Redband Trout Restoration Prioritization Tool for the Spokane Watershed Sub-basin

University of Washington
GEOG 569 GIS Workshop
MGIS Summer 2019 Capstone Project
August 23rd, 2019

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Executive Summary

The Spokane Tribal Fisheries Anadromous Program is tasked with returning anadromous species to the waters of the Spokane Tribe. These waters include the Spokane River watershed, which is a sub-basin of the Upper Columbia River basin. Within the Spokane River watershed, the study area included three sub-basins: Little Spokane, Lower Spokane and Hangman.

Spokane Tribal Fisheries sought to develop an online web mapping application to determine priority habitat for the genetically distinct resident redband trout (subspecies of Rainbow Trout, O. mykiss gairdneri) within the three sub-basins. The intended purpose of the application is to identify geographic information regarding these potential habitat sites, which can be shared with various stakeholders, to manage redband trout populations.

The sponsor provided a clear concept to initiate this project with a visual prototype and many data resources. This report presents an in-depth usability reference for the methodology, process, and implementation involved in the development, the technical use, and suggestions for future modification of the prioritization tool.

The end product is a useful tool for visualization of redband trout watershed extent and habitat quality. The web app produced the desired outcome which is a method for creating a composite habitat prioritization layer. The tool is expected to be used by Spokane Tribal Fisheries upon completion of this report and modified over time as new data and perspective is compiled by stakeholders. This tool will provide a platform and visual baseline for management for redband trout resources. This platform may be useful for planning management efforts for redband trout in the Spokane Watershed sub-basin.

The key recommendations for future endeavors include identifying data gaps, improving data, refining restoration priorities, and working on a comprehensive management plan for redband trout.

A link to the web app tool can be found below:

https://uw-geog.maps.arcgis.com/apps/webappviewer/index.html?id=cf86ec3ff403480dad5dd40898ef7c4d

**Note: This URL will change once the web app is transferred to its final platform and will be managed by the Spokane Tribal Fisheries*

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1. Introduction

The Spokane Tribal Fisheries is integrating an online web mapping application for determining priority habitat for the genetically distinct resident redband trout (subspecies of Rainbow Trout, O. mykiss gairdneri) in the Spokane River watershed sub-basin of the Upper Columbia River Basin. The intended purpose of the application is to share geographic information regarding these potential habitat sites with various stakeholders working to protect and reintroduce the species to the area. To help this group accomplish the final product, we have determined an overarching research question, established an overall goal, and created objectives in the form of need-to-know questions to accomplish this task. A redband trout species account can be found in Appendix A.

1.1. Background

1.1.1. Study Area

The study area for the web application includes portions of the Spokane River watershed within Washington State and a small portion of Idaho (Figure 1).

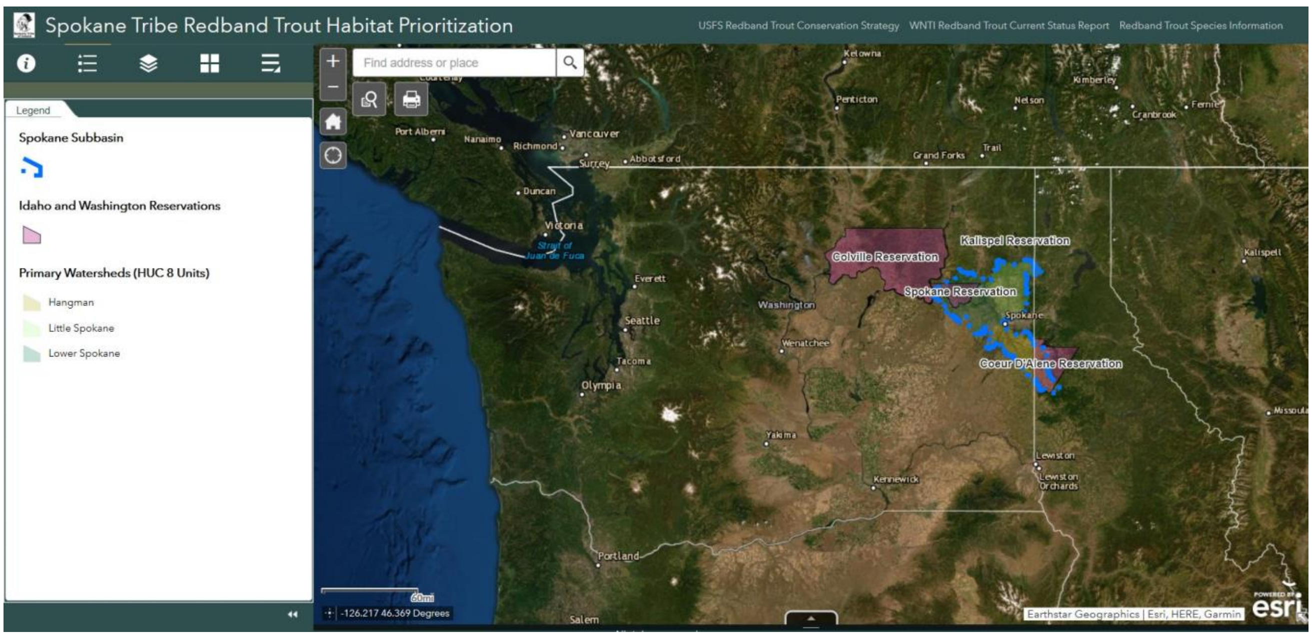

Figure 1: Project Study Area

The Spokane River watershed includes many sub-basins, three of which are included in this web application. These are the Lower Spokane, the Little Spokane, and Hangman Creek sub-basins (Figure 2).

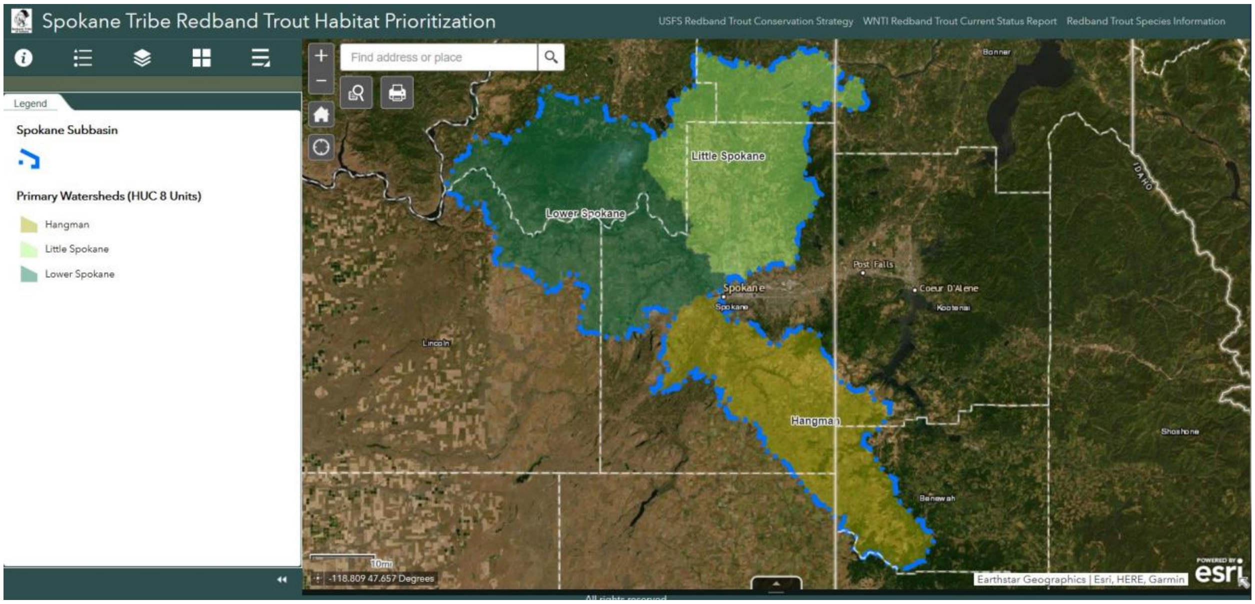

Figure 2: Spokane River Watershed Sub-basins

Washington State has formed a Watershed Planning and Implementation group for the watersheds that comprise the Spokane River drainage (Figure 3). The administrative functions of this group endeavors to gain time and cost efficiencies and further coordinate regional watershed planning and implementation. Within Washington State, the regional group includes the WRIA 54, WRIA 55/57, and WRIA 56 groups.

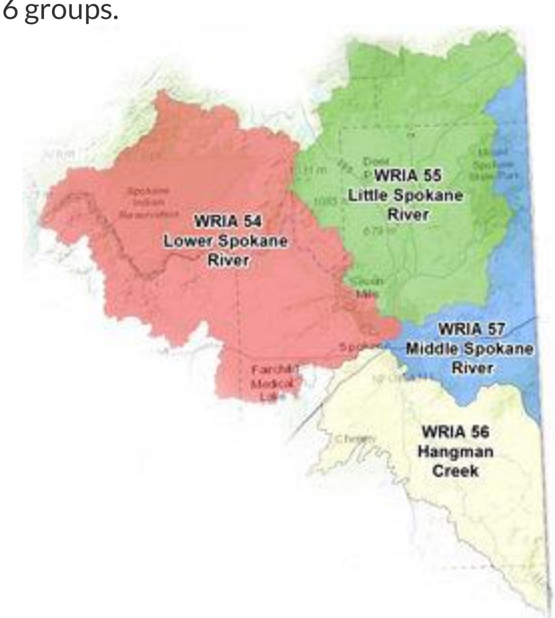

Figure 3: Washington State WRIAs from Spokane Watersheds

1.1.2. The Spokane Tribe and Spokane Tribal Fisheries

The Spokane Tribe are salmon people, who historically relied on the bountiful runs of salmon and steelhead that thrived in the Spokane and Columbia Rivers as their primary form of sustenance. Many factors through time have led to the extirpation of local salmon populations. Since the late 19th and early 20th centuries, overharvest in the lower Columbia River, driven by the canning industry, took a significant toll on upriver stocks. Hydroelectric dams built on the Spokane River in the early 1900's barred salmon from most reaches of the Spokane River. In the 1940's, the construction of the Grand Coulee Dam effectively blocked salmon and steelhead from reaching the upstream-most 1,100 miles of the Columbia River and its tributaries.

Spokane Tribal Fisheries is committed to caring for the aquatic resources of their region while also preparing their waters for the return of salmon and steelhead. This web application visualization project will contribute to this effort by synthesizing some of the spatial data into one platform.

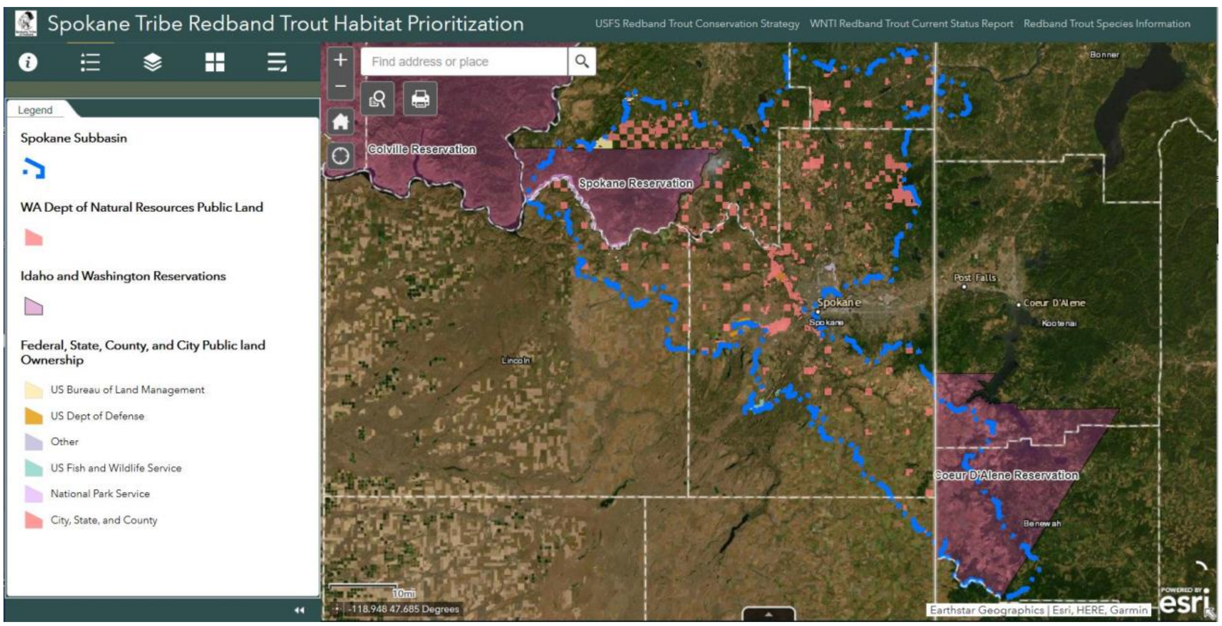

Figure 4: Land Ownership in the Project Area

The primary client and stakeholder involved in this project is the Spokane Tribal Fisheries Anadromous Program. Primarily responsible for co-managing the fisheries of Lake Roosevelt, the program is also engaged in aquatic resources throughout the Tribe's usual and accustomed area. Many of these waters and their fisheries are co-managed by the Spokane Tribe of Indians (STI), the Colville Confederated Tribes (CCT), the Coeur d'Alene Tribe of Indians (CDATI), and the Washington State Department of Fish and Wildlife (WDFW). The concept of this specific project came from the Spokane Tribe, but it will be useful to the regional co-managers and other local stakeholders

Like many of the tribes located in Washington, management of fisheries has significant cultural, economic, and subsistence implications. Today, the Spokane Tribe and its partners actively manage their original ancestral territory around Spokane, WA. Their main goals are to effectively manage and protect populations of fish, wildlife, and associated habitats through best management practices for present and future generations. The Washington State Department Wildlife has a similar mission while also including recreational and commercial opportunities at sustainable levels for residents of Washington.

1.1.3. Literature Review

A brief literature review was conducted for the interior redband trout. There were many digital articles referencing interior redband trout, and the conservation efforts of the Spokane Tribe, local entities, and state and federal agencies. In addition, three documents were found that address the specific species and location for this project. The first is *The Conservation Strategy for Interior Redband Trout* (Interior Redband Conservation Team, 2016) which provides goals and objectives for redband conservation across its range, and specific stepwise goals, objectives and actions for Geographic Management Units (GMUs).

