It was determined by the project's cartographic advisor that the number of vertices were specifically impacting processing during ArcGIS Pro editing. Due to this, portions of the project schedule were slowed. However, the client wished to have a high level of detail in the region polygons as they are important study areas for the project. As a result, the realities surrounding processing were acceptable to the client to achieve the level of detail implemented in the regions.

For the "All_African_Ports" layer, which provides the latitude and longitude for the "totals" features, the creation process requires researching and identifying through historical literature, the locations of ports (largely done by client), and creating a base feature layer containing all African port locations. This is then used to facilitate the ports totals. Then, through using "Create," the points are digitized at the identified historical locations. During the project work once this digitization was completed, new requests were made by the client and advisor which related to the regions previously provided. These changes resulted in re-digitizing and reformatting the region features provided by the client to the specifications of the project's cartographic advisor in terms of color, feature orientation, type (polygon to lines), and symbology. After this, the process was documented for future editors. This process put simply, requires taking out the polygon vertices which extended out into the Atlantic Ocean and deleting all that are not on land until the polygon appears only along the coast. These polygons would be used for the creation process of the core project layers. These same polygons would later be converted into line features for the "Inland_Africa_Region_Lines" feature in ArcGIS Pro, which displays the coastal regions by the designated color scheme. These polygons and lines are provided as shape files to the client to ensure that these regions can be replicated in the future.

At this point in the process, once the ports (points) were placed, the XY (longitude/latitude) data for “Ports Totals” was created and used in the creation of the 25-year and annual port layers. For obtaining coordinates with the “Regions by Year” features the “Regions Totals” polygons were converted to points, then these points were moved to the exact designated locations for the project regions. During this work coordinates were documented so they could be provided for future editors, therefore, future editors will just have to place the points with those provided coordinates, or snap to pre-existing features.

Within the Excel tables for 25-year and annual values, all values that were oriented horizontally by port or region (of origin) across and with years down were re-formatted. As a result, for every port or region there was an equal number of each origin name to the number of years for that data’s timeline – which was performed for every port or region. Then with the coordinates acquired previously, the XY information was filled in for the 25-year and annual data, so that all features of the same port or region name had equal XY coordinates. For the Africa region values: “Regions Totals” and “Regions 25-year,” the previously created polygon layer for regions was used, then “Feature Class to Feature Class” was used to create a new feature. Then the next step was to use “Join Field” in order to add the necessary fields to the new feature for totals. Once that was done, the process for “Regions 25-year” was the same – except, once a new feature was created, the number of 25-year periods were counted, then all the regions were selected within the attribute table. At this point, the select tool was activated under the edits group on the ribbon, then copy and paste was used until there were as many copies as there were 25-year periods for that destination’s data. This ensured that the shape information was the same.

The next portion of the project plan was identifying fields that have contextual value to living descendants of those brought over by the Trans-Atlantic Slave Trade. The qualitative fields of worth identified were:

Voyage ID	Vessel Name	Vessel Owner	Flag	Rig of vessel
Guns mounted	Voyage itinerary imputed port where began	Voyage itinerary imputed principal place of slave purchase	Voyage itinerary imputed principal port of slave disembarkation	Year of arrival at port of disembarkation
Slaves arrived at 1st port	Percent men	Percent women	Percent children	Slaves died during middle passage
Mortality rate	Crew at voyage outs	Crew deaths during voyage	Captain's name	Sources
Particular outcome label				

Table 3.5: Qualitative Contextual Fields

The quantitative fields of value added to ports, regions, and the destination islands were:

Embarked slaves	Disembarked slaves
Average middle passage time (days)	Average standardized ship tonnage

Table 3.6: Quantitative Contextual Fields

The next task in the process was going to SlaveVoyages and extracting the “voyage table” data with the above-identified columns selected in the filter. All contextual data fields were selected and place of landing was used in the itinerary – set as the island destination in question. All values were extracted. In the end, there should be a single table for each island destination. These become the relational tables. Within Excel, the Unique ID Creation Guide (given to client/ shown in Table 4.5) should be used to create the various values required (specifically, to create the initial Unique IDs for all feature classes). This must be done within the previous tables used to create the feature classes themselves and within the “Voyages Tables” accordingly. Once all features have had their Unique IDs completed, these tables must be connected through a folder connection in the catalog, then joined to their feature classes by “ObjectID.” If for any reason inconsistencies occur, first check that no mistakes were made during the join and then check the equivalent data on SlaveVoyages, and within the Excels used for feature creation. In cross-checking, identify if it would be easier to change the feature class or create specific join IDs for the scenario. It’s recommended that all ports’ values have a region field specifying their related region (which will be needed for later joins). Once completed, move on to adding the Unique IDs to the relational table. Eight fields were needed for the relational table’s Unique IDs, 3 for ports, 3 for regions, and 2 for the island destinations – beginning with “Annual Ports” and “25-year ports” in Excel. Once all of the Unique IDs were created for these fields in the Excel document, it was necessary to move from Excel to ArcGIS Pro – in order to create the relational table data using the “Annual Ports” and “25-Year Ports” fields. The remaining fields were created using the “select by attributes” and “calculate” capabilities to create the new values for the following tables. For “Regions Annual,” the individual tables for each region of origin with their specific Unique ID values were created from the feature layers previously made. Once all the individual tables were created and transferred into ArcGIS Pro, each regions values were selected one at a time, then I accessed the folder the individual tables were housed in. I used a join with those specific region records selected – joining by year to the relational table created, specifically for the region records selected. From this point, the following records could be more easily done in a similar fashion. I ensured all Unique IDs were present in the table and in the feature layers related. Finally, I used the “Create Relationship Class” tool to create one-to-many relationships between the features and the single relational table (for the island in question). This was accomplished for all ports, regions, and island layers. In the end there would be eight relationship classes per feature dataset.

Next, I customized symbols to match the client’s wishes: Originally the plan was to use “3D by Attribute” to create 3D symbols for the various layers, however, due to the wish to consolidate layers so that the geodatabase had eight layers versus sixteen for each destination, it was decided by the client that the features include both the embarkation and disembarkation values for the ports or regions, instead of displaying them as separate

layers. As a result, the plan to use “3D by Attribute” no longer was functionally sound as each feature had various different values for embarked or disembarked slaves. Due to this, it was decided that these values would simply be symbolized in 3D by graduated cylindrical symbols. The client requested cylinders varying in height dependent upon slave embarkation or disembarkation values. To achieve this, the same layer is used twice in each ArcGIS Pro map to display embarkation and disembarkation values separately. The client confirmed that island disembarkation symbols are viable as spheres. The color scheme should be representative of the African region in question for ports and for region cylinders, however, island symbol color either should identify amount by attribute, or identify all destinations by a single color. This would be red for the destinations and for the regions the color designations are: 1.) Senegambia in faded light blue (#BED2FF), 2.) Sierra Leone in bright purple (#C500FF), 3.) Windward Coast in bright neon green (#55FF00), 4.) Gold Coast in bleached yellow (#FFEBAF), 5.) Bight of Benin in azure/sky blue (#73DFFF), 6.) Bight of Biafra in a faded red (#FF7F7F), 7.) West Central Africa in “turquoise dust” (#9ED7C2), and 8.) South Africa in a dark pink (#F57AB6).

At this juncture, it was decided that there was not sufficient spatial analysis or context being provided to the user. As a result, the decision was made to calculate the distance between the points of embarkation and disembarkation, which would be useful information. In order to provide this, use the “Generate Origin-Destination Links” tool on ports and regions as origin, with links to the island in question as the destination. Ensure that the symbols match the color scheme for regions. Ensure only embarkation values are included for the African port or region in question, and then ensure that the necessary values are joined from the African ports or regions layers to the origin to destination line feature class created. Use these new fields to create time properties for the lines and test functionality with both island and port or region features also turned on.

To implement the decided final naming conventions and format of the geodatabase, the format is as follows: for each island create a feature dataset housing all layers relevant to that island. Create a feature dataset named “Africa_Locations,” which houses all the region polygon features, ports, and unspecified ports, or various other layers relevant to the project for geographic context. Create another feature dataset named “Base_Layers” which contains all base map related content. In the end, the three island datasets must contain thirteen features each: these are the three region layers, three port layers, the two island (destination) layers, the four “Generate Origin-Destination Links” line tool layers, and finally the island polygon feature class. Other than this, there are eight relationship classes. Outside the feature datasets, there must only be a single relational table for each island destination. Ensure all feature datasets, feature layers, and tables follow the naming convention.

Next comes the creation of “Domains” and “Contingent Values.” The client requested for empty feature classes to be created for in the field edits; these included windmills, forts, towns, roads, cattle mills, and churches. Otherwise, various domains were created in order to reduce error in the future. Domains for the point coordinates were created (for all West African ports in slave voyages database), for names and aliases, for color identification fields, and more. These domains are being used in tandem with contingent values in order to ensure that the names and aliases of ports always match to specified coordinates, and that the field names match to the correct “Color ID” on each layer ensuring the color scheme designations are correct.

Once the project ArcGIS Pro work is completed, create a copy of the project at its most final stage before the facilitation of the class and public copies. The original should be set up so that only the client can edit and access this version. Once the original is created, the second “Class Version” should be made. Once this class version is set up, the domains should already be properly in place (already made). The public version is a version that allows for no editing unless the user has administrative access as the client. This means editing requires administrative access on the ArcGIS Pro project. The ArcGIS Online maps either allow no edits, or only allow edits on an exportable copy downloadable by users. The Web Application is set up to allow no edits. Both the class and public versions have domains and contingent values implemented to improve data reviewing and quality checks.

The project encountered significant issues when approaching the planned method of housing the project data and geodatabase on the University of Redlands Microsoft SQL hosted server. Over the course of a month, the project advisor, Nathan Strout, and myself worked to transfer the data onto the created server for the project. We discovered then that the incorporated capabilities of the project’s ArcGIS Pro work were too new for the University of Redlands Microsoft SQL Server. The resulting reality was that the contingent values used in the project to reduce the likelihood of future error rendered the data impossible to upload onto the server. The project, therefore, had to pivot. There were two options: One, remove the contingent values and forego any quality control measures of meaning; or two, use ArcGIS Online instead of the Microsoft SQL Server deployment to facilitate the project. In the end the decision was made to use ArcGIS Online in order to keep the functionality of the contingent values since those capabilities are important for the project’s data quality, and for ensuring consistency in the future. Using ArcGIS Online means the permissions are set by the organization account, and there is no opportunity for the same level of ownership over the project as it is not hosted by the University of Redlands as we had intended.

Here it may be helpful to explain the original plan and some of the benefits it would have provided. The original intent was to create a server using Postgres SQL at the start, but this was changed to Microsoft SQL Server because the University of Redlands uses Microsoft SQL Server. Once the server was set up, the intended process was to transfer all data onto this server from the original file geodatabase, then finalize its organization, and lastly ensure the connection to the Web App. The data would be transported to the server, hosted, and finalized. At this point the original version should be 100% set up already. The only task would’ve been ensuring a copy was made and not including it in anything further, which would be its “deployment.” Second, the class version should have its domains in place, and once set up and enabled this should function without edits and be transportable to the server. Use this data on the newly created server to create a web map, then set up this web map to connect to Field Maps, ensure Field Maps pulls directly from the server and that the enterprise geodatabase for the “Class Version” is manageable/updatable via an ArcGIS Pro project. Test the connection between the Field Maps application, the enterprise geodatabase and server, and the class version and ensure it functions. If edits seamlessly transfer from Field Maps to ArcGIS Pro then the intended capability is functioning. Lastly, the public version would have been more work than the others as it requires the set up and finalization of the public facing application. The process of creation requires that the previous

connection between the enterprise geodatabase and ArcGIS Online is functioning. After the connection is ensured, the project becomes accessible via logging into the specified portal which is similar to logging into ArcGIS Online, but instead is its own deployment and page similar to UR Spatial itself. Once accomplished, create the Web Applications, and begin the process of implementing the necessary capabilities using the hosted data. After this is complete the project would be much closer to its final form and would reduce the amount of finalization work required in the presentation of the product in the public application. The intent with using the server was to consolidate the data requirements and provide a place where all data for the project would be stored. This would have improved accessibility of the project data and would simply require that two versions of the same data be hosted (these would correlate to the Field Maps and Web Application versions). Further, through having the data hosted in this way it is likely that the processing burden of the 3D visualizations would be reduced. By doing this the data would be housed in a single place, easily accessed by editors, and would inherently prevent access by unwanted audiences by providing a secure platform. Additionally, the sever incorporates permission settings to control who can access the project's data. Lastly, the metadata process is simplified and would have been immediately transferred since it would already exist within the hosted data. Through creating a new server instance under the already existing University of Redlands enterprise deployment, the project would have been routinely updated when the University committed updates. Further, the server would have been hosted by the University of Redlands on the school's servers and the project would therefore fundamentally be under the ownership of the University. This would have provided The University of Redlands with more ground to affiliate this project with the University versus Esri. All of these benefits were forgone when the project pivoted to the ArcGIS Online method.

Due to the switch, significant work had to be devoted to finalizing the symbology of the ArcGIS Online versions and significant challenges were encountered in the facilitation of the data in 3D on ArcGIS Online. For example, in 3D scenes on ArcGIS Online tabular data (in a table) cannot be added to a scene. This means none of the relationship classes can access the essential data required to facilitate those connections. This is not able to overcome at this time. Further, time sliders are not a capability of 3D global scenes naturally. The only way to achieve something similar, to the best of our knowledge, is through the use of ArcGIS Enterprise, a server, the ArcGIS API for Javascript, and custom filters, which require a proficiency in JavaScript. Further, the application of an API key is required in order to influence and republish a service like a map. I came to recognize that the ArcGIS Online access versus the server's may also be different, and after much research and attempting to influence the code of the created Web App on ArcGIS Online itself – I felt there must be some differences. This was confirmed through personal communication with Sajit Thomas and others. I initially did this by finding the admin side of the REST end point services page for my Web App on ArcGIS Online, specifically for the temporarily published Web Application. This allowed me to try and influence the code. In entering new code to try and facilitate a time-slider I found that none of the changes I made were being saved. This made me conclude that this was not the correct method. After significantly more research I came to a better understanding of the API keys, but also realized that it was not feasible to come to a deep understanding on how API keys are applied and used. As a result, it is very possible that

someone with more experience with JavaScript would be capable of accomplishing this. The symbology from ArcGIS Pro, which took hundreds of hours over months to perfect, was lost completely due to the inability to use map image layers (a capability of using the server set up). Primarily, this is due to the fact the server could not be used and that, as of the time of this writing, ArcGIS Pro – when trying to share a web layer to ArcGIS Online from a global scene – does not allow one to share a web layer as a vector tile, raster tile, or any other form than a scene “feature.” Simply put, this means all the symbology is lost in transfer. In trying to work around this, another issue encountered, was that custom color schemes cannot be uploaded to ArcGIS Online. Luckily, it was possible to use the color designations in ArcGIS Pro to manually recreate the color scheme using those numeric codes. The features themselves, however, are nowhere near as precise or refined as the ArcGIS Pro version.

The plan is to create a 2D version of the project so as to be able to implement the ArcGIS Pro capabilities such as relationship classes, time sliders, and contingent values. So far, there has been no identifiable method to get the 3D version fully operational. As a result, the current plan is to produce a more visually oriented, basic project in terms of the data presented, which uses 3D features and slides to facilitate a time slider effect. This timeline does not operate like a time-slider; instead, it will have to operate much more like a PowerPoint presentation where the user clicks through slides that display different information. Once all reviews with the client are accomplished, the last task is to organize all of the applications onto a Site Hub, publish them, and then find a way to host them on Redlands.edu.

3.5 Summary

In this chapter the problem the project is attempting to address is touched upon again briefly, which clarifies that the focus of this project is to combat against the overwhelming obscurity present in data from the Trans-Atlantic Slave Trade through GIS capabilities, 3D visualizations, and 3D scenes – further improving upon the accessibility of the data being collected by SlaveVoyages. The chapter discusses the requirements created which relate to solving this and further the specific project deliverables. Next, the design of the project’s data is detailed, specifically covered is the creation of the relationship classes, the reformatting of the data for time, and the creation of domains and contingent values. Finally, the project’s major tasks are discussed in depth. Many of the various issues encountered and overcome are discussed, as well as specifics on creation techniques. Importantly, the two primary issues stated at the end of this chapter are discussed in terms of the understanding at the point this section was written. Those issues being the efforts to implement the time slider on a 3D scene in ArcGIS Online, and the inability to add a table to a 3D scene were confirmed through personal communications with Philip Mielke and Sajit Thomas (discussed further in the “Web Application Creation and Organization” section).

