A Trail System Improvement Approach to Sustainability Management
Hood River County, Oregon

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Abbreviations

ATV	All Terrain Vehicle
DEM	Digital Elevation Model
FRTC	Forest Recreation Trails Committee
GIS	Geographic Information System
GPS	Global Positioning System
HLT	Hollatz, Lund, and Tanahara (as in the ‘HLT Team’)
HRATS	Hood River Area Trail Stewards
HRC	Hood River County
HRCBOC	Hood River County Board of Commissioners
HRCFD	Hood River County Forestry Department
NED	National Elevation Dataset
NPS	National Park Service
ODFW	Oregon Department of Fish & Wildlife
RTSMP	Recreation Trail System Master Plan
USDA	United States Department of Agriculture

Introduction

This project is focused on creating an improved trail system management plan with an approach to sustainability management for Hood River County, Oregon. The emphasis of this project is to implement a trail management database design, physical map design, and web map design that support ideas of sustainability management. This project provides an implementation plan to be considered by Hood River County Forestry Department for improving sustainable recreation management on their land.

Background

Hood River County Forestry Department (HRCFD) manages 31,064 acres of forest land in Hood River County. The land is primarily managed for commercial timber production. Over time, a large network of unmanaged trails developed in the Hood River County (HRC) forest lands, and eventually the County adopted a more managed approach to recreational trails. In 2003 the Hood River County Board of Commissioners (HRCBOC) passed an ordinance requiring HRCFD to manage the system of recreation trails. It also called for the creation of a Forest Recreation Trail Committee (FRTC) that would be composed of members of the public representing a diverse spectrum of stakeholders. The ordinance also required the HRCFD to develop a Recreation Trail System Master Plan (RTSMP) which initiated a long process of planning and working toward that goal. The development of the RTSMP incorporated a wide range of stakeholder groups, funding sources, and assistance from outside organizations (Figure 1). After many years of work, the RTSMP was finalized and adopted by Hood River County in December 2010. Throughout this process the HRCFD has recognized the many direct and indirect social, economic, and health related benefits that come from having recreational trails as a public resource, but the department has limited financial resources to commit to recreation management since there is little direct return of revenue to the department from these activities. HRCFD has been fortunate to acquire several recreation-focused grants for on-the-ground projects, but these typically have fallen short of providing funding for staff time to improve the trail system GIS data and map products. Several years ago HRCFD obtained grant funds for commercial printing of a trail map. At that time HRCFD staff used GPS equipment to collect all trail locations and then they created the first trail system map for public distribution. The original map has served the public and the HRCFD well for several years; however, at the initiation of this project the trail system map is significantly outdated and inaccurate. The HRCFD has requested that it be completely redesigned and improved by someone with expertise in GIS and cartography. Nyerges and Jankowski define a complete GIS as "a combination of hardware, software, data, people, procedures, and institutional arrangements for collecting, storing, manipulating, analyzing, and displaying information about spatially distributed phenomena for the purpose of inventory, decision making, and/or problem solving within operations, management, and strategic contexts as related to issues at hand" (Nyerges & Jankowski, 2010). HRCFD does not need a completely redesigned GIS, but they do request assistance in developing some workflow enhancements to their current GIS. In the process of developing a redesigned map, HRCFD has also requested assistance with data design improvements that will help them better manage their trail system datasets going forward. The HRCFD has stated that they lack the technical skills necessary for a professional redesigned map and manipulation of the associated data.

The HRCFD has stressed the importance of developing a high quality and current trail system map for trail and land management. The map is the document that links the HRCFD as a management agency to the physical trail system on the ground, and it also links them with the public. It is therefore an extremely important part of their recreation management. Also, the Forest Recreation Trails Committee, which meets monthly, is responsible for making decisions and recommendations for trail management. But in order for them to make good decisions, they need current and accurate maps and data. The types of recreation that are very popular in the trail network include hiking, running, mountain biking, horseback riding, motorcycle and All Terrain Vehicle (ATV) riding. The trail map is the primary means for HRCFD to define the trail designations for the various use types. Since the public makes extensive use of the recreation map for making good decisions, they can clearly benefit from a better designed and more informative map. And finally, the availability of an accurate trail map is critically important to emergency responders when dispatching to incidents in the forest.