The second document, provided by the project proponent, is the *Project Summary for Project 1997-004-00 - Resident Fish above Chief Joseph and Grand Coulee Dams*, by the Columbia Basin Fish and Wildlife Program, which states that " Work on redband trout…was described with little discussion of how the information informed management. For redbands, three paragraphs on accomplishments emphasize the development of "standardized methods" and pilot projects. A three-year population study was to be done in the Upper Spokane River in 2007-09, but virtually no results are given." This statement emphasizes the need for additional tools to communicate data and species-specific information on interior redband trout.

The third document is *Fine-scale population structure of rainbow trout (Oncorhynchus mykiss gairdneri)* (Small et al., 2007), in the Spokane River drainage in relation to hatchery stocking and barriers. This paper discusses the population structure of redband trout in the Spokane River basin.

1.2. Project Purpose

The intended purpose of the application is to share geographic information regarding these potential habitat sites with various stakeholders working to protect and reintroduce the species to the area. To help this group accomplish the final product, we have determined an overarching research question, established goals, and created objectives in the form of need-to-know questions to accomplish this task.

1.2.1. Institutional Benefits

Provide a much-needed tool to help guide stream restoration actions for the benefit of redband trout while also improving habitats for when anadromous species return to the region.

1.2.2. Educational Benefits

Satisfaction that this tool will be used to improve aquatic ecosystems and their species for the betterment of the region as a whole. AGOL appears to be rapidly expanding. Learning and applying AGOL skills as part of a collaborative project would strongly supplement one's resume.

1.3. Project Goals and Problem Statement

1.3.1. Project Goals

The main goal of this project was to deliver an updated version of the existing web application tool developed by the Spokane Tribal Fisheries for redband trout priority habitat areas. This tool was created on the ArcGIS Online platform and intends to help guide stream habitat and fishery restoration as well as preservation activities for the benefit of redband trout in the Spokane watershed sub-basin.

In order to accomplish this task, the following smaller project goals are outlined here:

- Readily available and easily accessible
- Ability to navigate the tool at a layperson level
- Information about redband trout genetic population(s)
- Information on habitat quality
- Information on barriers that may impede fish crossings
- Other information that may offer context
- Ability to have enough information to make restoration decisions

1.3.2. Problem Statement

From the overarching goal provided by our client as well as the established smaller goals, the following problem statement was created:

> *What information and functionality is necessary for a web-based tool to be effective in prioritizing areas of redband trout for restoration?*

1.3.3. Project Objectives

Based on the project goals and from our problem statement, the project objectives were developed. The objectives are presented in question form as "need to know" questions. By choosing these objectives and presenting them as questions to be answered, it establishes a structured framework that guides the creation of the final product. Below is our list of project objectives:

1. Where are areas of relatively low genetic hybridization of redband trout?
2. Based on the "Intrinsic Potential" dataset, where are areas of moderate and high habitat ratings?
3. Where do areas of relatively low genetic hybridization of redband trout overlap with moderate and high habitat rating areas?

4. What types of barriers are preventing redband trout access to moderate and high habitat rated areas?
5. Where are the barriers located that are preventing redband trout access to moderate and high habitat rated areas?
6. What datasets offer context to the final product?

1.4. Project Organization

1.4.1. Communication

Conor Giorgi, the Anadromous Program Manager, is our primary contact for this project. After discussing with him and what has worked for our group in the past, we decided that email would be our primary form of communication. Conor was included in email regarding project updates, questions, completed school assignments and organizational needs. As far as project management and detailed development of the tool, we kept our communications within the University of Washington Canvas platform.

1.4.2. Project Schedule

Development of this web application was limited to 8 weeks during the Summer Quarter of 2019. The work schedule was developed within this time frame and with the scope of work presented by the project sponsor. The tasks to achieve our goals and objectives were delineated and mapped out in a PERT chart and Gantt chart (Appendix B).

2. System Resources

The system resources required to endeavor the deliverable include data, software, hardware, personnel, and institutional resources. Some of the data resource requirements were acquired from the project sponsor and retrieved from other applicable resources, described in more detail in the following sections.

2.1. Data Resource Requirements

The data resource requirements were established based on the objectives sorted into varying information categories. Table 1 below shows the objectives sorted into the appropriate information categories that motivated acquisition of necessary data layers.

2.1.1. Objective-Based Information Categories

Information Categories	Associated Objectives
Redband Trout Population Location	Where are areas of relatively low genetic hybridization of redband trout?
	Where do areas of relatively low genetic hybridization of redband trout overlap with moderate and high habitat rating areas?
	What datasets offer context to the final product?
Fish Barrier Inventory	What types of barriers are preventing redband trout access to moderate and high habitat rated areas?
	Where are the barriers located that are preventing redband trout access to moderate and high habitat rated areas?
	What datasets offer context to the final product?
Habitat Quality Assessment	Based on the “Intrinsic Potential” dataset, where are areas of moderate and high habitat ratings?
	Where do areas of relatively low genetic hybridization of redband trout overlap with moderate and high habitat rating areas?
	Where are the barriers located that are preventing redband trout access to moderate and high habitat rated areas?
	What datasets offer context to the final product?

Table 1: Initial Information Categories

2.1.2. Required Feature Layers

1. Fish Passage Inventory Feature Class - Washington Department of Fish and Wildlife
2. Genetic Status Feature Class - Western Native Trout Initiative
3. Habitat Intrinsic Potential Output Feature Class
4. Redband Trout Priority Habitat Feature Class - Derived

2.1.3. Contextual Feature Layers

1. Spokane Sub-basin
2. Washington Cadastral Townships
3. Washington Cadastral Sections
4. Idaho Cadastral Townships
5. Idaho Cadastral Sections
6. Washington Department of Natural Resources Public Land
7. Idaho and Washington Reservations
8. Federal, State, County, and City Public Land Ownership
9. Spokane Sub-basin River and Streams
10. Spokane Sub-basin Water Bodies
11. Spokane Sub-basin Land Cover
12. Bonner County Land Use Descriptions
13. Kootenai County Zoning Descriptions
14. Washington Land Use Descriptions
15. Primary Watersheds (HUC 8)
16. HUC 10 Watersheds
17. HUC 12 Watersheds

2.2. Software Resource Requirements

2.2.1. ArcMap 10.6.1

The software platform used to review, refine, and select necessary data was the desktop application ArcMap Version 10.6.1. ArcMap is a comprehensive mapping application that allowed more options for data processing. Table 2 shows the various tools and operations found within this software that were used.

Tools and Operations Used in ArcMap 10.6.1	
Clip	Select
Buffer	Symbology
Intersect	Querying
Merge	Create New Fields

Table 2: Tools and Operations Used

2.2.2. Implementing the Web-Application

In order to move the tool from a desktop application to a more readily available tool in ArcGIS online, a web-browser software application is required. For this project, we used Google Chrome to access ArcGIS online and associated content.

Additionally, most of the written assignments and content were created within a shared Google Drive on a web-browser that all three students and the client could access. Supporting documents and data files were also shared this way.

2.3. Hardware Resource Requirements

The estimates found below are based on the knowledge of what currently exists in our Google Drive, data transformations and processing, and the nature of files like word documents, graphs, and charts created. Additionally, we utilized ArcGIS Online Enterprise accounts managed by the University of Washington and the Spokane Tribal Fisheries that are responsible for maintaining the credit(s) and storage that is accessed by the entire organization, leaving that information as somewhat unknown. The following are estimates of how much data storage we needed overall. We predict a range of .30-.50 GB.

2.3.1. Computer Requirements

- 4 GB Disk Space (minimum)
- 4 GB RAM/Memory (minimum)
- 2.2 GHz CPU (minimum)

2.3.2. Data Input Storage Requirements

The current datasets use about 300 MB of storage

2.3.3. Data Processing Storage Requirements

Based on the current datasets and the data processing we performed, 500 MB is enough

2.3.4. Data Output Storage Requirements

From current and expected storage needs, the final products do not utilize more than 500 MB of data storage

2.4. Personnel Resource Requirements

Based on Huxhold's definitions of listed roles from *Multipurpose Land Information Systems Guidebook - Chapter 16 Needs Assessment*, the following descriptions are decided roles that each person will play for the duration of this project. The descriptions we created are based on Huxhold's definitions but are tailored for our project.

2.4.1. University of Washington Group

Analyst - Amy was the analyst for this project. Her experience with local government, working with Washington watersheds and associated entities, and being able to decipher and locate helpful resources suits her for this role. Overall her job as the analyst was to be a bridge between the real-world and the technical aspects to ensure that any data or resources used adequately represent the needs and wants of the client.

Manager **-** Samantha took over the role as the manager during this project. She was responsible for ensuring communication between group members is clear, responsible for deadlines, updating and tracking Gantt and PERT charts, keeping the group focused and organized. Her type-A personality and knack for color coding were strengths for this role.

Programmer/Processor - Patrick was the technical specialist as the programmer/processor for this project. His experience working with geodatabases and SDE's, extensive familiarity with the ArcGIS suite, and experience as a cartographic technician makes him more than fit to ensure that the technological aspects required for this project are suitable for the client.

2.4.2. Spokane Tribal Fisheries

Project Manager/Leader - Conor was the client/user and is in a sense the leader of this group. He directed and guided the group based on what his organization needed. Based on their needs and wants for the products, he assisted the University of Washington group with what we needed to create a working and effective product. Without Conor representing the Spokane Tribal Fisheries, it would be difficult to collaborate effectively.

2.5. Institutional Resource Requirements

Though the work on this web tool has been between the University of Washington students and the Spokane Tribal Fisheries Anadromous Program, there are other groups who will utilize this application. These include additional state government agencies that work with fish and water resources, such as the Department of Ecology and the Department of Natural Resources, as well as federal government entities such as the U.S. Fish and Wildlife Service. Non-profit groups and recreational stakeholders include, but may not be limited to, the Spokane Riverkeeper, Western Native Trout Initiative, the Spokane Falls Chapter of Trout Unlimited, and local universities. The general public may be another stakeholder as it could include fish enthusiasts, educators, and landowners with an interest in water resources.

3. Business Case Evaluation

The business case for the Redband Trout Habitat Prioritization Tool will provide people an overview for understanding the ‘value’ of this type of GIS application. Some of the value is financial, and some is value-added or social equity based. Value can be termed as the comparison of the cost and the benefit, or net benefit. The financial benefit elements are relatively straightforward to estimate and quantify with raw numbers. The social equity and value-added elements of the benefit is often intangible and unquantifiable until it becomes reality, but can be estimated based on opportunity, or the presence and absence of an opportunity.

Additionally, the estimates used in this business case are not guaranteed to be fully accurate but are a reasonable and thoughtful assessment. With the charts and tables presented here, it is clear that the GIS effort to produce this tool is proving to be worth the financial benefit. By enlisting the University of Washington students to assist with this project, the financial savings are higher. This cost savings shown here could be put toward further research and data collection, as well as additional maintenance of the tool. Distribution and collaboration of the tool with other groups may hold future opportunities. The non-financial benefits will become clearer with time and opportunity as well.

The purpose of a business case is to assess the costs of a project compared to the benefits of a project, or a cost-benefit analysis. For the Spokane Tribal Fisheries, the Anadromous Fisheries Program is new to their organization. Their goal is to improve habitat, water quality, and create areas that allow for successful restoration of salmon and steelhead fish species back into the Spokane and Columbia rivers within the Spokane sub-basin. This task requires consideration of many factors that may not be easily accounted for. To help assist the organization with this project, the client has indicated that a publicly available ArcGIS online web application may be helpful but do the benefits of implementing GIS tools outweigh the costs? This business case has been created based on previous works from Antenucci, and Huxhold, as well as additional external resources to help answer the above question.

3.1. Types of Benefits

Developing a web-based tool that is accessible by the public will provide many benefits to both the Spokane Tribal Fisheries group and other local practitioners who are involved with the restoration of anadromous species, specifically redband trout. Being able to view and utilize relevant datasets that have been refined for the purposes of this project will improve productivity and aid in decision-making processes that are important for this species. The following is a list of benefits by category based on the work of Antenucci:

1. Type 1: Quantifiable efficiencies in current practice, or improvements to existing practices such as cost reduction of labor. Decrease in operating expenses caused by savings in time, principally staff time.

2. Type 2: Quantifiable expanded or added capabilities to be more effective with work activities. Adding more of an activity that was too costly to perform in the past.

3. Type 3: Quantifiable unpredictable events that can take advantage of geographic information.

4. Type 4: Intangible benefits related to intangible advantages - equity of access to an information capability.

5. Type 5: Quantifiable sale of information - selling/licensing of data or maps.

3.2. Type 1 Benefits

Based on Antenucci's categories, type 1 benefits improve the current practices and methods. This type includes improved automation and reductions in time-consuming activities. Within the parameters of this project, this type of benefit looks like less field work, less data searching, and improvement for quicker map creation for targeted areas. Redband trout are valued in the Spokane sub-basin as a special status species and being able to reduce time to inspect and decide on habitat restoration areas will allow for an enhanced prioritization function. Additionally, locating specific genetic analysis areas with this tool will increase efficiency for restoration efforts.

3.3. Type 2 Benefits

Antenucci describes type 2 benefits as an increase, expansion or an addition of capabilities. Aside from the type 1 benefits previously listed, we have identified a few type 2 benefits. One benefit we identified was that the prioritization tool will allow program managers to focus funding for areas with restoration or preservation potential. Currently, there are multiple groups that are looking at free data resources and creating their own maps and doing their own investigative work into habitat restoration, but this tool can help to unify cooperative efforts. This tool benefits the other groups and jurisdictions as well to be able to use the tool for an increased knowledge base from their own work. This tool has information on land ownership, fish distribution, and fish barriers over a substantial area - and it does not require any one individual to share that information.

3.4. Type 3 Benefits

Type 3 benefits occur during situations of unpredictable events. Natural hazard events, such as landslides, floods or wildfires, could occur in the project area. These types of events are unpredictable, but tangible, and quantifiable when they occur. Geographic information produced by this study could be useful for the impact analysis and remediation for natural hazards. The cost for these events is unpredictable, since type, location, and magnitude play into the equation of cost. But the most obvious benefit from having this toolset is that natural disasters could negatively affect the existing fish barriers or create additional ones. By being able to georeference the data in this tool with impacted areas, there is the possibility that restoration and clean-up efforts post-disaster can be streamlined and reprioritized because of this tool.

3.5. Type 4 Benefits

Type 4 benefits are not necessarily quantifiable or tangible but are still advantageous. This project will result in a publicly available intuitive web map, depicting habitat restoration and prioritization areas, that will provide easy access to visual information about the Spokane watershed sub-basin.

