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Creating An ArcGIS Dashboard For Climate Data Management And Visualization

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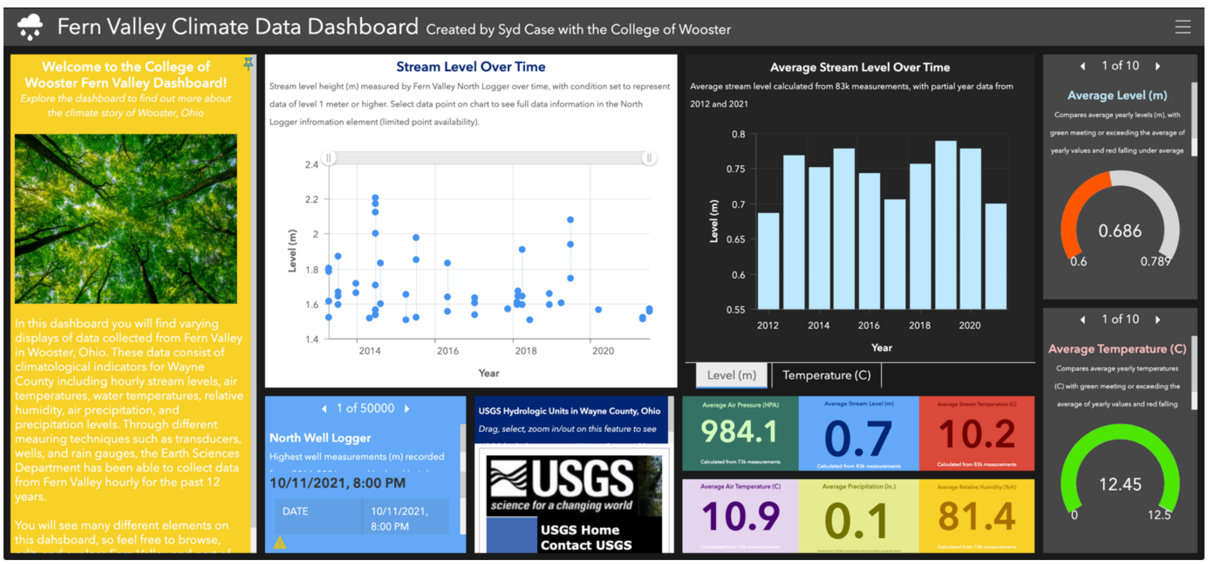

by

Sydney Case

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THE COLLEGE OF
WOOSTER

Abstract

The College of Wooster Department of Earth Sciences has collected over the past 12 years (and continues to collect) hourly local climate indicator data including stream level and temperature, air temperature and pressure, precipitation levels, and relative humidity. This data is collected at the College's research station, Fern Valley, located in Holmes County, Ohio and serves as a storytelling component for regional climate change. Upon initial investigation, the extensive dataset revealed a fundamental data storage problem within Earth Sciences, as there lacked a singular location to store complex datasets. Several technological solutions were explored to create a long-term data storage, management, and visualization solution. These solutions included establishing an ArcGIS enterprise geodatabase, restructuring the current local server architecture at The College of Wooster, and creating an online group through ArcGIS Online, all with the eventual goal of constructing an ArcGIS Dashboard as a data visualization tool. Although the enterprise geodatabase was (and remains) the most efficient and streamlined solution to the problem, time constraints and data limitations prevented the implementation of an enterprise software structure. Adapted from the enterprise geodatabase theory, an online group was formed by The College of Wooster database administrator that enabled a partial multiuser data sharing experience. After being faced with further data limitations when using the online group, an alternative solution was pursued that incorporated two separate data upload strategies: geoprocessing via web layer sharing in ArcGIS Pro and hosted layer uploading in ArcGIS Online. Following the data upload, the Fern Valley Climate Data Dashboard was created. The dashboard is currently active and utilizes a tactical strategy, incorporates intentional element selection, supports deep interactivity, and enhances the overall user data visualization experience. Though partially limited, the dashboard serves as an excellent representation of the potential ArcGIS Dashboards has for transforming traditional data management and visualization solutions. Considering future exploration of ArcGIS Dashboards as a data management solution in the future is recommended for The College of Wooster as it would provide opportunities for holistic data visualization, cross-organizational multiuser collaboration, and multidisciplinary educational advancements.

Acknowledgements

I would like to extend my warmest acknowledgements to my co-advisor, Dr. Shelley Judge, for supporting me through the rollercoaster of triumphs and defeats this semester has brought me. Her continued belief in me as a student, leader, and person is extremely humbling and something I will forever be grateful for.

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Finally, I would like to send thanks to my family (Jason and Angie Case, Dianna Case, and my older sister Allie), my best friends (Benjamin Hines, Trinity Harmon, and Lucy Kinser), and my amazing coaching staff (Sarah Davis and Taylor Mathews). Their constant support, love, and encouragement has allowed me to pursue my dreams at the highest level possible, and I cannot thank them enough for that.

Table of Contents

	Page Number
Abstract…………………………………………………………………..	1
Acknowledgements ……………………………………...………………	2
Introduction…………………………………………………………………	4
CHAPTER 1: Technological Challenges of Setting up a Data Framework	
1.1 Timeline and Challenges………..…………………………………….	6
1.2 Background……………………..…………………………………….	7
1.3 Finding the Ideal Solution………..……………………..………….	9
1.4 Understanding the Proposed Solution……………………………..….	12
1.5 Creating the Actual Solution………..…………………..…………….	18
CHAPTER 2: Understanding ArcGIS Dashboards	
2.1 ArcGIS Dashboard Background………..…………………………….	19
2.2 Course Summary………..…………………………………………….	20
2.3 Data Used………..……………………………...……………….	24
CHAPTER 3: Dashboard Creation	
3.1 Organizing Data………..………………………………..…………….	25
3.2 Audience Consideration…….………………………….…………….	27
3.3 Methods: Constructing the Elements………..……………….……….	29
3.4 Methods: Adding Interactivity…………………………..…………….	33
3.5 Results………..………………………...……….………………	35
CHAPTER 4: Tutorials	
4.1 Tutorial Overview………..…………..…………………..…………….	36
4.2 Tutorials………..………………………….……………………….	37
CHAPTER 5: Future Work	
5.1 Dashboard Vision and Impact.…………………………..……………	47
5.2 Conclusions………..…………………………………..………...…….	48
References Cited…………….……..………………………….…………….	50

Introduction

Data management and visualization is a vital component of data analysis in both small and large-scale organizations. Without a comprehensive structure and strategy for management, organizations shield themselves from complex data collection and investigation. The College of Wooster serves as an example of a mid-range organization with access to real time, continuous data collection. Faculty of the Department of Earth Sciences at the college have been recording hourly local climate indicator data for the part 12 years and have gathered an impressive dataset that tells the story of climate change in Holmes County, Ohio. These data are collected from a stream that flows through the field site, Wilkin Run (unofficial name) by a set of loggers, gauges, and transducers (Wiles, 2013). The Fern Valley North Logger data was used in this project and includes stream level and temperature, air level and temperature, precipitation, and relative humidity. Although this data is extensive, the department lacked an efficient and comprehensive solution for long-term data storage and management. To solve this problem, several techniques were proposed surrounding database reconstruction and online data management.

The solution proposed involved the use of ArcGIS Dashboards as an avenue for data visualization in the online realm, allowing open user access to the data collected at The College of Wooster. ArcGIS Dashboards is a multifaceted web application where users can visually analyze and interpret complex data. Dashboards was created by the Environmental Services Research Institute (Esri), a geospatial software corporation that specializes in geospatial data storage, management, and visualization strategies (GISGeography, 2021). Esri products connect users ranging from students to major worldwide organizations and provides the public with an efficient form of data analysis. Although dashboards are streamlined in their displays, the construction process is far from simple. Behind every dashboard and data management technique, there are many technological requirements, data limitations, and configuration decisions that are made in order to produce a fully functioning visualization tool. This project explores multiple technological solutions for establishing a long-term data management system at The College of Wooster and investigates the extent to which an ArcGIS Dashboard can be used to store, manage, and visually represent complex data.

CHAPTER 1: Technological Challenges of Setting up a Data Framework

1.1 Timeline and Challenges

The initial objective of this project was to create a multiuser relational geodatabase where data could be uploaded, edited, and shared amongst multiple users as part of a long-term data management and storage solution for the Earth Sciences Department. The process of engineering a solution to the given problem was extremely challenging. Though the initial solution satisfied the necessary requirements to host this database, the resulting framework was created from a different perspective. The IT Department used traditional software problem-solving techniques instead of incorporating the Esri software functionality into the solution, making the proposed solution inefficient. Due to faculty resource shortage, time constraints, a misunderstanding of Esri software, and poor communication, the timeline of this project was severely affected. Although an initial collaboration with IT was established in September 2021 and a solution was proposed in early October 2021, there were no progress updates shared until mid-January 2022.

Following the update that there was unfinished work on the proposed network, the project timeline was in a waiting period. During this pause, the project was not developed to include datasets because there was a risk of complete project loss. Due to the lack of multiuser access, any progress made on file creation, data transfer, layer editing, and the dashboard itself would have been likely lost upon expiration of the user account. The risk of project loss and inability to bypass technological problems forced the construction of the resulting dashboard to be delayed until the short-term solution could be finalized (Figure 1).

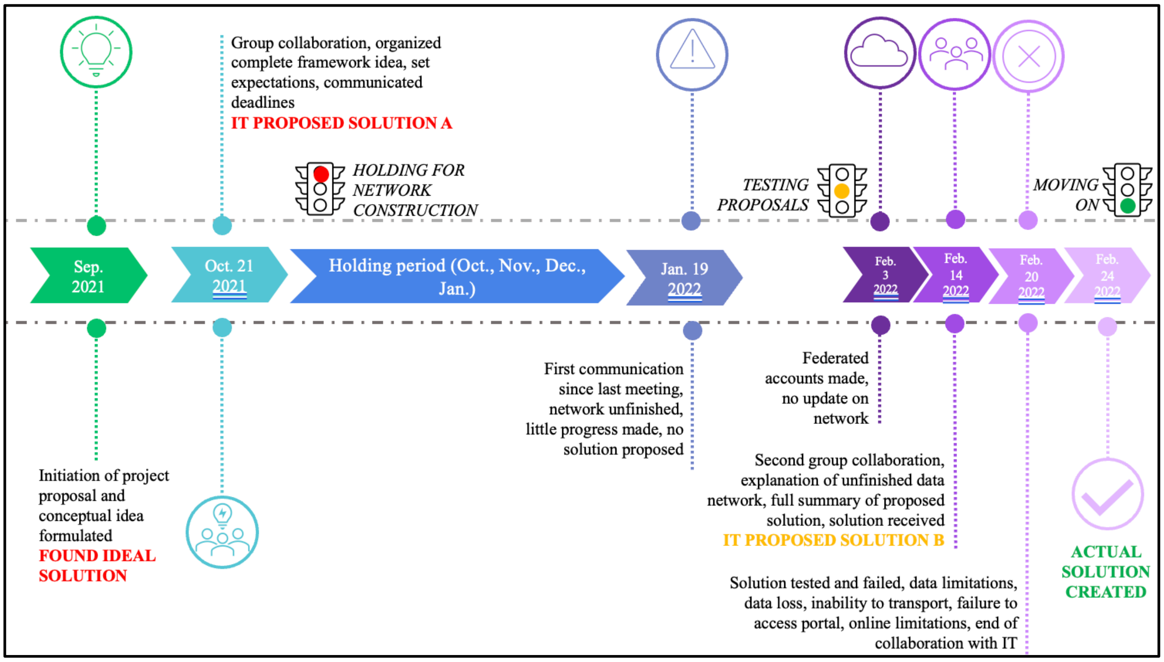


Figure 1. Timeline of technological challenges regarding holding period and solution progress.

The following sections outline the three main phases of this technical process: Finding the ideal solution, understanding the proposed solution, and creating the actual solution. The actual solution summarized in the end of this chapter serves as a temporary fix, but it is important to note that the resulting dashboard of this project is built on a technologically fractured foundation and uses inefficient methods of data transport and sharing.

1.2 Background

Esri Overview and ArcGIS Structure

Behind every organization that utilizes geographic information systems (GIS), there is a complex data structure consisting of technological variables that enable actions including uploading data, streamlining collaboration, and strategizing long term data management. Esri is the main hub of geospatial technologies as they support organizations by providing access to specialized geospatial software, data management systems, online data sharing platforms, and advanced mapping tools. In addition to enabling geographic analysis tools, they also store external source data that comes from organizations around the world (Esri, 2018). The College of Wooster is just one example of many organizations that utilize the power of Esri to outsource geographic analysis and data management. Esri's data structure is vital for managing the college's geographic data and if paralleled locally at the college, creates opportunity for establishing a multiuser data storage and management solution.