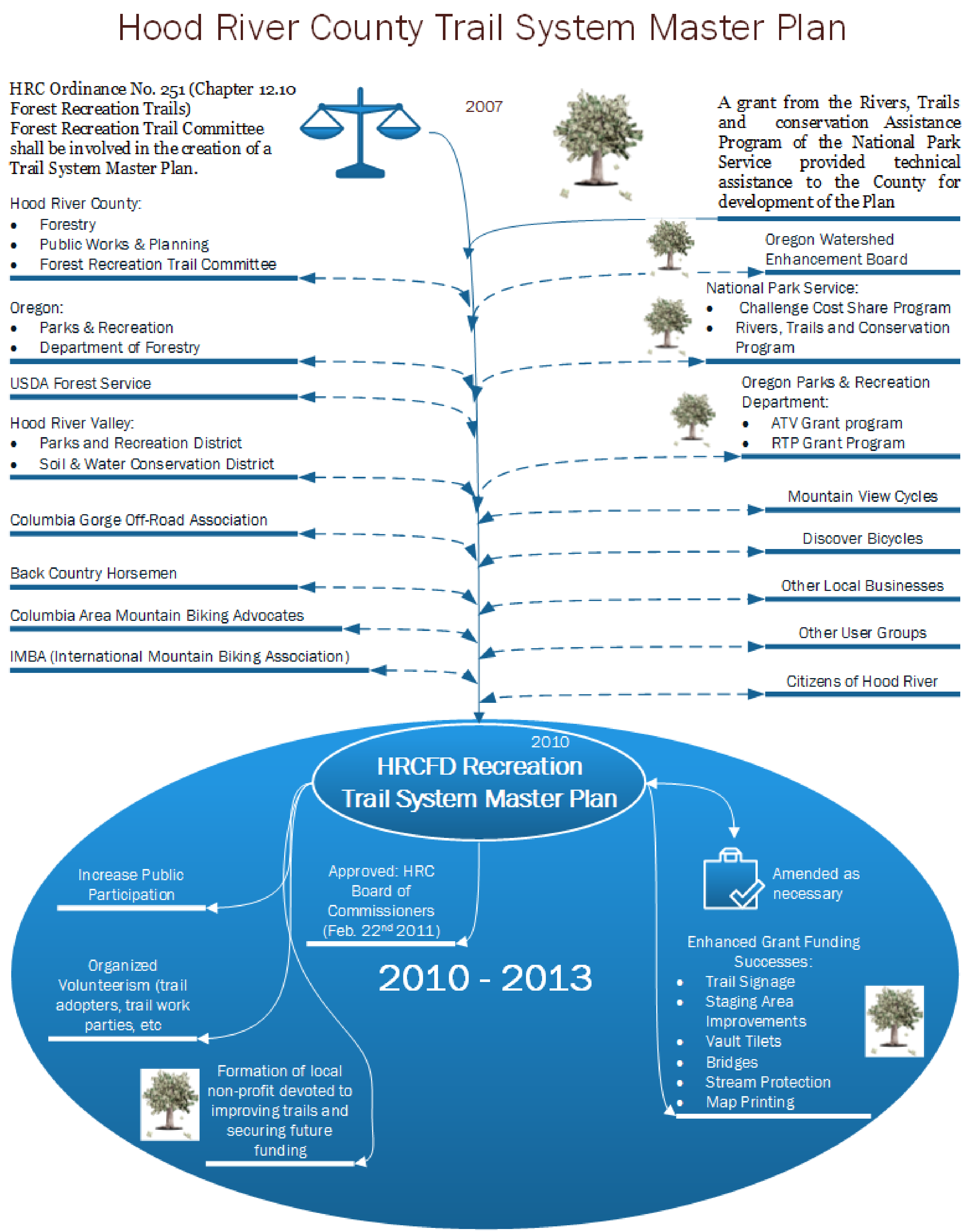


Figure 1: Hood River County Recreation Trail System Master Plan Flowchart

The creation of the RTSMP and the efforts during the three years since it's development have set HRC on a path towards a sustainable system of recreation trails that are used year-round by residents and visitors. Sustainability was built into the RTSMP, which is likely the single most important aspect of the HRCFD efforts. Based on research, "The goal of sustainable environment planning, policies, and governance is to design processes that return our planet to a more balanced level of use" (Wade, 2013). Maintaining a high level of sustainability, despite heavy tourism to the HRC area, requires a delicate balance of management, enjoyment and ongoing efforts as described in the RTSMP. In 2003, the HRC Forest 'trail' system consisted of over 160 miles of unauthorized, dangerous, environmentally damaging and unsustainable trails spread over 31,064 acres of HRC forest land and private property. Geographic information system technology is an essential tool for designing and implementing sustainable processes at any scale (Wade, 2013).

According to recent research, "Sustainability is commonly misunderstood as being equal to self-sufficiency, but in a globalized world virtually nothing at a local scale is self-sufficient. To become meaningful, urban sustainability therefore has to address appropriate scales, which always would be larger than an individual city" (Elmqvist, 2013). At this relatively small scale (31K acres), the Hood River County forests may be self-sufficient in terms of maintaining forest land, plants and animals. However, it is not self-sufficient, as a recreational site, especially with thousands of visitors per year hiking, biking, riding horseback, motorcycles, quads and 4x4's within. There must be a balance of recreation and recreation management to facilitate the continued processes of timber harvesting and user enjoyment.

Based on research by Elmqvist, "Complex systems are, according to resilience thinking, rarely static and linear, instead they are often in constant flux, highly unpredictable and self-organizing, with feedbacks across time and space" (Elmqvist, 2013). The resilience of the HRC forest is in constant flux, highly unpredictable and somewhat self-organizing, however, without organization, it will become temporally less resilient.