This information could be used by the general public as an educational resource, for volunteer efforts, or for planning and development. All the data and the tool are in one place and can be used by a single web-link. Additionally, any person within the organization could help to answer pertinent questions. It eliminates timely activities, can increase the staff knowledge-base, be used in creative and critical thinking projects, and eliminates the need for a heavily GIS/geographic savvy individual in this context by being easily readable.

3.6. Type 5 Benefits

The last type of benefit Antenucci references is a type 5 benefit as a result of a sale of information or information services. There is a future potential for licensing individual maps from the application widget. However, the data currently on the tool is free data but additional private sources could be added. This widget gives users the ability to make a basic map for a specific geographic area within the Spokane sub-basin.

3.7. Estimated Project Costs

3.7.1. Capital Costs

Capital costs include one-time fixed expenses incurred on the purchase of equipment and services. For this project some of these costs were incurred by students. However, to replicate this project the capital costs are estimated below.

1. *Database*

   Hosting costs for an enterprise GIS database. Depending on the server space, number of users in the organization and if the organization owns the server on site or rents server space, the cost will vary, but for an organization like the Spokane Tribe, the cost will be approximately $12,000/year.

2. *Hardware*
   - Dual Monitors, per user = $150 x 2 per user (4) = $1200 once
   - CPU, RAM, HDD, GPU = $1000 x per user (4) = $4000 once
   - Desktop for each user = $1000 x each user (4) = $4000 once
   - Laptop for one user for travel = $2000 once
   - Tablet for one user for field collection = $500 once

3. *Software*
   - ESRI ArcGIS License (ArcPro, Online) = $3800/year per user (4) = $15,200/year

4. *Implementation*
   - Server for organization and implementation = $400/year

3.7.2. Operating Costs

Operating costs are those expenditures incurred to engage in activities not directly related to the production of goods and services and are general or administrative in nature. For this specific project, the personnel costs and overhead were not incurred, and the project manager is estimated. For future projects, the rates and costs will need to be adjusted.

1. *Personnel*
    - Developers (3) at $30/hr x 45 hrs (# class hours (5) x 9wks) = $1350 each developer = $4050 total developer cost/year
    - Project Manager (PM) (1) at $45/hr x 52 hrs (1hr wk x 52 wks) = $2340 total PM cost/year

2. *Overhead*
    - Generally overhead is 3 to 11 % = Total capital costs / labor costs. However, at this time, there are no additional overhead fees our client would need to address

3. *Maintenance Fees*
    - The maintenance fees associated with this project are just ensuring necessary software is always accessible ; approximately $1300/month

4. *Utilities*
    - Wi-Fi connection ($45-month x per users (4) = $180/month
    - Electrical costs = Spokane commercial rate is $5.62kWh. The result of the calculation is $205.15-year x per user (4) = $820.60 year

5. *Supplies*
    - Temporary storage (flash drive) = $40 each x per user (4) = $160 once
    - Permanent storage (CD-ROM, DVD) = $50 x per user (4) = $200 once

3.8. Benefit-Cost Analysis

3.8.1. Estimated Cost Tables

The following tables were created based on the estimated project costs described above. Table 3 estimates total estimated cost for one year and breaks that down into the average monthly costs based on Cost Type.

Cost Type	Total Estimated Annual Cost	Average Monthly Cost
Database	$12,000.00	$1,000.00
Hardware	$11,700.00	$975.00
Software	$15,200.00	$1,266.00
Implementation	$400.00	$33.00
Utilities	$2,980.00	$250.00
Supplies	$360.00	$30.00
Labor	$6,390.00	$532.00

Table 3: Estimated Total Yearly Costs and Average Monthly Costs by Type

Table 4 is a more detailed summary of cost type for this project and breaks down individual monthly costs by cost type. These estimates are based on the level of work that a GIS Analyst may charge in conjunction with what our client organization already has access to.

Cost Type	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
Database	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00
Hardware	11,700.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Software	15,200.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implementation	400.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utilities	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00	248.00
Supplies	360.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor	645.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00

Table 4: Estimated Monthly Project Costs Projected for 1-Year

3.8.2. Cost Savings and Comparison Table

The next table shown is the cost savings table that was developed based on three different project levels. This cost savings table was created by reviewing table one and applying that to the actual cost of this project as students, the projected GIS plan developed, and adding a third tier which represents what the GIS plan would be replacing. For the actual project cost, our client only needs to pay for what their organization already pays for. The Tribal GIS enterprise account they are associated with, utilities, server, database and their current software. Since students are working on this, our labor is free, we already have access to our own computers and storage devices, and we are using our associated ArcGIS accounts with the University of Washington. Additionally, the data is all freely provided by other organizations or it was provided before the start of this project.

The GIS plan we have developed is based on table 3. The only difference is that there is a total estimated monthly cost based on the averages. The final addition to the cost savings table is what it may cost to manually do the field work and data collection. For our project, the most quantifiable benefit is the type 1 benefit of reducing field work and data collection times. We spoke with Conor about any financial planning they may have done, and he expressed that they had not considered financial costs and our estimates would suffice. The field work and data collection column maintains the cost of the Spokane Tribal Fisheries access to the Tribal GIS enterprise system with the hardware, software, utilities etc. but includes a new row for data collection. Now, field work and data collection costs were not as easily quantifiable due to time constraints, lack of involvement with the actual collection, and the varying cost of transportation, technicians, and equipment. To enumerate, we chose to utilize the average salary of a wildlife biologist, about $63,420, who would not be using GIS tools to quantify these costs. With that in mind, this is likely an underestimate of what level of field work would be required to accomplish what the tool was designed to achieve.

Cost Type	Actual	GIS Work	Field Work + Data Collection
Database	$1,000.00	$1,000.00	$1,000.00
Hardware	$-	$975.00	$975.00
Software	$1,266.00	$1,266.00	$1,266.00
Implementation	$33.00	$33.00	$33.00
Utilities	$250.00	$250.00	$250.00
Supplies	$-	$30.00	$30.00
GIS Labor	$-	$532.00	$-
Data Collection	$-	$-	$5,285.00
Total Monthly	*$2,549.00*	*$4,086.00*	*$8,839.00*

Table 5: Estimated Cost Savings for 1-Month

3.8.3. Payback Charts

These next two figures represent the payback accumulations for one year from the different plans discussed in the previous section. Both a 3-month comparison and a yearly comparison are shown between the three plans.

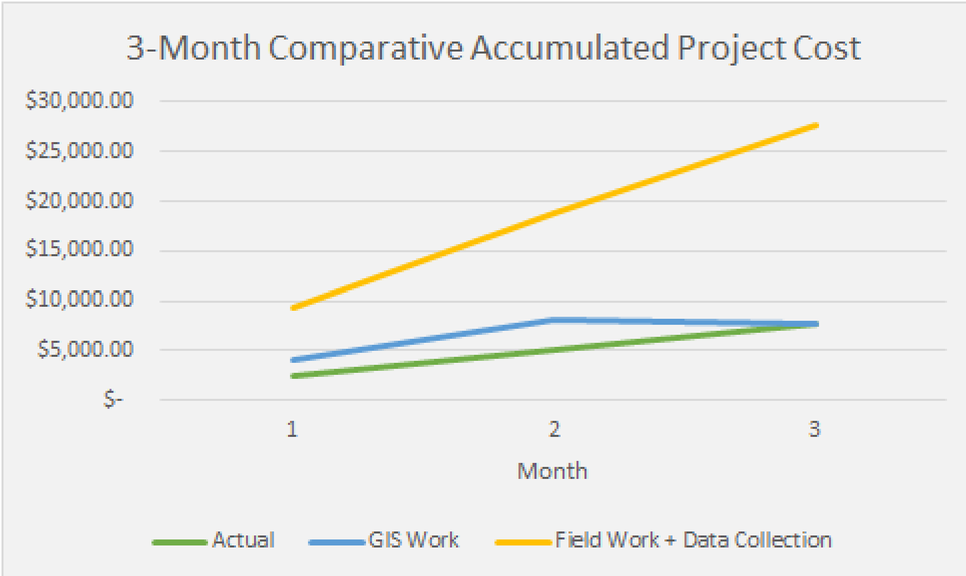

Figure 5: 3-Month Accumulated Project Costs

The actual costs and GIS work costs plan increase initially in the first two months and then accumulate steadily due to maintenance cost of the client organization. The field work and data collection has a higher starting rate and increase at a higher rate. Typically, field work ends for the winter months, so the drop in the yellow line in the yearly comparison chart shows a three-month lapse with the data collection costs.

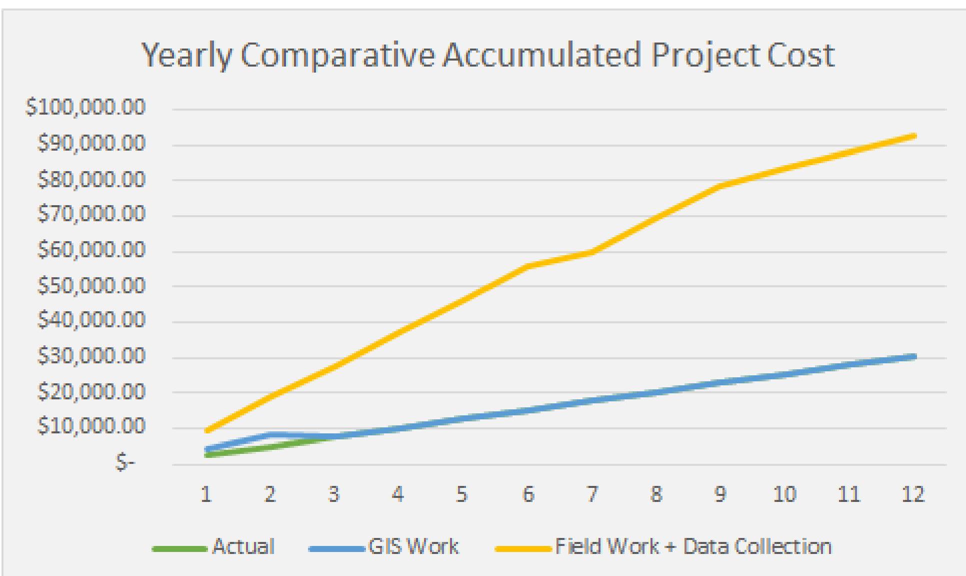

Figure 6: Yearly Accumulated Project Costs

3.8.4. Baseline Comparison Table and Chart

The baseline comparison table and associated chart represent the monthly total costs of the GIS plan and the field work and data collection plan. The GIS plan is the total monthly estimates and the fieldwork and data collection plan is based on no GIS labor costs but includes the cost of a wildlife biologist for one year - including the payback implications previously discussed. The GIS plan represents the benefits and the field work and data collection represent the cost.

	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20
Benefit: GIS Plan	$29,553.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00	$1,443.00
Cost: Field Work + Data Collection	$34,643.00	$6,533.00	$6,533.00	$6,533.00	$6,533.00	$6,533.00	$1,248.00	$1,248.00	$1,248.00	$6,533.00	$6,533.00	$6,533.00

Table 6: Benefit-Cost Comparison Table for 1-Year

Figure 7 shows a timeline of the difference of estimates for each plan. The current total costs are estimated to be $90,651.00 per year while the proposed benefit is estimated at $45,426.00 per year.

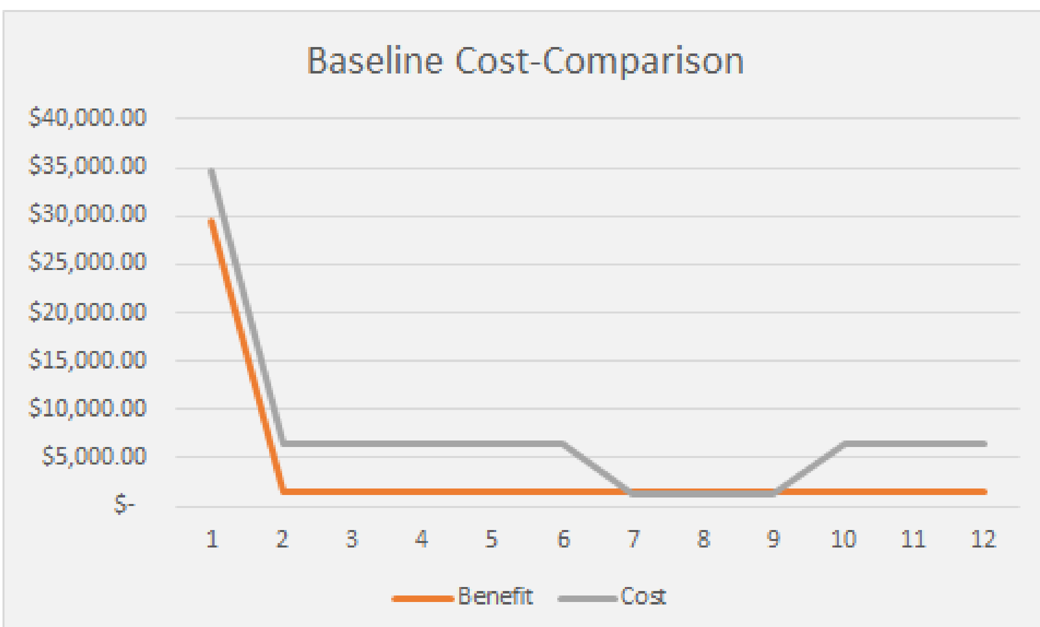

Figure 7: Baseline Cost-Comparison

4. Data Development

4.1. Data Acquisition

The data acquisition began with receiving the primary layers from Conor via email. They are the Western Native Trout Initiative layers for streams and water bodies and intrinsic potential output. All additional layers were downloaded from multiple public and private sources including the Bureau of Land Management, Washington Department of Fish and Wildlife, Washington Department of Natural Resources, Washington Department of Transportation, Bureau of Indian Affairs, National Oceanic and Atmospheric Administration, the Spokane Tribe, US Geological Survey, Bonner County, and Kootenai County.

4.2. Data Quality

In terms of the data, some of the challenges included downloading data from multiple GIS portals with government agencies in two separate states, Washington and Idaho. Data standards and expectations were different between the states and the counties. In particular, the land use layers that can be used for analysis and reference in the application, do not have universal standards for land use or zoning. The study area of the Spokane sub-basin goes into three separate Idaho counties. While Washington has a statewide layer for land use, Idaho does not. Two out of the three Idaho counties have some kind of land use or zoning layer, but Benewah county where the Coeur D'Alene Reservation is located, does not have any kind of zoning regulations and therefore, no available land use GIS data.