ArcGIS structure consists of four major components: ArcGIS Server, ArcGIS Databases, ArcGIS Portal, and ArcGIS Online (Figure 2, (Esri, 2015). ArcGIS Server (ArcGIS PostgreSQL server) is the most expansive component of the structure as it is the software package responsible for enabling organization user access to data sources. In other words, it is the main software that controls pretty much all actions that can be completed within an Esri program (Esri, 2015). Additionally, the server houses geodatabases (gdb) in either a file format (file gdb [Fgdb]) or as a larger relational database (enterprise [Egdb]). Each gdb type has specific technological requirements and unique advantages, making geodatabase construction crucial for proper data management. Though requiring a complete restructuring of the current data outsourcing method at The College of Wooster (Figure 2), the implementation of an enterprise geodatabase would enable the college and Earth Sciences to set data management preferences, operate a multiuser data sharing experience, and establish a long-term solution for data storage and organization (Esri, 2020).

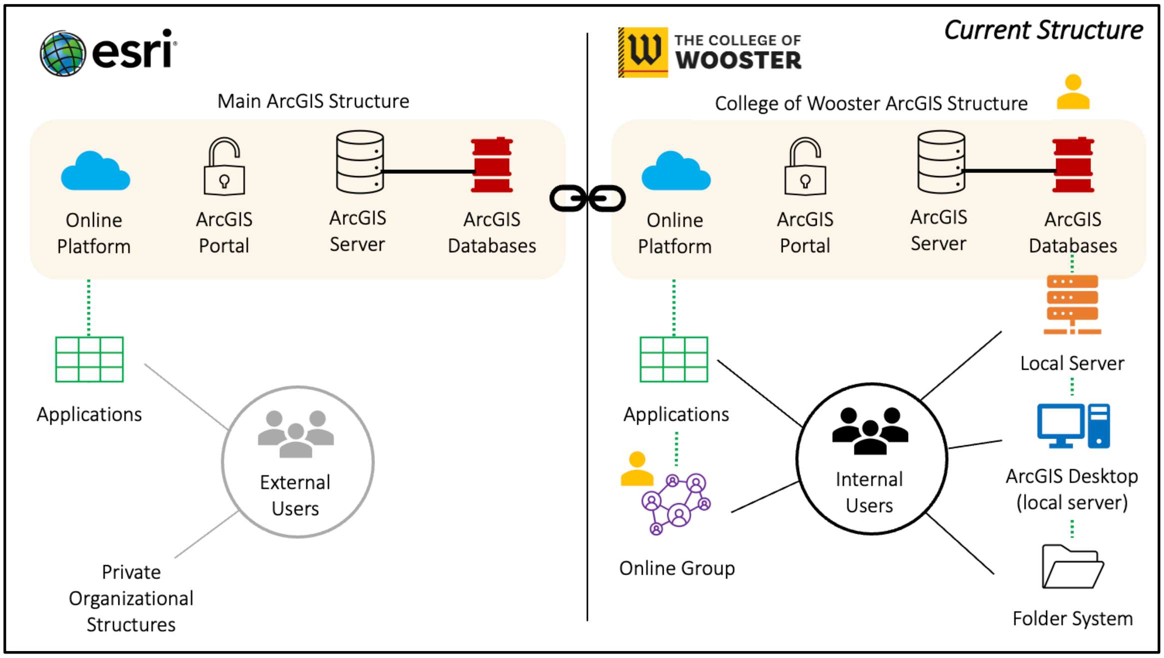


Figure 2.Current ArcGIS structure of The College of Wooster organization, showing outsourcing connection (link) between the College and Esri.

1.3 Finding the Ideal Solution

Choosing a Database Type

Geodatabases are housing locations within an ArcGIS structure that can store data of varying complexity including "…attribute data, geographic features, satellite and aerial images (raster data), CAD data, surface modeling or 3D data, utility and transportation network systems, GPS coordinates, and survey measurements…" (Esri, 2008). There are two main subgroups of geodatabases: single user and multiuser (eGIS Associates, 2012a). Single user geodatabases, or file geodatabases, (Fgdb) are isolated to one user and stored on a local server system. Fgdb's are useful when managing private data that will not be accessed by the public or edited simultaneously by several users within one organization.

This format is best for data that changes infrequently as it lacks multiuser capabilities such as versioning and archiving (mentioned below) (Shields and Gough, 2020).

The Department of Earth Science would benefit from a multiuser geodatabase, or enterprise geodatabase (Egdb). More specifically, the College could take advantage of the versioning and archiving tools within an Egdb. Versioning allows multiple users to branch off from an original dataset to create their own project. The original dataset remains unchanged while the versioned data can be isolated and managed by a particular user, allowing for simultaneous alterations (eGIS Associates, 2012a). When working with climate indicator datasets, there could be instances where a single dataset can be used for different projects. Essentially, versioning would allow multiple users to manipulate a singular dataset. In order to organize the multiuser platform, archiving would be enabled to keep track of all changes and versions made to the data (Esri, 2008). In combination, versioning and archiving present an ideal solution for the Earth Sciences by supporting multiuser data access and editing. In order to have access to these features, the enterprise geodatabase would need to be properly connected to a server system. This process is intricate and requires an in-depth understanding of server technology, as it is not a simple "right click" creation process.

Enterprise Background

Due to the complex structure, an enterprise geodatabase cannot be housed completely through the ArcGIS PostgreSQL server like a traditional, outsourced Fgdb or ArcGIS Online project. In other words, there would be no use of Esri's DB structure, because everything would be locally controlled. The enterprise geodatabase would require an external database management system (DBMS) to run on. Several of these include PostgreSQL, Microsoft SQL, Oracle, HANA, and IBM db2 (eGIS Associates, 2012b). In order to link the Egdb to the DBMS, a connection is established by either a.) *creating* an enterprise geodatabase or b.) *enabling* an enterprise geodatabase. Both actions are geoprocessing tools available in ArcGIS. Before selecting one of these options, a distinction must be made regarding the chosen DBMS, the database administrator (DBA), and the geodatabase administrator (gDBA) (Shields and Gough, 2020).

For this project, the DBMS requires a Microsoft SQL server. Prerequisites for creating the Egdb include confirming compatibility of the Egdb and DBMS, obtaining a keycodes file for future authorization use, and determining the DBA and gDBA users. (eGIS Associates, 2012b). In this case, the DBA would be the head of the IT department with access to the college's SQL server, and the gDBA user would be a departmental account that could be accessed by any of the Earth Sciences faculty and students (with permission/login information). Because these users are not the same, the geoprocessing tool needed is the enable tool, which is run by the DBA. Following the initial database creation, the gDBA would have control over the schema, design of the Egdb, and data administration tools whereas the DBA would have access to system security and storage. It is important to note that coordination between the DBA and gDBA would be vital because the user at the college (gDBA) would not have direct access to the server settings- the gDBA is essentially "plugged in" to the SQL server and configuration.

This ideal solution (Figure 3) presents technological and logistical limitations for this project given the lack of an informational center specializing in Esri products and Esri related software complications. Though the IT department at The College of Wooster attempted to parallel this enterprise solution, the network was unfinished. The local server remained disconnected from the larger user interface, leading to a proposed solution that consisted of several technological obstacles.

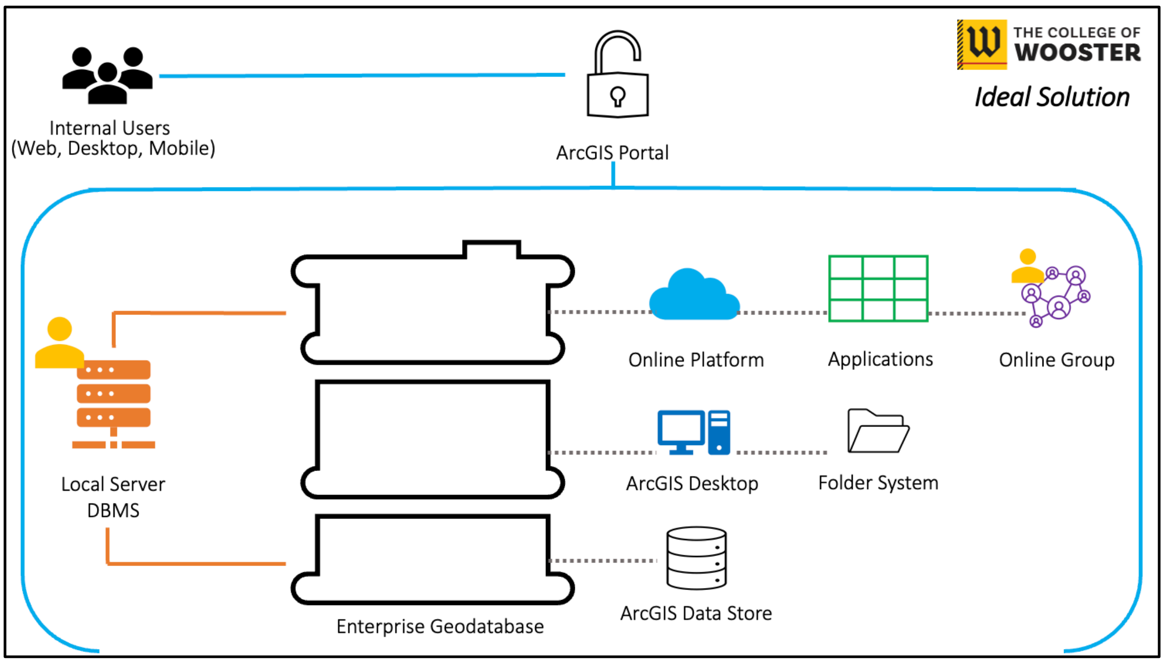


Figure 3. Ideal solution utilizing an ArcGIS Portal, enterprise geodatabase, and connection to a local server.

1.4 Understanding the Proposed Solution

Creating a Data Network

The College of Wooster IT department was originally tasked with creating a data network that would parallel what was previously described as an enterprise geodatabase (Figure 3). Although the Egdb was incorporated into the blueprint, the solution that was created by IT required a restructuring of the current server organization and did not incorporate the expected flow between the user and the server. The proposed solution required three main components: the ArcGIS Server, an ArcGIS Portal, and an enterprise geodatabase.

When interacting with one another, these components would provide sharing across the organization, enabling data access for all College of Wooster users. However, the inclusion of an Egdb was lost in translation, as the connection between an Egdb and the local server was never made. Instead, focus was put on the portal connection and online realm (Figure 4). This focus started a chain of events that resulted in the inability for a user to connect ArcGIS Desktop to any other sharing and saving location besides a local machine. In other words, any data uploaded, edited, or stored by a user could not be exported by that user, or seen by any other user in the organization. Due to the inability for the Esri products to "communicate" with one another, faculty time constraints, and lack of knowledge on Esri software, IT developed a short-term solution for data uploading and sharing. (It is important to note that without the completed data network or and established Egdb, there was no official database storage for this project. Instead, the project data was stored within the Esri data structure (explained in 1.1)).

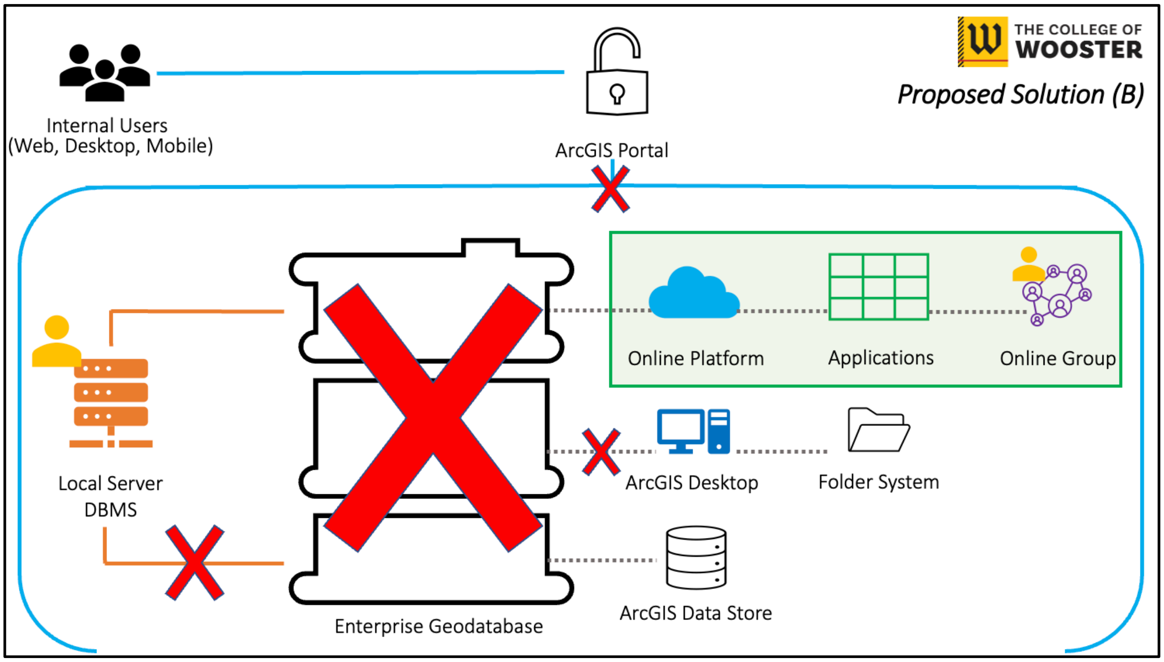


Figure 4. Unfinished network that led to a redirected focus to developing an online-only solution.