Elmqvist points out that the local city scale is too narrow for true resilience and sustainability thinking (Elmqvist, 2013). Perhaps the scale of the Hood River project is 'too narrow' to understand forestry resilience and sustainability while a much larger scale would provide more insight. A narrow focus on a single city is often counterproductive and may even be destructive since building resilience in one city often may erode it somewhere else with multiple negative effects across the globe (Elmqvist, 2013). With that being said, it would be illogical to NOT carry through with this GIS Improvement project because the scale may be too narrow. It may however, given the aforementioned research, be difficult in the end to declare that the HRC timber forest and recreational trails are sustainable and resilient.

As manager of the trail system (in coordination with multiple user groups, agencies, and business leaders), the project sponsor has very limited face to face contact with the thousands of users on the trail system. They stated that the only true connection they have with the users is through the 'data' that they ‘share’ via a map. It is through this data sharing that the sponsor indirectly drives the local recreation economy, establishes rules and regulations, and makes improvements to maintain/enhance the safety of the trail system while maintaining a sustainable logging operation in the HRC forest.

Based on research, trail design and trail management are very important when it comes to sustainability management. According to researchers, “a trail system that facilitates access to remote ecotourism destinations, provides safe, high quality recreational experiences, and concentrates traffic on durable treads maintained to minimize resource degradation can only result from professional planning and management” (Marion & Leung, 2004).Other researchers have discussed the use of developing a well-designed database composed of field data as well as examining the use of regression tree analysis . Also, researchers have utilized GIS to create a least-cost path for an optimized trail route (Tomczyk, & Ewertowski, 2013). With that being said, we are continuing to work towards providing Hood River County with improved data as well as a trail management system that will help the County sustain and maintain the future use of trails. While this is a project for GEOG 569, technically our processes should be termed a program because this is starting out as a project; however the goal is to enhance the sustainability management of the HRC Recreational Trail system (Somers, 2010). While our time is limited for new additional analysis, we decided we could work towards future sustainable trail management analysis ideas for our project sponsors to consider for the future.