4.3. Data Preparation

Preparing the data focused on making the data ready for the AGOL platform and its limitations, which will be discussed in later sections. Using ArcMap 10.6, the selected feature classes were clipped to the study area of the Spokane sub-basin. Additional geoprocessing included reclassification, creating a tool for ideal habitat areas, and changing attribute fields. Ideally, we intended to keep the number of attribute fields to a minimum so that the application user does not feel overburdened by technical or esoteric information. Symbology, visibility extent, and labeling were all performed in the AGOL platform.

4.4. Database Schema

Data File Name	Data Sources	Spatial Object Type	Attribute Field
Intrinsic Potential Output (IntrinsicPotentialOutput)	National Oceanic & Atmospheric Administration (NOAA)	Line	STHDRATE: 2 (Moderate), 3 (High)
Subbasins Upper Columbia River (Subbasins_UCR)	Spokane Tribe	Polygon	Sub-basin: Spokane
WDFW Fish Passage Barriers (WDFWFishPassage)	Washington Department of Fish and Wildlife	Point	FeatureType: Culvert, Dam, Non-Culvert Xing, Other
Western Native Trout Initiative Trout Distribution (WNTI_CurCist)	Western Native Trout Initiative	Line	GeneticSta: <1% Unaltered, >1%-10%, Not Tested - Suspected Unaltered

Table 7: Overview of Database Schema

4.5. Descriptions of Attribute Tables

The following table is an example of how attribute tables for the different key layers are presented. The layer used here is the Sub-basins Upper Columbia River (Subbasins_UCR) polygon. It shows the field names for each attribute, the type of data, the length of the data, and the decimal place as needed. For the full list of layers with descriptions of the attributes, refer to Appendix C.

Field Name	Data Type	Length	Decimal Position
ObjectID	Long	10	---
Subbasin	String	50	---
Shape_Length	Double	0	0
Shape_Area	Double	0	0

Table 8: Spokane Sub-basin Attribute Table Description

4.6. Metadata Descriptions

4.6.1. Intrinsic Potential Output

A relative ranking of fish habitat quality for anadromous fish using preference curves and a geometric mean approach, based on Burnett et al. (2007). The tools can use default parameter values for Coho (Oncorhynchus kisutch), steelhead (O. mykiss) (Burnett et al.

2007), and Chinook salmon (O. tshawytscha) (Busch et al. 2011). In NetMap's 'Create Aquatic Habitat' Tool, a user selects a field name for the model output. Current options include: 1) habitat intrinsic potential_species (i.e., species specific including Coho, steelhead) based on the approach developed by Burnett et al. 2003, 2007. Other predictions can include biological hotspots and habitat sensitivity.

4.6.2. Sub-basins Upper Columbia River

This layer depicts the different sub-watersheds of the Upper Columbia River. For the location and scope of this project, the Spokane sub-basin was the extracted feature for the other layers to be clipped to.

4.6.3. Washington Department of Fish and Wildlife Fish Passage Barriers

These data are used to identify, locate, and prioritize correction of man-made barriers to fish passage. Identifying and correcting fish passage barriers is a key component of salmon and other anadromous fish recovery. The data may be used by any group interested in salmon and habitat recovery. These data are also used to track where inventory efforts have occurred.

4.6.4. Western Native Trout Initiative Trout Distribution

This layer identifies current distribution of redband trout in streams. Current distribution was based on site specific information and professional judgment related to the presence of redband trout. The intent was to make the determination of current redband trout distribution as objective as possible. Only those redband trout that were supported by natural reproduction were included. These self-sustaining redband trout may be the residue of aboriginal stocks or they could have been the result of population restoration. Streams determined to be currently occupied were either treated in total or subdivided into stream segments. Each stream or stream segment was attributed with a standard set of characterizations. Those characterizations included: information on "life forms" (either non-anadromous, anadromous or mixed), information on fish stocking, redband genetic status, population density, a determination of habitat quality, and, presence of non-native fishes. Each currently occupied lake was treated as a single independent habitat segment. Attributes associated with lakes included: "life form" (either non-anadromous, anadromous or mixed); information on fish stocking; redband genetic status; population abundance; and, presence of non-native fishes.

5. Workflow Implementation

5.1. Creating A Workflow Process

In order to develop a workflow, the first step is brainstorming what will be produced based on the needs and wants from the community partner. Using our objective-based information categories and starting to conceptualize provided data, we established a "to-do" list for each information category:

- Redband Trout Population Location
  - Investigate the WNTI data set
  - Evaluate the species hybridization within the WNTI data set
  - Create priority stream reaches with low genetic hybridization populations
  - Create priority stream reaches with low hybridization and moderate or high habitat ratings

- Habitat Quality Assessment
  - Investigate the Intrinsic Potential data set
  - Evaluate the moderate and high habitat ratings in the Intrinsic Potential data set
  - Create priority stream reaches with moderate or high habitat ratings
  - Create priority stream reaches with low hybridization and moderate or high habitat ratings
  - Identify conservation areas vs. restoration areas based on land use

- Fish Barriers
  - Investigate the WDFW data set
  - Evaluate the barriers for passage or access
  - Create priority areas with barriers isolating or preventing access
  - Create priority areas with barriers or access issues that correspond to the low hybridization, with moderate or high habitat ratings
  - Identify conservation areas vs. restoration areas based on land use

5.2. Objective-Based Workflow

From there, we were able to detail initial workflow setups for each objective since we had previously sorted the objectives into the appropriate information categories. In order to create the final product, the objectives (need-to-know questions) needed to be answered. For each objective, we have created a unique workflow that helped us to answer each question. We chose to create data flow diagrams for this step. Objectives 1-5 are similar questions that the client needs to answer. Objective 6 is used to demonstrate how other contextual layers can be added for the creation of a comprehensive product.

5.2.1. Objective 1

Answering the question presented in objective 1 requires data processing of the WNTI dataset. This contains information on genetic hybridization of redband trout. The habitat areas of low genetic hybridization are characterized by the fields 'GeneticSta' and 'NonNative'. A SQL Query pulled out the 'Not tested - suspected unaltered' and 'Unaltered (<1%)', and '>1-<10%' categories from the 'GeneticSta' field, and 'None' or 'Unknown" from the 'NonNative' field, to depict the habitat areas with the lowest hybridization of redband trout. After the new feature class was created, the shapefile is exported into a separate folder and zipped for uploading to the UW AGOL platform.

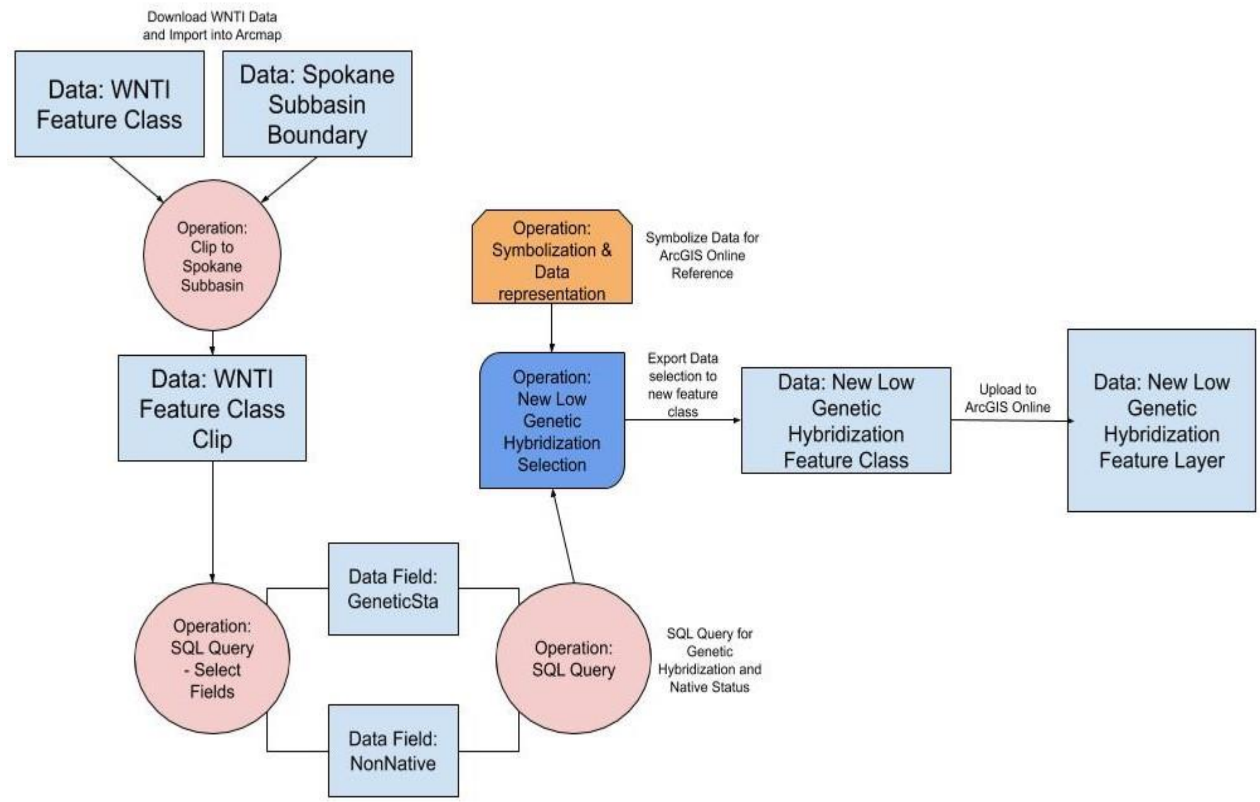

Figure 8: Objective 1 - Where are areas of relatively low genetic hybridization of redband trout?

5.2.2. Objective 2

Similar to the previous workflow, objective 2 focuses on the intrinsic potential dataset. In ArcMap, the intrinsic potential shapefile is clipped to the Spokane Sub-basin boundary. Then, a SQL query for intrinsic potential moderate and high areas or values 2 and 3 is run for the STHDRATE field, creating a selection from the feature class. The SQL query is as follows: 'STHDRATE IN (2 , 3)'. Once the new layer is created with the selected data, the shapefile is then exported into a separate folder and zipped for uploading to the UW AGOL platform.

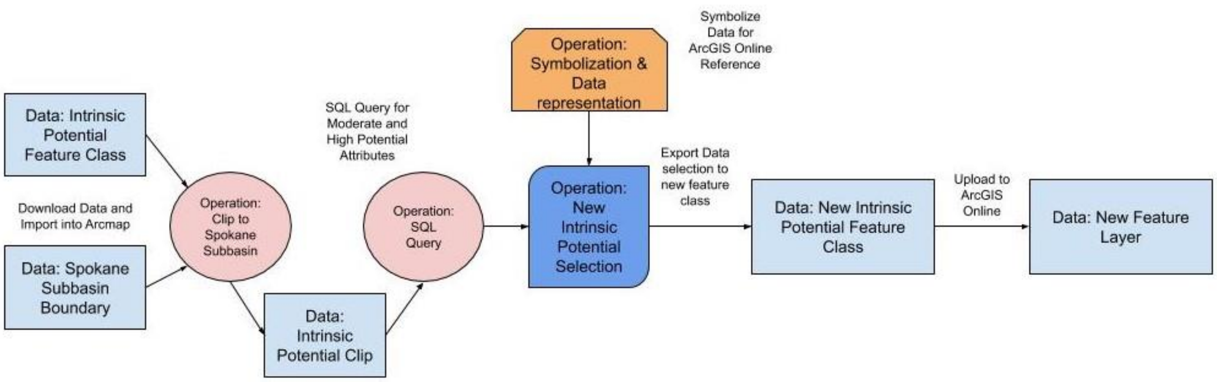

Figure 9: Objective 2 - Based on the "Intrinsic Potential" dataset, where are areas of moderate and high habitat ratings?

5.2.3. Objective 3

Objective 3 workflow focuses on the locations where genetic status is poor, but the habitat is moderate to high. The WNTI dataset has a field called 'HabitatQua' that rates quality of habitat as 'Unknown', 'Poor', 'Fair', 'Good' and 'Excellent'. The Moderate habitat rating areas could be selected as 'Fair' and 'Good'. The 'Excellent' habitat rating areas could be selected as high. This becomes a New Habitat Quality Selection. It can be clipped to the Spokane Subbasin. The New Low Genetic Hybridization Feature Class and the New Intrinsic Potential feature class can be combined with the New Habitat Quality Selection. As previously stated, the new shapefile is exported into a separate folder and zipped for uploading to the UW AGOL platform.

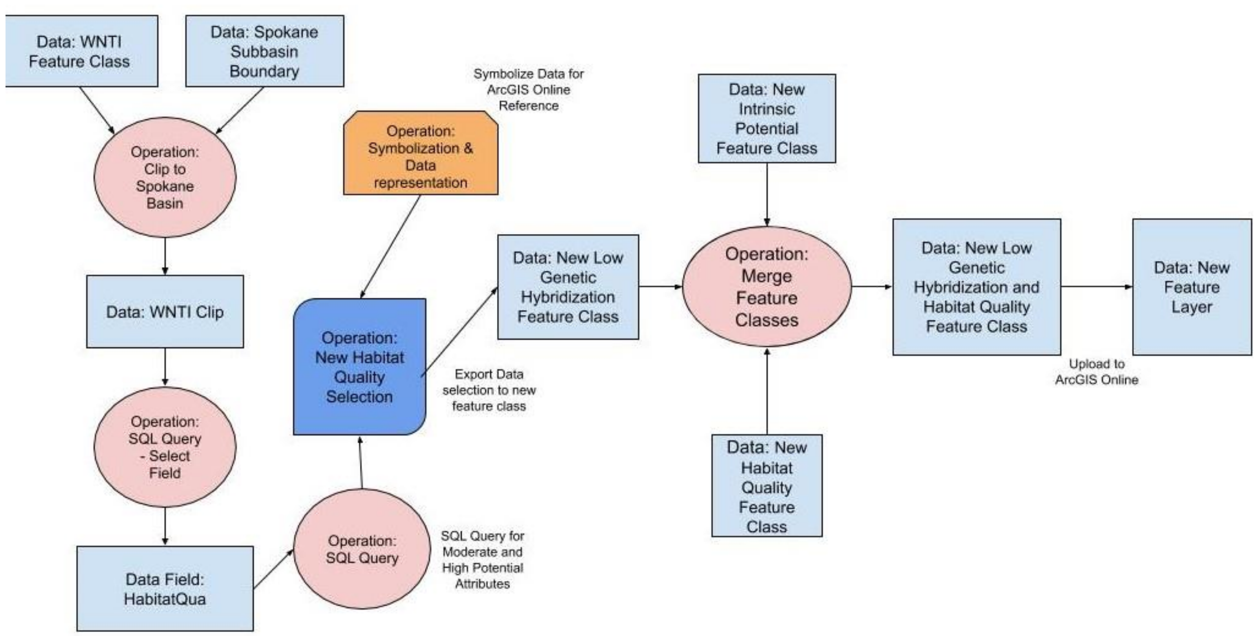

Figure 10: Objective 3 - Where do areas of relatively low genetic hybridization of redband trout overlap with moderate and high habitat rating areas?