Chapter 4 – Database Design

This section details the design of the project's data and pertinent presentations of that data. It first details the conceptual model which identifies the physical organization of the Trans-Atlantic Slave Trade in terms of its real-world logistics. The chapter continues on to discuss the data collection, organization, and logical decisions in terms of facilitating the project, the pivots that were made, and more. The Logical model section also provides a model which is specific to the scope of the project. The issues encountered during creation are discussed in detail in the data scrubbing and loading section. This chapter details the data involved in the creation of this project, the issues encountered, and some of how the data was facilitated.

4.1 Conceptual Data Model

The orientation of the data in the project was based off of a few primary factors: One, the use of multiple features, which interact with the data uniquely required the setup of a relational database. The second factor was that the data is oriented around the Trans-Atlantic Slave Trade which confines the data to a specific enterprise with specific activities. Simply put, the physical realities related to the data, plus the organization of SlaveVoyages data which is largely based in historical reasoning. The data in the database may not always be presented in the clearest manner, or according to pre-designated database schema, but often is presented in the most historically accurate manner. The third factor worth note is that the project focus is to provide spatial context surrounding the displaced slaves by identifying origin ports, regions, and destination islands specifically, not the ships. This is because there is no individualized data on the slaves within each ship, therefore, it was required that the project identify another physical entity to express this data through. In order to provide further spatial context for the user, this was done through the use of “immobile entities,” as previously mentioned in this report. The intent here was to provide a better sense of location through origin and destination points so that the user could click on features representing ports, regions, or destinations and be presented with data on those locations, and related data having to do with the voyages that went between these points. Last but not least, the final factor which impacted the organization of the database was the use of ArcGIS Online for the final implementation versus the server for reasons explained in the “Project Plan” and “Logical Implementation” sections.

Figure 4-1: Conceptual Data Model

The requirement that the project use relationships was managed through the implementation of relationship classes in ArcGIS Pro relating the data between the regions, ports, the island destinations, and the voyages. The “Voyages_Table” provides important qualitative information about the ship, the journey, and various other information that was deemed relevant to the slaves being transported. The project is attempting to create better supporting information that is more contextually significant in terms of the slaves themselves. It is accomplishing that by using the origin and destination points as entities. Of course, there is no way to focus on each individual person displaced because there is no individualized data. Due to this, the project attempts to achieve better contextual information surrounding the transported slaves themselves by using their origin and destination points instead of a mobile physical entity like the ship (which ultimately results in the data feeling less personal). As can be seen in the conceptual diagram shown in Figure 4-1, there is a reality that the origin point on the coast “Place of Purchase” is not a true original origin point in the case of any slaves brought to that port by caravan or river. As a result, the project cannot obtain the original origin for those transported, nor can it achieve the final destination with the data that has been extracted. The reasons for this are discussed in Chapter 2 under the “African History and the Trans-Atlantic Slave Trade” section.

The second motive of the project team was to stay true to SlaveVoyages data and not stray from it significantly. This became especially critical during the data creation and facilitation because the project team decided to consolidate the unknown location category on SlaveVoyages. This resulted in changes to the data’s organization (these changes are also discussed in the “Results” section). The primary change was the consolidation of varying port values which all were subsets of the larger “Other Africa” designation. This designation simply means the location of origin is unknown. The

problem with this is that different island destination's data (Antigua, Nevis, etc.) would have different ports in this unknown category, and at times these port values would not align in terms of their data. This resulted in inconsistencies across the regions' and ports' values on SlaveVoyages. The problem with this is that logically, the ports' values should be equivalent to that of the parent regions. It was identified by the project team that the inconsistencies within the data were a result of these port designations (specifically the ones that all were still correlating the unknown locations) which did not all correlate to the "Other Africa" region value, even though they should. As a result of this, some of the port designations were removed entirely and they were consolidated into a single category across the ports and regions named "Africa Unspecified." This made it so that the values for the unknown locations (or "Other Africa") were consistent across the ports and regions in our project's "Africa Unspecified" field. This is shown in Table 6.1 and Table 6.2 in the "Results" section.

The third important factor is what the project is about. This project is intentionally oriented differently from the data that it was originally created from. The data is facilitated by information retrieved from shipping logs, insurance, and or legal suits which resulted in documentation of slaving vessels. Due to this, the data is oriented around the "business" of the slave trade, specifically the ships. The project attempts to re-orient this data instead to the origin and destination points in Africa or the Americas. Due to this re-orientation it's important to recognize that the conceptual model will be reduced significantly in the logical model. It will instead focus on the sections of data align to the project purpose and are able to be analyzed and visualized through GIS. Through previously discussed work done by Dr. Glover, the various port locations were identified (these are not included in SlaveVoyages). This, therefore, added an important piece to the successful facilitation of this project. Once these required locations were collected, they could be manipulated in ArcGIS Pro in order to create the primary project layers.

The final factor was simply the use of ArcGIS Online which impacted the final organization of the data significantly. This was a result of the previously explained issues surrounding the server's implementation. The result is shown in the Logical Model in section 4.4, but most importantly this resulted in a different organization of the data and consolidation of the overall number of layers present. Having said that, this version's data is not oriented any differently from that of ArcGIS Pro. The relationship classes, the core data components, their organization, and the physical connections between the data are still consistent. The primary difference is that this data is significantly more tedious, time consuming, and troublesome to work with on ArcGIS Online for editors.

4.2 Data Sources

One source for data used in our project was the client himself who provided a few feature layers and most of the initial extracted data. Specifically, the client provided the port locations for the ports across Africa which participated in the Trans-Atlantic Slave Trade. He further provided the original polygon layers created by Dr. Alana Belcon.

Another contributor for the project data was the projects cartographic advisor who provided the more generalized version of the Antigua feature, used to provide the shape data displaying the land area of the island. The other layer that was provided by the

project advisor was the “World_Continents_Vignette” layer which was used only in the ArcGIS Pro project.

The primary external source for the data used in the project is the SlaveVoyages international study, which allows for data extraction in Excel and CSV formats. This was the primary method of extracting the attribute data relevant to the project topic. This means all Trans-Atlantic Slave Trade related information including embarked, disembarked, middle passage, tonnage values and all other contextual data are the work of SlaveVoyages and Emory University. The sources for the features of Nevis, the world base layer, and countries was the University of Redlands One Drive “countries” layer, which was provided through Lisa Benvenuti. The only other source for data used in the project was a layer for continents found on ArcGIS Online which had the National Geographic Society cited as the source for the layer data. This continents layer is a generalized layer which depicts the continents of the world. The layer is simplified and therefore not 100% accurate to the coastlines, and its most optimal scale extent is 1: 150,000,000 - 1: 5,000,000. This layer was used to extract the Jamaica shape information for its destination feature as well. This is the primary data for the continents which make up a part of the base map layers. There are the set countries and continents layers for the project named just “continents” and “countries.” These provide no extent shift and are set to act as a base map. Then there is “continents detailed” and “continents simple” and the same convention exists with the countries’ layers. These allow for extent improvements in the ArcGIS Pro map. The layers were simplified using the Wagner method, the setting for what qualifies as a significant curve is 35,000 feet, and for the more generalized (simple) version it is 60,000 feet. The continent and countries layer fields are equal to the layer the continents data was retrieved from. The destination islands features, however, have been edited so as to simplify the fields, so the destinations only provide continent, country, and capital in their attribute information.

There are various metadata included in the project. There are some layers which are more crucial in terms of metadata than others, specifically the ports, regions, destination layers, and “Voyages Tables.” These contain metadata to explain the processes which were undertaken to create them, descriptions on their intended use, data contained, and more are provided. These layers are the center focus of the project, and therefore, their metadata is highly detailed. In relation to these features are the “Voyages Tables,” of which there are three. These encompass the scope of the project Antigua, Nevis and Jamaica. The “Voyages Tables” contain the voyage specific data contained in SlaveVoyages which relates to each destination. These are related in the previously detailed one-to-many relationships to the features discussed above. These tables contain over thirty fields of information which support the data presented in the feature classes. Through using these tables, importantly, physical features for the ships were not created. This was intentional and provides increased focus on the immobile entities such as ports or regions. As a result, this means these tables must be descriptive, and explain how this data is oriented in relation to the feature classes themselves. Therefore, these tables have the most detailed and sophisticated metadata through-out the project. Further, all of these features contain a citation for the SlaveVoyages study and detail that the primary source for their data is the SlaveVoyages Trans-Atlantic Slave Trade database.

4.3 Data Collection Methods

A portion of the data was provided by the client, including some of the initial extractions of data and the delineation of the port features in the project (in terms of identifying a precise latitude and longitude). Being a specialist in West African History, the client combed through historical journals and sources to identify the real-world locations of port names used in the SlaveVoyages database. At this point these locations were used for the creation of the various other features in the geodatabase. This is because the project incorporates time and layers with varying time increments surrounding the same data. To create these features that incorporate time, the mentioned point locations were required. Once these were identified the process of creating the port features started. This process would not require further data extraction from this point, but it would require additions and edits as the project continued. Importantly, this port data is the primary enhancement of the data relevant to the Trans-Atlantic Slave Trade – these more specific locations are some of the most important data included in the project.

Significant data extraction from SlaveVoyages was required in this project, as hinted at in prior sections. This extraction was done from the SlaveVoyages database by exporting data in .csv and .xlsx formats. There were various reasons for this beyond human error: One, the client extracted data had been done over a period of a year or more in time. This meant that the data had been updated or changed by time we used the previously extracted data the client had created for Antigua. This required portions of that data to be re-extracted or updated. Second, the project team debated what the correct settings for the extraction on SlaveVoyages were. Since the data from SlaveVoyages is formatted by column, row, and cell, that meant we had to be extremely consistent in the values used and search settings used to format the tabular data on SlaveVoyages. For instance, there are values labeled with a designator “IMP” (imputed results) on SlaveVoyages – the project team found that these data are more consistent than the non-IMP versions of them. This, therefore, was a point where in some cases the client had extracted data for Jamaica with the same field name (with no IMP), but that data was not the same set of data from SlaveVoyages that we had been using. This meant the data values did not align. This data would need to be re-extracted as a result (SlaveVoyages, 2019).

The other primary extraction required from SlaveVoyages was the voyage’s data. This data is the key data in the SlaveVoyages international study, and from this, all the other tables, charts and more are created. The “Voyages Tables” hold significant contextual information, which is not otherwise provided, including over 50 categories of information that can be configured to be shown. Of the many contextual fields available, the project team discussed which would be the most valuable and informative for the intended project user (to restate who that is, a living descendent of a slave who was brought over the Atlantic during the Trans-Atlantic Slave Trade). In the end it was decided to include:

OBJECTID	Voyage ID	Vessel Name	Vessel Owner	Flag
Rig of vessel	Guns mounted	Voyage itinerary imputed port where began	Voyage itinerary imputed principal place of slave purchase	Voyage itinerary imputed principal port of slave disembarkation
Total embarked	Total disembarked	Year of arrival at port of disembarkation	Slaves arrived at 1st port	Percent men
Percent women	Percent children	Slaves died during middle passage	Mortality rate	Captain's name
Crew at voyage outs	Crew deaths during voyage	Middle passage	Standardized tonnage	Sources
Particular outcome label				

Table 4.1: Fields included in the “Voyages Tables” (SlaveVoyages, 2019)

These names are equivalent to the naming convention on SlaveVoyages in order to improve the ability for future editors to cross analyze the data. Another important factor about these data is that they can be summarized or averaged to mathematically align to ports or regions, instead of the individual voyages. Some categories of information were not able to be calculated in this way, or would not fit the intended entity (ports or regions). These tables are the “master key” of sorts, since they hold all the information for all data presented in the Trans-Atlantic Slave Trade database. This makes them perfect for being the “many” in the discussed relationship classes in Figures 3.1 to 3.3 in the “System Design” section. As a result, these tables needed to be extracted and set up to provide the essential information to complete the project’s intended purpose.

4.4 Logical Data Model

The project required significant consideration when organizing the data which would be presented (this is previously discussed in “System Design”) and largely surrounds the realities in terms of the project’s primary objective, the inherent obscurity of the topic’s data, and the intended result. The objective was to identify pertinent contextual information for the descendants of those displaced as a result of the Trans-Atlantic Slave Trade, improve the accessibility of the data, as well as include the project requirements discussed in the “Requirements Analysis” section. To achieve these, the data had to be consolidated in the logical model in order to refine the focus of the project. Our primary focus being the data surrounding the middle passage, the “place of purchase,” and the “principal point of landing,” whilst including the voyage information separately. The rest of the connections detailed in the conceptual model would be forgone primarily because of a lack of data. As stated in the “African History and the Trans-Atlantic Slave Trade” section, there is little to no data on the travels of African slave caravans. It is almost unheard of for African caravan merchants to have kept records, therefore, there is not enough data to facilitate this interior activity. Changes like this are

displayed well by comparing Figures 4.1 and 4.2 in this chapter. As can be seen when comparing these figures, the various connections that exist in the physical world are mimicked in the data, but the logical model is more refined and specific. The intent is for the data to be oriented as it would be in real life within logical model, however, due to the focus of the project these values are consolidated and compiled into the “Voyages_Table” to provide that information, but simultaneously eliminate those complexities which exist in the physical process. The data on SlaveVoyages is focused on the voyages of vessels that participated in the Trans-Atlantic Slave Trade, therefore, the data is not individual to the slaves on board those vessels. In an attempt to provide more informative data that is contextually significant in terms of the slaves, versus the ships, it was decided the project entities would be ports and regions in Africa, and destination islands in the Americas. This does not circumvent the non-individual nature of the data, but attempts to shift the focus of the data away from these voyages (removing them as map entities) and instead replaces that focus with the port or region origin points and the island destinations. This reorientation of the data results in a visualization that is ultimately more informative for the user in terms of the slaves on these voyages, helping to better identify spatial origins and destinations, while removing the focus on the voyages and ships. The important piece being that there were various aspects of the process which occur in physical reality that were purposefully not included within our project. This was for the specific purpose of simplifying the presentation of this data down to the project scope.

Figure 4-2: Logical Data Model

The various data included in these ships’ logs is still provided and is the same data being used to facilitate the attribute information for the port, region, or destination features. This data is very important to the project’s overarching goal of providing spatial and historical information which is of contextual value. This is displayed in Figure 4-2 where it can clearly be seen that the large table of attribute information

(“Voyages_Table”) holds all of the various data included in the project that is oriented around the voyages. This data is used to facilitate the values for the various other entities included in Figure 4-2. The relationships and how the data correlates is presented in the “Logical Implementation” section in Chapter 5. The logical model is in the Unified Modeling Language and displays how the data is oriented inside the project, what the cardinality of the relationship between the layers is, and specifically how the data is organized in relation to the other data included. Some aspects of this organization were required to achieve the client’s wishes, which resulted in the right-hand section of the model detailing the transportation of slaves from an origin point to a destination. This needed to be done in order to successfully re-orient the data to provide the basis for using the voyages as the contextual table of information, instead of being the entity on the map. Meanwhile, the rest of the data is being consolidated into a single “Voyages_Table” per each destination. Therefore, the primary feature entities in the geodatabase are the “Ports of call,” “Regions,” and finally the “Island” destinations. The process from the starting point of the origin to the island destination is the focus of the project. None of the processes before or after these points are included as of this time.

The data within the feature datasets is organized according to the destination in the Caribbean. All features which relate to a destination are included in that feature dataset (named after said destination). For example, in the dataset Antigua, all layers including the ports and regions in Africa with values that relate to Antigua, the origin to destination links, relationship classes, and destination data (that also relate to Antigua) are included within that dataset. This format is consistent for the rest of the feature datasets in the geodatabase. This provides a simplistic method for organizing the data which provides consistency across feature datasets.