The short-term solution created relied solely on the ArcGIS Online realm, a branch of Esri used for project creation, data sharing, and web-based data analysis (Figure 5). The ArcGIS Online platform is accessible by both external and internal users (everyone who owns an Esri license). Through ArcGIS Online, users can upload and download data, make maps, create geospatial analysis projects, and share amongst organizations (White, 2021). One of the tools ArcGIS Online offers users is the group creation feature. These groups are managed by either the user, or in most cases, the database administrator (DBA) and can be tailored to the specific needs of an organization regarding data sharing and open data settings. For this project, the DBA (IT department) created a group that increased data sharing capabilities within the department. This group was and continues to be crucial because it serves as the hub for all the data used in the resulting dashboard.

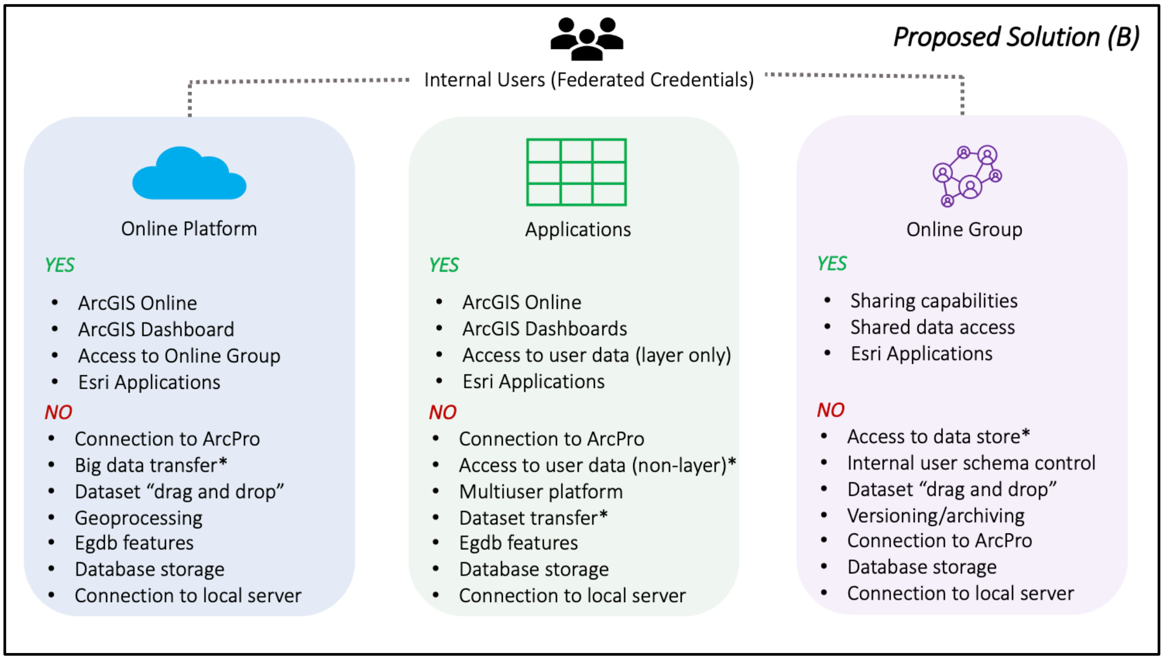


Figure 5. Attributes of the online realm (ArcOnline [online platform], applications, and the online group).

Online Group Construction

The online group created uses federated credentials for all users of The College of Wooster organization and enables multiuser access. This group was viewed as the Wooster IT solution simply because it allowed for data sharing, though the data limitations were not investigated and became an immediate problem for large data uploads. Though an online group would be efficient for a basic user, it brought about more unforeseen challenges including map and data loss, user sign in confusion, unnecessary two factor authentication, and inability to export data. Regardless of the challenges, the federated credentials and online group remained in use, providing a space where multiple users can access the same space in the online realm (within the organization).

Although these users could have created their own groups, the database administrator (Wooster IT department) was authorized to modify traditional group settings that would have otherwise prevented multiuser activity. The online group used has all the capabilities of a traditional group as well as “shared update” and “open data” features. These allow for members of the group to upload and download data regardless of who the original data belongs to. The implementation of data sharing increased collaboration within the department and provided a location (the online group) for data to be stored and organized. However, given the already restricted capacity of ArcGIS Online, there were important limitations and challenges faced before the project could have been housed in the online group.

Limitations

Because the online group is not stored in a physical location local to Wooster but instead on the Esri ArcGIS structure and exists as a branch of the online realm, many problems presented themselves. These limitations, outlined in Table 1, are regarding user access, data transfer, and analysis capabilities. Essentially, without an enterprise structure or local server access, the online group is not a viable long-term solution (Esri, 2020). However, given extreme time and resource restraints, the online group served as a partial solution as it supported the basic sharing capabilities needed to move forward with the project.

Table 1. Limitations of using an online only solution. These limitations apply to the proposed solution described in section 1.4.

Limitation	Explanation	Solution (for future/long term)
No local database	There is no connection to a local server or database due to the continued use of Esri's ArcGIS Structure, so all data is stored on an individual machine. The data used will only be accessible through one machine unless downloaded separately by another user (and then re uploaded).	*Establish "ideal solution": Enterprise geodatabase*
No enterprise geodatabase features (versioning, archiving, multiuser, etc.)	Since there is no database connection, no features of an Egdb are available. This includes all benefits of establishing a multiuser database that would be connected to a local server. No users will be able to have access to other data/projects unless in the online realm (limited).	*Establish "ideal solution": Enterprise geodatabase*
No connection between the server and online realm	The use of ArcPro on desktop is not directly linked to an online account. In other words, unless using specific tools that bypass a traditional user connection, projects and data created/analyzed within Desktop will not be available anywhere else within a user account.	*Connect an Egdb to the organization local server*
Online credit limit	All maps/projects created in a user account spend credits allocated to the organization. These credits are limited and force the online solution to be short term.	*Store big data in Egdb*
Online data transfer limit	When transferring data within the online realm, there is a 1,000 limit on rows acceptable in uploaded data, regardless of format. This prevents any large datasets from being uploaded.	*Connect local server and Egdb by way of an ArcGIS Portal. Store big data in one of these two locations and access through the ArcGIS Portal.*
Little access to geoprocessing	Because this solution does not connect the online realm and the desktop user, all layers added within the online realm have little-no access to geoprocessing tools. This severely decreases the potential analyses of the dataset being used.	*Work in ArcPro and transfer work by way of ArcGIS Portal.*
No direct access to the portal	When navigating as the user, there is no direct access to the ArcGIS Portal. With no direct connection, all projects created MUST be saved to a local machine. This prevents the user from being able to access Desktop projects in the online realm.	*Connect portal to local ArcGIS Structure*
User account access	Users within the organization are now limited to a federated credential account. This has limited viewing and edited access to previous accounts registered within the organization, causing map, project, and data loss.	*Transfer all projects from previously accessed account to new federated account, then delete old accounts.*
Potential loss of project data (risk of data transfer)	Any project created by a single user has the potential to be lost following termination of the account due to "ownership" at the creator level. Without organizational access at the server/database level, other users will not be able to directly access/transfer projects made by a user. This creates the possibility of all project data being permanently deleted (unless transferred to a different account).	*Create a third-party account OR establish multiuser access by way of an Egdb and ArcGIS Portal.*

1.5 Creating the Actual Solution

Merging ArcGIS Pro and ArcGIS Online

In order to move forward with the project, pieces from both the ideal and actual solutions were modified to create a system of web layer and group sharing. Using functions from both ArcGIS Pro and ArcGIS Online allowed for a semi-efficient mode of data transfer and although it is not a recommended solution, sufficed for preparing the data for eventual upload into the dashboard. The function used from ArcGIS Pro, web layer sharing, transformed the original uploaded data (csv file type) to a web layer. The resulting layer from this feature is like traditional layers found in map projects, though instead of being saved to a local machine, it can be saved to the ArcGIS Portal. This portal, unaffiliated with the Wooster organization structure, serves as a gateway between the Desktop and Online realms.

Transferring and uploading data is not a drag and drop system, making the connection crucial for establishing a data pathway within the user account. From the portal, the data was then uploaded to a specific folder in the ArcGIS Online user account and subsequently uploaded to the online group previously mentioned. The final data upload, sharing, and retrieving process is outlined in Figure 6. The finalization of the data uploading, editing, and sharing method initiated the next phase of this project, constructing an ArcGIS Dashboard for data management and visualization.

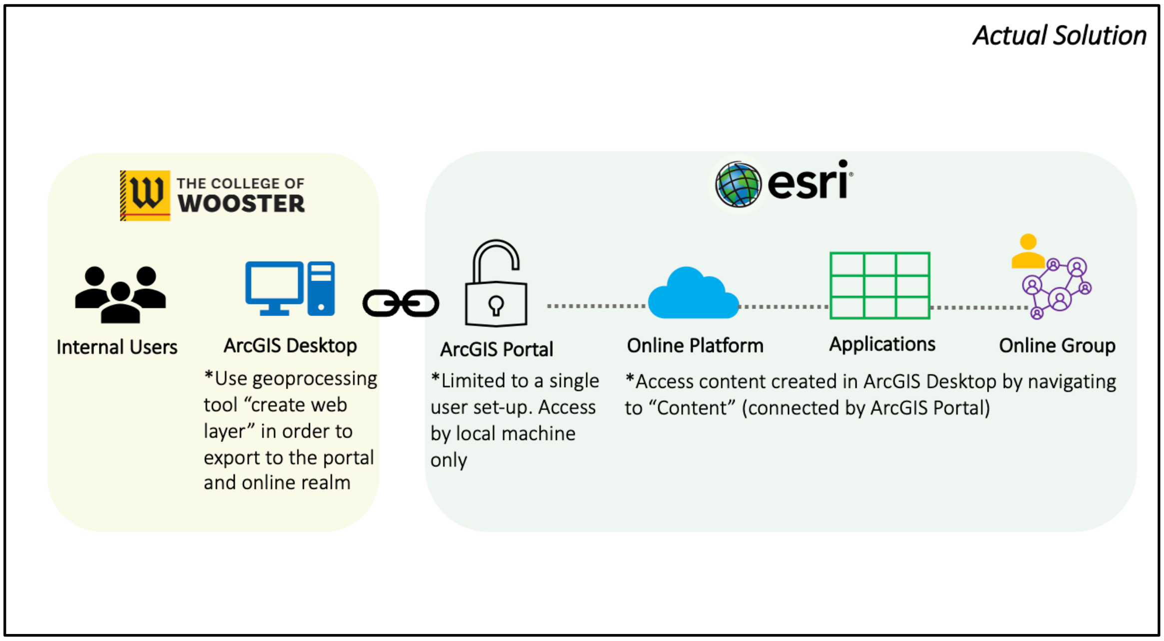


Figure 6. Actual solution created by merging ArcGIS Desktop with ArcGIS Online by way of geoprocessing tools and an ArcGIS Portal. Combination requires both College of Wooster structure (yellow) and Esri software (green).

CHAPTER 2: Understanding ArcGIS Dashboards

2.1 ArcGIS Dashboard Background

ArcGIS Dashboards is a multifaceted Esri application that is used to manage and visually represent data for users ranging from individual researchers to large organizations (White, 2021). Esri is the technological hub for geospatial software and analysis tools. The software created and used by Esri allows for the manipulation of data through mapping processes and provides a holistic platform where data can be stored, managed, and analyzed. The Esri platform consists of interconnected applications where data can be transferred within user projects and housed in either a single or multiuser database management system (DBMS). Applications most often utilized by Esri users include ArcGIS Pro, ArcGIS Online, Survey123, StoryMaps, and Dashboards (White, 2021). These interfaces provide users with the ability to create maps, surveys, and map-embedded presentations from preexisting or original datasets. This project primarily focuses on the use of ArcGIS Dashboards, an application specializing in interactive data visualization.

Through a combination of maps, serial charts, tables, and embedded content, a dashboard creates a space where users can access and analyze real time or static data. This is useful for both private and public users due to the increasing need for streamlined data management strategies. Esri has categorized dashboards into four types based off projected use and benefits for companies. These include strategic, operational, informational, and tactical (White, 2021). Both strategic and operational dashboards are used to track live indicators or understand events on a real-time basis, whereas informational dashboards often utilize static data visualization to inform users and engage the community.

This project is most representative of the tactical dashboard. Tactical dashboards use both historical and present data with the intent of discovering patterns and visualizing trends (White, 2021). This strategy is useful for large datasets collected over longer periods of time and is fitting for the data collected by the Department of Earth Sciences at The College of Wooster. The climate data dashboard allows for continuous data updates and provides a platform for both students and faculty to view large datasets without being overwhelmed. The dashboard consists of climate change indicator data collected Earth Sciences faculty, staff and students that is displayed through a variety of serial charts, maps, and lists.