5.2.4. Objective 4

Our sponsor expressed interest in fielding the fish barriers, especially the fish barriers that are the result of anthropogenic activity. The workflow for objective 4 focuses on distinguishing between natural and man-made barriers using the WA Department of Fish and Wildlife (WDFW) Fish Passage Barrier dataset instead of the WA Department of Transportation dataset, as the latter is not as comprehensive. Since the WDFW dataset is so extensive, the need to filter, reclassify, and recategorize the data is the main geoprocessing task shown above. Querying/select by attribute, field calculator, symbolizing, simplifying and exporting the data are the leading operations for this dataset to shape it to our project's needs. The final result is a simplified dataset that can be imported to the UW AGOL web-tool.

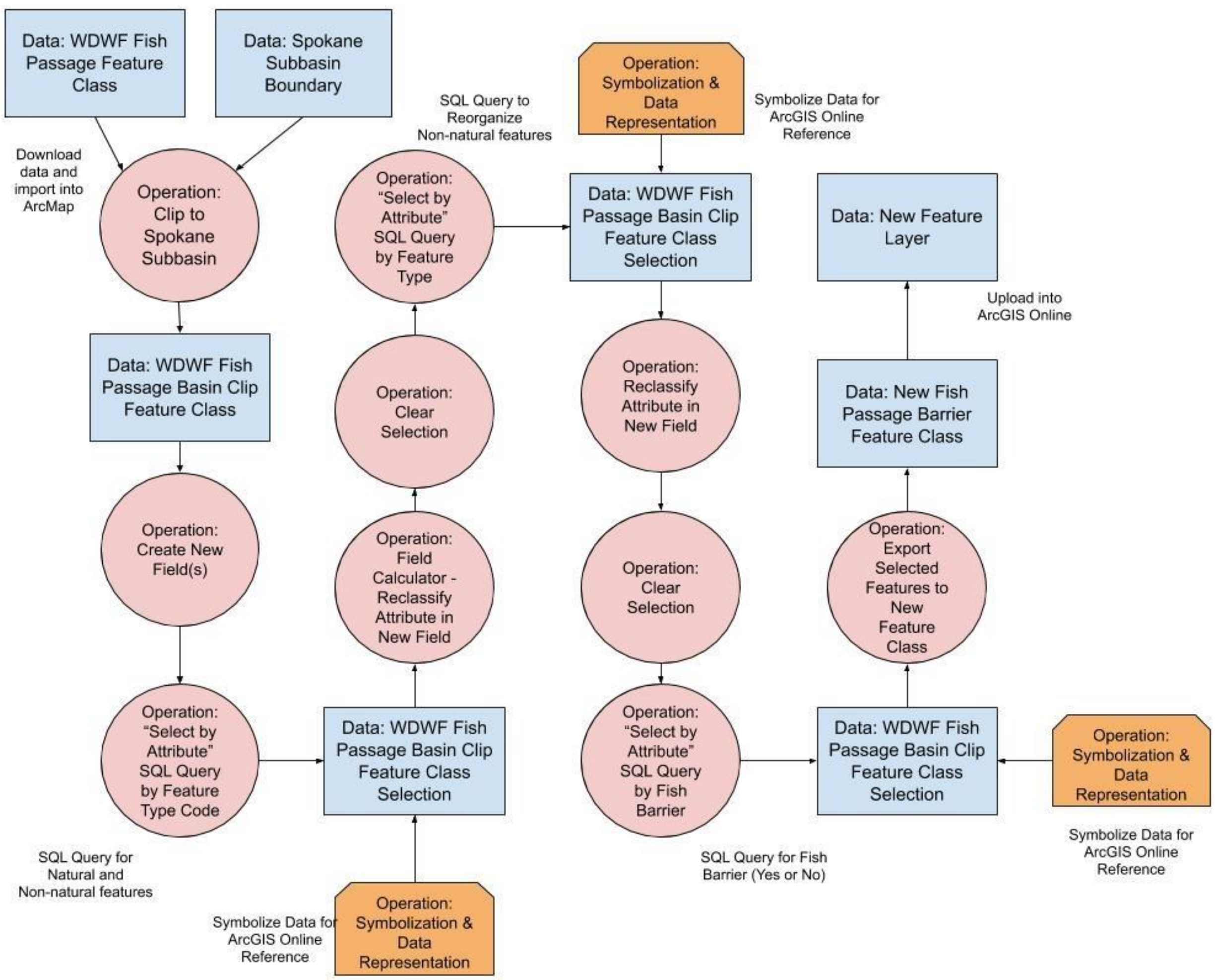

Figure 11: Objective 4 - What types of barriers are preventing redband trout access to moderate and high habitat rated areas?

5.2.5. Objective 5

The objective 5 workflow combines two derived datasets that helped to answer previously listed objectives. The first step is using the new Intrinsic Potential Feature Class and creating a buffer around it. The buffer is used as a safety-net for what is being modeled with the data for the real-world since the datasets being derived were not collected from the same groups and it increases the reach of moderate and high habitat areas. The distance of the buffer is yet to be determined with the client. Once the buffer is created, the new buffer layer and the newly created Fish Passage Barrier are combined using the intersect tool. This will isolate areas where the fish barriers are located in areas of moderate and high habitat ratings. The final result is a new feature class: Fish Barrier - Habitat Ratings that can be uploaded into AGOL as a new feature layer.

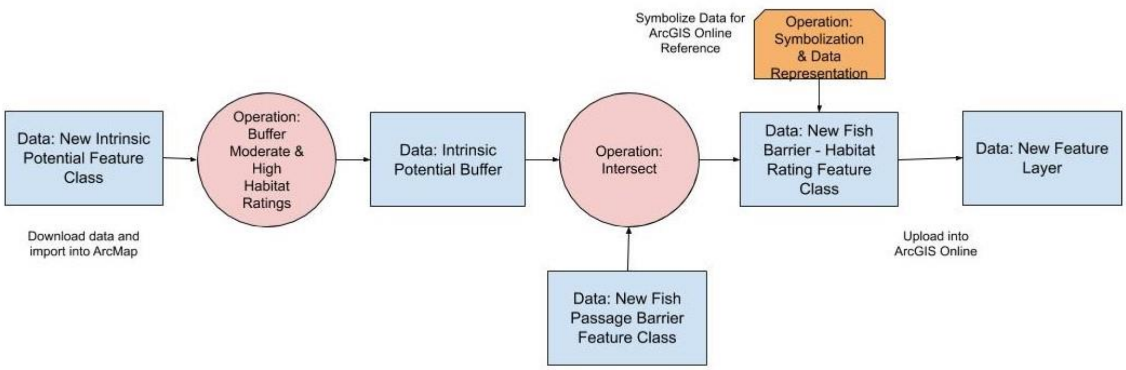

Figure 12: Objective 5 - Where are the barriers located that are preventing redband trout access to moderate and high habitat rated areas?

5.2.6. Objective 6

The last objective workflow shows datasets that are not necessary for the basic creation and use of the web-application, but they offer an enhanced level of context that cannot be provided with just the datasets that complete the first five objectives. Since the final product is going to be viewable to the public and possibly used by different organizations, it is important that there is enough supportive information to complete the entire picture. Being able to look at these layers and have them available on the web-application will allow for a complete, all-in-one product. The workflow outlined above is simple and is intended to refine the data to fit the needs of this project. The main operations are clipping and refining the attributes. The final feature layers will be uploaded to the AGOL web-application.

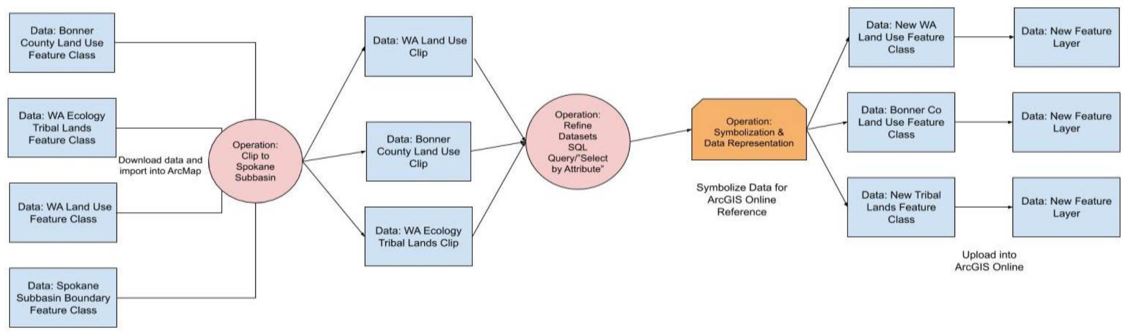

Figure 13: Objective 6 - What datasets offer context to the final product?

5.3. Final Priority Habitat

Once we started the data geoprocessing, we followed most of the steps we had created in the above workflows. We simplified and condensed steps as needed and as they made logical sense while working in ArcMap. The final result in ArcMap was the Final Habitat Priority shapefile. Figure 14 below outlines the steps taken prior to zipping the shapefile and associated files into a folder to be uploaded onto the AGOL platform.

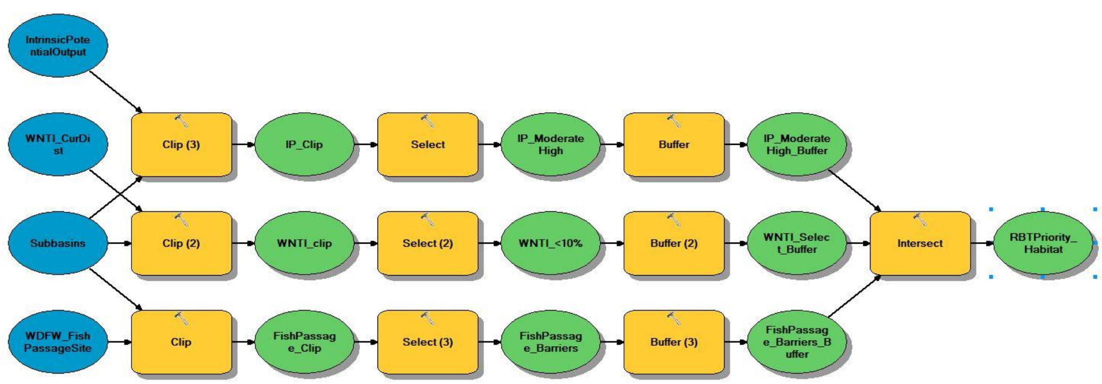

Figure 14: Final Priority Habitat Workflow - Take 1

However, once the layer was uploaded, we realized it needed to be improved so that the community partner and others who may use this prioritization tool would be able to easily see the parameter differences among the various locations. We decided to utilize a “good, better, best” approach for the priority locations and instead created 6 individual layers that followed the same workflow except for the attribute queries. The final result was a merged polygon showing the different habitats and different criteria. Figure 15 shows the standard workflow used in creating each criteria combination . The following list iterates which criteria combinations were created:

1. High IP, Unaltered Genetic Status, Man-Made Fish Barriers
2. High IP, >1% - <10% Genetic Hybridization Status, Man-Made Fish Barriers
3. High IP, Suspected Unaltered Genetic Status, Man-Made Fish Barriers
4. Moderate IP, Unaltered Genetic Status, Man-Made Fish Barriers
5. Moderate IP, >1% - <10% Genetic Hybridization Status, Man-Made Fish Barriers
6. Moderate IP, Suspected Unaltered Genetic Status, Man-Made Fish Barriers

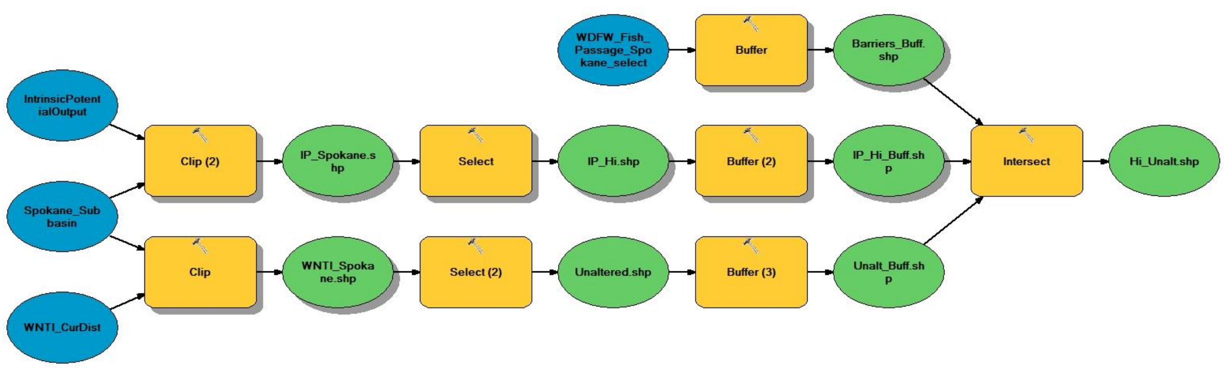

Figure 15: Final Priority Habitat Workflow - Take 2

5.4. Working in ArcGIS Online

It is important to reiterate that nearly all data processing occurred in ArcMap before the data was uploaded onto the AGOL platform. Each of the datasets in Table 9 were clipped to the Spokane Sub-basin boundaries and uploaded to the University of Washington AGOL platform. Once these layers were all uploaded as feature services, they were placed in a web map for further customization with symbology, layer visibility and labeling.