The data included in the features, within these datasets, correlate to the island destinations which the dataset is named after. The fields within those features, however, are all consistent, meaning that whether you’re in Antigua, Nevis, or Jamaica’s dataset, the naming convention for features will be consistent (other than the destination islands name). The field aliases will be consistent within features and across datasets, the organization of the fields will also be equivalent across features of equal-year increments. For example, for ports totals in any dataset the fields will be as follows:

OBJECTID	Port (origin)	Alias Name	Alternate Name	Total embarked slaves by port
Total disembarked slaves by port	Avg. Middle Passage Time (days)	Avg. Standardized Ship Tonnage	Origin Region	Region_Color_ID
Port Totals ID	Shape	Point_X	Point_Y	GlobalID

Table 4.2: Totals Feature Layer Fields by Alias

By doing this the naming conventions are alike enough to SlaveVoyage’s naming conventions to allow for cross-analysis which will improve manual edits that may need to be done in the future. The only differences that will be seen are that the disembarkation values for the destinations will state those destinations names accordingly. The number of rows will change as one analyzes across features (since each has unique data). Further, there will be differences across features of different year increments: for example, the 25-

year increment layers will say “embarked slaves by 25-yr period” and will have two extra columns containing the start and end years required for the time properties implemented. Therefore, this will be different than in the annual layers where there will be a single year field, or the totals layers where there will be no time field. The only other differences will be the fields which were previously used for joins in the project and cannot be taken out without breaking the feature layers. This is a result of the data set up process and it did in some cases impact consistency of field names, however, not aliases. It should be noted that most of the joins were required in all layers of that same time increment format, therefore it was easy to create consistent and identifiable aliases (for example “Year_ID”). As a result, there will be slight differences between features of different time increments. Otherwise, the field formats will be entirely consistent. One method for easing this was the implementation of consistent alias names for fields – this allowed for consistent naming conventions to be implemented even though the field names were largely set in stone due to the creation process and relationship classes. Although the designated field name in the data may change and at times be unintuitive, the aliases are all entirely consistent and should allow any future editors to easily identify the field in question.

One topic worth discussing is the variation of the designations on SlaveVoyages. The reason there are both regions and ports in SlaveVoyages is likely a result of there being inconsistency in the original data sources. However, this is confusing because these values are not always consistent. The difference in naming conventions only arises when investigating the “Other Africa” category for specific destinations. It is the project team’s belief that either by some automated algorithmic ordering process, on purpose, or accidentally by mistake, the designation of values was not consistent for this category. These values are not necessarily wrong, they are simply being oriented around a different origin – for example, if one cross analyzed the values contained in “Other Africa” for regions, with the values in the “Africa Unspecified” field in ports, the values do not align. This is explained in the results section in terms of our project’s specific changes and results. This is detailed in Table 4.3, which displays Jamaica’s inconsistencies in red.

Ports:						Regions:	
Year	Windward +	Windward				Year	
Range	Ivory +	Coast	Gold	Casna	Africa.,	Range	Other
	Gold...	(Nunez...	Coast, Fr...	-sonis	port uns...		Africa
1576-1600	0	0	0	0	0	1576-1600	0
1601-1625	0	0	0	0	1,491	1601-1625	1,491
1651-1675	0	0	0	0	4,044	1651-1675	4,044
1676-1700	0	0	0	0	22,048	1676-1700	22,048
1701-1725	0	0	0	0	66,148	1701-1725	66,148
1726-1750	993	0	0	0	111,028	1726-1750	112,021
1751-1775	1,132	304	0	352	39,848	1751-1775	41,636
1776-1800	0	1,632	618	0	15,836	1776-1800	18,086
1801-1825	0	598	0	0	4,987	1801-1825	5,585
1826-1850	0	0	0	0	648	1826-1850	0

Table 4.3: Organizational inconsistencies in the Jamaica Data

This had to do with various inconsistencies in the designations, the first and foremost being that for ports there is “Windward + Ivory + Gold + Benin,” “Windward Coast (Nunez-Assini),” “Gold Coast, Fr. Definition,” “Casnasonis (location undetermined),” and “Africa., port unspecified.” However, for regions there is only “Other Africa.” The project team believes this is a result of coming from a historical perspective and not placing points on a map for these port names. However, in GIS, one would never place points for something that has no known location, even if it’s named. This expansion of the fields in the port’s values occurred with both Jamaica and Antigua, however, did not with Nevis. The project team felt this was a confusing inconsistency and as a result it was decided to ensure they were all entirely consistent. The second inconsistency worth note is the six hundred and forty-eight in red from Table 4.3 (1826-1850). This value is for the ship Ulisses. It is designated as coming from both the “Bight of Benin., port unspecified” and “Africa., port unspecified.” This is shown also in Table 4.4. This was changed so that instead, the values for this ship are always found within “Africa Unspecified” or “Other Africa” field. This was the only real record inconsistency found in the SlaveVoyages data used for this project. The project team was not able to find a historical reason that might account for this specific inconsistency.

PORTS:										
Bight of Benin										
Year	Benin	Ardra	Epe	Popo	Jacquin	Whydah	Lagos, Onin	Porto Novo	Bight of Benin, port unspecified	
1826-1850	0	0	0	0	0	0	0	0	0	
Other Africa										
Year	Africa., port unspecified	Windward	Windward (Gold Coast, Casnasonis)							
1826-1850	648	0	0	0	0					

Regions:		
Year	Other Africa	Bight of Benin
1826-1850	648	0

Table 4.4: Ulisses Ship Inconsistency

These changes to the organization of the data within the features did not impact the organization of the project’s geodatabase. These did, however, impact the relationship classes and feature values, which is discussed in the “Results” section of the report. There are further assistive layers used in setting up the display of the African continent such as major rivers and feature dataset for basemap data as well. These layers do not participate in the relational database set up. The only layers that participate in the relationships are the features contained inside the island feature datasets (Antigua, Nevis, Jamaica) and the accompanying “Voyages Table.” These features are not included in the logical model because they are outside the primary focus of the project. The main layers worth mention are within the “Africa_Features” dataset, which houses important contextual layers for the setup of the study area. This feature dataset contains features specific to providing geographic context on the continent of Africa. If these were shown in the logical model they would be a separate box without associations or any connections to the other features in the model.

The final organization of the project would be done through the use of ArcGIS Online. The data, which is organized by feature datasets in ArcGIS Pro, was uploaded to ArcGIS Online in the form of web feature layers. It’s important to keep in mind that when sharing from ArcGIS Pro to ArcGIS Online, the layers shared are oriented around the map which is active – not the geodatabase. This means that in some ways data can be consolidated more easily since it is solely oriented around what is needed to visualize the

map. As a result of this, where in ArcGIS Pro there are separate datasets for “Africa_Features” and “Base_Layers,” in the ArcGIS Online web layers all of these layers are provided within the destination web layers (Antigua, Nevis, and Jamaica). To explain, the Antigua web layers, named “Antigua_2D” contain the “Africa_Features” layers and the “Base_Layers,” which facilitate the Antigua base map. This is true for each of the three destinations’ web layers. This means there are only three web layers which contain all the data necessary for all of the maps. These features require that they are all together since the coordinated relationships from the table interact with the primary 8 features present in these destination web layers. By doing this, the features, their relationships, the table of related data, and the necessary layers for the generation of a map are all provided together.

This consolidation provides a level of simplicity for the client. It should also be noted that not all layers present in the ArcGIS Pro version were required for use in the ArcGIS Online version. Due to this, there was a further reduction in the number of layers which needed to be managed. This does not mean no other layers were provided. For example, a web layer for the general delineation of all the ports which are present across the SlaveVoyages database is provided in the original 3 web features, symbolized with smaller points (called “All_Africa_Ports_3D”). However, to fulfill a request by the project advisor, these were re-uploaded with significantly larger sizes – this is what the separately provided “All_African_Ports_3D_X2” layer is used to achieve. Another layer is provided for the “Major_Africa_Rivers,” which is updated and contains attribute data. There are also three Origin Destination Link matrixes provided, designated by their destinations – Antigua, Jamaica, and Nevis. These web layers have 4 layers each and have been downgraded to 2D from ArcGIS Pro for their visualizations currently. In the end, none of the Origin Destination Link matrixes were used in the ArcGIS Online product, per client request – it was decided these require complex processes in order to correctly display on ArcGIS Online in a way that would be satisfactory. The original lines were simply intended to provide accurate distances in miles through the calculation of geodesic lines. Therefore, it is possible these links may be forgone and simply have their data implemented into the origin and destination points. As a result of all of this, there are nine web layers to manage in ArcGIS Online versus 87 feature layers across 5 feature datasets, plus 3 tables. This is improved comparatively from ArcGIS Pro. This will be discussed again in terms of implementation in the “Logical Implementation” section.

4.5 Data Scrubbing and Loading

There were significant data quality checks required in the project as a result of extraction errors, formatting errors, and even inconsistencies within the data itself. As a result of these issues, significant manual quality control work had to be done to ensure the data was accurate and consistent.

One of the primary issues was that the data was not correctly formatted for the implementation of time properties. To solve this, the following steps were required: First, copy the entire timeline (year range) for the destination in question and transpose that according to the number of columns there are (or origin points). Second, transpose the

origin point names accordingly – at the start year for each renewed timeline, or year range, the name value should change, and similarly at the end of the year range it should end and then change to a new origin (keeping zero's values during formatting is advised). Third, transpose the values for embarkation (or whichever values are the focus) into the accompanying cells which correlate to the origin point and year for that value. Do this for every origin point by year, repeat the process to add disembarked, average middle passage, and average standardized ship tonnage. For example, if there were 200 years and the first port was Accra, there would be 200 values vertically for Accra, each with its own unique year (ascending) and unique embarked value. For 25-year, do the same, except for every 25-year increment there should be a feature with the same name. If doing this for the destination, this process will be done one time for that destination. This process is shown in Figure 4-3 below, and had to be done for 18 feature classes, specifically six of each set of 21 layers held within each island destination dataset. Once done, the data is formatted and correctly set up for time properties in ArcGIS Pro.

Figure 4-3: Data Reformatting for Time Properties

The other significant data related requirement which forced deep quality checking, but also created some human error, was the creation of unique identifiers (Unique IDs) for the relationship classes. This process was influenced by the geodatabase organization and the time properties employed in the project which further complicated the process. To facilitate a relationship class these unique identifiers are required so the relationship can identify which records relate to which. The unique identifier must be entirely unique, meaning each origin or destination point must have its own Unique ID within and across datasets inside the geodatabase. However, logically, this is extremely

confusing when working with time data (four dimensional). Further, during the creation process it was decided that the naming categories across regions and ports were slightly inconsistent in the SlaveVoyages database, specifically with the “Other Africa” category. This category indicated that the origin point was unknown. For the region values in SlaveVoyages there is only a single category for these unknown locations and that is “Other Africa.” However, in the port values within the SlaveVoyages database various named ports were identified which were still categorized under the “Other Africa” values in the regions data. This inconsistency was explained in depth in the “Logical Data Model” section and will be further discussed in “Results.” As a result, this required taking a step back from the project to physically design a formatting guide for the creation of these unique identifiers to keep track of them in the future. In identifying the best way to create this, the primary consideration was what the project was going to be used for in the future. Since it would expand to eventually encompass the Caribbean and Americas it needs to be a unique identifier which can have great breadth. Further, this unique identifier not only has to be unique within layers, but across them too. This means that each of the 8 layers had to be entirely unique, otherwise data from one layer could be falsely related to data in another. This meant that instead of just creating unique identifiers which differentiate between one aspect of the data, this would need to be a unique identifier that would differentiate across four aspects of the data. Those would be destination, feature type, location, and time.

In order to better explain this, see the Table 4.5 diagram which displays the creation format:

	Totals	25yr	Annual
Island		X;#	X:#
Region	X_#	X~#. #	X*#. #
Port	#.#	#~#. #	#*#. #
X = Letter Value			
# = Integer value			

Table 4.5: Unique Identifier Creation Guide

To explain the Unique ID format: The X values in the Africa regions indicate a letter value, and this letter value will correlate to the destination name in the Caribbean or Americas. For the Africa port values, this first value instead is a number value which is also indicating the destination. The symbol to the right of the first value is the piece which differentiates feature type. Next, the third value in the key only appears in the bottom right-most four boxes because the data jumps from requiring a two-dimensional unique identifier to a four-dimensional unique identifier at this point. The third value is differentiating the locations or origin points. These number values can follow the same convention since the first two digits for each category are unique. After the third value is a decimal point, which simply acts as a separator between the location differentiation value and the time differentiation value (for the four-dimensional identifiers), therefore, the final digit is the time differentiating unique identifier.

These values will be kept track of using a table which is the same as shown in Table 4.6. This shows how through using this convention, keeping track of the various Unique IDs is as easy as listing their formats as shown below. Therefore, tracking the Unique IDs does not require that every individual ID be recorded, just the formats.

Names	Tot Port	Tot Reg.	Island 25yr	Island Annual	Region 25 yr	Region Annual	Port 25yr	Port Annual
Antigua	1.#	A_#	A;#	A:#	A~#.#	A*#.#	1~#.#	1*#.#
Nevis	2.#	N_#	N;#	N:#	N~#.#	N*#.#	2~#.#	2*#.#
Jamaica	3.#	J_#	J;#	J:#	J~#.#	J*#.#	3~#.#	3*#.#
...	...	...	...	...	...	...	...	...

Table 4.6: Unique Identifier Tracking Format

Through doing all of this, the creation process should be simple and consistent in the future. After delineating the Unique IDs and proving the project method functions during this work, it now would be possible to start the process of identifying how to semi-automate this process. Until there was proof of concept, it did not make sense to try and automate a process we did not fully know, nor which had been previously done how the client specifically wished. However, now that the process has been confirmed, this portion of the data set up could be partially automated in the future. It would still require significant manual quality control, and there is a likelihood there would be errors anyways, but it would be worth trying. This is further discussed in the “Table Creation Automation” section under “Future Work.”

After completing these relationship classes and the voyage tables while doing quality control, there was further data extraction and changes which had to be made. Some as a result of human error, and some as a result of consolidating the Africa Unspecified field. Due to these mistakes, and changes in designations, there was a reality that some of the tonnage and middle passage values had not been correctly joined, and were not taking into account the values that had been moved (therefore the averages were incorrect). To fix this, with the newly consolidated information in the feature classes, a summary statistics and join field tool were used in ModelBuilder. This transfers multiple cell values from the voyages data and summarizes them into the rows within the feature class in question. Embarkation, disembarkation, middle passage time, and standardized tonnage values could then be updated within the feature classes by using the “Voyages Table.” The embarkation values and disembarkation values were extracted from SlaveVoyages and were correct since much of the manual QC was focused on these values. Alternatively, the middle passage time and standardized tonnage were created using data which was within the “Voyages_Table” already in conjunction with the ModelBuilder tool mentioned. Because of the previously mentioned work of consolidating the ports into Africa Unspecified, these values were checked against the SlaveVoyages database and the project team is confident they are accurate.

4.6 Summary

To summarize this chapter: First, the organization of the project's data and its conceptual organization are detailed. Second, extracted data issues are covered and what caused them is explained. Third, the various methods and types of data collected from SlaveVoyages are discussed. Fourth, the "Logical Data Model" section details the organization of the data within the project and specifically what was included. Finally, the implementation of time properties required significant reformatting of the extracted data which is discussed in detail in the "Data Scrubbing and Loading" section. Also discussed is the project's Unique IDs and the logic behind them which was required in order to fundamentally organize them for the projects use – this relates to the previous organization of the data for time properties and the organization of the geodatabase which impacted this format. All together this chapter details the organization of the data in the project and the logic behind that organization.

Chapter 5 – Implementation

To begin the discussion surrounding implementation it is first important to re-touch upon the realities surrounding the end implementation versus the original planned implementation. Originally, it was planned to implement the project geodatabase using a Microsoft SQL Server, hosted and run by the University of Redlands. This, however, was not possible because the project incorporated contingent values, which are too new of a feature for the university's server. Data transferred to the server would lose all relationships, the contingent values and domains connected to them, and the feature dataset organization. It was theorized that this would not occur if the contingent values were eliminated, however, the editing assistance provided through the contingent values was something which the project team felt was important to ensuring quality in the data, especially going forward. Nathan Strout also indicated that the issues with doing this may have been deeper than simply having to delete the contingent values. This was evidenced by the fact that in practice neither I, nor Nathan Strout, were able to get a fully functioning copy onto the server. Additionally, Nathan Strout (the facilitator of the server and our primary connection point to managing this work) personally suggested we not use this route anymore. Due to this input we decided to pivot away from using the server. Losing the fundamental capabilities the project provides (i.e. relationships, contingent values, domains, and the geodatabase organization) using the server, however, obviously was an unacceptable outcome for the project team, and as a result a new method for implementation had to be created.