2.2 Course Summary

Following the construction of the online group mentioned in Chapter 1, I needed to increase my foundational knowledge on the technical and design aspects of building an

ArcGIS Dashboard. Because the dashboard is the main point of access to the climate data for both Earth Sciences students and the public, it is important that the dashboard is intentionally designed for a particular audience and constructed in a way that supports long term data management. Although these topics are described online, I determined the most efficient way to learn about dashboards was through an Esri instructor-led course. "Get Started with ArcGIS Dashboards," is an online course delivered by Arc Desktop Associate and Professional, Brittney White, over 9 hours by way of remote desktop connection. The course was divided into multiple learning units and led us through a step-by-step tutorial using existing Esri data, resulting in a sample dashboard. To create the sample dashboard, we learned about dashboard basics, dashboard elements, and how to implement interactivity.

In the first phase of the course, I learned about the different types of dashboards and their benefits. These types include operational, strategic, informational, and tactical. Operational and strategic dashboards display information on a broad scale, most often to help users monitor progress on large tasks or make decisions based off real time performance. Organizations benefit from this because they can display all their summarizing information in one place, making the companies' indicator statistics navigable and easy to analyze (White, 2021). The informational dashboard slightly resembles operational and strategic dashboards due to the extensive data displayed, however, the information included has a different purpose. The informational dashboard informs the public and community by engaging the audience through graphical displays and a variety of summarizing data. This dashboard is often used in a broader sense, where the audience will not necessarily know any background information on the data being presented, but rather is looking for the story to be told on the dashboard itself (White, 2021).

I implemented the tactical design, which utilizes historical and present data to analyze trends and predict patterns within datasets. By using the tactical design, I am enabling the users to analyze multiple datasets that span across time and expanding the potential for users to find their own patterns within the data rather than just providing summary statistics. Due to the complexity of the tactical dashboard, the creation process requires intentionality and a deep understanding of the data being used. The data is represented by elements, which I learned about in the second phase of the course. Dashboard elements are used to organize the display and exhibit the data in different ways (full list and descriptions of dashboard elements found in Table 2;White, 2021).

Table 2. Elements of ArcGIS Dashboard. [Modified from White, 2021].

Element	Description	Icon
Header	Provides a title, subtitle, logo, and background for branding. Provides options for selectors, hyperlinks, and sign-out link.	
Side panel	Contains selectors for interactivity. Provides a title, description, and an option to expand for use and then retract.	
Map element	Displays geographic and spatial data in a web map. Provides a title and description. Can enable pop-ups, map tools, and other web map functionality. Uses map and layer actions to provide interactivity.	
Map legend	Provides a legend for a map element. Provides title and description properties.	
Serial chart	Make comparisons between different groups or tracks changes over time. Supports bar, line, and smooth line charts.	
Pie chart	Shows part-to-whole relationships. Provides option for chart legends or labels.	
Indicator	Displays counts, summary statistics, or comparisons. Can apply filters and conditional formatting.	
Gauge	Shows the value of a single metric compared to minimum and maximum values.	
List	Displays a collection of features or rows from a data source. Can format the content displayed as well as sort and filter the content.	
Details	Displays specific details about features or rows from a layer. Is based on the layer's pop-up information.	
Rich text	Allows for text content being displayed in the dashboard. Is used to provide credits, additional information, or other static content.	
Embedded content	Provides a way to add other web-based content to the dashboard.	

After learning how to add elements to the dashboard, interactivity was introduced. Interactivity is often understood at the user-element level, where a user can perform actions within an element such as selecting list values, zooming in and out, and filtering (White, 2021). However, when constructing these elements in the dashboard, a new level of interactivity is established between the elements themselves (element-element). For example, a list selection made by the user will alter the map extent, or a selection on a bar graph will also change a coinciding pie chart. These elements are interacting by established code that is set up in the construction process. Because of the infinite possibilities of element-element interactivity, I needed to have a deep understanding of the data I was uploading so that my interactivity was intentional. This interactivity allows the audience find relationships within the datasets that may have been difficult to see without the elements ever changing.

Using this knowledge on dashboard types and element interactivity, I was able to determine the best strategy for design and create complex interactivity within my own dashboard. The dashboard I constructed highlights trends found in the data collected by the Earth Sciences department. This data includes a particular selection of climate indicator data including stream temperature and level, air temperature and level, precipitation, and relative humidity.

2.3 Data Used

The data used in this project is continuously collected by Earth Sciences faculty, staff, and students at The College of Wooster and extends up to 12 years in the past. The site with data represented on the dashboard is Fern Valley, coming from the north logger. Although the datasets cover a wide range of climatological factors, the ones being utilized for the dashboard include hourly stream levels, air temperatures, water temperatures, relative humidity, air precipitation, and precipitation levels. Fern Valley is in northern Holmes County, Ohio and serves as The College of Wooster's research field station for both Biology and Earth Sciences. The land was donated by Betty and David Wilkin in 2012 and spans 56 acres (College of Wooster, n.d.). Although the landscape is mostly agricultural, the geomorphology is varied as the area includes hills, valleys, and multiple stream systems (College of Wooster, n.d.). The data is collected by a series of transducers, wells, and gauges placed by the College of Wooster faculty and staff. These data provide a foundation for local climate studies at the College and when managed correctly, encourage efficient and streamlined visualization of the data being collected.

CHAPTER 3: Dashboard Creation

3.1 Organizing Data

Data organization within the ArcGIS Dashboard is a crucial component of the construction process. Every element of the dashboard that is created is connected to the user content within an Esri account. This content can be a combination of data created in the online realm, data transferred by way of an ArcGIS Portal or Enterprise system as well as any project or project layers created by that user. As described in chapter 1, the data used for this project is extensive and without a proper data store, forces many limitations in the online realm. When using dashboards specifically, the data limit varies for certain elements. This limitation can be changed but requires an administrative manual reset of the coding script. Because the script was not changed in the construction process, there are several instances on the dashboard where data visualization is limited to 50k measurements out of the total 83k. In order to account for extensive data overflow and online geoprocessing limitations, uploading data via hosted feature layers was also adopted as a strategy (in addition to the web layer sharing method described in chapter 1).

Hosted layers serve as a container for data to be manipulated once the user has appended the layer to a project, map, or in this case, dashboard elements. This is essentially the same thing as a shared web layer except the hosted layer created in the online realm cannot be edited via geoprocessing. The hosted layers used in the elements of this dashboard were added as "new items" and then uploaded as CSV hosted table layers. The uploading process has multiple steps, including choosing a device file, selecting layer type and characteristics, and matching field types. Due to online credit limitations, the layer characteristic chosen does not contain location information, editing in the third dimension, or connection to map features. In other words, it is a traditional table that is acting as a layer (Figure 7).

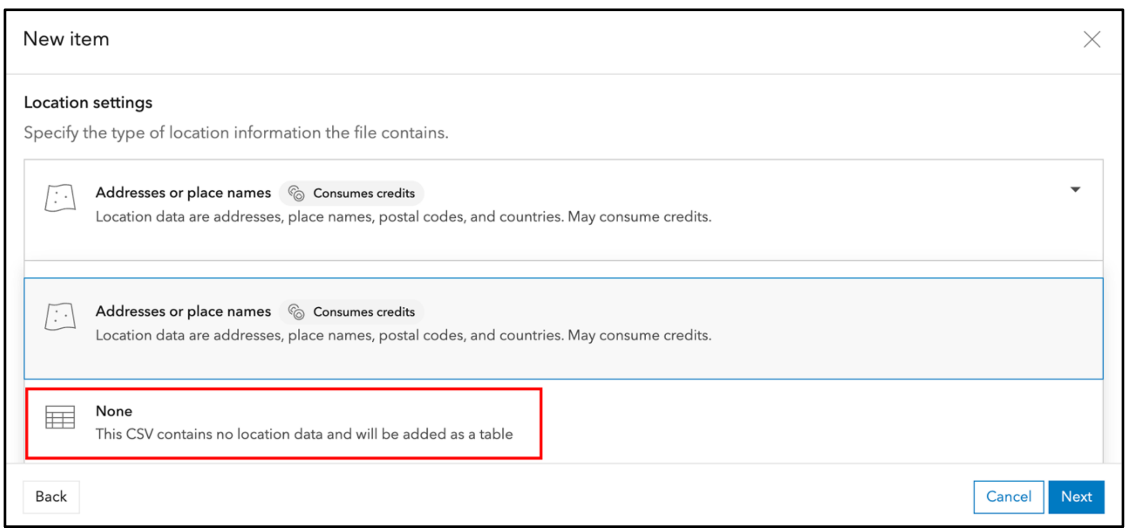


Figure 7. The chosen option, "None", for the location characteristic of the hosted table that was created in ArcGIS Online.

Within the table, there is an Object ID followed by field types that coincide with the columns in the original data. Field matching was performed on each individual hosted layer upload. The last major component of the layer uploading process is selecting a data type within fields. Second to field matching, this is the most important step for creating functioning elements. Data types are categories that characterize a given dataset such as date, time, integer, double, and string. These descriptors are based on the script make-up of the data, or the type of coding used for each individual value. This project required varying selections as the data included dates [DATE], times [DATE], and decimal measurements [DOUBLE] (Figure 8). In the event the data contained words or integer values, the data types selected would have been [STRING] and [INTEGER].

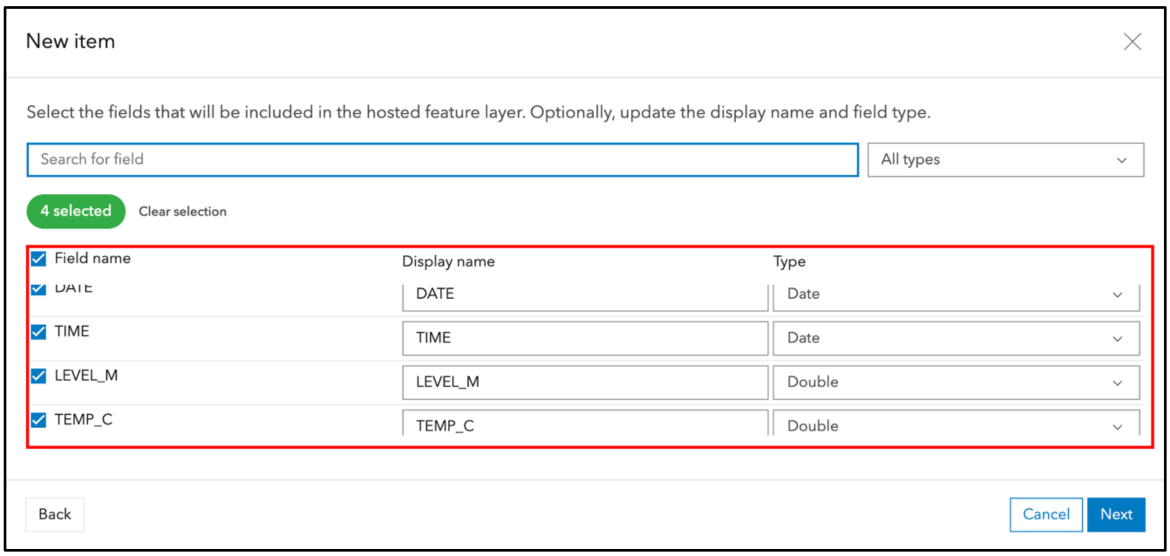


Figure 8. Menu display for field matching and data type selection for the hosted table created in ArcGIS Online.

3.2 Audience Consideration

Following successful data uploads, a plan for audience consideration was made. The three main variables to consider when creating a dashboard are knowledge of the subject matter, text and font size, and color theory (White, 2021). The resulting dashboard was intentionally constructed for Wooster student, staff, faculty, and public use. Therefore, the dashboard is balanced with complex datasets, interactive charts, and informational indicators for a more direct form of data visualization. The dashboard was constructed with the intention of creating a space where the user could choose whether to interact with the elements, providing just as much useful information if the user is not interacting with the display. In other words, there are few hidden tricks on the dashboard, which contrasts some elaborate displays created for larger organizations such as the Johns Hopkins COVID or local traffic dashboards (Figure 9) (White, 2021).

Figure 9. Johns Hopkins dashboard (top) and Arkansas Department of Transportation dashboard (bottom) showing potential dashboard complexity. Dashboards found at https://coronavirus.jhu.edu/map.html, https://www.arcgis.com/apps/opsdashboard/index.html#/22 (White, 2021).

In addition to complexity, text size and color were adjusted to account for potential visual impairments of users. The purpose of this is to broadly account for difficulty seeing contrast. So, colors are chosen that have high contrast to increase visibility of the graphics. This is an important consideration that is often overlooked when operating with traditional data. However, establishing text size and color schemes can not only enhance accessibility for users, but increase the information retention rate (White, 2021). In this dashboard, a dark theme with blue accents was chosen to illustrate the water component of data while creating a significant contrast between the background, data, and text. Additionally, a primary color scheme was utilized to place contrast between the data represented by a blue hue and the remaining elements. Although it may seem simple, creating a design that reflects the proper theme, while also considering vision impairment is vital for user retention.