The table below provides an overview for the data that is currently being used in the application in chronological order:

Data	Data Description
Spokane Sub-Basin	Spokane Sub-basin boundaries of Upper Columbia River basin.
Redband Trout Priority Habitat	Model output layer showing ideal habitat areas for Redband Trout.
WA Township PLSS	Washington State Public Land Survey System Township and Range in Spokane Sub-basin
WA Sections PLSS	Washington State Public Land Survey System Sections in Spokane Sub-basin
ID Township PLSS	Idaho State Public Land Survey System Township and Range in Spokane Sub-basin
ID Sections PLSS	Idaho State Public Land Survey System Sections in Spokane Sub-basin
Washington Department of Fish and Wildlife (WDFW) Fish Passage Inventory	WDFW's point file for fish passage barriers near water sources
Western Native Trout Institute (WNTI) Stream Fish Distribution	WNTI's fish distribution genetic status for various streams and rivers in the Spokane sub-basin
WNTI Waterbodies Fish Distribution	WNTI's fish distribution genetic status for various water bodies in the Spokane sub-basin
Intrinsic Potential Output	Northwest Fisheries Science Center and Spokane tribe of Indians model output for habitat potential in various streams and rivers
Department of Natural Resources (DNR) Land	Washington DNR State Ownership
Idaho and Washington Reservations	Native American Reservation boundaries in Washington and Oregon
Non-DNR (Federal, State, County, and City) Public Land Ownership	Federal, State, County and City land ownership layer
Spokane Sub-basin National Hydrology Dataset (NHD)	USGS NHD data for streams and rivers
Spokane Sub-basin National Hydrology Dataset (NHD) Water bodies	USGS NHD data for water bodies
Spokane National Land Cover Dataset (NLCD)	NLCD land cover data within the Spokane Sub-basin
Bonner County Land Use	Land use and zoning layer for Bonner County, Idaho
Kootenai County Zoning	Kootenai County, Idaho Zoning layer
Washington land use	Washington State-wide land use layer
Hydrologic Unit Codes (HUC) 8 Units	HUC units or primary watershed boundaries in the Spokane sub-basin boundaries
HUC 10 Units	Smaller watershed boundaries of Spokane Sub-basin
HUC 12 Units	Smallest watershed boundaries of Spokane Sub-basin

*Table 9: Feature Layers in Web-Tool *Datasets with primary layers in white and additional/reference layers in gray*

Compared to ArcMap and ArcPro, symbolization is very limited in the AGOL platform, so we had to determine the best symbolization for the app within the web map. Once all the layers were added with proper labeling and symbolization, layer visibility for various layers were customized based on the number of features in a layer and its importance. For example, the land use layers are easier to understand at a larger, county to city scale rather than a smaller regional scale. The layers were also prioritized based on client feedback that determined which layers were necessary for the applications purpose and which were not necessary or will only be for additional reference. As seen in the dataset table, the colors show which were prioritized as primary or not. The non-primary layers were turned off in the web map layer list, which means users would have to manually turn on those layers in the application.

The web map was turned into a web application using the ESRI Web Appbuilder. It provides several tools, or widgets, to support the application purpose for Habitat Prioritization. These widgets proved to be resourceful towards the application purpose for Redband Trout Habitat prioritization. This application builder is a JavaScript API, although coding is not necessary with the various templates. Web maps are the foundation for the builder which allows users on an AGOL platform to create a web application with various tools for analysis and templates for application design. There are multiple template themes based on certain data analysis purposes and map presentation. We choose a common theme seen in multiple government agency AGOL apps-the tab theme. This is a simple, yet effective, design allowing users to focus on a web map with various tools and resources in links and tabs. The tools, or widgets, we choose for this app are as follows:

1. *Information tab*- overview of application purpose a user guide on widgets, data information and Spokane tribe fisheries staff contact information.
2. *Legend tab*- straightforward legend displaying symbology of active layers.
3. *Layer tab*- List of layers that the user can turn on or off.
4. *Basemap tab*- offers the user multiple ESRI basemap options
5. *Add data tab*- A widget that allows users to upload data from an AGOL platform or a computer.
6. *Draw tab*- Users can draw a point, line or polygon around an area or interest.
7. *Bookmark tab*- five listed locations that zoom to the stated geographic areas.
8. *Query Tab*- Users can query the four primary redband layers to highlight or select features based on a set SQL query.
9. *Print tab*- creates a custom map of a zoomed area with all basic map features.

The application went through a few iterations after the client provided feedback on the visible and primary layers. In the first iteration, the watershed Hydrologic Unit Codes (HUC) from USGS broke down from the three primary watersheds in the Sub-basin to multiple, smaller watershed units as the user zooms further into the web map. Conor provided feedback about only having the three primary watersheds visible as he did not think the smaller HUC units were necessary. The smaller HUCs are still on the application for additional layers, but the user must turn them on in the layers tab. Three links to supporting documents and websites were included in the application for further background about the Red Band Trout. These include the US Forest Service Conservation Plan, Western Native Trout Institute (WNTI) Current Status report on the Species, and the WNTI website on Redband trout species information. The documents are meant to provide additional information regarding the Redband Trout for all stakeholders and anyone interested in the species.

6. Results

6.1. Findings

The final result of this project is an AGOL tool that can be used to visualize redband trout presence (Figure 16), habitat blockages (Figures 17 and 18), genetic hybridization, and potential prioritization opportunities (Figure 19). When we initially started the development of this tool, we had an idea of what data would be relevant or helpful for the tool as a resource for the Spokane Tribe. As the project went further along, we had to eliminate certain datasets and processing steps based on data availability, data necessity and the client needs. For example, as previously mentioned in the processing section, we initially wanted to include raster datasets such as the USGS National Land Cover Dataset and National Agricultural Imagery (NAIP), but with the presence of high-resolution imagery base maps in the tool, the NAIP imagery were not necessary. The NLCD data was converted from a raster to a shapefile and remains in the application as a secondary layer for reference. As we discussed in the processing plan, the necessary data was geo-processed in ArcGIS Desktop 10.6 using operations like clipping, reclassification, and simplifying attribute table fields. Once these operations were complete, the data was uploaded to the Processor's University of Washington AGOL account and shared in the project AGOL workgroup with the other group member's accounts as well as the clients.

There were a number of successful outcomes during the making of this application, such as making it functional and user-friendly so that a non-GIS layperson can understand how to use the tool. Each group members had friends, family, and work colleagues with GIS experience ranging from professional to none view and test the application. Overall, they were pleased with the functionality of the application, but did not understand some of the layer names. In response, most of the layers were renamed to make them somewhat understand to a non-GIS layperson, such as HUC unit layers renamed "HUC Watersheds". The primary redband layers-WNTI layers, fish barrier inventory, and intrinsic potential-are named as is since they are mentioned in detail in the disclaimer and information tab. Additionally, the disclaimer text about how to use the application and its data, was changed a bit to make the text bigger and no transparency in the pop-up window to make it readable. It is recommended that the development of any AGOL application be tested by both professional and lay people to make the tool better and easier to understand. Feedback from stakeholders regarding the software would be helpful to keep the application user friendly and functional into the future.