The new process required that the server be forgone entirely along with the benefits it would have provided. The decided sacrifice here was to forgo the full transfer of data which would have been achieved from Field Maps to ArcGIS Pro, as well as the benefit of the data being entirely housed in a single place. It was decided it was better to sacrifice these capabilities rather than the essential capabilities of the project which make it useful like the relationship classes, domains, and contingent values. The increased difficulty in terms of the data management, and transfer of Field Maps material, were less drastically impacted by this change – the Field Maps app doesn't necessarily need to ever operate in ArcGIS Pro for the client to be satisfied. Furthermore, the management of the data in the project going forward is not made impossible through the use of ArcGIS Online, just more tedious.

5.1 Logical Implementation

The project objective was a Web Application product incorporating 3D features, 3D scenes, employing relationships to correlate the data between origin and destination, time properties, and implementation of a color scheme oriented around the historical regions in Africa. The intent here was to achieve the operational capabilities which exist in ArcGIS Pro within ArcGIS Online and further use 3D scenes and objects. This was not entirely possible for various reasons discussed. As a result, the primary requirements in the end were partially reduced. The requirements the project achieved are as follows: First, the project employed the correct organization of the geodatabase in ArcGIS Pro and

the requirement that this be true on the server as well has been dropped. The second requirement, that the data be visualized in 3D in some form, even if the capabilities of a time slider and relationship class cannot coexist within a 3D scene on ArcGIS Online, has also been achieved. The final requirement was that the project must be accessible to the public and must not require Esri or University of Redlands credentials – this has been tested and achieved. The project will result in the various end applications, and a user manual.

There were various decisions made in ArcGIS Pro in terms of the symbology and presentation of the data, which were not fully transferable to the final product in ArcGIS Online. However, those changes are still worth mentioning as they apply to the ArcGIS Pro project and some realities with the ArcGIS Online product. The primary changes were: First, the original regions provided by the client extended from the coastline into the Atlantic Ocean. These polygons contained graduated fills which faded in color the farther from the coast the polygon extended. This delineation was something our cartographic advisor felt was unintuitive and should be changed. As a result, it was decided to reverse these polygons so instead of fading out into the Atlantic, they faded into the African interior. The idea here was to bring these features on to land where they truly would be located, and to visually show how our historical knowledge of the African continent at this time is only accurate at the coastline. These would eventually go through another evolution and for the 2D display would be converted into lines instead of polygons, so they only display the coastline. The second major decision in terms of the presentation of features was the debate on whether all features should be points, or if the ports should be points and the regions polygons. The issue was discussed in terms of how this would impact the end symbology if anything were to occur with the server, and also how the creation process of the region layers was significantly more complex and time consuming than creating the layers as points. The debate here was surrounding the fact that the destination datasets all varied widely in size – this was a problem because although it was feasible to create the polygon layers for the totals and 25-year increment layers, it was not feasible to create the annual layers by the same method. This method was taking the polygon areas previously discussed, creating a feature class, and copying the features and pasting them accordingly with the number of values there were. When doing this for 25-year layers, depending on the dataset this ranged from being 6-11 copies per region, however, in the annual range layers for Jamaica it would be 299 copies for each region. There was no way to circumvent this work. Even with using the “Append” tool, this process would have been immensely time consuming. Due to this, and the reality that these polygons would be an immense burden on processing, the executive decision was made by the project’s advisor and client that points could be used for the annual time increment layers, whether ports or regions. During creation of the polygon and point layers, initially, the team had planned to place the points over the top of the polygon symbols. However, this was not done because there was the realization that the 3D symbol for the polygons would appear at the centroid of the polygon. This was not a problem for every region, however, for some such as the Bight of Biafra and Bight of Benin (which are shaped similar to a crescent) the centroid of these polygons sits miles off the coast of Africa in the Atlantic Ocean. The polygons indicate that these points are the true center of the polygons even though that center is outside the boundary of the polygon itself. Attempting to change this either resulted in nothing occurring, or if the

settings were changed to place the 3D symbol inside the boundaries, it suddenly started disappearing as a result of the polygon being too skinny, or at times, the feature would be placed somewhere very illogical during extent changes. Due to these issues, the decision was made to leave it how it was. This resulted in a slight difference in the location of the end features – all ports are in equivalent locations down to the ninth decimal, however, the region symbols other than the annual region layers have some slight difference. Since the 3D symbols are placed at the geometric center of each polygon – the point symbols are in a slightly different location than the polygon symbols; specifically, the point features are where our project’s cartographic advisor had wanted the polygon symbols to appear. This leads to the third decision, which was that it was more important for the polygons to be accurate to the coastline in terms of their boundaries, than for the feature symbols to be entirely equal or accurate to the placement of the annual regions layers which are points. This was approved by the client as well.

The final implementation of the project would be done through the use of ArcGIS Online and web feature layers. In ArcGIS Online the data organization is slightly different, the data is not oriented around a geodatabase nor the feature datasets within. It is instead oriented around the map visualized in ArcGIS Pro. This was an easy transition for our project because the data was organized within feature datasets which correlated to the data being shown in each different map. In the ArcGIS Pro project each feature dataset’s data would always have been displayed on a separate map except for the “Africa_Features” data and “Base_Map_Data” feature datasets. This made it so that when uploading to ArcGIS Online, the data could simply be shared from each map within the ArcGIS Pro project. Therefore, each web feature layer container in ArcGIS Online acts similarly to the feature datasets in ArcGIS Pro. Each web layer was created from one map with all of the necessary data for the creation of that map included. The main difference here is that these web feature layers contain all the needed “Africa_Features” data and “Base_Map_Data” required for the creation of the map. In ArcGIS Pro this data is always separate and contained within the “Africa_Features” and “Base_Map_Data” feature datasets, not consolidated into the same feature datasets as the destinations. This organization was a result of the requirement that when uploading to ArcGIS Online the map must have a basemap with a consistent coordinate system to the other features within the map, therefore it was not possible to remove the basemap data and solely upload the feature datasets data specific to the destination. In ArcGIS Online, as a result each destination’s web layer contains all of this additional data. The “Base_Maps_Data” and “Africa_Features” data that was necessary for upload to create the final products were included separately as well within their own web feature layers. This was partially because our project cartographic advisor requested changes to the features once uploaded to ArcGIS Online, and partially to mimic the organization of ArcGIS Pro as best as was possible. The feature datasets are compared to the web feature layers in the following table:

ArcGIS Pro	ArcGIS Online
Africa_Features	Antigua_WebVersion
Antigua	Nevis_WebVersion
Nevis	Jamaica_WebVersion
Jamaica	Base_Layers
Base_Map_Layers	Antigua_OriginDestination_Links
	Nevis_OriginDestination_Links
	Jamaica_OriginDestination_Links

Table 5.1: ArcGIS Pro Feature Datasets vs ArcGIS Online Web Feature Layers

Within each of these feature datasets would be multiple feature layers and relationship classes. The above table is a simplification, and it should be stated there were other feature layers included as a result of needing to work around ArcGIS Online and some as a result of human error. A specific example would be the region boundaries. Very simply, on ArcGIS Pro one can symbolize polygons in 3D through 3D symbols, however, on ArcGIS online this is not possible and polygons must be visualized via extrusions. Because of this, the boundaries of the features included in the 3D region layers suddenly became an issue, whereas previously the project team thought it wouldn't matter because of our use of 3D symbols. This ended up not being the case, and as a result, a new web feature layer needed to be added to ArcGIS Online to provide the most up to date polygon boundaries. These new layers were re-uploaded without relationship classes because they were not needed, due to the fact the relationship classes do not function in 3D scenes. As a result, these required significantly less work to compile and produce and took only a day or two. Because of all of this there is an extra layer providing the regions data in 25-year increments named "Visualization Regions 25yr Layers for 3D Scene." The only misstep in this process was not sharing the "Africa_Major_Rivers" features class within the original web feature layers. As a result, this had to be shared separately and was not included in the 3 primary web feature layers for each destination. In the end the organization is slightly different than in ArcGIS Pro, but not significantly different.

5.2 Web Application Creation and Organization

There were a few primary challenges which were confronted when coordinating and creating the Web Applications in ArcGIS Online. First, the Scene Viewer on ArcGIS Online does not provide the capability to add tables to a scene. Due to this, none of the relationship classes will function in 3D. Second, 3D scenes do not provide the capability to incorporate a time slider (both confirmed through personal

communication with Esri 3D specialist Philip Mielke). Third, the slides cannot account for varying filtration on the same layer (meaning multiple layers are required). Fourth, 3D effects don't take account of filters (identified through personal communication with Sajit Thomas, creator of Cool Maps). Fifth, and possibly most important, the flexibility and customizability of 3D features in ArcGIS Online scenes is significantly reduced in comparison to ArcGIS Pro. So much so, that in order to achieve the customized color scheme, required by the client, the features sizing was only able to be achieved through the use of the pre-created size options given by Esri. This meant very simply, that the Z value could only be visualized in centimeters, inches, feet, meters, yard, kilometers, and miles. What should be derived from this introduction is that these realities impacted the final product in various ways. The last hurdle that had to be overcome was the addition of fields to visualize the date fields and allow querying as well as filtering in the applications. Some of these challenges might have been avoided through the use of a server, but that will only be possible once the University of Redlands Microsoft SQL Server is updated. In the following section, these challenges and the successes will be discussed in terms of implementation and how they were achieved will be delineated in detail.

5.2.1 Challenges in Implementation

To cover the first of the challenges, it's important to recognize that relationship classes and related data fundamentally require the support of a table in order to function. Simply, a relationship connects the data between two tables by a unique identifier field which is shared between tables. In our specific case, the tables with the primary keys are housed within the features on the map, while the secondary keys are in a table of information which is not visualized on the map – instead, it simply provides qualitative data to assist the features inside the map. The information inside these tables relates to voyages, which are the true source for all the data facilitated in the features. These tables provide the supporting information on individual voyages, significantly improve the depth of the data, and ability for users to understand it, as well as better allow cross analyzation. Without this table, the primary capability of the project, the relationships, are rendered impossible in 3D. Without this ability, the only value the ArcGIS Online 3D maps could hold was a visualization in 3D, and at best could include a simplified presentation of the data. As a result, all the 3D applications created for the project will not provide the related contextual information that the 2D applications do. As stated, this is a result of the fundamental capabilities of the technology at this time, and of course this will likely change in the future.

The second challenge discussed was the inability for 3D scenes to implement a time slider. This has been confirmed through personal communications with Esri specialists Sajit Thomas and Philip Mielke, who discussed some methods of working around this – but also confirmed that these capabilities have not been implemented in standard ArcGIS Online 3D scenes as of this writing. The reality is that all time formatted layers in 3D must be facilitated with the use of a filter instead of a time slider. This reduces the overall dynamic nature of the map and its data, impacts processing, and forces the use of slides as well as many layers with different filters. This causes a large burden on processing when the map is initially opened. It's important to recognize how expansive the data is in terms of time covered and number of records, because simply

put, the previously explained issue rendered the use of the annual layers impossible in 3D (discussed towards the end of pg. 59). The process for creating filtered layers at different time increments, is, for every year increment, create a copy of the data, and for each of those copied layers, filter them in accordance with the year increment required. This process is only manageable when discussing 25-year increments. (As previously stated, there are six for Antigua, seven for Nevis, and eleven for Jamaica.) This results in the creation of 24 separate copies of the layers all being filtered differently in the 3D scene. However, just these 24 layer filters placed a significant burden on processing – the scene itself will often take between three and five minutes to load due to these filters when opened. This was confirmed by Philip Mielke, who investigated this for us after we shared the project with him. He explained that the feature layers themselves load without issue, but that the filter is actually timing out or overloading due to Esri's own code, not our layers, or data. The project creator had suspicions of this before because of investigating the developer tools when encountering this error initially. It was identified that in the maps where various layers were not loading – there was no error other than the filters timing out, and as a result the layer would not display. This happened significantly more when trying to combine the regions and ports into a single 3D scene, so as a result, these were separated for better performance. However, one can imagine that if this was to be done with the annual layers (which in some cases would require around two hundred copies), it would result in extreme processing issues. Due to this, and the realities in terms of time, the decision was made to not include annual layers in the 3D applications.

The third issue relates to the work post-pivoting to use filters in the 3D scenes and applications. When creating the various slides, the possibility of using 3D effects was discussed. Specifically, in terms of trying to implement the Origin to Destination Links which had been previously created, as well as to possibly circumvent some of the issues with the symbol sizes of features. In trying to learn more, our project's advisor reached out to Sajit Thomas who discussed with us how the 3D effects app might be applicable to our work. Originally, our project advisor wanted to know about the Cool Maps site and how to facilitate a similar website, as well as how Sajit had implemented some of the 3D effects. Sajit Thomas's site, Cool Maps, was using a format similar to the presenter view in PowerPoint to house the various works on the website (Thomas, 2021). Thomas explained to us how many of the capabilities present in the Cool Maps are present and only possible because of the use of the ArcGIS API for JavaScript. Projects created through the Javascript API have more flexibility in terms of customizing the end products. Put simply, this requires doing all of the work in terms of finalization within an API Key, or possibly multiple API keys. Applying that API key and interacting with the project via those means to reorganize the data that is already there and present it differently. None of our project team felt confident enough in their JavaScript ability to take this on and simply put our cohort did not ever get JavaScript training. I myself have the most experience of our team with JavaScript (2 years – in high school) and in the time allotted, it just was not feasible to learn the JavaScript API and all the unique aspects of truly applying it to published work. It was also clear that this solution would in some ways present new challenges that may not be able to be overcome themselves. We found that the 3D effects widget cannot account for filters, and that Sajit Thomas had instead had to create multiple individual versions of the data (as layer views) to facilitate the Cool Maps products (Thomas, 2021). In our own case, the work to do this for our project

would be immense. Further it would not follow best practices in GIS, or database management. The decision was made that this largely rendered 3D effects useless in our specific case. If it had worked it would have provided much cleaner cylinders for the project, which would have not conflicted each other, but simultaneously this method would also have prevented the implementation of the customized color scheme.

The final challenge to be discussed were the intricacies encountered with the sizing of features. The project features are being displayed in 3D by using the attributes of embarkation or disembarkation as the Z value. Doing this means that the feature heights can vary widely. For example, the lowest record in our data is 5 slaves transported by ship across the Atlantic, but the maximum is 75,000+ in some of the 25-year increment port values. The issue with this came about when using the 3D Objects symbology in the ArcGIS Online scenes, which provide the ability to differentiate features sizes by an attribute – but only allow that attribute's size to be delineated in centimeters, inches, feet, meters, yard, kilometers, or miles. The problem arises when you realize that when viewing the earth from space the difference between meters and kilometers, especially when talking about values ranging from 5 - 75,000 or more, is quite literally the difference of that feature being invisible in meters, or being the size of the planet in kilometers. For the port of Bonny in the Bight of Biafra, across the years 1776-1800, 76,970 people were transported to Jamaica alone. This value is either a tiny pin on the African continent at 76 kilometers above the ground (a problem because it's one of the larger values in the project), or it is 76, 970 kilometers tall and is so massive that at maximum scale you'd still be inside the feature unless you pan over to the western hemisphere – as shown in the image below (Figure 5-1). In order to see these features, I had to rotate the entire planet so as to not be inside them at the maximum scale.