Problem Statement

Based on the HRCBOC ordinance, the HRCFD has been required to manage and maintain the recreational trail system. The ordinance has also required the development of a Forest Recreation Trail Committee and a Recreation Trail System Master Plan. With several years of hard work, the Recreation Trail System Master Plan was created in December 2010. While the plan was created, there is still much work that needs to be done to create a system for maintaining the recreational trails. The HRCFD has had to deal with little financial and GIS resources for managing and updating recreational trails. Due to limited resources, the County has been faced with outdated recreation trail data and paper maps. The HRCFD would like to update and redesign their trail maps as well as find a database management design that will help them better manage and maintain recreational trails for the future.

Project Goals

The first goal of this project will be to design an improved trail system management plan. The goal will be to create a trail database that will help the HRCFD organize and standardize their data while making updates in the future.

A second goal of this project will be to provide an updated Hood River County non-motorized trail map ready for commercial printing. The updated trail map will be printed and made available to the public. This printed map will be very useful for trail users as well as County employees in charge of managing the trails.

A third goal of the project will be to offer suggestions for further study and analysis as the County works towards maintaining a sustainable trail management system. The goal will be to provide sustainable examples of maintaining recreational trails based on current research. Also, the goal will be to provide some new GIS ideas based on growing trends such as online web maps.

Lastly, a fourth goal of the project will be to complete a financial analysis based on the research (Lerner & Technology Association, 2007). The goal of the financial analysis will be to help the County determine if it is financially feasible to incorporate our sustainable trail management system recommendations into their workflow.

Tomlinson notes that in order to "develop an effective GIS, the GIS planner must have a clear understanding of what the agency or company does, it's working plan to do it and how GIS can help accomplish the mission" (Tomlinson, 2011). The overall goal/mission of the Recreation Trail System Master Plan is to, "provide a sustainable system of recreation trails within the HRC forest lands that is managed cooperatively by the HRC Forestry Department, all recreation user groups, and trail partners, for the benefit and enjoyment of HRC residents and visitors" (Hood River County, 2010). Preparing a well-designed trail system will assist in keeping visitors from trampling into sensitive off-trail areas as well as providing a highly effective resource protection strategy (Cahill, Marion, & Lawson, 2008). These strategies, combined with a highly detailed and accurate map will preserve the fragile landscape, thus increasing the resilience of the landscape. Such techniques and practices constitute a core component of sustainable tourism and trail management. (Marion & Leung, 2004; Newsome, 2002). Trail impacts such as muddiness, which causes widening and erosion can be effectively addressed by relocating a trail to a side-hill alignment with design features to avoid these common problems (G. A. O. United States, 2004). Hood River County practices are focused on sustainable remedies to maintain trail system resilience without mandating restricted use and access. HRC provides a continually updated and managed recreation area to locals and visitors from around the world. Visitors utilize signage and maps to self-manage their activities throughout the county trail system. By providing visitors with up-to-date trail information alongside sustainability 'best practices' in the form of ancillary text (on the 'back' of the map), the map facilitates further protection of the natural landscape.

Objectives

To achieve our project goals, we developed a dynamic project workflow process/diagram that will address, manage and guide the development of additional steps that are necessary to accomplish our goals within the eight week timeline (Figure 2).