3.3 Methods: Constructing the Elements

Element Action Overview

Establishing elements within the dashboard display was the bulk of creating the dashboard. Without the elements, the display would be a blank page. Intentional element selection was necessary in order to produce the most coherent and streamlined summary of the original datasets. Elements vary in complexity and consist of many different selectors that can alter metadata, series data, color, text, size, position on the dashboard, and coding scripts. Regarding dashboard position, the elements can be manipulated to better fit the composition of the display. Positioning actions include stacking, docking as a row or column, and grouping (Figure 10; White, 2021).

Figure 10. Element positioning visual of stacking, docking, and grouping on a dashboard. (White, 2021).

These actions are important for navigating the dashboard and will be referred to in the following paragraphs. The creation process, though tedious, required attention to detail and many reworkings to result in a dashboard that contains functioning, interactive, and easy to read elements. Elements created for this dashboard required a particular focus on data selection and interactivity. The following outlines the construction process for every individual element used on the dashboard and includes figures illustrating some of the selection options for each element.

Header, side panel, and embedded content

The header and side panel were constructed first to frame the display and outline the purpose of the dashboard. Within the header, there are two additional selectors titled "The College of Wooster-Earth Science Department" and "Fern Valley Bridge Cameras". These selectors are external links sourced out of the header element and take the user to a separate webpage that is linked via element configuration. The side panel includes a description and embedded photograph whereas the embedded content contains an outsourced interactive map. The embedded content element frame shows an external USGS web page where a user can interact with the USGS map and selector tools within the dashboard interface (Figure 11). This element type has great potential as the creator can link any functioning web page, interactive or not, to the dashboard display. In this case, the USGS web page allows users to dive deeper into the hydrologic units in Wayne-Holmes Counties using the National Water Information System.

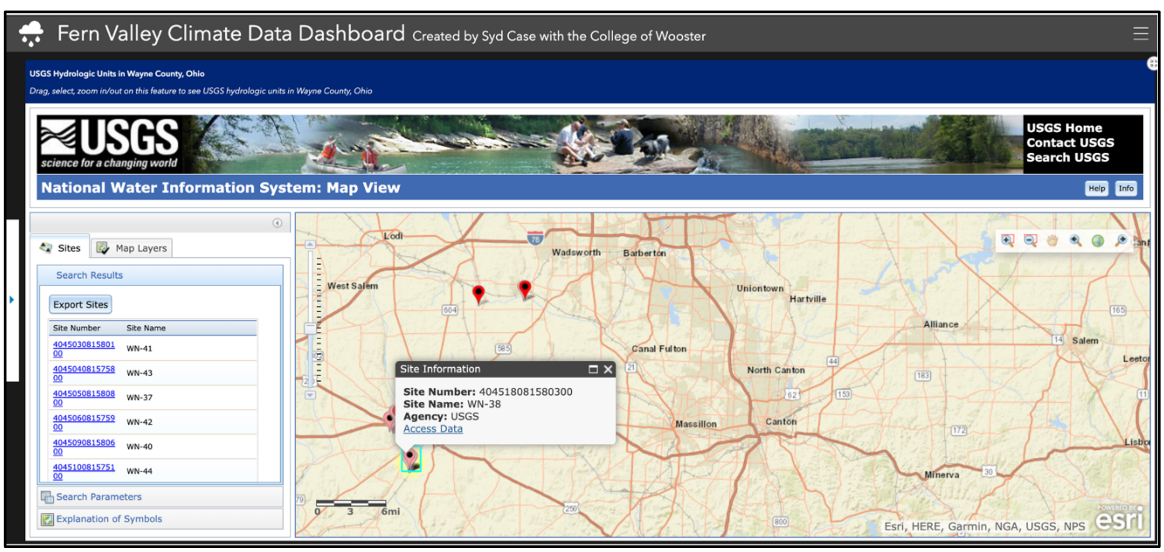


Figure 11. USGS embedded content element expanded pane located on the Fern Valley Climate Data Dashboard.

Indicators

The indicators included in the dashboard are relatively simple compared to the other elements. Stream level and temperature, air pressure and temperature, precipitation levels, and relative humidity data sets were analyzed and averaged from either 73k or 83k measurements. The indicators were grouped together in two separate rows as well as docked as a row beneath one of the serial charts. They were grouped so that a user, regardless of previous exposure to the dataset, can easily access a summary statistic of all factors being analyzed across the dashboard. Although these indicators were not constructed to have interactivity, they were placed at the center viewing point of the display, emphasizing the importance of static average measurements over time. These indicators can be updated like any other element, by changing the dataset being used and selecting different analysis tools within the element itself (Figure 12).

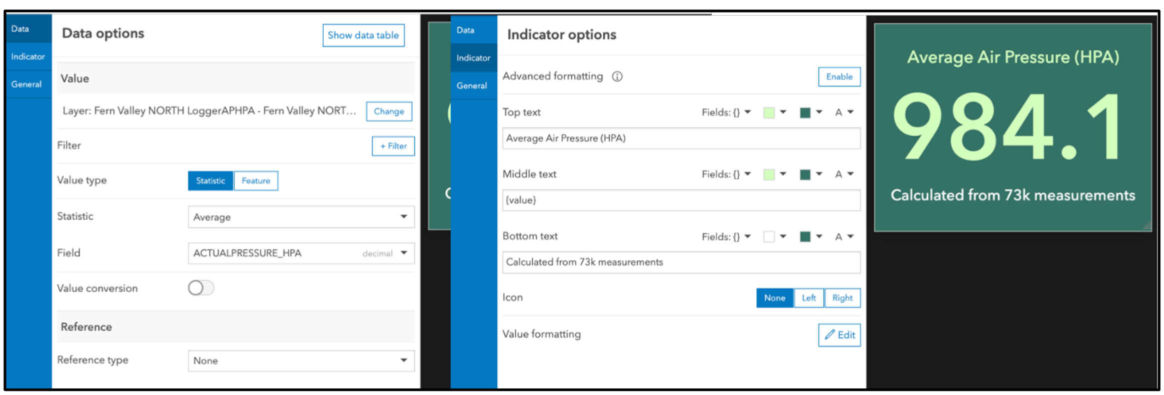


Figure 12. Configuration editing menus for an indicator element. Example indicator shown on the righthand side in green, calculating average air pressure from 73k measurements.

Serial Charts

Three separate serial chart elements were included in the dashboard: stream level over time, average stream levels, and average stream temperatures. The serial charts varied in series characteristics. Stream level over time consists of a line series with no connected gaps and both average charts are data displayed by columns. The data in the stream level chart was best represented by a line due to the extensive data available but was filtered for highest records (up to 50k) from 2016-2021 due to an exceeding data count. This count is a coded script within the element configuration process that limits the amount of data rows that can be imported by a user and cannot be changed unless an Esri administrator is contacted (Law, 2020). Contrasting the plotted points, the averages over time for stream level and temperature were charted using a column style to account for the parsed year dates and small range in values. Serial charts were the most complex element to create, excluding ones with interactivity, due to the endless options of data visualization techniques and appearance variables (Figure 13).

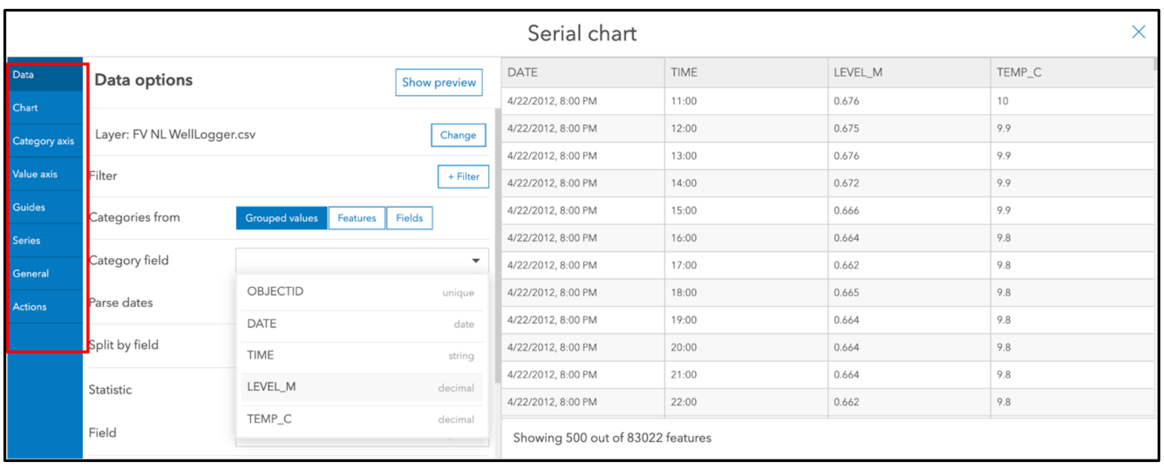


Figure 13. Serial chart element configuration tabs. Table shown is a data preview, intended to show how data is seen in the configuration setting.

3.4 Methods: Adding Interactivity

Interactivity is established by the creator configuring an element action. This action is labeled as a "target" and has virtually infinite possibilities. Establishing interactivity between two elements allows the dashboard to become interactive on the user-user level as well as the element-element level. This enhances the dashboard experience and emphasizes aspects of the data being displayed (White, 2021). For this dashboard, interactivity was established within a “details” element as well as two gauges. “Details” was included to assist the user in navigating the stream level over time serial chart. When selecting data points in the serial chart, the details element will search its data store and reflect the data point that is selected. Included in the details is information about the date, time, level, and temperature of the selected data point.

The added interactivity enhances the user experience by making the data easy to find so the user is not scrolling through 83k rows of hourly data. In addition to the details, two gauges were added to the dashboard to interact with the average serial charts (one gauge per chart). The gauges show the static average value of the coinciding data tables when any column from the chart is selected. In order to further enhance this data, a threshold within the gauge was configured by establishing a percentage based off the average values. The percentage was calculating using an above or below average threshold amongst the yearly values. So, the mean value of the averages was used and any value above the mean is visualized differently than a value below the average.

This threshold was coded to show a red color when selected data is below the average and to show green when the selected data is above the average (Figure 14). Percentage choice varies with data and was chosen in this instance based off a static value. However, percentages of larger data sets could be used to show relationships between correlated factors, not just static information. Though this is smaller scale data, establishing a threshold with color change is an effective method for comparative data analysis and is highly recommended at a larger scale.

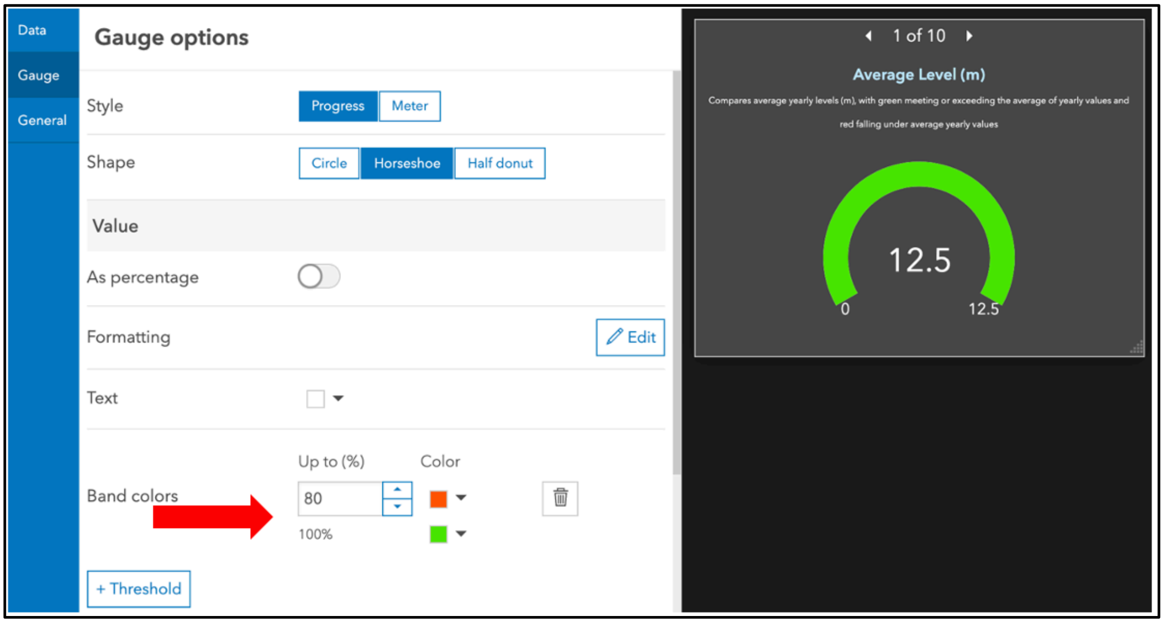


Figure 14. Gauge configuration menu showing gauge threshold construction.