Figure 5-1: Exponential Size Features

The difference here was unacceptable because it either rendered the features so massive they ruined the entire map, or so small that the scale was too drastically different from the original project scale – which should range from around 1:150,000,000, to 1:10,000,000. Not to mention, the reduction in sizes would render significant portions of the data invisible to the human eye (on the map). To overcome this in ArcGIS Online, I simply implemented a set of visualization fields in each feature, named “Cyl_Z_Emb” or “Cyl_Z_Dis,” in order to run a calculation on the original values to reduce them to an amount which was acceptable. Importantly, these values were always kept consistent with each destination’s set of data (i.e. all data for a given destination will be reduced by an equal amount so as to not impact the analysis). The end reduction amounts for Antigua and Nevis ports were multiplying the embarkation and disembarkation values by one fourth across the board, while Jamaica’s port values were reduced by one sixteenth across the board alternatively. In the regions data all are reduced by one sixteenth and there are no differences (meaning Antigua, Nevis, and Jamaica’s regions are reduced by one sixteenth). The destination features all contain the necessary reductions (sometimes two fields) to accommodate the different reductions across the ports and regions with Antigua and Nevis. Alternatively, Jamaica’s destination feature is only reduced by one sixteenth. This was decided after significant work to ensure that the analysis was not being impacted by these reductions, and in order to ensure that the project still achieved relative consistency across the port data where Jamaica is differently sized than Antigua or Nevis. This means that the data being used to facilitate the visualization within the ports by 25-year increments technically cannot be said to be 100% accurate visually in terms of analysis between Jamaica to Nevis, or Jamaica to Antigua. Having said that, it is as close

as was possible to achieve with the challenges confronted. This is displayed well in the images provided (Figures 5-2 to 5-4).

Figure 5-2: Nevis, largest known port value

Figure 5-3: Antigua, largest known port value

Figure 5-4: Jamaica, largest known port value

Even with the significant reduction, the project team all agreed that it was almost unnoticeable that Jamaica's values and its related African port features, had been reduced by three times what the other destination data were. This is displayed in the images above, where the largest features (values) for each dataset are shown – these are New Calabar for Nevis which embarked 1,600 slaves from 1676-1700, Bonny for Antigua which embarked 7,982 slaves from 1751-1775, and lastly Bonny for Jamaica which embarked 76, 970 slaves from 1776-1800. As one can clearly see, the reduction of Jamaica's features has actually improved the visualization of the data and does not seem out of place. It is not otherworldly to suggest that Jamaica's Bonny feature is about seven to ten times larger than that of Antigua's, which is right about the range it should be. Importantly, none of this affects the data presented to the user in the pop ups – all of this work was entirely based in the symbols and their visualization on the map. These fields, as a result, are not displayed to the end user and have no true meaning. This method, however, solved the sizing issues and allowed for the visualization of these 3D features and further allowed for the true data to be provided, and still visually correlate with the features present in the map.

In the applications there were some changes that were required in order to achieve the widget functionality the project team wished for. This related specifically to the date field in the feature classes. As a result of a logical error in creation, the project team did not realize that the use of the Coordinated Universal Time (time zone) in ArcGIS Pro time properties would result in the date fields being automatically updated in ArcGIS Online. When universal time is uploaded to ArcGIS Online, instead of remaining equal to its format in ArcGIS Pro, the fields suddenly gain a time zone which is based off the designated time zone your computer is set for (Esri, 2021). This resulted in the year values suddenly gaining month, day, and hour values which were meaningless in this project's context. However, if these are edited it impacts the time properties of the layer on ArcGIS Online. Simply stated, ArcGIS online does not support "YYYY" format, therefore these edits broke the layer's time properties. Originally, a "Year ID" field was implemented on every layer in ArcGIS Pro so in theory this should have allowed for a work around. This would functionally work on the 25-year increment layers, however, on

the annual layers the implemented “Year ID” Strings were behaving very oddly. In confusion, each layer was checked in-depth to ensure that the year identifiers were indeed there, and all the values that should be there were able to be found, they just would not appear in the Web Applications. There was no good reason for this. The identifiers are string values which read “yrXXXX” the X’s being the year in question. This should functionally present no problems, however, for some reason it did. For example, in Antigua more than 30 years of time were simply not listed in the filter selection list or query list when using these ID’s. To work around this, the project creator had to implement an extra field in ArcGIS Online which is equal to the years and solely contains the year values. It was found that it is not possible to calculate any field equal to the date field, other than a String, therefore, the project creator ended up using a String to replace the already-not-working-one. In doing this, the creator added fields for the various year fields and ensured that for the string length of each field, the maximum length was 4 characters. This forced the much longer date field to only read the first four digits, which are the year. This ensured that all that was in this new field were the four digits the project team was interested in. After accomplishing this, the project creator had to change the queries and filters over to function off of this new field instead. In the end, everything works now, both filters and queries. At the end of the day the issues related to the date field and “YearID” field have been overcome, yet it’s still a mystery why the original “YearID’s” did not work.

5.2.2 Successes in Implementation

Along with overcoming the challenges above, were various things accomplished which are worth mentioning. The customized color scheme required by the client has been kept and achieved through individual manual implementation. The various sets of data have been separated and organized in four separate Web Applications, and a single Experience Builder App that seeks to provide 2D capabilities with the 3D data. The 2D maps and Web Applications incorporate the full dynamic nature of the ArcGIS Pro version, incorporate the related data, the time properties, and the custom color scheme. The 2D map, therefore, provides the full functionality we had hoped to achieve and at least provides a method for the user to identify further contextual information related to their ancestors through our application.

The primary success in the project was really the 2D Web Maps and Web Apps, which provide all the core functionality that was present in ArcGIS Pro. The only differences being these are not in 3D, nor contain the ability to filter the time slider increments by layer. These versions incorporate a fully dynamic time-slider and fully functioning relationship classes to correlate the data between the origins, destinations, and the “Voyages Tables.” Further all domains and contingent values are properly operating in the 2D versions. The features in these maps are visualized according to the color scheme defined by the client, and none of the sizing issues present in the 3D version occurred in the 2D maps. The 2D maps do not separate data by topic, as the 3D do, instead the 2D maps are differentiated by their time increments. There is a 25-year 2D map, and a by Year 2D map. This was a result of the fact that without the two maps, the user would have to operate advanced time slider settings in order to change the time increments used. This was decided to be too complex for the average viewer. In the end,

the project team felt that this organization was better as it allows for two separate apps to be provided. This way, if a viewer is less assured of the certain time period their ancestor might have traveled, they can use the 25-year increment app which only requires knowledge on the general decade their ancestor might have traveled during. This application still provides the same related data as the annual app, just in larger chunks. Therefore, this app provides more data to the viewer at a time. In the annual 2D app, if users can narrow their search down to a specific year their ancestor traveled, they will have the highest likelihood of identifying the ship their ancestor might have traveled upon. This map reduces the amount of data the viewer is being confronted with at one time. And, in the relationships, data is significantly more focused and will allow for more specific answers to be gleaned – depending on the information the user starts with.

The 2D circles which display the embarkation or disembarkation values are symbolized according to the previously mentioned custom color scheme which differentiates regions. The region data is more transparent than the port data, specifically so that the port data (which is more specific) stands out to a higher degree. This was done to allow the layers to function better all together if viewers would simply like to see the most active animation possible. Altogether, the 2D maps and applications were the most operational and provide the best experience to the end users.

The 3D scenes and 3D applications were confronted with many more challenges compared to the 2D. Although this is true, there were some major successes in this. First of all, originally there were immense struggles with feature sizes and types, the standing cylinders initially used in the ArcGIS Pro project when converted over to ArcGIS Online would appear as the standardized cylinders. These cylinders are dimensionally locked, meaning that they are as wide as they are tall (or possibly 50% wide as they are tall). This meant that all the cylinders overlapped one another resulting in an inability to select anything underneath. Another issue with this is that these are points, and the bases of these features would be thousands of miles across resulting in the obliteration of the sense of location. For a week this really impacted progress until the project creator tried using schematic vegetation instead. The project creator eventually identified a symbol which provided a solution to this issue, that was the “Sunflower” symbol. This symbol is very similar to a drop pin, which is why it was used. This provided slender cylinders which dropped all the way down to the coastline indicating the location of the port point more accurately. This was a major improvement, since the bases of the features were slender enough to allow the sphere at the tops (which were wide enough) to jut out from those bases. These inevitably overlap, however these new symbols allow for those features that would otherwise be completely consumed by their neighbor, to instead be selectable, as shown in Figure 5-5. This means that the point features can still be interacted with, and general data still gleaned from these 3D features pop ups.

Figure 5-5: Overlapping features example, improved.

The final major success worth discussion was the implementation of the 3D scenes and features through the use of slides and filters. Incorporating these versions meant that the significant ArcGIS Pro work that went into the creation of the 3D scenes and features was not lost entirely. Sadly, however, the relationship classes, and time properties were not able to be implemented in full. These problems were discussed with experienced Esri specialists including Philip Mielke, who specifically suggests updates and modifications to the 3D team for Esri. Through our discussions we were able to identify that our project team was not wrong, and that these capabilities were not implemented yet. They had been planned and were sadly dropped for this round of updates. It seemed most these capabilities release dates were impacted as a result of COVID-19 and other realities. The 3D capabilities that would provide the full operation and functionality of our project are planned according to Philip Mielke and will be implemented at some point. Therefore, on a happy note, these capabilities will be implemented in the future, and at that point the project can easily be re-shared or re-organized to take full advantage of those capabilities.

5.3 Summary

To summarize, the chapter introduction prefaces the discussions which will occur in the section by discussing the occurrences which led to the current method of implementation. Then, in section 5.1, the logical process for the implementation of the relationship classes and data is discussed including what was transported onto ArcGIS Online, and also how that data was organized in ArcGIS Online. Then in the section titled “Web Application Creation and Implementation,” the specific realities and work arounds surrounding the implementation of the project in 2D and in 3D are discussed

in detail. These are further covered in the section titled “Challenges in Implementation,” which just like it sounds, discusses various hurdles which had to be overcome during implementation. Then there is the “Successes in Implementation” section which discusses more of the creation process and includes discussion on where the project succeeded in meeting its goals. These sections both detail many aspects of the processes which required new symbol types, new fields to be added for visualization and widget related purposes, as well as differences between the 2D and 3D creation processes. These sections provide a comprehensive view into the process of implementation.

Chapter 6 – Results and Analysis

To restate, the project's objectives were to provide an application which will allow living descendants of those displaced by the Trans-Atlantic Slave Trade to identify spatial and contextual information possibly related to their ancestor's specific case. The primary goal is to use GIS capabilities, i.e. relationship classes, time properties, 3D scenes, and 3D features in order to present data gathered by SlaveVoyages in a simplified, more interactive, and visual way. By improving the accessibility of this data through better visualizations of this complex historical data, we can cater the projects end product towards the specific goal of identifying geographic and historical contextual information related to enslaved Africans. The project in terms of its capabilities and the coordination of the existing data, is capable of this feat, however, the project's ability to provide specific case related information is entirely dependent on the user's personal knowledge of their family history. Future updates to the project will certainly make it possible to deliver even more visually dynamic information to the viewers as well as more valuable information. It is the project team's belief that this project has met this objective within the time allotted and even exceeded it in many places.

6.1 Capabilities Employed

Many of the planned capabilities for the project were employed in the end, however, there were two specific capabilities that were dropped. Those were the server and the full transferability of the data from Field Maps to ArcGIS Pro. Outside of these, all of the intended project capabilities were employed through various means.

The primary capabilities which are worth note are the 3D visualizations, time properties, relationship classes, domains, and contingent values. The 3D visualizations and the issues related to them have been discussed in detail already in "Chapter 5 – Implementation". Alternatively, the main successes in the 3D visualizations present in the project were the ability for the port features to better identify location of origin due to the incorporation of a Z value allowing for height to change instead of width. This was achieved in ArcGIS Online through the use of the schematic vegetation symbol for sunflowers. The drop pin effect these have provided is similar to the tall and skinny cylinders used in ArcGIS Pro. As a result of this, we did not lose this fundamental cartographic benefit these symbols provide. The other major success in the 3D visualization was providing layers that still have the customized color schema requested by the client. This was not an easy thing to implement due to the reality that graduated symbols have set graduated color schemes, and 3D objects sizing is so extreme that it causes implementation of these custom 3D objects to be very difficult. Even though this was the case, through significant work an acceptable product was created.

Time properties were employed and function dynamically in both the ArcGIS Pro versions and the 2D versions on ArcGIS Online. These versions are all capable of a time slider and allow for the data to be played or paused. The 3D versions of the project on ArcGIS Online function somewhat differently, achieving the time formatting through the use of layer filters and slides. This allowed for the 25-year increment data to be facilitated on ArcGIS Online in 3D too. Therefore, the time in the 3D scenes on ArcGIS Online and

the accompanying applications all function similarly to a PowerPoint presentation with each slide detailing the specific year increment and destination the data is associated with. This allows for a semi-dynamic experience where the user may still interact with the data and view it as a timeline.

The relationship classes are another capability that has been discussed in depth. These relationships, as previously stated, are providing connections through the use of a key field to correlate the data between map features and the “Voyages Tables” which hold further contextual information. Relationship classes allow for the data to be formatted in such a way that it operates akin to how a relational database would, therefore allowing for improved querying capabilities and the implementation of the project on relational database servers such as those created by Microsoft SQL Server. Even though this was not implemented during this round of work, it is still likely to be a planned expansion for the project in the near future. Therefore, the project is still set up to be easily transferable onto the server. The effect the relationships have for the viewer is very important to achieving the project’s overarching goals: to provide a better sense of location of origin than is provided by SlaveVoyages and to provide further contextual information associated with those locations. The relationships provide data on the vessels which brought slaves from Africa to locations in the Western Hemisphere, as a result the relationship allows for this data to be provided in the form of a table instead of a group of features on the map. This is important to achieving the client’s requests for the visualization of the data, which is meant to be centered around static locations instead of mobile entities. Further, these relationships allowed for the data to be correlated in ways that allow for a deeper understanding of the information contained in the voyage’s data.

The domains were created originally to be implemented on the features which were going to be used in the Field Maps app. However, as the project was in its later phases and significant manual quality control work was being done, the idea to use these domains to solidify certain fields and track the many Unique IDs that were implemented was agreed upon by the project team. These decisions came about as a result of debating what the best method for providing some level of quality assurance was. In the end, after investigating various suggestions, two primary options were identified: The first, was using Python or SQL to write scripts to perform quality control. The second, was the use of contingent values to ensure quality. Performing quality control checks through Python requires scripts that read the reformatted .csv files in advance of their set up and use in ArcGIS Pro. These scripts would use search and update cursors to check and change any incorrect values. Alternatively, in SQL this would be done through using queries and expressions to check the various values and return the errors. It was decided that the process of coding a script for quality control was too significant a task to be included as an addition to the project. This was largely because the process for creating and finalizing the project had not yet been deciphered. Instead, after further investigation into attribute rules and ArcGIS Pro methods of quality control, it was decided that the second option of contingent values (a very new feature in ArcGIS Pro) would be used to ensure data quality going forward. The process for creating these is not difficult and is something the client, or any future graduate student could achieve with little instruction. These contingent values require that domains be created and implemented for the fields they are used to manage, as a result many domains were created. Since the client is more familiar with domains and their uses than any of the other suggested means of doing quality

control, it was decided that this was the best method. The domains encompass the names, alias naming convention, the longitude and latitude values for the point data, the color identifiers, and the various other domains related to the Field Maps. These domains are then used in tandem with the contingent values (for certain features fields) to lock the records inside the tables so specific aliases must have specific coordinates associated with them inside the attribute tables, and must have specific naming conventions ensuring the locations are correctly identified. These contingent values are not difficult to create and no more than two are implemented for any one layer. It was decided less was better here, in the sense that the less the client must manage the better. The most mistake prone data are the port locations which must be stacked exactly on top of one another for time properties so that the points don't appear in different locations. These points must be congruent across maps as well. As a result, the use of contingent values ensures the longitude and latitude are equivalent to what they should be. This will be very helpful during the creation process because it is very difficult to identify these mistakes without these contingent values highlighting the incorrect rows in the attribute table. This is because the scale that the project is normally operating at makes most of these tiny differences practically invisible. However, these would be noticeable if a user zoomed in to try and view a specific location at the small building visible range. These contingent values highlight records in bold red when a rule is broken, or alternatively when a record does not meet the specific requirements. If the data is incorrect the contingent value will prevent that information from being saved too. This will ensure that in the future if changes are made that the data added is correct and in alignment with the rest of the data, however, for new data contingent values will need to be re-implemented and possibly remade in certain cases. The other portion of the contingent values is they lock the color scheme – these contingent values ensure that the name matches the correct corresponding color identifier designated in every feature. These color identifiers range from one through nine and allow for the custom region-oriented color scheme to be implemented. Even further, the domains once implemented make it so that when symbolizing these in new maps, or with new data, the editor sees the name of the region the identifier relates to instead of the number itself reducing confusion. The implementation of these contingent values allows for improved consistency in the data and will provide quality control where it counts most in this project's work.