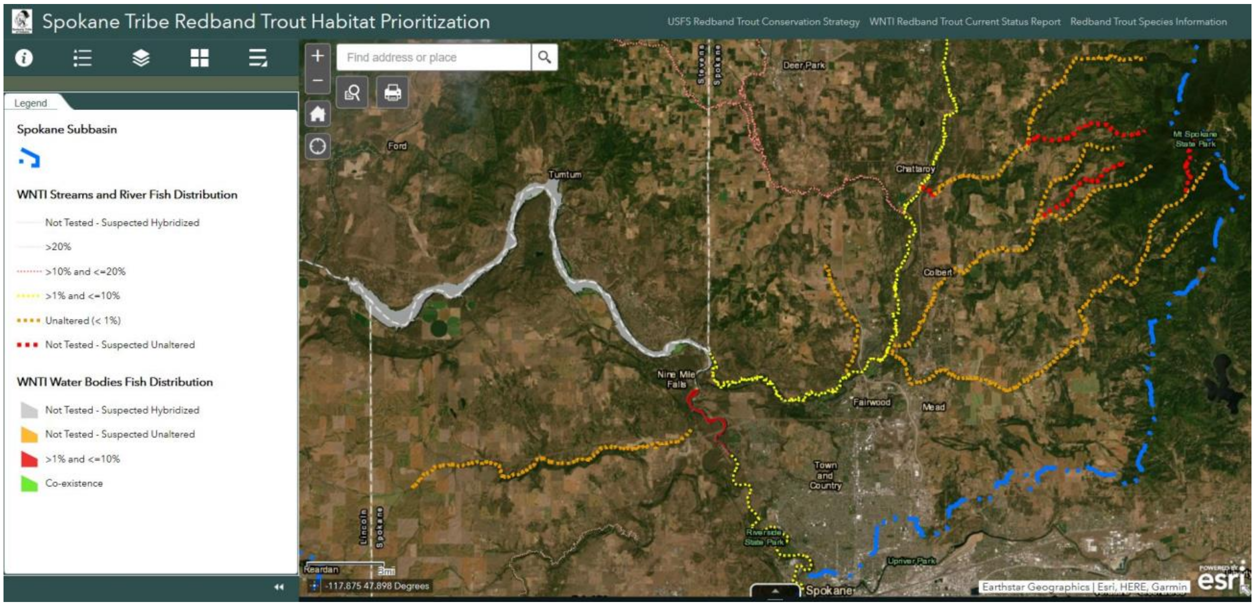

Figure 16: Known Redband Trout Species Distribution

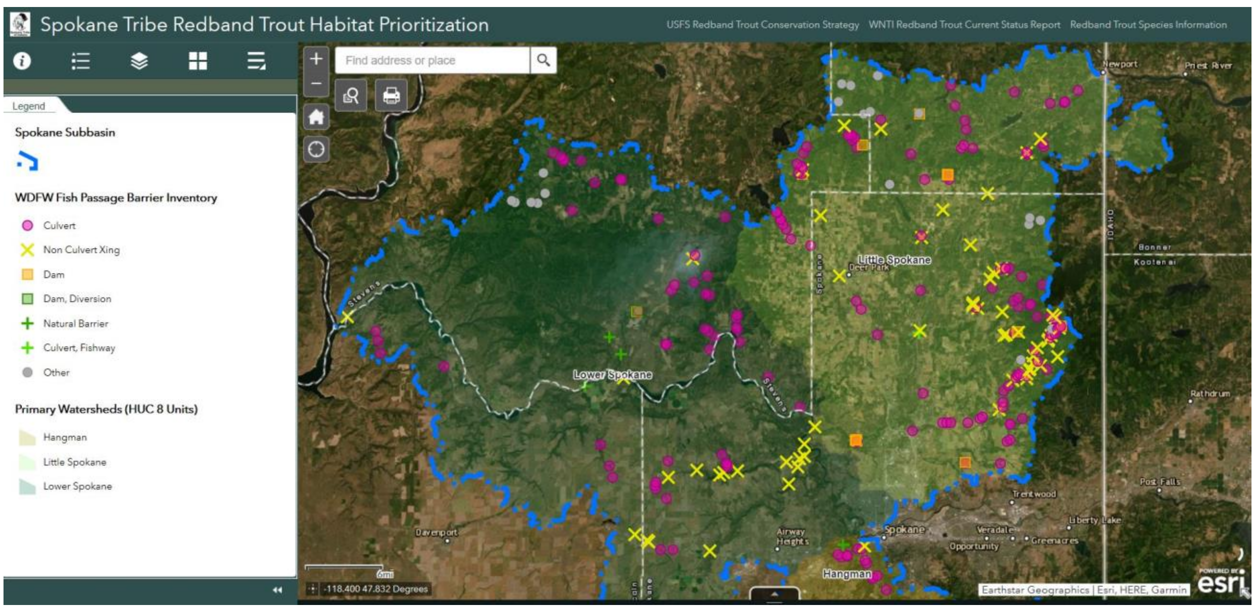

Figure 17: Lower and Little Spokane Sub-Basin Fish Barriers

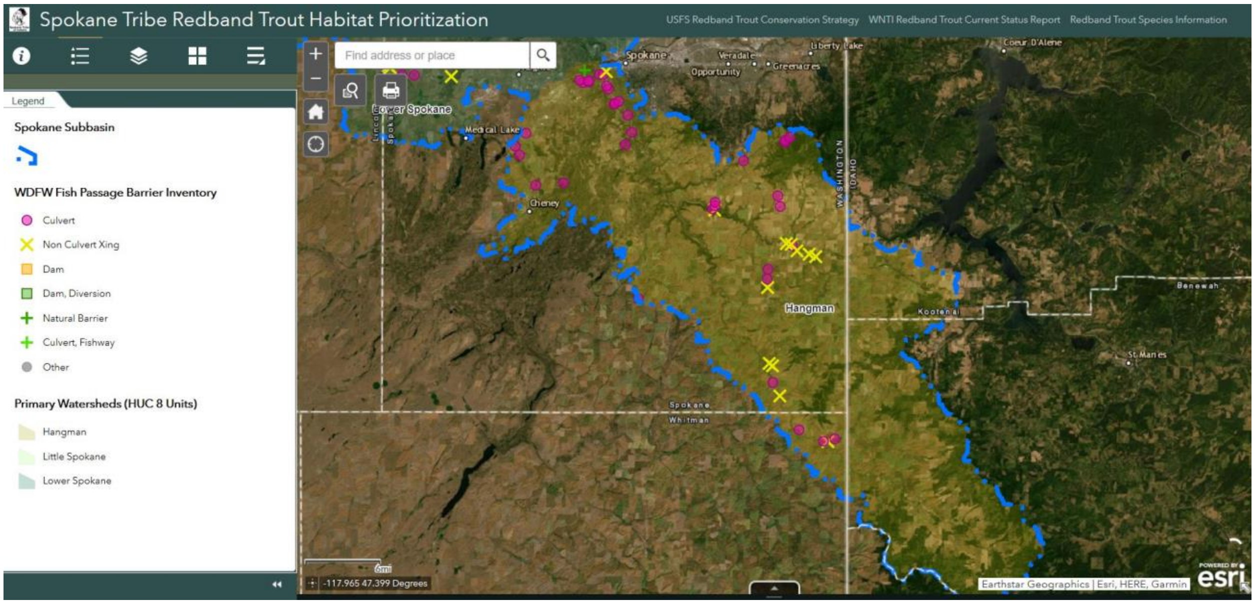

Figure 18: Hangman Sub-Basin Fish Barriers

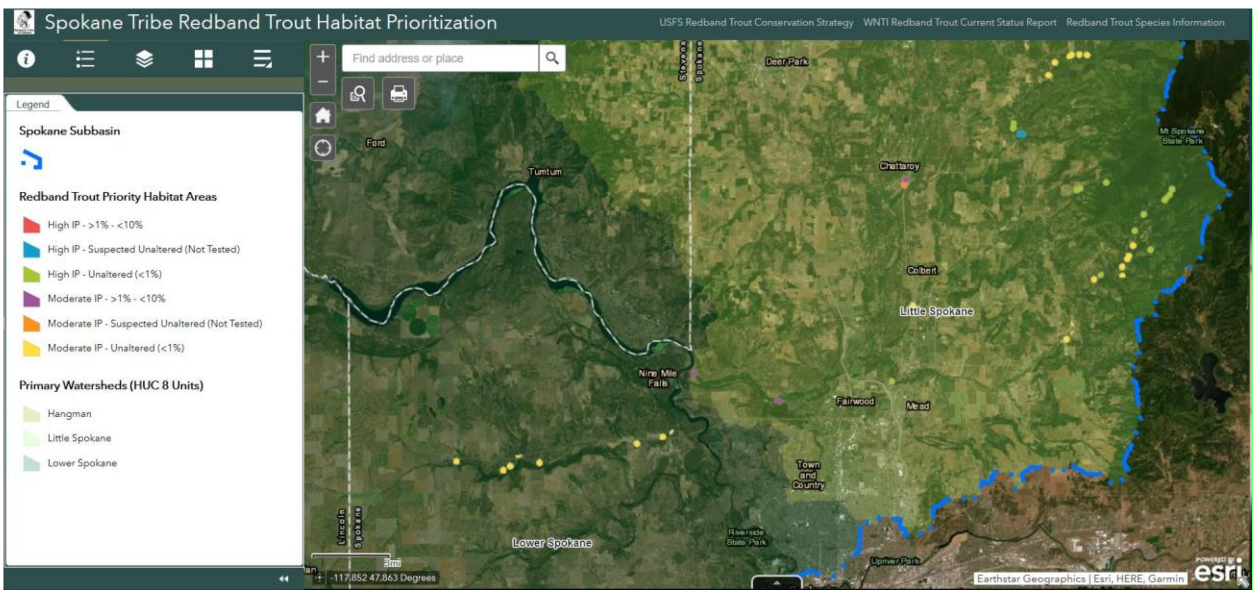

Figure 19: Redband Trout Prioritization Opportunities

6.2. Discussion

Our main challenge, at the time of writing this report is still to transfer over control to the community partner so their staff can change and update the application in the future. We do have a few methods for transfer, but the tribe has a limited amount of resources with AGOL platforms. ESRI does have a tool for cross platform actions on AGOL called the ArcGIS online assistant. It allows for different actions to migrate feature services, web maps and applications to separate organization AGOL platforms and accounts. The tool options include changing the URL of each data element and copying elements from one account to another account on a separate organizational platform. However, the Spokane Tribe does not necessarily have its own AGOL platform and according to our email exchanges with our client contacts, they operate through the National Tribal Geographic Information Support Center (NTGISC). NTGISC is a centralized GIS organizational service specifically for tribes, universities and other organizations. At the time of writing this report, we have contacted NTGISC on how to proceed with the transfer.

7. Conclusions and Recommendations

7.1. Conclusions

Most likely, ArcGIS Pro will be the standard in the near future for any GIS work on an ESRI platform, which does integrate with AGOL a bit more seamlessly than ArcGIS Desktop. Users and developers will need to know how to use the new software in the future, especially with the AGOL platform. Any additional updates for the application that could make it better with newer iterations of AGOL or any ESRI software is highly recommended to keep up to date with future technology. Finally, the transfer of the application should be tested with the AGOL assistant before any permanent changes are made to the application. There are several components including multiple feature services and the web maps that come with the application, so testing the transfer with minor feature services would be highly recommended before the full migration.

The sponsor provided a clear concept to initiate this project with a visual prototype and many data resources. This report presents an in-depth usability reference for the methodology, process, and implementation involved in the development, the technical use, and suggestions for future modification of the prioritization tool.

The end product is a useful tool for visualization of redband trout watershed extent and habitat quality. The web app produced the desired outcome which is a method for creating a composite habitat prioritization layer.

7.2. Recommendations

The key recommendations for future endeavors include identifying data gaps, improving data, refining restoration priorities, and working on a comprehensive management plan for redband trout.

The reaches that were previously studied had good data. However, some of the data for the watershed sub-basin was old, incomplete, or non-existent. It is recommended that the quality and quantity of the data be improved, then integrated into this tool. Ideally, this tool will set the stage to identify the data gaps and fuel the discovery of new data and funding sources for habitat restoration. Visualization of the existing data may fuel the need for a comprehensive management plan for the redband trout.

The tool is expected to be used by Spokane Tribal Fisheries upon completion of this report and modified over time as new data and perspective is compiled by stakeholders. This tool will provide a platform and visual baseline for management for redband trout resources. This platform may be useful for planning management efforts for redband trout in the Spokane Watershed sub-basin.

7.3. Lessons Learned

One primary lesson learned through embarking on the production of this tool is that open communication with the project manager and project team is key to producing a useful GIS visualization tool. Identification of clear goals and parameters for the topic is also an important lesson. The scoping process should be thorough up front to set the stage for a smooth transition from each step through the work process.

For the long-term management of the application, keeping the data up to date with fish passage barriers or any additional data that can help with habitat prioritization would be helpful. Any additional updates to the data layers from the various GIS portals will also need to stay updated. Also, some further development of the application using the developer version of the Web appbuilder can help make the tool more user-friendly. For example, with the information tab providing a user guide to all the widgets, each logo for the widget should link to the widget tool. So, if a user reads about the draw tool, ideally, they can click the logo and the tool will open. For any other development features, it would be recommended to use the developer version of the Web App builder. Most likely, the developer will need to have some level of skills with JavaScript coding. As for the application transfer, we a suitable platform where the tribe will have consistent access to the tool with full management capabilities, such as updating data. The potential platforms we discussed in the previous section included the NTGISC and potentially USGS, but those options are still up in the air.

To summarize, the key lessons learned are:

- Open communication with the project manager and project team is key to producing a useful GIS visualization tool
- The scoping process should be thorough up front with clear goals and objectives
- Identifying software and hardware needs, and transfer of data pathway is important

8. References

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9. Technical Appendices

9.1. Appendix A: Redband Trout Species Account

From the Spokane Tribal Fisheries Website:
Redband trout are a group of three recognized subspecies of rainbow trout (*Oncorhynchus mykiss*).[1] They occur in three distinct regions in Pacific basin tributaries and endorheic basins in the western United States. The three subspecies are the Columbia River redband trout (*O. m. gairdneri*), the McCloud River redband trout (*O. m. stonei*) and the Great Basin redband trout (*O. m. newberrii*).

The Columbia River redband trout is found in the Columbia River and its tributaries in Montana, Oregon, Washington and Idaho. Anadromous populations of *O. m. gairdneri* are known as redband steelhead. The McCloud River redband trout is found in small tributaries of the McCloud River and Pit River which are tributaries of California's Sacramento River. The Great Basin redband trout is found in seven distinct basins in southeastern Oregon, and parts of California and Nevada on the periphery of the Great Basin.[1] Redband trout have often been confused with cutthroat trout (*Oncorhynchus clarki*). Redband trout are prized game fish.
https://en.wikipedia.org/wiki/Redband_trout

Redband trout are generally similar in appearance to the coastal rainbow trout (*O. m. irideus*) but have larger, more rounded spots, parr marks that tend to remain into adulthood, are more orange-red around the lateral line and have very distinct white tips on the anal, dorsal and pectoral fins. They will exceed 10 inches (25 cm) at maturity, which they reach within three years. The redband trout subspecies find their ideal habitat in clean, cool, relatively small and low gradient streams, but are capable of enduring higher water temperatures (75–80 °F; 24–27 °C) than other trout that may co-habit the same streams. As with other trout, they feed on insects, crustaceans and forage fish, depending on their size.

The Washington Department of Fish and Wildlife (WDFW) consider the Redband trout to be a sentinel species and a barometer of aquatic health. Redband trout are prized game fish, and is a keystone species for a thriving recreational fishery. https://wdfw.wa.gov/publications/01711

The US Fish and Wildlife Service webpage for redband trout was last updated on September 8, 2016 to state that Interior Redband Trout (*Oncorhynchus mykiss spp.*) is listed as a 'species of concern' in under the Endangered Species Act. Habitat loss, fragmentation of current habitat, isolation of existing populations, and hybridization with coastal rainbow trout and cutthroat trout are the principal issues facing inland redband trout. Activities such as logging, mining, grazing, dams, over harvest by fishing, climate change, and hybridization and competition with other fish contribute to the decline of abundance distribution and genetic diversity in their native range. Many populations may find refugia in headwater streams until conservation management plans are effective.

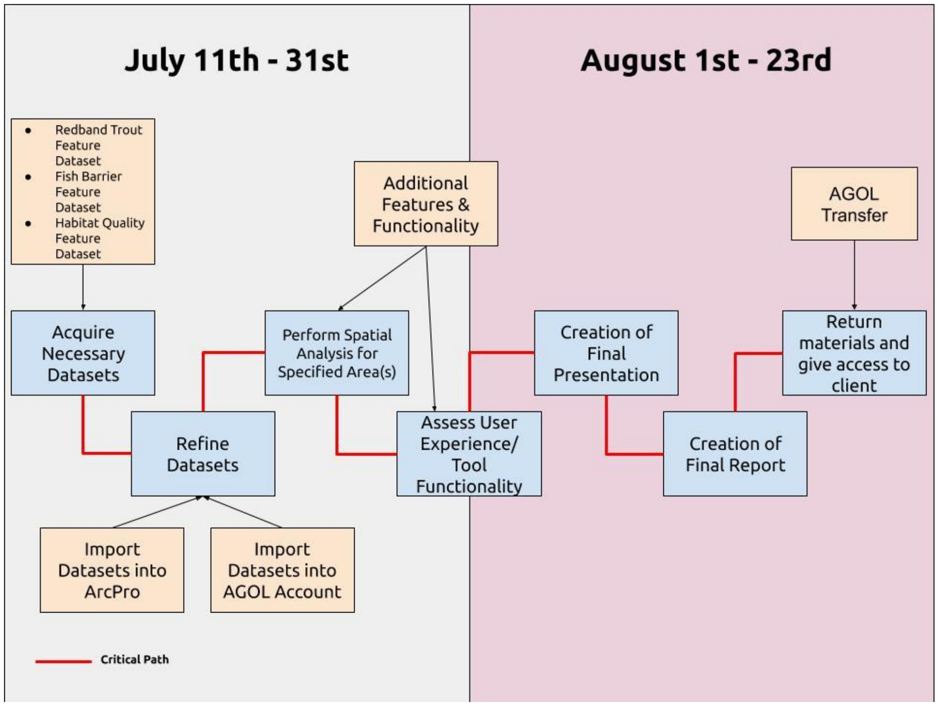
Collaborative efforts to protect and conserve the interior redband trout, a Conservation Agreement has been signed by six states, four federal agencies, one non-governmental organization and multiple tribal governments. A Conservation Agreement is a cooperative effort among agencies and tribes to promote conservation of a species, reduce potential threats to the species, and potentially preclude future needs for listing under the ESA as threatened or endangered. https://www.fws.gov/pacific/fisheries/IntRedbandTrout.cfm

The Spokane Tribe are salmon people. Since time immemorial they relied on the bountiful runs of salmon and steelhead that thrived in the Spokane and Columbia Rivers as their primary form of sustenance. A combination of factors led to the extirpation of local salmon populations in the late 19th and early 20th centuries; repressing the tribe's lifestyle and culture. Over-harvest in the lower Columbia, driven by the canning industry, took a significant toll on upriver stocks. Construction of hydroelectric dams on the Spokane River in the early 1900's barred salmon from most of the Spokane River, as none of the dams are equipped with fish passage facilities. The lower 29 miles of the Spokane River still supported salmon until approximately 1940, when Grand Coulee Dam blocked salmon and steelhead from reaching the upstream-most 1,100 miles of the Columbia River and its tributaries. Since their departure, the Spokane Tribe has sought the return of salmon. https://spokanetribalfisheries.com/programs/anadromous/

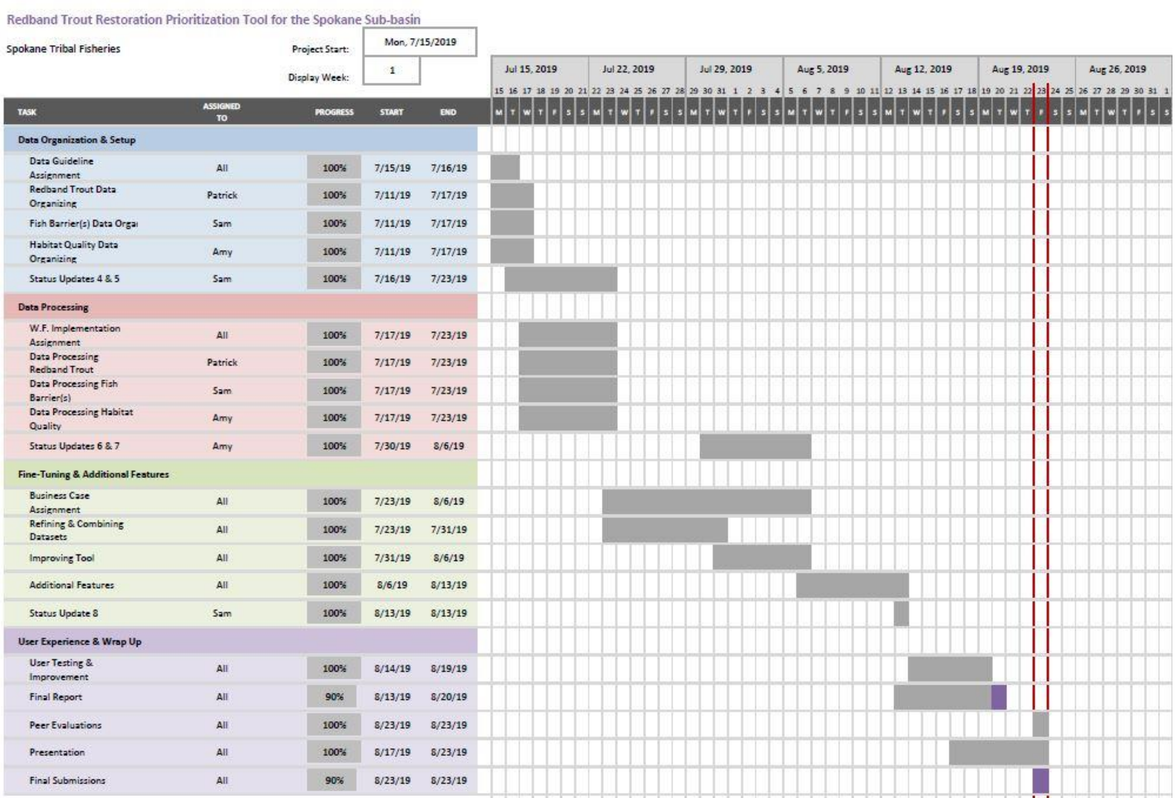
The Spokane Tribal Fisheries Anadromous Program has participated in or led several research projects that will be essential to informing the feasibility of reintroducing salmon and steelhead to the blocked area upstream of Chief Joseph and Grand Coulee dams. Beginning with a Reintroduction Risk and Donor Stock Assessment, this project identifies which anadromous species, and their sources, are most appropriate for the region as well as identifying the ecological, genetic, and pathogenic risks associated with their reintroduction. Multiple habitat assessments have performed for smaller tributaries as well as larger bodies of water such as the mainstem Spokane River and Lake Roosevelt. Productivity information derived from these habitat assessments are used to populate a Life-Cycle Model that evaluates how well reintroduced species can thrive in the Blocked Area as well as help establish goals for conservation, harvest, and artificial production. Ultimately the Program will work with regional partners and synthesize all relevant works into a Phase 1 Report that will be crucial to inform the region as to the feasibility of reintroduction.