3.5 Results

The final dashboard product consists of 15 elements, 3 element-element interactive configurations, 2 external links, and 1 externally sourced web page. The combination of these elements tells a partial climate story of Fern Valley by emphasizing varying levels and temperatures recorded over a long period of time. Though the data is limited in the serial charts and details, this dashboard serves as an intermediate example of how ArcGIS Dashboards can be used to manage and visualize large datasets (Figure 15).

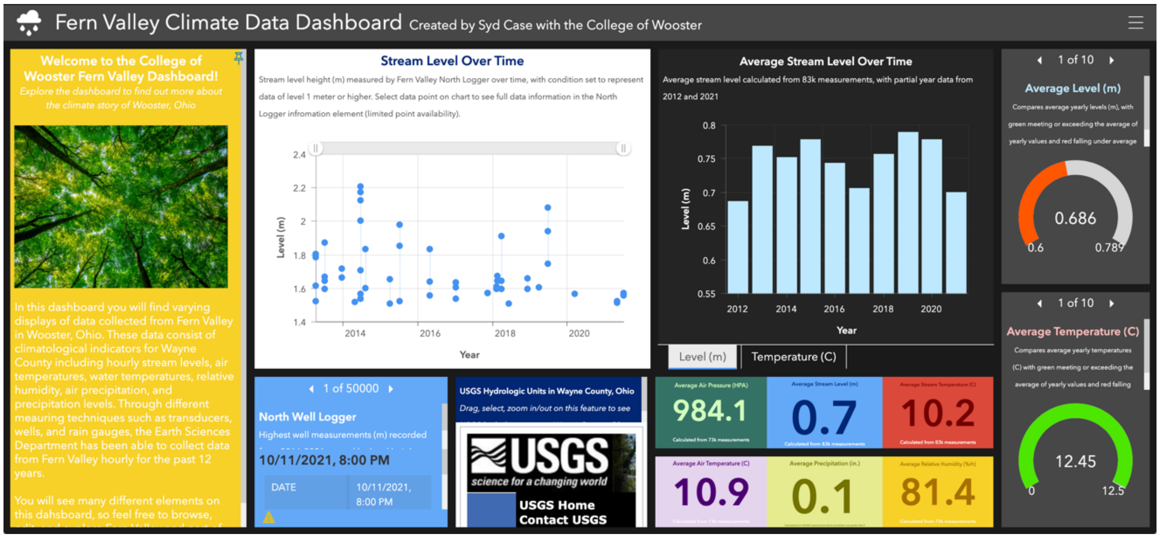


Figure 15. Final display of the Fern Valley Climate Data Dashboard. Interactive dashboard found at https://wooster.maps.arcgis.com/apps/dashboards/de0b237f67ce4f04b958d1e3e8521faa.

CHAPTER 4: Tutorials

4.1 Tutorial Overview

The following section consists of two different tutorials. The first is a data user tutorial and the second is a dashboard user tutorial. These tutorials are designed to enhance user awareness of this project's technological process and resulting dashboard functionality. Tutorial A, "How to upload data to the online realm without an enterprise structure," takes users through a step-by-step process on how to implement the two strategies used in this project regarding data upload. Tutorial B, "Navigating the dashboard," poses a series of guided questions to the user, challenging them to understand the dashboard display, the elements used, and the data presented. Following the guided questions, there is an accompanying answer key as well as supporting figures.

4.2 Tutorials

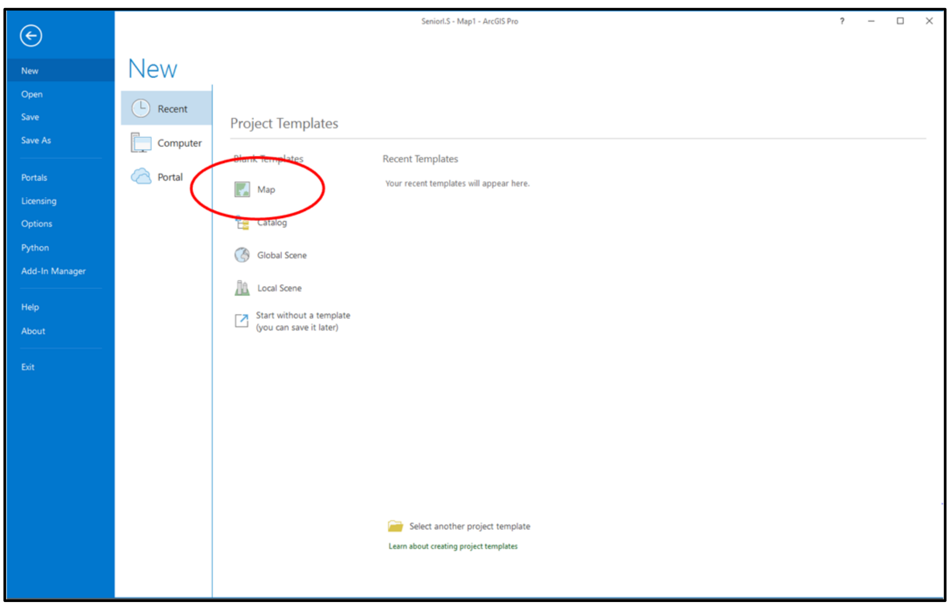
Tutorial A: HOW TO UPLOAD DATA TO THE ONLINE REALM WITHOUT AN ENTERPRISE STRUCTURE

Instructions: Follow these steps to produce content layers that can be used within a dashboard.

Note: Strategy 1 requires use of the desktop version of ArcGIS Pro and strategy 2 requires use of ArcGIS Online. To benefit from this tutorial, the user must have an existing Esri account.

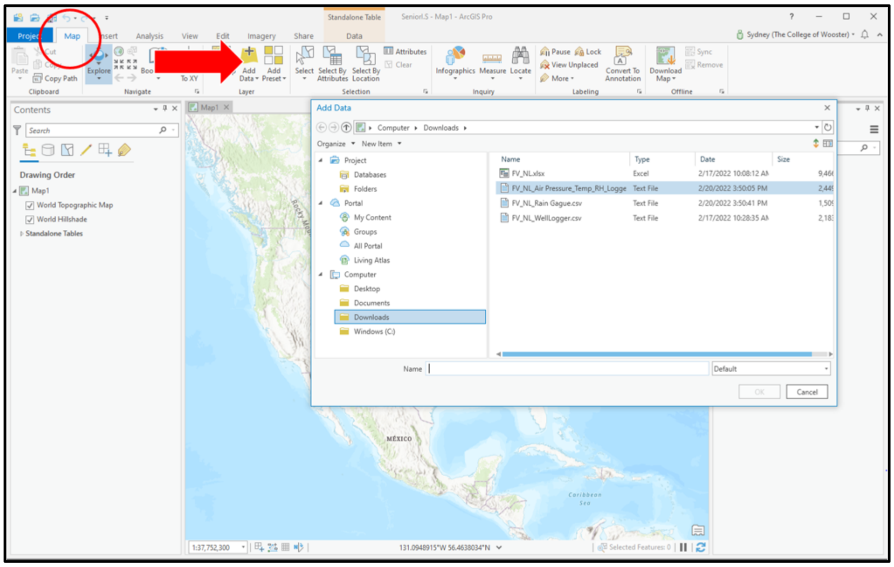
Step 1. Log in to ArcGIS Pro and create a new project. Name the project.

Note: There are several options for templates but for the purpose of simplicity and cohesiveness throughout this tutorial, select the Map template.

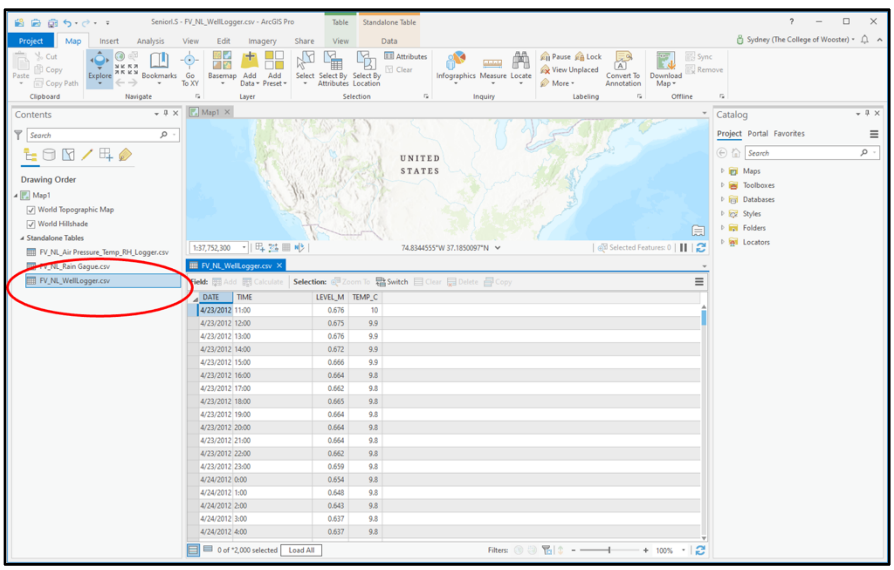


Step 2. Click on the Map tab and select "Add Data". When selected, a window will pop up with your device file explorer. Select the data file you want to upload.

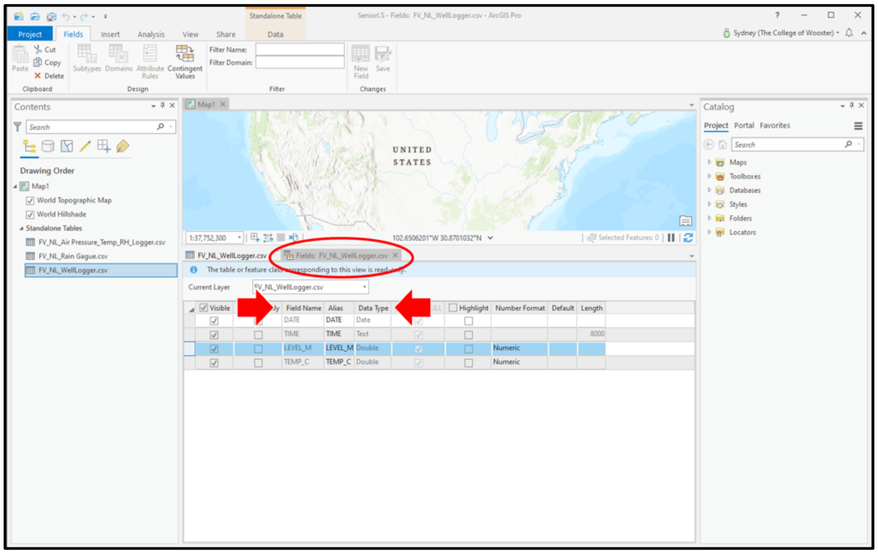
Note: Recommended file types when uploading tables are .csv, .txt, and .xlsx).



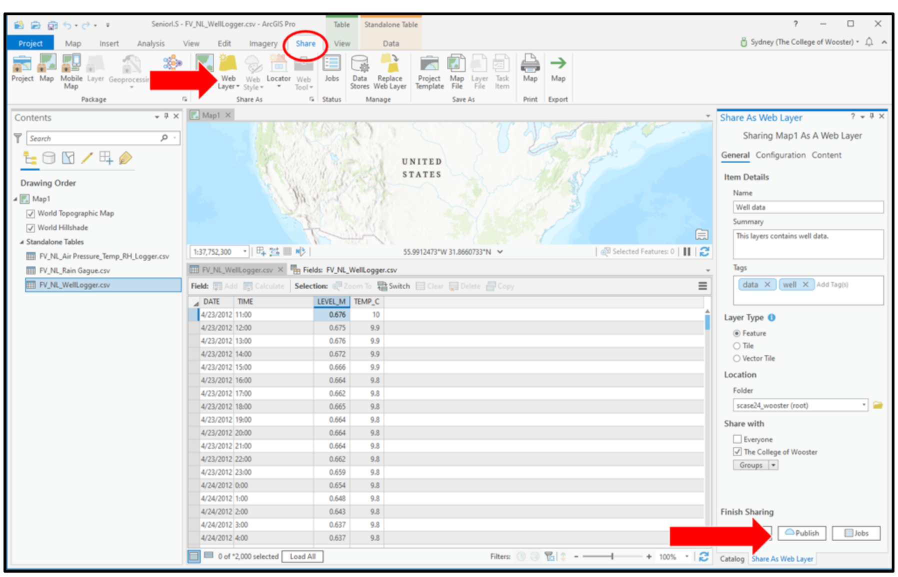
Step 3. The table will be in the Contents pane under "standalone tables". Right-click the table and select "Open". The table will appear below the Map frame with the data loaded in their respective columns.



Step 4. To double-check your fields and data types, right-click one of the field values and select "Fields". In the Fields tab that appears, make sure your field name does not have any errors and the correct data type is selected.