All of these capabilities will improve the visualization presented to the viewer and will provide significant improvements for the future facilitation of data from SlaveVoyages. The various improvements to the project have provided 3D visualizations, and related data that is essential (through relationship classes) to the intended user in an accessible and more refined manner. Further, the project has achieved the implementation of time, graduated symbols, and a custom color scheme all together on ArcGIS Online. Last but not least, the project has provided the client with a methodology and significant basis for the further expansion of the project and has various implementations to improve that process in the future. Altogether, the project has achieved the goals and capabilities that were set in the requirements.

6.2 Analysis

The primary goal of the analysis was to provide static locations-of-origin in Africa (where slaves were embarked) which relate to the specific destinations of Antigua, Nevis, and Jamaica – as well as include further contextual data contained on SlaveVoyages which was deemed valuable to the intended user. The client requested the inclusion of layers displaying ports and regions in totals (no-time), 25-year, and annual increments. The analysis done in the project achieved the goal of including static and consistent port locations across the three destination datasets. The analysis further succeeded in providing regions as polygon layers for use in the project. These polygon layers are meant to be displayed as cylinders and the boundaries are not accurate to any African nation or kingdom at the time of the data – these are simply historical regions delineated through interactions with the coastline settlements by European vessels. The African kingdoms and the delineation of their territories during the period the project maps are poorly documented, and in most cases highly debated. Due to this, the regions are meant to be most prominent at the coastlines. The ArcGIS Online version will show the regions as extrusions, however, as stated these regions only hold meaning at the coastline – the polygons themselves (which will go farther inland than the coast) are simply for visualization purposes. The end analysis succeeded in providing features which display the data related to the ports and regions of origin in Africa.

During the database set up work, it was discovered that there were slight inconsistencies between the region's and port's naming designations – as a result the values were inconsistent. This is a flaw in the SlaveVoyages database, but truly only one record was an actual flaw; the rest were a matter of disorganized naming conventions. The ports, for instance, had up to five named fields for unspecified territories versus the regions only ever had one named field – “Other Africa.” As a result, in our project's data these values were consolidated so that there was only one field for unspecified values, whether in ports or regions. This required some reorganization of the data. This did cause a level of human error to be introduced, which after significant manual quality control, and the implantation of unique identifiers, relationships, domains, and contingent values, were eventually all eliminated (to the best of the project team's knowledge).

Out of the 4000+ records only one true error was found (from SlaveVoyages) which had to do with a record (specifically the ship *Ulysses*) that had two different designated origin points (SlaveVoyages, 2019). The rest of the changes made were preferential re-organization to improve simplicity for the end user. By the Acceptable Quality Level (AQL) process, if the lot size is around four thousand, then the sample size would be around 200 (category L) and the highest quality limit would be 0.065% meaning that if there is one error in any of the 200 in the batch, that batch is rejected. In our data's case, SlaveVoyage's level of error would have been significantly less than even this. Since, as previously stated, there was only one “error” found out of over 4000 records. This does not mean our own project's AQL is this refined, obviously there is a level of human error that could have been introduced. None the less, since this is a scientific as well as historical project, and the data is largely provided by SlaveVoyages, the team sought to achieve equal quality to SlaveVoyage's database. Therefore, the ideal goal would be to have an AQL of 0.065%, the lowest amount of error for the sample size category, therefore, having less than one error per 200 records. In total this would mean

that as long as there are less than ten errors across the entire project, it would pass this acceptable quality limit threshold. After significant quality checks over a period of months the project team believes this has been achieved. The ability to cross calculate and see that the values are exactly correct time after time is a satisfying feeling, but took significant work to achieve. The data in our project, importantly, is changed from SlaveVoyages and the totals are not the same as the values in SlaveVoyages (intentionally). Instead, both the ports and regions are equivalent now as a result of the already discussed consolidation of the data. This will be covered further in the “Results” section. This was a significant portion of the analysis on the database side of the project.

Finally, the implementation of time properties and relationship classes filters the data and provides a refined view into the data for the end user. Instead of scanning through tables and statistics the viewer can surf through a map and click on colorful features which display the data in a simple and user-friendly format. The time properties as they are turned on (or played) reduce the amount of features the user is confronted with and provide a format that the vast majority of people can easily interpret. Finally, as users watch this animation of the data, they are able to click on individual origin points, or destination points, and connect through a second click to the related data, which is presented as a list following the naming convention used by SlaveVoyages. This is in order to allow users to more easily cross analyze and find the same record in SlaveVoyages (which does have more contextual fields). All of this takes care of a significant portion of the analysis required for a user to otherwise accomplish this for themselves. Although the SlaveVoyages data is an incredible accomplishment, it is not very accessible for the average person. As a result, very few people delve into the database. By accomplishing the analysis explained above the project has made this data vastly more accessible and has provided the basis for further expansion of the project.

6.3 Results

It is important to state that the changes made to the organization of the SlaveVoyages database came from a statistical and cartographic perspective in terms of simplification, and it should be noted that there could be historical reasons for the decisions made by SlaveVoyages. Therefore, it can't be said that our project's organization is necessarily more accurate than their organization. The effect our consolidation had was simplification for the viewer. Any differences in the database revolve around consolidating fields or simplifying them. The results of the analysis are best displayed in charts of various types. These will be included later in this section. The changes during consolidation have made it so that the “Africa Unspecified” field, or “Other Africa” field is equivalent across ports and regions within the destination datasets. The other fields have similarly been checked and the changes resulting from the updates to “Africa Unspecified” only resulted in a single record change outside of the consolidation of the unspecified port fields. This had to do with a voyage, specifically a ship named Ulisses that is previously mentioned in this report. Ulisses has two separate origin points given, one being the Bight of Biafra and the other being “Africa Unspecified.” Outside of this record and the “Africa Unspecified” field, the records should be equivalent to SlaveVoyage's data (SlaveVoyages, 2019).

In order to express the differences in SlaveVoyage’s “Other Africa” field, and our “Africa Unspecified” field, the differing totals will be listed. To begin will be SlaveVoyage’s values:

Destination	Embarked	Disembarked
Antigua (Regions)	52,695	43,903
Antigua (Ports)	50,205	41,632
Nevis (Regions)	11,538	9350
Nevis (Ports)	11,538	9350
Jamaica (Regions)	271,059	223,737
Jamaica (Ports)	266,078	219,333

Table 6.1: SlaveVoyages Regions & Ports Totals Data (SlaveVoyages, 2019)

As can be seen, all except Nevis are inconsistent. In changing this, our projects values read consistently:

Destination (Ports/Reg.)	Embarked	Disembarked
Antigua	52,695	43,903
Nevis	11,538	9,350
Jamaica	271,707	224,270

Table 6.2: Mapping the Trans-Atlantic Slave Trade Project Totals (SlaveVoyages, 2019)

The reason our project’s end values are somewhat larger than that of the originals is the decision related to the voyage record for the ship *Ulisses* which has an embarked value of 648 and a disembarked value of 533. This record, as previously mentioned, was identified as having two origin locations, first “Africa Unspecified” in regions and second Bight of Biafra in ports. Due to this, it has been placed solely in “Africa Unspecified” in our project’s data. Otherwise more statistics will be provided in the following figures detailing various statistics about the data. The primary addition, which provided a better sense of location, was the inclusion of port locations by the client through historical research and analysis. These port locations are not contained on SlaveVoyages and have

significantly refined the accuracy of the origin points which are only displayed as regions in the SlaveVoyages database (SlaveVoyages, 2019). This took significant work on the client's part and would not have been possible without his knowledge and specialization in West African History. This has improved the ability for users to discern specific locations dramatically, and further provides significantly greater spatial context for users trying to identify information about their possible origins.

Figure 6-1: Embarked Slaves to Antigua by Year

Figure 6-2: Disembarked Slaves on Antigua by Year

Figure 6-3: Embarked Slaves to Nevis by Year

Figure 6-4: Disembarked Slaves on Nevis by Year

Figure 6-5: Embarked Slaves to Jamaica by Year

Figure 6-6: Disembarked Slave on Jamaica by Year

Figure 6-7: Embarked Slave to Antigua by Hist. African Region

Figure 6-8: Disembarked Slaves on Antigua by Hist. African Region

Figure 6-9: Embarked Slaves to Nevis by Hist. African Region

Figure 6-10: Disembarked Slaves on Nevis by Hist. African Region

Figure 6-11: Embarked Slaves to Jamaica by Hist. African Region

Figure 6-12: Disembarked Slaves on Jamaica by Hist. African Region

Figure 6-13: Embarked Slave to Antigua by African Port

Figure 6-14: Disembarked Slaves on Antigua by African Port

Figure 6-15: Embarked Slaves to Nevis by African Port

Figure 6-16: Disembarked Slaves on Nevis by African Port

Figure 6-17: Disembarked Slaves to Jamaica by African Port

Figure 6-18: Disembarked Slave on Jamaica by African Port

Chapter 7 – Conclusions and Future Work

7.1 Conclusion

In conclusion, there were a few project capabilities which we were not able to be implemented for reasons explained in earlier sections. Specifically, the Microsoft SQL Server and its related benefits regarding the seamless transfer of data were not able to be achieved because of out-of-date servers. These prevented us from influencing this situation in any way. Another small shortcoming of the project was the lack of implementation of the origin to destination links in the ArcGIS Online product. This was specifically requested by the client (to not include these features) due to the fact that no viable method for visualization was able to be found. This did not impact the end product, nor were they a requirement. It did, however, result in some of the project's work not being incorporated. The last shortcoming, which also was not a requirement specified by the client or program advisor, was the possibility for semi-automation. There are some ModelBuilder tools included in the project, however, not all of the processes done were created as ModelBuilder tools since so many of those processes are case-specific and require selections within feature attribute tables and other more detailed processes. It is possible that in the future, some of the core processes for layer creation might be automatable, or at least Unique ID creation.

The true project requirements were that one, the project geodatabase be organized as specified with all data housed in feature datasets which are oriented around the destination that the data relates too. The second requirement was that there be 3D scenes and 3D feature visualizations which allow users to explore the data in 3D, akin to Google Earth. This was achieved through the use of 3D scenes and the implementation of 3D features with the custom color scheme required by the client, in ArcGIS Pro and ArcGIS Online. The third requirement was that the end product be accessible without ArcGIS Online credentials or a University of Redlands login. All three of these requirements have been achieved as of this point, and as discussed previously, the various hurdles related were overcome in different ways, so a 3D visualization was able to be produced.

Lastly, the deliverables for the project include the project file geodatabase, which will be given to the client over OneDrive or through Lisa Benvenuti. Then the projects themselves, which likely will be transferred via the same method. The requirement that the project be accessible has been tested by the project advisor and the various applications and maps will be accessible without an ArcGIS Online account or credentials. Therefore, the three requirements for the project and the two deliverables are taken care of.

7.2 Future Work

While the project was confronted with various challenges along the way, significant work was put into meeting with specialists and working to find methods around issues encountered. These efforts were not wasted because they provided possibilities for improving upon the current organization and delineation of the project. It should be noted here that significant effort was put into finding the most operational product as the project stands already, and many of the more advanced capabilities ended up negatively impacting the project, not improving it. Specifically, there are three major sectors where future work could improve the project significantly: First, the implementation of Python scripts or further ModelBuilder tools to enhance the interaction with the project and improve the creation process for layers in the project. The second major improvement that could be done is the implementation of the ArcGIS API for Javascript, which might provide methods for creating a more customized and perfected end-product. The last, but most viable and most important of the suggestions, would be the eventual implementation of the Microsoft SQL Server which was already set up by the Redlands I.T. department and Nathan Strout. This will be ready once the server is updated in August or September of 2021. In the following sections I will discuss these in further depth and the possible benefits they might provide to the project. Further, the future application of the planned Field Maps portion of the project will be discussed.

7.2.1 Table Creation Automation

The process for formatting the data for time properties and creating the unique identifiers could be semi-automated through the use of Python. There is the reality that even with this being automated it would need to be checked in depth manually afterwards, but automating this process would cut down on the creation time required in adding to the dataset significantly. The creation process for the project is complex and took significant time to initially identify and delineate which impacted the viability of this method during my own work. Now that there are examples and a basis for the project, this process has been made possible.

This work is something that could be accomplished by a graduate student and could be done in the time that the accelerated degree allots. This process will be significantly easier with the guides included with this project. It is suspected that the creation process for the time formatting will be more complex than that of the Unique ID creation. The time properties will likely not be entirely automatable; it will be semi-automatable though. The suggested route to accomplishing this would be to create a Python script which uses a csv reader, a search cursor, an update cursor, along with a script that compiles the rows of data extracted accordingly with the defined year increments. This code will need to read through the exported .csv file from SlaveVoyages, extract every column after the initial one (will start at 1 not 0), row by row, and transpose these according to the origin points and years— this will require that the script then transposes the data into a single column in a different .csv sheet. This script will require that the start, end, and total number of years in each timeline, or destinations dataset, be entered into the script each time it is re-run in order to ensure that

the number of rows created for the name column match the values that will be transposed by the process just explained. Figure 7-1 illustrates this example:

Figure 7-1: Reformatting Example

This will need to be done from the Voyages Table data extracted from SlaveVoyages, or from individual table extractions from SlaveVoyages. This script will only be able to be semi-automated because of this required extraction, plus the fact the number of rows for each port or region added will change accordingly with the number of years in the timeline, and because the number of columns and rows will also change with every new destination. These are the difficulties with automating this data, and further the script will require methods for skipping over null values and returning an error when there are issues because without those capabilities it is almost certain to create significant inconsistencies when the data is cross analyzed with SlaveVoyage's database. As stated, the time section of this process will likely be the most difficult.

To briefly explain some of the process related to automating the unique identifier creation, first look back at Table 4.5 and 4.6, which detail the Unique ID creation table. As can be seen, the code will need to also use a .csv reader and a search and update cursor. However, the process for creating these values should be able to be set and left, other than entering the number of years each time the script is run on a new set of data. The Unique IDs are facilitated in a way that should allow their creation process to be largely automated. The code will need to do various things, however, first it will need to be able to store some level of information so that when it is run on new data it recognizes how many times it has run before. This could be done through a list which increases every time the script is run. The first digit in the unique identifiers specifies whether the destination has changed, this digit will either be a number or a letter depending on whether the unique identifier is attached to a port or a region/destination. If it is a port, it will always be a number, and if it is a region or destination, it will be a letter. The letter value is determined off the name of the destination and how many destinations prior to it have that same letter. The second variable is a symbol which is related to what feature

layer the data is in. The third variable identifies the location, and the value will increase for each new location. The fourth digit, which is only present in the layers with time properties, is always a period or decimal which separates the final two digits. The fifth and final digit identifies each individual record origin uniquely according to the changing years. This allows for every record to be unique in the features and allows for multiple records inside the relational table to be connected to that single row.

Deciphering how to best to do this process would be a task for a future graduate student and would require significant Python knowledge. Creating this tool, however, would be a huge aid to the client who will struggle to do this level of work on his own, and could use a script to help ease this process. The truth is, until the base version was created, none of the project team was sure such automation was even possible, but today the project creator can confidently say that it is semi-automatable – and even semi-automation would drastically reduce the time required in creating these unique identifiers.