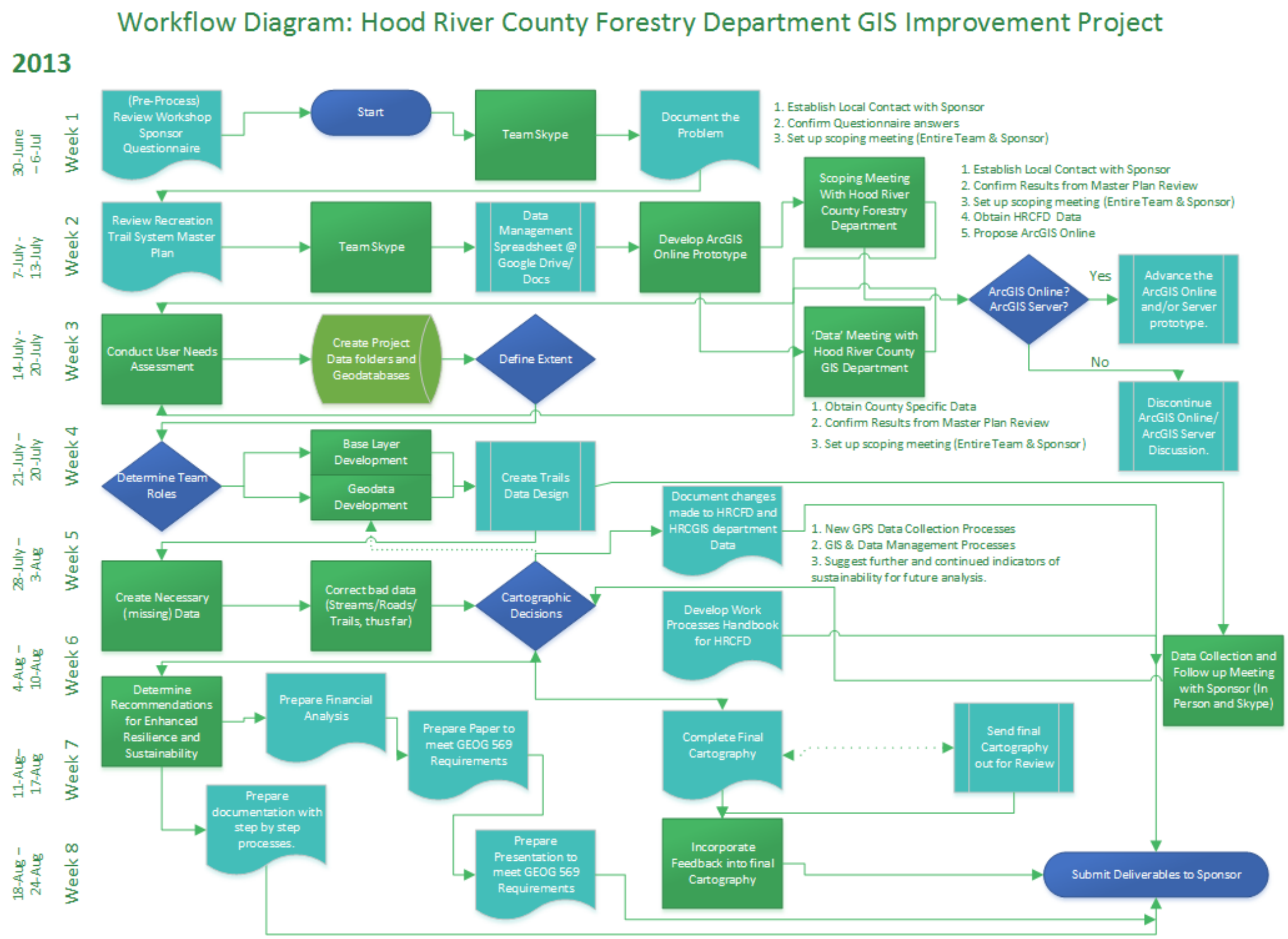


Figure 2: Workflow diagram.

In regards to our first goal, we thoroughly analyzed the trail data to determine a method that will allow a more streamlined approach to data maintenance. We developed a proposed trail database design that will enhance the Forestry Department's data management efficiency.

To accomplish our second goal, we compiled all of the necessary data and reference information for creating the non-motorized trail map. Then each of us will be responsible for creating, updating, and symbolizing a set of layers. By week five our plan is to be done with any data editing. Between weeks five and six we plan to compile the data layers into a draft map to present to our project sponsors.

In order to reach our third goal, our plan will be to do extensive research on sustainable trail management as well as GIS technology ideas to provide as future recommendations. By week seven we plan to compile our research ideas and come up with an example to present to our project sponsors.

To achieve our fourth goal, we plan to compose a financial analysis by using the business case template that was suggested based on research. During weeks six and seven, we developed a complete financial analysis of our proposed solutions.