9.2. Appendix B: Project Work Schedule

9.2.1. PERT Chart



9.2.2. Gantt Chart



Redband Trout Restoration Prioritization Tool for the Spokane Sub-basin

Spokane Tribal Fisheries

Project Start: Mon, 7/15/2019

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Data Organization & Setup				
Data Guideline Assignment	All	100%	7/15/19	7/16/19
Redband Trout Data Organizing	Patrick	100%	7/11/19	7/17/19
Fish Barrier(s) Data Orga	Sam	100%	7/11/19	7/17/19
Habitat Quality Data Organizing	Amy	100%	7/11/19	7/17/19
Status Updates 4 & 5	Sam	100%	7/16/19	7/23/19
Data Processing				
W.F. Implementation Assignment	All	100%	7/17/19	7/23/19
Data Processing Redband Trout	Patrick	100%	7/17/19	7/23/19
Data Processing Fish Barrier(s)	Sam	100%	7/17/19	7/23/19
Data Processing Habitat Quality	Amy	100%	7/17/19	7/23/19
Status Updates 6 & 7	Amy	100%	7/30/19	8/6/19
Fine-Tuning & Additional Features				
Business Case Assignment	All	100%	7/23/19	8/6/19
Refining & Combining Datasets	All	100%	7/23/19	7/31/19
Improving Tool	All	100%	7/31/19	8/6/19
Additional Features	All	100%	8/6/19	8/13/19
Status Update 8	Sam	100%	8/13/19	8/13/19
User Experience & Wrap Up				
User Testing & Improvement	All	100%	8/14/19	8/19/19
Final Report	All	90%	8/13/19	8/20/19
Peer Evaluations	All	100%	8/23/19	8/23/19
Presentation	All	100%	8/17/19	8/23/19
Final Submissions	All	90%	8/23/19	8/23/19

9.3. Appendix C: Data Design Tables
9.3.1. Database Schema

Data File Name	Data Sources	Spatial Object Type	Attribute Field
Intrinsic Potential Output (IntrinsicPotentialOutput)	National Oceanic & Atmospheric Administration (NOAA)	Line	STHDRATE: 2 (Moderate), 3 (High)
Subbasins Upper Columbia River (Subbasins_UCR)	Spokane Tribe	Polygon	Sub-basin: Spokane
WDFW Fish Passage Barriers (WDFWFishPassage)	Washington Department of Fish and Wildlife	Point	FeatureType: Culvert, Dam, Non-Culvert Xing, Other
Western Native Trout Initiative Trout Distribution (WNTI_CurCist)	Western Native Trout Initiative	Line	GeneticSta: <1% Unaltered, >1%-10%, Not Tested - Suspected Unaltered

9.3.2. Attribute Table Data Descriptions

Intrinsic Potential Output

Field Name	Data Type	Length	Decimal Position
ObjectID	Long	10	---
Join_Count	Long	10	---
Target_FID	Long	10	---
Join_Cou_1	Long	10	---
Name	String	25	---
LLID	String	25	---
Strmname	String	55	---
Length_Met	Double	0	0
Elev	Double	0	0
Gradient	Double	0	0
Wide_WW	Double	0	0

Wide_BF	Double	0	0
Area_WW	Double	0	0
Area_BF	Double	0	0
BlockGrad	Double	0	0
BlockNatu	Double	0	0
Inlake	Double	0	0
RateCodes	String	16	---
RateCodec	String	25	---
SthdRate	Double	0	0
ChinRate	Double	0	0
WS_Factor	Double	0	0
Area_WS	Double	0	0
Length_WS	Double	0	0
WC_Factor	Double	0	0
Area_WC	Double	0	0
Length_WC	Double	0	0
MaxWaterB	Double	0	0
From_C	Double	0	0
To_C	Double	0	0
From_S	Double	0	0
To_S	Double	0	0
BFromVal	Double	0	0
Branch_S	Double	0	0
Branch_C	Double	0	0
Shape_Leng	Double	0	0
LoadDate_1	Date	---	---
Name_12	String	120	---

States_1	String	50	---
Subbasin_1	String	50	---
HUC_ID_1	Double	0	0
Shape_Le_1	Double	0	0
Shape_Le_2	Double	0	0
Shape_Length	Double	0	0

Subbasins Upper Columbia River

Field Name	**Data Type**	**Length**	**Decimal Position**
ObjectID	Long	10	---
Subbasin	String	50	---
Shape_Length	Double	0	0
Shape_Area	Double	0	0

WDFW Fish Passage Barriers

Field Name	**Data Type**	**Length**	**Decimal Position**
ObjectID	Long	---	---
SiteRecordID	Double	0	0
SiteID	String	20	---
Latitude	Double	0	0
Longitude	Double	0	0
FeatureTypeCode	Short	---	---
FeatureType	String	50	---
StreamName	String	50	---
TributaryToName	String	50	---

FishUseCode	Short	---	---
FishUseCriteriaCode	Short	---	---
RoadName	String	25	---
RoadMilePostMeasurement	Double	0	0
FishPassageBarrierStatusCode	Short	---	---
FishPassageBarrierReasonCode	Short	---	---
PercentFishPassableCode	Short	---	---
SignificantReachCode	Short	---	---
OwnerTypeCode	Short	---	---
DataSource	String	60	---
SurveyDate	String	15	---
LinealGainMeasurement	Long		---
PriorityIndexTotalQuantity	Double	0	0
PotentialSpecies	String	150	---
BarrierCorrectionTypeCode	Short	---	---
BarrierCorrectionYearsText	String	50	---
CaseAreaFLag	Short	---	---
FormLinkURL	String	254	---
WRIANumber	Short		---
CountyName	String	16	---
IncorporatedCityName	String	40	---

HUC12Name	String	80	---

Western Native Trout Initiative Trout Distribution

Field Name	Data Type	Length	Decimal Position
ObjectID	Long	10	---
HUC8	String	8	---
rid	String	14	---
fmeas	Double	0	0
tmeas	Double	0	0
GNIS_Name	String	254	---
ReachCode	String	14	---
fshID	String	15	---
cpID	String	15	---
Own_Type	String	50	---
Own_Name	String	60	---
P_Des_Tp	String	75	---
State_Nm	String	50	---
TSN	Long		---
Type	String	254	---
Origin	String	254	---
UniqueAttr	String	254	---
Status	String	254	---

Stocking	String	10	---
GeneticSta	String	254	---
NonNative	String	10	---
NonNativeS	String	100	---
HabitatQua	String	254	---
StreamWidt	String	254	---
HabitatSou	String	100	---
PopDensity	String	254	---
Population	String	100	---
Comments	String	254	---
Miles	Double	0	0
Kilometers	Double	0	0
Shape_Leng	Double	0	0

9.4. Appendix E: Additional Resources

Colville Confederated Tribes - Fish and Wildlife Department
https://www.colvilletribes.com/fish-wildlife

Electricity Local - Spokane, Washington
https://www.electricitylocal.com/states/washington/spokane/

Energy Use Calculator
https://energyusecalculator.com/electricity_computer.htm

GIS Stack Exchange
https://gis.stackexchange.com/questions/182730/transferring-arcgis-online-content-from-one-organization-to-another

Great Basin Redband Trout Genetic Status Assessment
http://www.westernnativetrout.org/media/2012-funded-projects/final_-report_great_basin_redband_genetics_4-24-15.pdf

It's your fish, we protect it
https://www.spokaneriverkeeper.org/spokanes-redband-trout

Landers: Redbands in upstream battle
http://www.spokesman.com/stories/2013/mar/28/landers-redbands-in-upstream-battle/

Lower Spokane River Redband Trout Spawning Habitat: Monroe Street Dam to Nine-Mile Dam Pool - Department of Ecology
https://ecology.wa.gov/DOE/files/e6/e6475f49-77e5-457f-bdf6-bad4de1a79ad.pdf

Montana's Fish Species of Special Concern – Redband Trout
http://www.fisheriessociety.org/AFSmontana/SSCpages/redban%20status2.htm

National Fish Habitat Partnership
http://www.fishhabitat.org/

Northwest Fly Fishing
https://northwest-fly-fishing.myshopify.com/blogs/features/15714004-spokane-river-wa

Rangewide Conservation Agreement
https://www.fws.gov/pacific/fisheries/sphabcon/species/Interior%20Redband%20Trout%20%28Color%29.pdf

Redband Rally _______
https://www.milb.com/spokane/community/redbandrally

Spokane Tribe of Indians
http://spokanetribe.com/

Spokane Tribal Fisheries
https://spokanetribalfisheries.com/meet-the-team/

Spokane Watersheds
http://www.spokanewatersheds.org/

Status and Conservation of Interior Redband Trout - Muhlfeld
https://www.tandfonline.com/doi/pdf/10.1080/02755947.2014.951807

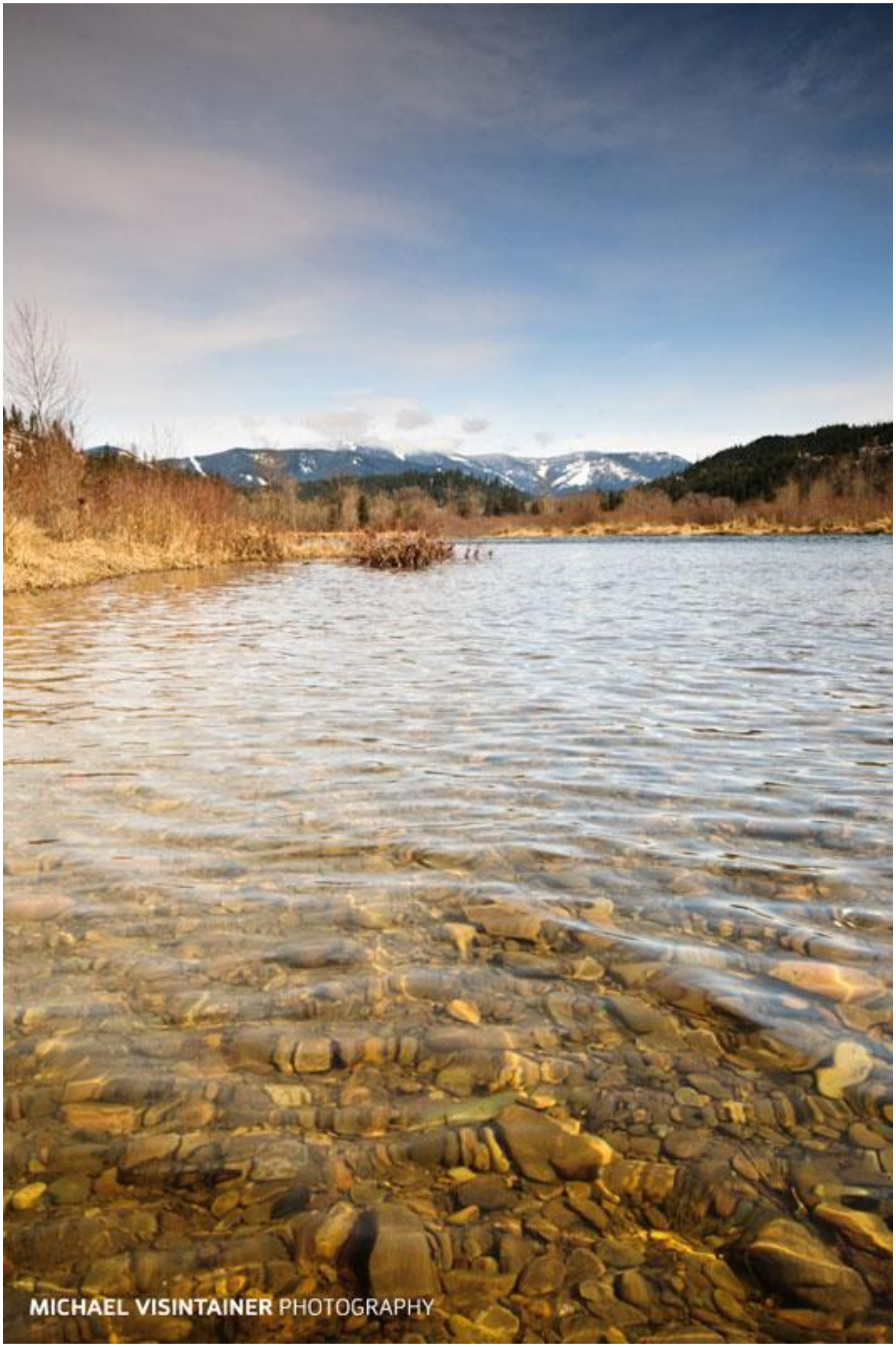
Trout Unlimited – Spokane Falls
https://spokanefallstu.org/

Western Native Trout Initiative
http://westernnativetrout.org/redband-trout/

Redband Trout Wikipedia
https://en.wikipedia.org/wiki/Redband_trout

Washington Department of Fish and Wildlife – Redband Trout
https://wdfw.wa.gov/species-habitats/species/oncorhynchus-mykiss

9.5. Appendix F: Supplemental Images


MICHAEL VISINTAINER PHOTOGRAPHY