7.2.2 ArcGIS API for JavaScript

ArcGIS API for JavaScript presents many opportunities which would otherwise be unachievable. Its benefits would also be taken advantage of more readily if this project were to be housed on the University of Redland's Microsoft SQL server. This enterprise level deployment would provide flexibility and access to the code with more administrative capability than is available on ArcGIS Online. To start this process, an application programming interface key will need to be generated. This will provide a method of access that will lay the basis for the public-facing application. After this is done, it should be possible to access the project, whether on ArcGIS Online or the server, and perform various customizations to improve the final product. It is possible, according to Sajit Thomas, to create slides and filters in conjunction with 3D effects this way (difficulties discussed in section 5.2.). This could significantly improve the visual for the end-users, converting slides into simple labels for example, creating 3D effects which visualize the data through various views of each layer, and allow for those layer views to be used more readily as filters. Even further, the JavaScript API can be used to incorporate "Jet Streams" to replace the original Origin Destination Links. These are an improved visualization of this data which would be applicable to our project, but isn't right now simply due to the fact that the 3D effects widget is not capable of taking account of layer filters. It is not possible at the time of this writing, but time sliders may also soon be able to be implemented in 3D scenes through the ArcGIS API for JavaScript. This may provide a method for implementing the time slider. With that said, the customizations that could be done to the slides would be preferred likely by the client since the original "Origin Destination Links" and their visualization were not viable due to the fact that they were geodesic lines, however, could not be accurate distance calculations if they were not geodesic lines. As a result, there was a difference of opinion which largely resulted in them not being included. At the end of the day though, the client and project advisor both felt that "Jet Streams" would provide a viable method for implementing the "Origin Destination Links" information.

It was also clear through further discussions with Sajit Thomas that the ArcGIS API for JavaScript is capable of much more than even what is listed above, and it is possible there are further improvements that could be made. This work is without a doubt

worthy of a Major Individual Project and would require JavaScript experience. The project team would recommend contacting Sajit Thomas if any future graduate student wishes to take this on. Further, it should be discussed with the client as to the viability of implementing this for him, and whether or not he would be able to edit or interact with it at that point.

7.2.3 Microsoft SQL Server

One addition, that should be easy to do and may also provide room for exploration into JavaScript, would be the implementation of the server which was originally planned. This server should be up to date after this semester and is already set up and ready for data to be imported. The next graduate student should be sure to re-transfer the project onto the server with the most recent version (the one that will be owned by the client). The server should be updated by the end of Sept. 2021; therefore, someone in the next cohort could easily take up this project and complete this work. After transporting the data to the server, the student would need to recreate most of the end maps and applications for the project. Further, the Field Maps application would need to be re-setup to provide the seamless transfer of data from Field Maps to ArcGIS Pro. This can only be done with the use of the server; however, it is not a difficult process. Very simply, the existing Field Map features will just need to have their data extracted, then appended or joined to the hosted data on the server. These hosted layers will then need to be added to the original Web Map (or the Web Map could be remade) and used instead of the web layers on ArcGIS Online from the project creator's work. This will also need to be done for all of the Web Applications and the Experience Builder App. It is possible that there may be a way to do this work and then expand upon the project instead too. It may not affect the end map if the layers from this project's web layers are kept in their current format; however, the project creator suggests updating this data by transporting it onto the sever so that the data is entirely housed in a single place.

7.2.4 Field Maps

The final important aspect to the future work of the project is the ability for edits in the field to be done by the clients future May term class – which plans to go to Antigua to explore the history related to the Trans-Atlantic Slave Trade Activity on the island and identify additional contextual information that might support users of the project. This supporting contextual information includes the addition of features displaying forts, churches, cattle mills, roads, towns, and windmills. These will provide supporting information related to the happenings on Antigua just through their plotting on a map, specifically windmills indicate sugar production, forts military presence, and cattle mills are a source of slave labor. Further, roads and towns can indicate much about the level of integration that existed, as do churches through who had access to them. Significant information can be gleaned from these features and as a result it was decided that a Field Maps application was highly applicable to the project in this respect. The second improvement these features will provide (once plotted in the future) is the added

contextual information contained in the attribute fields. This attribute data will be related to the individual destinations (for now only Antigua), which are alternatively often the origin points for the dispersion of the descendants of displaced Africans who ended up in the Americas – because of this fact, the contextual information on the project destinations is extremely valuable to those descendants. The map and Field Maps app have already been created and activated for use in the field. Therefore, the future work does not require that these be set up, instead the future work involved here is a planned aspect of the project. The plotting of the points will be done by Dr. Glovers May term course in 2022. The set up and specific fields included for these features is discussed in the “System Design” section.

These features all have GPS fields added and will immediately fill this information once the points are digitized. This will allow for the creation of time formatted layers and 3D feature visualizations like done with the rest of the core features in the project. Therefore, in the future, these points and contextual additions could also be visualized in 3D for users. The hope is that with the addition of these contextual fields, this GPS information, and the features themselves, that in time a significantly more in-depth view into these destinations and their participation in the slave trade can be created. This could provide incredibly important data to the study of the Trans-Atlantic Slave Trade as a whole, not just simply this project. This is because significant portions of the historical context related to these destinations has not yet been digitized, especially in the form of GIS. It is important to recognize that the destination points for slaves in the Trans-Atlantic Slave Trade can simultaneously be the origin point for slaves in the Intra-American Slave Trade. This means that once the work for the Trans-Atlantic Slave Trade portion of the project is completed, this could be used to start to facilitate a separate project or expansion to this project which starts to compile the Intra-American Slave Trade as well. In the future, the contextual information provided by a GIS 3D scene and this significantly expansive data, would be revolutionary for the study of the slave trade as a whole. In the more near term, the addition of field edits will hopefully provide significantly improved spatial and historic context for the project in relation to the destinations of Antigua, Nevis, and Jamaica.

Works Cited

- Ancestry. (2020). *Every family has a story. Find yours*. Retrieved Oct. 18 2020 from <https://www.ancestry.com/>
- Berry, L. (2019). *Visualizing population migration by where people filed their taxes*. Retrieved July, 28 2021 from <https://www.esri.com/arcgis-blog/products/arcgis-online/mapping/visualizing-population-migration-by-where-people-filed-their-taxes/>
- Eltis, D. (2010). *Atlas of the transatlantic slave trade*. Yale University Press
- Emory University. (n/a). *Documenting slave voyages*. Retrieved Oct. 24, 2020 from <https://news.emory.edu/features/2019/06/slave-voyages/index.html>
- ESRI. (2017). *The ArcGIS book 2nd ed*. Esri Press. Pp. 87-96
- ESRI. (2019). *Visualize temporal data*. Retrieved Oct. 24, 2020 from <https://pro.arcgis.com/en/pro-app/get-started/visualize-temporal-data.htm>
- ESRI. (2021). *Work with date fields*. Retrieved July 17, 2021 from <https://doc.arcgis.com/en/arcgis-online/manage-data/work-with-date-fields.htm>
- Gates, H. [@HenryLouisGates]. (2019, December 18). *A massive new database will connect billions of historic records to tell the full story of American slavery* [Tweet]. Twitter. <https://twitter.com/HenryLouisGates/status/1207417079185448961>
- Graft-Johnson, J. (2021). *Mūsā I of Mali*. *Encyclopedia Britannica*. Retrieved August 30, 2021 from <https://www.britannica.com/biography/Musa-I-of-Mali>
- Green, K. (2019). *How Ancestry.com has failed African American customers*. WASHPOST. Retrieved Oct. 18, 2020 from <https://www.washingtonpost.com/outlook/2019/05/31/how-ancestrycom-has-failed-african-american-customers/>
- Heidt, A. (2020, July 23). *African American genomes yield insight into slavery practices*. *The Scientist*. Retrieved, Oct 25 2020 from <https://www.the-scientist.com/news-opinion/african-american-genomes-yield-insight-into-slavery-practices-67766>
- Micheletti, S. Bryc, K. Esselmann, S. Freyman, W. Moreno, M. Poznik, G. Shastri, A. (2020). AJHG: Genetic consequences of transatlantic slave trade in the Americas. *American Journal of Human Genetics*, 107 (2), 265-277. 10.1016/j.ajhg.2020.06.012
- Neblier, S. (2008). *The Harvard map project*. Retrieved Oct, 24 2020 from <http://worldmap.harvard.edu/maps/1374/info/>

- Newitt, M. (2010). *The Portuguese in West Africa, 1415-1670: a documentary history*. Cambridge University Press.
- Ross, J. (2019). *Ancestry.com ad pulled, criticized for sugarcoating slavery*. NBC. Retrieved Oct. 18, 2020 from <https://www.nbcnews.com/news/nbcblk/ancestry-com-ad-pulled-criticized-sugarcoating-slavery-n996771>
- SlaveVoyages. (2018a). *About the project*. Retrieved Nov. 19, 2020 from <https://slavevoyages.org/about/about>
- SlaveVoyages. (2018b). *Explore the dispersal of enslaved Africans across the Atlantic World*. Retrieved Oct. 18, 2020 from <https://slavevoyages.org/>
- SlaveVoyages. (2019). *Trans-Atlantic slave trade – database*. Retrieved Nov. 19, 2020 from <https://slavevoyages.org/voyage/database>
- Timothy, B. (2012). *How the public actually uses local government web maps: metrics from Denver*. Retrieved Nov. 2, 2020 from <https://mapbrief.com/2012/08/01/how-the-public-actually-uses-local-government-web-maps-metrics-from-denver/>
- Thomas, S. (2021). *Cool maps*. Retrieved July, 2021 from <https://coolmaps.esri.com/#9>
- Thornton, J. (1992). *Africa and Africans in the making of the Atlantic world, 1400-1680*. Cambridge University Press.

Appendix A. User Manual

Note: The user manual will detail the methods of interacting with the 5 applications which were the final products on ArcGIS Online. All Apps can be accessed on the <https://mapping-the-trans-atlantic-slave-trade-database-univredlands.hub.arcgis.com/> hub site. In this tutorial all apps except the Experience Builder app will be accessed here. This is because the Experience Builder Apps performance is improved when accessing the application directly.

Chapter 1 – User Manual

1.1 2D by 25-Year App

Pre-Prep:

1. Open a google browser
2. Search for “ <https://mapping-the-trans-atlantic-slave-trade-database-univredlands.hub.arcgis.com/>”
3. You will see the title section stating the project name “Mapping the Trans-Atlantic Slave Trade”
4. Scroll until the “25 Year App:” is visible.
5. Select “Open” in red under the “Mapping the Trans-Atlantic Slave Trade 25yr App”
6. The application opens.

1.1.1 App Use

The primary use for the 2D by Year and 2D by 25-Year apps is to provide the related voyages data that is not otherwise able to be provided in 3D. These applications provide the full functionality intended by Dr. John Glover and importantly provide significantly more contextual information in terms of data. These do not provide the improved visual context that the 3D layers do.

1.1.2 Timeline

1. To activate the timeline first ensure that the “pre-prep” steps were completed.
2. Once the application is open, there will be an information panel on the left. To collapse this, hover your cursor over the small black bar to the right of the “scroll bar”:

3. A set of buttons should appear that look like this:

4. Click the grey “ i ” symbol.
5. The details pane should collapse making the application view larger.
6. Locate the three buttons in the upper right-hand corner of the map.

7. Navigate your cursor to, and select the clock symbol:

8. The timeline will immediately start to play through. This will play on a loop if you allow it, but you may also click on the shadowed bar on the bottom of the screen to activate the settings. Allowing you to pause, fast forward, or skip back. Note that if you click the arrows on the edges of the time slider, you may modify the year increments being viewed. The “1X” in the bottom right-hand corner allows you to speed up or slow down the rate of the timeline.

9. To de-activate the timeline, simply select the “X” in the upper right hand of the timeline box.

1.1.3 Filter

You may Filter by Year alone, by Port and Year, or by Region and Year:

- “Filter by year increment (Destination name): 25yr” will filter purely by year.
- “Filter by year increment (Destination name): Africa Port 25yr” will filter by year and only will filter ports.
- “Filter by year increment (Destination name): Africa Reg. 25yr” will filter by year and only will filter regions.

1. Locate the three buttons in the upper right-hand corner of the application.

2. Click on the Filter Symbol which looks like this:

3. Once the Filter Window opens you will be able to input filters for any or all of the layer in the map. The window will start without any filters active. In order to activate a filter:
 - a. First select the “From Year” which is the year that defines the start of the 25-year increment

A screenshot of a 'Filter' window. At the top, it says 'Filter' with a dropdown arrow, a square icon, and a close 'X' icon. Below this, there is a section titled 'Filter by year increment Jamaica: 25yr' with a toggle switch to its right. Underneath, there are two input fields. The first is labeled 'From Year is' and contains the value '1776'. The second is labeled 'To Year is' and contains the value '1800'. Both input fields have a yellow border.

- b. Second select the “To Year” which is the year that defines the end of the 25-year increment

c. Locate the greyed out slider button on the top right.

d. Activate it.

4. Importantly, this will only filter for the destination stated – so in this examples case that would be “Jamaica.” In order to have the entire maps data filter to the year increment you wish, fill out the “Filter by year increment (Destination name): 25yr” filters for each destination. Ensure the name of the Filter matches other than the destination name.
5. Once all these filters have been filled out, the entire map should be filtered to the 25-year increment you have selected.
6. You may then collapse the Filter by pressing:
7. This will keep the Filter settings active but simply allow you to better view the map data/features.
8. Once done exploring, navigate back to the Filter button from step 2.
9. Select it and de-activate the filters before proceeding to the Query section.

1.1.4 Query

Note: The Query works much like the filter except it will return results that can be exported on their own and provide the fun capability of highlighting and zooming to your query result.

1. Locate the three buttons in the upper right-hand corner of the application.

2. Click on the Query Symbol which looks like this:

3. Fill out the “From Year” indicating the start of the year increment and fill out the “To Year” indicating the end of the year increment.

4. Select “Apply”
5. The window zooms to the target and presents you with the feature associated with that query. Example:

Jamaica

Country (Destination): Jamaica

Years: 1726 - 1750

Disembarked: 170,642

Voyages Information:

Avg. Middle Passage Time (Days): 97

Avg. Ship Tonnage: 174.6

Voyages_Jamaica

6. You can export these results and do much more by accessing the “More options” (...):

7. Once selected you will be able to see in the expanded window the various options for exporting, or the option of deactivating the query (Remove this result).

1.1.5 Bookmarks

1. Click on the Bookmark Symbol:

2. You will be presented with these Options:
 - a. Antigua
 - b. Nevis
 - c. Jamaica
 - d. Senegambia
 - e. Sierra Leone
 - f. Windward Coast
 - g. Gold Coast
 - h. Bight of Benin
 - i. Bight of Biafra
 - j. West Central Africa
 - k. South East Africa
3. If you select any of these, they will zoom to the location on the map.
4. Importantly, with only Antigua, Nevis, and Jamaica – there exists a secondary capability: If select these will filter all map data to the destination selected. This means that:
 - a. If Antigua is selected, you will only get Antigua's data:

- b. If Nevis is selected, you will only get Nevis's data:

c. If Jamaica is selected, you will only get Jamaica's data:

5. To clear this, you must reload the app via the symbol on your google browser.

1.1.6 General Capabilities:

1.1.6.1 Legend

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Legend” Symbol:

3. The Legend appears
4. The Legend will detail information on all layers that are active on the map.

1.1.6.2 Layer List

1. Navigate your cursor to the left-hand bar within the app
2. Select the “Layer List” Symbol:

3. The Layer List appears.
4. To activate a layer, click the check box to the left of its name. When it is filled with a blue mark it is active.

5. To de-activate a layer click the active check box so that the blue highlighting disappears.

1.1.6.3 Base Maps

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Basemaps” symbol:

3. The Basemaps window appears with a selection of basemaps
4. Select any basemap to change the maps basemap.

1.1.6.4 Print

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Print” symbol:

3. Once selected a window appears:
 - a. Input the “Layout”
 - b. Input the “Format”
 - c. Select Print
 - d. Navigate to your printer
 - e. Print.

1.1.7 Related Records

Use:

- Accessing related information in the 2D 25yr App.