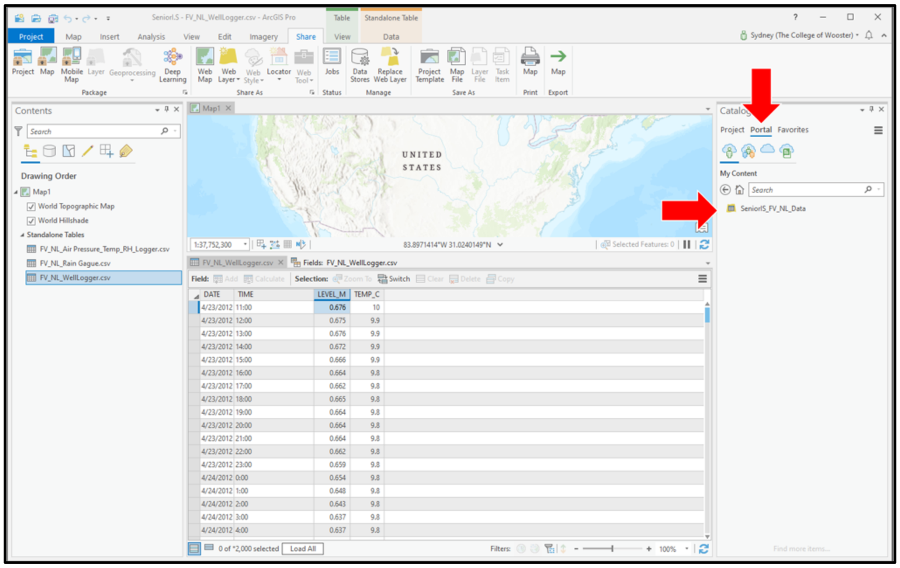


Step 5. Locate the Share tab, select Web Layer> Publish Web Layer. In the Share As Web Layer pane, name the layer, write a brief summary, and create tags for the layer. Select a layer type, folder location (this will be your user account), and any groups you want to share this layer with. Click publish.



Step 6. Locate the Catalog pane. Select Portal. Double check the web layer has transferred to your content.

Note: Another way to check this is to sign into your ArcGIS Online account and look under "Content".



END OF TUTORIAL A

Tutorial B: NAVIGATING THE DASHBOARD

Instructions: Use the real-time dashboard to answer the following questions.

Note: Dashboard available at:

https://wooster.maps.arcgis.com/apps/dashboards/de0b237f67ce4f04b958d1e3e8521faa

Question 1. What is the average air pressure? How many samples was this average calculated from? What element type is this information found in?

Question 2. What are the two threshold colors used in the dashboard? What element type are the thresholds used in?

Question 3. What is the title of the embedded content element on the dashboard?

Question 4. Locate the "Average Stream Levels Over Time" element. What type of element is this? What is the element positioning (Be specific)? (Hint: There are 3 right answers).

Question 5. Is the side panel collapsible?

Question 6. What was the average stream level in 2019? Is this above or below the mean value? Explain how you know this.

Question 7. What was the average temperature in 2017? Is this above or below the mean value? Explain how you know this.

Question 8. Which element would you use to find the Fern Valley bridge cameras?

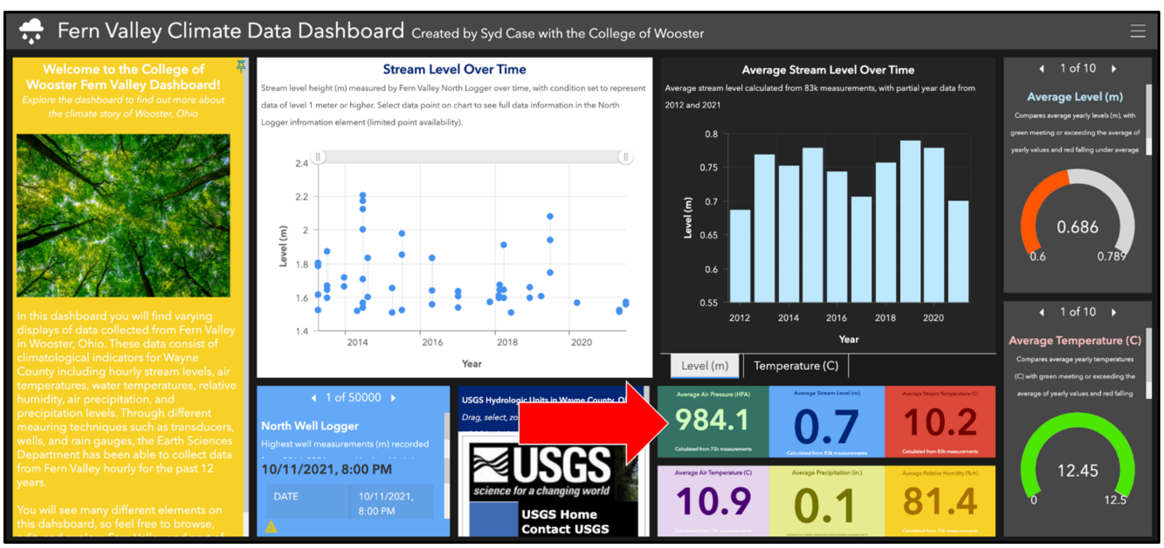
Question 9. Locate the "Stream Level Over Time" element. What type of element is this? Does this element have interactivity? How do you know?

Question 10. Locate the 2nd data point in the North Well Logger element. What was the temperature of this data point?

ANSWER KEY (TUTORIAL B)

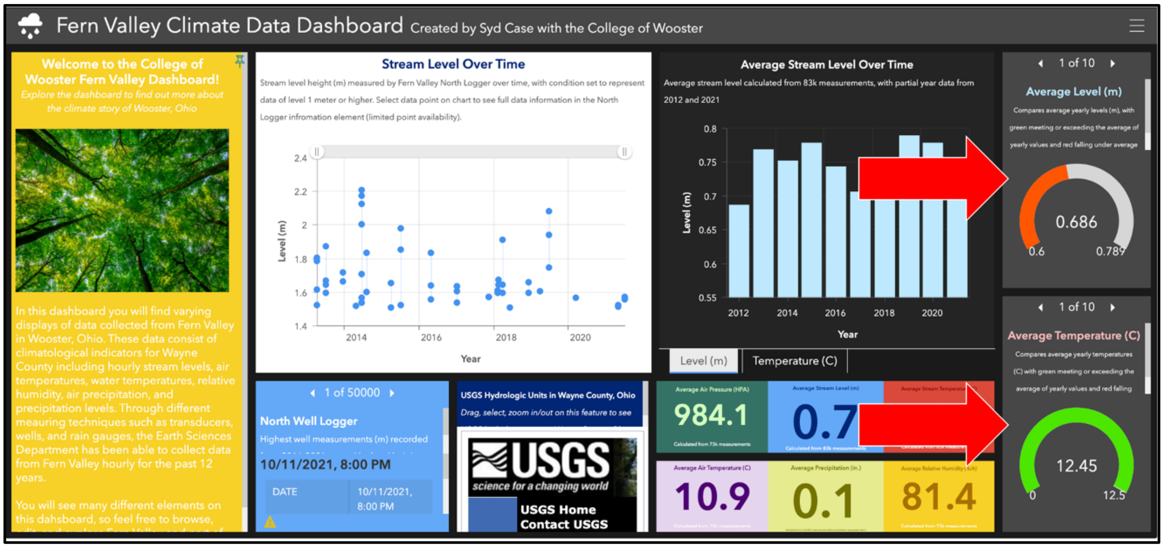
Question 1. What is the average air pressure? How many samples was this average calculated from? What element type is this information found in?

Answer: The average air pressure is 984.1 hpa that is calculated from 73,000 measurements. This information is found in an indicator.



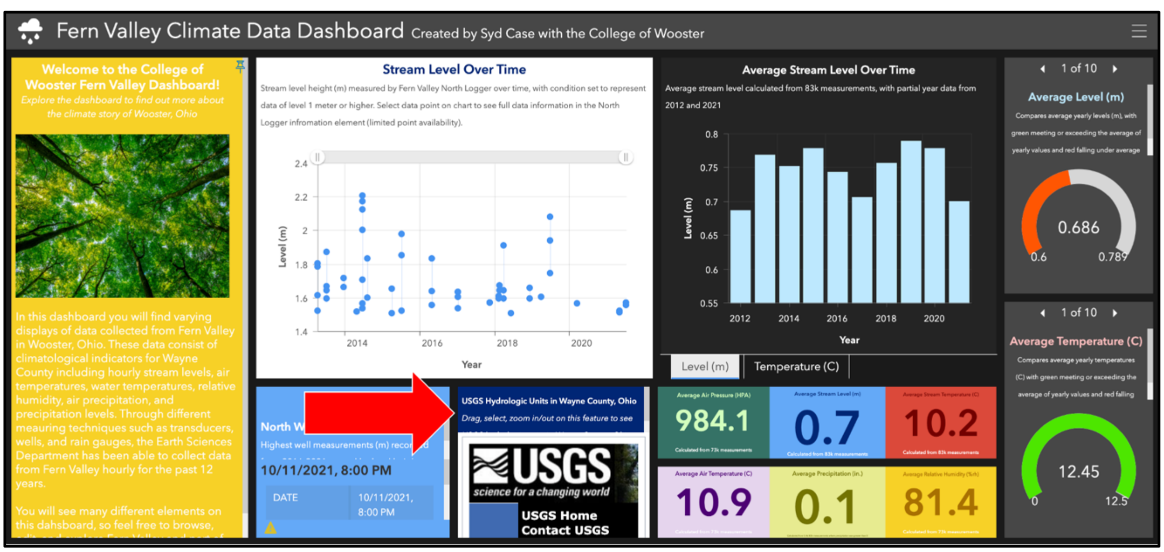
Question 2. What are the two threshold colors used in the dashboard? What element type are the thresholds used in?

Answer: The two threshold colors are red and green and can be found on the gauge elements.



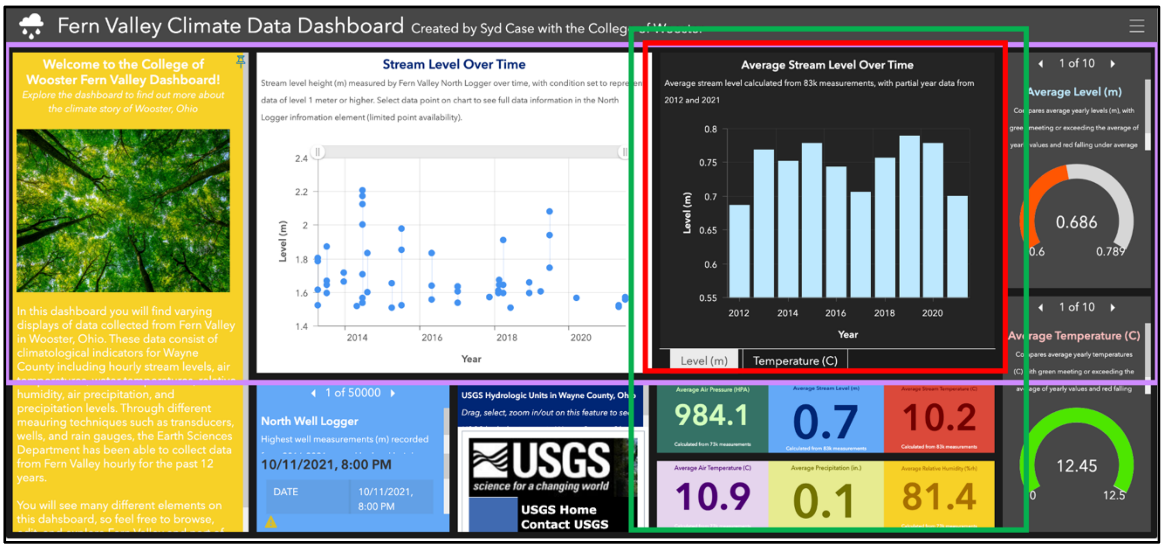
Question 3. What is the title of the embedded content element on the dashboard?

Answer: USGS Hydrologic Units in Wayne-Holmes Counties, Ohio



Question 4. Locate the “Average Stream Levels Over Time” element. What type of element is this? What is the element positioning (Be specific)? (Hint: There are 3 right answers).

Answer: This element is a serial chart with positioning as follows; docking as a column (3rd column including side panel), docking as a row (top row), and stacking with another serial chart (Temperature).

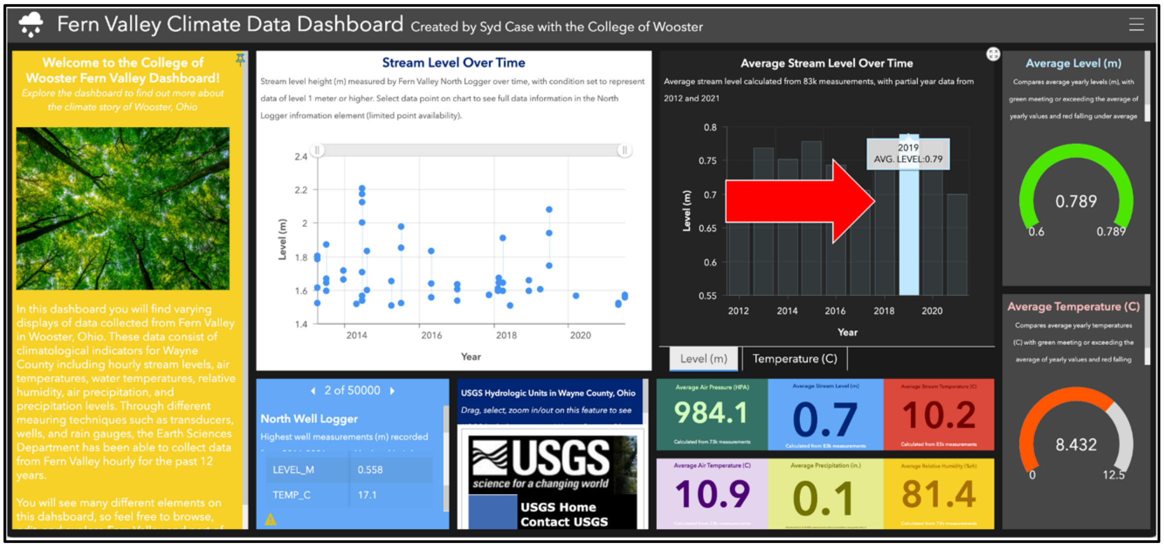


Question 5. Is the side panel collapsible?

Answer: Yes

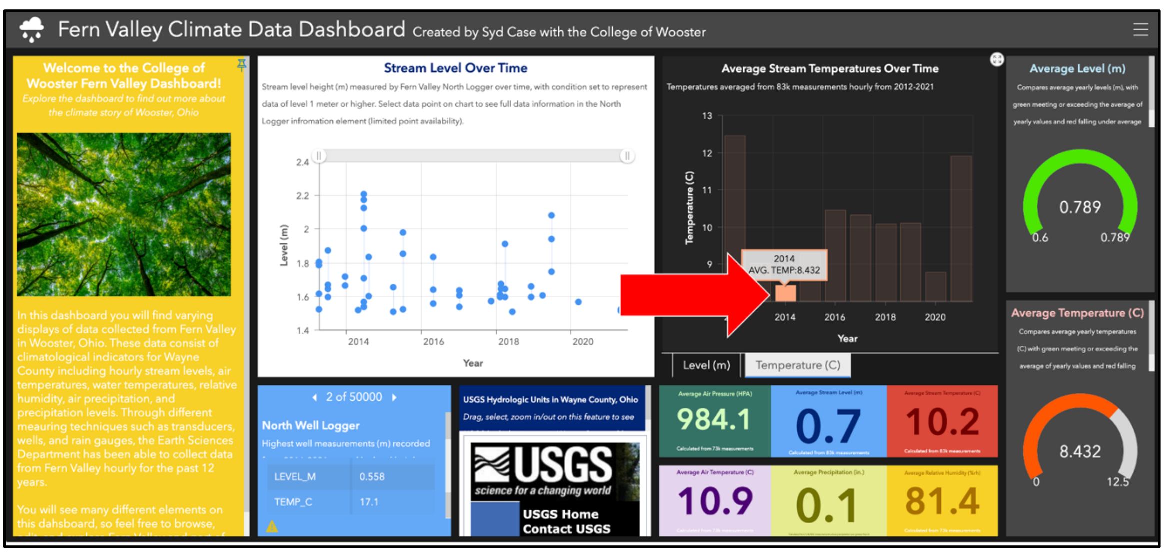
Question 6. What was the average stream level in 2019? Is this above or below the mean value? Explain how you know this.

Answer: The average stream level in 2019 was 0.789m. When selected, the gauge turns green which signals that 0.789m is above the mean value.



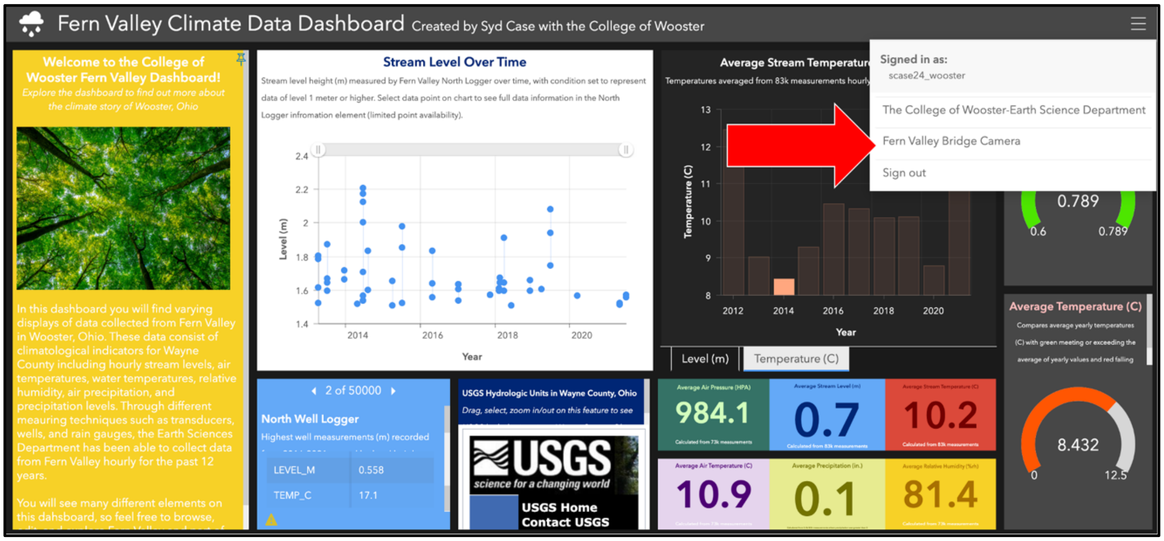
Question 7. What was the average temperature in 2014? Is this above or below the mean value? Explain how you know this.

Answer: The average temperature in 2014 was 8.432°C. When selected, the gauge turns red which signals that 8.432°C is below the mean value.



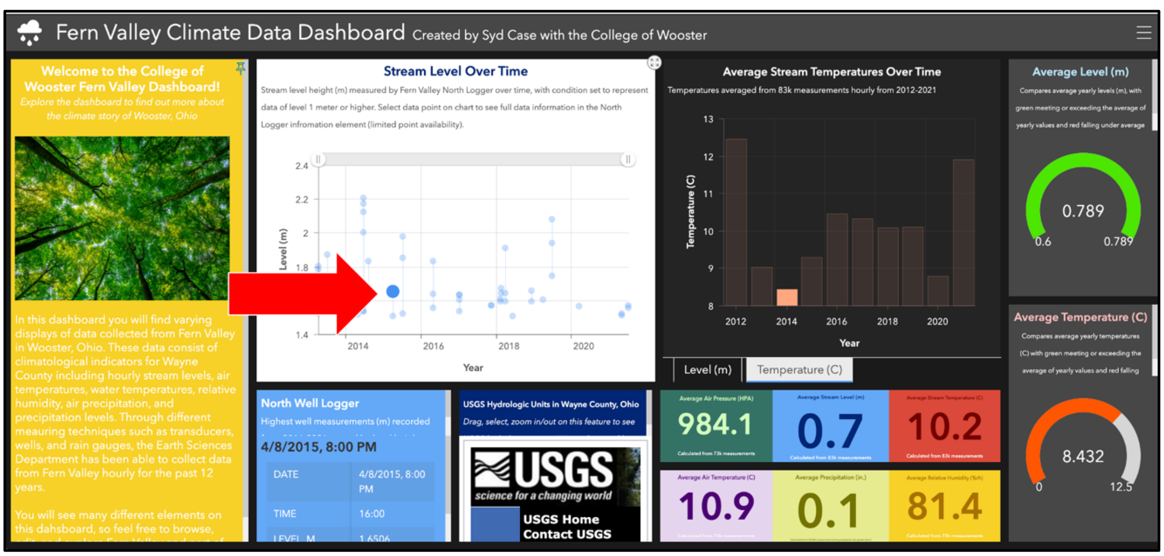
Question 8. Which element would you use to find the Fern Valley bride cameras?

Answer: To find the bridge cameras, you would use the header.



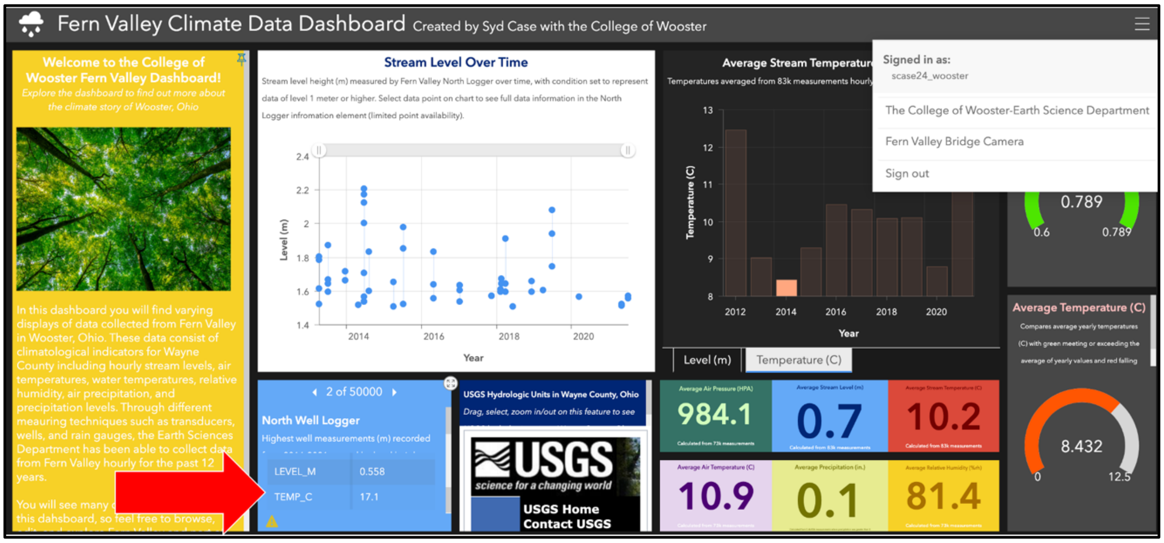
Question 9. Locate the "Stream Level Over Time" element. What type of element is this? Does this element have interactivity? How do you know?

Answer: The "Stream Level Over Time" is a serial chart with interactivity. This is because the data points can be selected, and the North Logger details element will also change.



Question 10. Locate the 2nd data point in the North Well Logger element. What was the temperature of this data point?

Answer: The temperature was 17.1°C.



CHAPTER 5: Future Work

5.1 Dashboard Vision and Impact

The vision of this climate dashboard extends beyond a singular dataset or even a singular department. Utilizing the same elemental configuration and intentionality, a more complex dashboard could be constructed following an installment of the enterprise geodatabase solution discussed in chapter 1. In the future, The College of Wooster would benefit from creating a series of dashboards that incorporate multiple data sets in order to tell a more robust climate story of Wayne-Holmes Counties, Ohio. Additional data that would provide a holistic experience for users includes isotope levels and geochemical recordings, dendrochronological information, and regional geomorphology. Further, the dashboards could involve other departments in the dashboard construction process by creating a College of Wooster Dashboard Series web page. This web page would consist of multiple interactive dashboards as well as accompanying sources of ArcGIS data visualization such as Story Maps and Survey123.

By including additional storytelling elements, The College of Wooster would open the doors to potential collaboration with regional environmental organizations as well as local educational programs. Examples of collaboration include incorporating regional environmental data into the dashboard or creating a prototype for other organizations to construct their own dashboard management system. Regarding educational purposes, dashboards are not only excellent tools for communicating a particular topic or real time story but are also an opportunity to educate the public and youth on the power and intentionality of data visualization. The demand for an understanding of how data is collected, how data is presented, and why data is important is steadily increasing as both technology and society advances. Dashboards are a powerful tool for understanding every aspect of data visualization beyond just the surface and would be an excellent opportunity for The College of Wooster to pursue further.

5.2 Conclusions

The College of Wooster is one of many organizations that collects extensive data and would benefit from a streamlined long-term data storage, management, and visualization solution. The investigation of several technological solutions including constructing an enterprise geodatabase, restructuring an existing local server system, and utilizing an online group, led to the highly recommended solution of establishing a locally housed ArcGIS enterprise system. This system would be capable of storing and managing data long term, supporting multiuser functionality, and enabling a connection between The College of Wooster local server and an expanded ArcGIS Portal. Although the methods of data upload used in this project are technologically inefficient, the resulting dashboard reflects the potential ArcGIS Dashboards has for displaying complex datasets and should be heavily considered for further expansion. With the proper software and geodatabase enhancements, the strategy of performing data management within ArcGIS software is sound and recommended for The College of Wooster, more specifically the Department of Earth Sciences.

The benefits of holistic data visualization, cross-organizational collaboration, and educational advancements far outweigh the technological obstacles that would need to be overcome upon further investment in this project. With the demand for data visualization increasing and the collection of data becoming more robust, The College of Wooster is presented with a unique opportunity to jumpstart a new wave of climate change and scientific data management and should be excited to explore the possibilities of data management through ArcGIS Dashboards.

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