Process:

1. Navigate your cursor to one of the ports or regions in the map:

2. Make a selection.

3. Press the arrow in the right hand of the selection box:

4. The popup information is now presented:

1 of 11	
NewCalabar	
Port (Origin): New Calabar	
Alternate Name:	
Voyages Destination: Jamaica	
Years: 1726 - 1750	
Embarked: 607	
Disembarked: 492	
Voyages Information	
Avg. Middle Passage Time (Days):	
Avg. Ship Tonnage: 173.3	
Related tables:	
Voyages_Jamaica	

5. Locate the “Related tables:”

Related tables:	
Voyages_Jamaica	

6. Click the grey highlighted “Voyages_(Destination name)”

Related tables:	
Voyages_Jamaica	

7. Once selected, new records will appear. These are the related voyage records for that port or region.

1 of 9	
Voyages_Jamaica	
Related records:	
Voyages_Jamaica: George	
Voyages_Jamaica: Princess Ann	

8. Select any records to view their information.

1 of 9	
Voyages_Jamaica: George	
Voyages_Jamaica: George	
Voyage ID	16672
Vessel name	George
Personal name	Jacob Senneker
Age	Great Britain
By what vessel	Ship
Personnel count	8
Voyage history (input) port where began	Britain
Voyage history (input) principal place of	New Calabar
with purchase (input)	
Voyage history (input) principal port of	Jamaica, port unspecified
from disembarkation	
Total embarked	276
Total disembarked	209
Days of arrival at port of disembarkation	5732
Middle passage	
Avg. Disembarkation Ship, Tonnage	182

9. Explore and recommit this process at your leisure.

1.2 2D by Year App

Pre-Prep:

1. Open a google browser
2. Search for “ <https://mapping-the-trans-atlantic-slave-trade-database-univredlands.hub.arcgis.com/>”
3. You will see the title section stating the project name “Mapping the Trans-Atlantic Slave Trade”
4. Scroll until the “By Year App:” is visible.
5. Select “Open” in red under the “Mapping the Trans-Atlantic Slave Trade by Year App”
6. The application opens.

Manual:

1.2.1 App Use

The primary use for the 2D by Year and 2D by 25-Year apps is to provide the related voyages data that is not otherwise able to be provided in 3D. These applications provide the full functionality intended by Dr. John Glover and importantly provide significantly more contextual information in terms of data. These do not provide the improved visual context that the 3D layers do.

1.2.2 Timeline

1. To activate the timeline first ensure that the “pre-prep” steps were completed.
2. Once the application is open, there will be an information panel on the left. To collapse this, hover your cursor over the small black bar to the right of the “scroll bar”:

3. A set of buttons should appear that look like this:

4. Click the grey “ i ” symbol.
5. The details pane should collapse making the application view larger.
6. Locate the three buttons in the upper right-hand corner of the map.

7. Navigate your cursor to, and select the clock symbol:

8. The timeline will immediately start to play through. This will play on a loop if you allow it, but you may also click on the shadowed bar on the bottom of the screen to activate the settings. Allowing you to pause, fast forward or skip back. The “1X” in the bottom right-hand corner allows you to speed up or slow down the rate of the timeline.

9. To de-activate the timeline, simply select the “X” in the upper right hand of the timeline box.

1.2.3 Filter

You may Filter by Year alone, by Port and Year, or by Region and Year:

-“Filter by year increment (Destination name): by year” will filter purely by year.

-“Filter by year increment (Destination name): Africa Port by year” will filter by year and only will filter ports.

-“Filter by year increment (Destination name): Africa Reg. by year” will filter by year and only will filter regions.

1. Locate the three buttons in the upper right-hand corner of the application.

2. Click on the Filter Symbol which looks like this:

3. Once the Filter Window opens you will be able to input filters for any or all of the layer in the map. The window will start without any filters active. In order to activate a filter:
 - a. First, identify if you want to filter by solely year, by year and ports, or by year and regions. Once identified, filter by the same type of filter for each destination.

Filter Name	Year is	Active
Filter by year increment Jamaica: by year	1687	Yes
Filter by year increment Jamaica: Africa Port by year	- empty -	No
Filter by year increment Jamaica: African Reg. by year	- empty -	No

- b. If I was filtering only by year: First, I would select the year for the “Filter by year increment (Destination name): by year.”

- c. Then activate the greyed-out activation button in the right hand corner of the filter.

- d. Activate it.

4. Proceed to apply the same process for the other Two destinations filters of the same type (or more) “Filter by year increment (Destination name): by year” filters.

1.2.4 Query

Note: The Query works much like the filter except it will return results that can be exported on their own and provide the fun capability of highlighting and zooming to your query result.

1. Locate the three buttons in the upper right-hand corner of the application.

2. Click on the Query Symbol which looks like this:

3. Fill out the “Year is” drop down by clicking the arrow to expand and selecting a year.

4. Select “Apply”
5. Once the query is applied, the map will zoom to the feature and the results will display the features pop up information.

6. You can export these results and do much more by accessing the “More options” (...):

7. Once selected you will be able to see in the expanded window the various options for exporting, or the option of deactivating the query (Remove this result).

1.2.5 Bookmarks

1. Click on the Bookmark Symbol:

2. You will be presented with these Options:
 - a. Antigua
 - b. Nevis
 - c. Jamaica
 - d. Senegambia
 - e. Sierra Leone
 - f. Windward Coast
 - g. Gold Coast
 - h. Bight of Benin
 - i. Bight of Biafra
 - j. West Central Africa
 - k. Southeast Africa
3. If you select any of these, they will zoom to the location on the map.
4. Importantly, with only Antigua, Nevis, and Jamaica – there exists a secondary capability: If select these will filter all map data to the destination selected. This means that:
 - a. If Antigua is selected, you will only get Antigua's data:

- b. If Nevis is selected, you will only get Nevis's data:

c. If Jamaica is selected, you will only get Jamaica's data:

5. To clear this, you must reload the app via the symbol on your google browser.

1.2.6 General Capabilities

1.2.6.1 Legend

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Legend” Symbol:

3. The Legend appears
4. The Legend will detail information on all layers that are active on the map.

1.2.6.2 Layer List

1. Navigate your cursor to the left-hand bar within the app
2. Select the “Layer List” Symbol:

3. The Layer List appears.
4. To activate a layer, click the check box to the left of its name. When it is filled with a blue mark it is active.

5. To de-activate a layer click the active check box so that the blue highlighting disappears.

1.2.6.3 Basemaps

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Basemaps” symbol:

3. The Basemaps window appears with a selection of basemaps
4. Select any basemap to change the maps basemap.

1.2.6.4 Print

1. Navigate your cursor to the left-hand bar within the app.
2. Select the “Print” symbol:

3. Once selected a window appears:
 - a. Input the “Layout”
 - b. Input the “Format”
 - c. Select Print
 - d. Navigate to your printer
 - e. Print.

1.2.7 Related Records

Use:

- Accessing related information in the 2D by Year App.
- Accessing related information in the 2D 25yr App.

Process:

1. Navigate your cursor to one of the ports or regions in the map:

2. Make a selection.

3. Press the arrow in the right hand of the selection box:

4. The popup information is now presented:

5. Locate the “Related tables:”

6. Click the grey highlighted “Voyages_(Destination name)”

7. Once selected, new records will appear. These are the related voyage records for that port or region.

8. Select any records to view their information.

9. Explore and recommit this process at your leisure.

1.3 3D 25-Year Ports App

Pre-Prep:

1. Open a google browser
2. Search for “ <https://mapping-the-trans-atlantic-slave-trade-database-univredlands.hub.arcgis.com/>”
3. You will see the title section stating the project name “Mapping the Trans-Atlantic Slave Trade”
4. Scroll until the “Explore in 3D!” is visible.
5. Select “Open” in red under the “Mapping the Trans-Atlantic Slave Trade 3D 25yr Ports App”
6. The application opens.

1.3.1 App Use

The primary purpose of the 3D applications is to provide a visualization of the data that is accurate to the destinations. The data is informative because of the visualization provided – while using the 3D apps related records therefore will not be available. Only the general pop-up information for the destinations will be identifiable. The importance of these apps is to visualize the difference in the sizes of feature across destinations and across year increments within their own data.

Manual:

1.3.2 General Capabilities

1.3.2.1 Timelines

1. Navigate to the upper left-hand corner of the application
2. Click: “Timelines”

3. Once activated a bar on the bottom will appear and will provide slides for each 25-year increment.

4. Hover over the slide to identify the year increment.
5. Select a slide.
6. The slide with the picture of the destination marks the start of that destination's timeline. As shown here in yellow.

7. Explore the slides at your leisure, the map features will change with each slide.

1.3.2.2 Daylight

1. Navigate to the upper left-hand corner of the application.
2. Click: "Daylight"

3. Once activated, use the slider to change the time of day.

4. This will change the time of day and, therefore, shadows on the earth's surface.
5. Greenwich Mean Time (GMT) can also be changed.

1.3.2.3 Layer List

1. Navigate to the middle-left hand area of the application with your cursor.
2. Locate and click: “Layer List”

3. You will be confronted with the many layers within the 3D maps. As is shown by the labels, each group of layers correlates to a destination and 25-year increment. Simply identify the destination and year increment you wish to view.

4. Expand the feature layer by clicking on the arrow to the left of the layer.
5. Select both layers are checked in the boxes to the left:

6. Once complete view the layer in the map.

1.3.2.4 Legend

1. First, navigate your cursor to the bottom left of the application view.
2. Locate the Legend button and click it.

3. Once selected a new view will appear with information on the layers active in the map. Scroll and view this information at your leisure.

1.3.2.5 Basemaps

1. First, navigate your cursor to the bottom left of the application view.
2. Locate the Basemaps button and click it.

3. Once activate a new window will appear displaying various Basemaps which can be added to the map.

4. To add a basemap, simply click on its name in the “Basemap Gallery.”

1.4 3D 25-Year Regions App

Pre-Prep:

1. Open a google browser
2. Search for “ <https://mapping-the-trans-atlantic-slave-trade-database-univredlands.hub.arcgis.com/>”
3. You will see the title section stating the project name “Mapping the Trans-Atlantic Slave Trade”
4. Scroll until the “Explore in 3D!” is visible.
5. Select “Open” in red under the “Mapping the Trans-Atlantic Slave Trade 3D 25yr Regions App”
6. The application opens.

1.4.1 App Use

The primary purpose of the 3D applications is to provide a visualization of the data that is accurate to the destinations. The data is informative because of the visualization provided – while using the 3D apps related records therefore will not be available. Only the general pop up information for the destinations will be identifiable. The importance of these apps is to visualize the difference in the sizes of feature across destinations and across year increments within their own data.

Manual:

1.4.2 General Capabilities

1.4.2.1 Timelines

1. Navigate to the upper left-hand corner of the application
2. Click: “Timelines”

3. Once activated a bar on the bottom will appear and will provide slides for each 25-year increment.

4. Hover over the slide to identify the year increment.
5. Select a slide.

6. The slide with the picture of the destination marks the start of that destinations timeline. As shown here in yellow.

7. Explore the slides at your leisure, the map features will change with each slide.

1.4.2.2 Daylight

1. Navigate to the upper left-hand corner of the application.
2. Click: “Daylight”

3. Once activated, use the slider to change the time of day.

4. This will change the shadows on the earth’s surface.
5. Greenwich Mean Time (GMT) can also be changed.

1.4.2.3 Layer List

1. Navigate to the middle-left hand area of the application with your cursor.
2. Locate and click: “Layer List”

3. You will be confronted with the many layers within the 3D maps. As is shown by the labels, each group of layers correlates to a destination and 25-year increment. Simply identify the destination and year increment you wish to view.

4. Expand the feature layer by clicking on the arrow to the left of the layer.
5. Select both layers are checked in the boxes to the left:

6. Once complete view the layer in the map.

1.4.2.4 Legend

1. First, navigate your cursor to the bottom left of the application view.
2. Locate the Legend button and click it.

3. Once selected a new view will appear with information on the layers active in the map. Scroll and view this information at your leisure.

1.4.2.5 Basemaps

1. First, navigate your cursor to the bottom left of the application view.
2. Locate the Basemaps button and click it.

3. Once activate a new window will appear displaying various Basemaps which can be added to the map.

4. To add a basemap, simply click on its name in the “Basemap Gallery.”

1.5 Experience Builder App

Pre-Prep:

1. Open a google browser
2. Search for
<https://experience.arcgis.com/experience/feebe5d22b6d4eea870bfa3d30acad83/>
3. The application opens.

Manual:

1.5.1 App Capabilities

1.5.1.1 Maps

Both 3D maps are visible in this application. This application attempts to circumvent the issues surrounding the inability to provide related data in 3D scenes in ArcGIS Online.

1. Locate the “25yr Ports” and “25yr Regions” map buttons located to the right of “Switch Maps:”

2. The map highlighted in blue is the one which is active. Select either to activate it.

1.5.1.2 Layer List

The maps should be switched in tandem with the layer list. The layer list applies to the map name stated. To change the layer list, select the map name that correlates to the data you wish to view.

1. First locate the “25yr Ports” and “25yr Regions” buttons for the “Layer List” located in the upper left-hand corner of the app.

2. The highlighted “Layer List” name is the one which is active. To activate simply click on the name whose layer you wish to view.
3. To view the layers first expand the layer you wish to view.

4. Activate the layers by clicking the eye symbol to the left of them. Ensure you also activate the group name or neither of the layers beneath will be visible.

5. Explore at your leisure.

1.5.1.3 Tables

The table view in the Experience builder app is meant to provide information on the layers within the maps. These tables cover all data contained in the 2D and 3D maps. The related tables are also included as the “Voyages_(Destination name)” selected in the table drop down. **Importantly, these tables do not automatically update when the map is changed or the layers. These must be manually changed in accordance with the map and layers being viewed.**

1. Navigate your cursor to the bottom right-hand corner of the app.
2. Locate the table view.

OBJECTID	Port (origin)	Alias Name	Alternate Name	Total embarked	Total disembark	Avg. M
1	AfricaUnspecified	Africa, port unspecified		52,695	43,903	42
2	Alampo	Alampo		132	92	
3	Ambria	Ambria		501	501	45
4	Andony	Andony		276	209	

3. Locate the drop down within the table view. This will allow you to change which layers data you are viewing.

OBJECTID	Port (origin)	Alias Name	Alternate Name	Total embarked	Total disembark	Avg. M
1	AfricaUnspecified	Africa, port unspecified		52,695	43,903	42
2	Alampo	Alampo		132	92	
3	Ambria	Ambria		501	501	45
4	Andony	Andony		276	209	

4. Locate the “Table Control” to the far bottom right of the app (shown in yellow). This will allow you to change the destination data – changing the data of the tables your viewing: Currently this contains Antigua, Nevis, and Jamaica.

OBJECTID	Port (origin)	Alias Name	Alternate Name	Total embarked	Total disembark	Avg. M
1	AfricaUnspecified	Africa, port unspecified		52,695	43,903	42
2	Alampo	Alampo		132	92	
3	Ambria	Ambria		501	501	45
4	Andony	Andony		276	209	

5. Interact with the arrows to change the dataset. The dataset is indicated by the first word of the layer within the table drop down. In these examples that is “Antigua.”
6. Interact with the Table drop down from step 3 to change the individual layers data you are viewing.

1.5.1.4 Charts

1. The charts are located in the bottom left-hand corner of the application on the primary scroll bar of the app.
2. This scroll bar contains this, the survey and a link to SlaveVoyages.
3. Importantly, the Charts are controlled by the “Control Charts:” section which has highlighted and non-highlighted names for the various charts. The totals charts are interactive but the charts by year are not. These charts are glitchy, and at times they load incorrectly.

Example:

If this occurs reload the page, these charts will randomly correct themselves via this process.

4. To interact with the charts, click on the names shown here:

Control Charts:

Antigua Values (Totals)

Antigua Values (25yr)

Antigua Values (by >

5. If you hover over the Totals Values, they will display the total numbers for you (what was meant by interactive in step 3).

6. Explore at your leisure.

1.5.1.5 Survey

The application survey is more for the public than students. However, students are more than welcome to participate – Suggestions are always welcome! To complete the survey, follow these steps:

1. Locate the Survey section in the bottom left-hand corner of the app. Simply hover your cursor over the “Charts” section and scroll down with your mouse wheel.

2. First fill out the app or map you used. This helps the project team identify what is being used the most.
3. Fill out the second question on whether you used an App, Map, or Scene?
4. Fill out what you believe may improve the contextual information provided in the project (1000 characters max).
5. Fill out “Do you have suggestions for improving application “ease of use”?” (1000 characters max).
6. Answer whether you had any issues worth note.
7. Fill out the time the survey was completed
8. Enter your email if you would like feedback.
9. Select “Submit”