Scope

Much of the 'Scope' for this project was clearly defined in the 'project questionnaire' provided to us from HRC and Professors Aguirre and Withers. Upon meeting with our project sponsors, we confirmed that the scope of our project is to provide an updated non-motorized trail map that can be printed and created into a water resistant hard copy map.

Information products

The hard copy map will be very useful for trail users, County staff, and maintenance workers. This project will also improve the County's trail system data management, design, processes, and workflows (a GIS program). The development and implementation of the improvements will allow Hood River County to better maintain their trail data and provide them with the ability to consistently produce up-to-date maps. All of these components will lead to improved sustainability management going forward.

People

- Henry Buckalew: Main organizer of the project
- Ellen Davis: Provided some data and will mostly be in charge of maintaining the data in the future
- Mike Schrankel (County GIS Coordinator): Provided some data and in charge of the GIS program for Hood River County
- Field crew (for GPS work): In charge of checking and maintaining trails

Hardware

Hardware considerations for this project were predicated upon what was already in use. HRCFD has two computers functioning adequately, as do all team members. HRCFD also has Trimble GPS units with which they gather data from the field. No additional hardware purchases are necessary. For the purpose of documenting what was used during analysis and cartography, the hardware specifics are listed below.

- Rick Hollatz: HP Pavillion Desktop PC running 64-bit Windows 7 Home Premium, Service Pack 1. Intel(R) Core (TM) i7 CPU @ 2.67 GHz, 8 GB RAM.

- Gregory Lund: Puget Systems custom laptop running 64-bit Windows 7 Professional service pack 1. Intel Core i7-3820QM CPU @ 2.7 GHZ, 32 GB RAM, two internal solid state hard drives (c: 250 GB & d: 250 GB).
- Alyssa Tanahara: MacBook Pro laptop running 32-bit Windows 7 Home Premium, Service Pack 1. Partitioned hard drive. Intel(R) Core(TM) i7-2620M CPU @ 2.70 GHz, 4 GB RAM.

Due to the absence of accessible server space, each team member stored a local copy of the data on their personal Hard Drives. All three team members utilized the c: drive for data storage. While editing a specific geodatabase, all other team-members refrained from editing until it was finalized by the member that was editing, uploaded and then re-downloaded (in its entirety). One important measure our group used in the data-management process was to keep all data in separate small geodatabases to facilitate easy manipulation and transfer amongst the team and eventually back to HRC and Mr. Buckalew. Google docs, Google Drive, Dropbox, and email data exchanges (for small files) have been leveraged along with a sophisticated real time online data-use log to prevent multiple renditions of the data.

Software

ArcGIS 10.0 SP3 was used to maintain the data throughout the project in an effort to replicate the sponsor's system as closely as possible. HRC maintains two ArcView licenses. Creating annotation layers will ensure accurate placement and consistency of the label location. For the purposes of creating a 'Map Service' on the UW Geography Server, one team member upgraded to ArcGIS 10.1. The map service on the UW Geography Server will be used to create a web map on ArcGIS.com. ArcGIS 10.1 is required to create a map service, because the UW Geography Server runs on ArcGIS Server 10.1. In order to publish a map service on a server they need to be in the same version. For example, a map document (.mxd) in ArcGIS 10.0 cannot be published into a map service on an ArcGIS 10.1 server. However, there are workarounds for publishing a 10.1 map on a 10.0 server.

Several types of online software allowed our group to work collaboratively on project components in real-time. Google documents were used for collaborative word processing and spreadsheet development. Also, each team member registered for a Microsoft SkyDrive account to access the collaborative capabilities of Visio in 'the cloud' to create workflow diagrams. This made it possible for us to all work on one Visio document without having to worry about redundancy or data overwrite problems that would likely occur if individual versions of the documents were being edited and then shared or compiled. Skype was used on many occasions for conference calls with all team members attending.

Data Acquisition

Much of the specific data necessary for this project was provided by the sponsor and the HRC GIS Department. Other data came from the USGS, Oregon State, USFS Mt. Hood, Skamania County-WA, and others as detailed in Appendix A - Data Sources Spreadsheet. The *DataSources_Spreadsheet* document on Google Drive was utilized to prevent data conflicts. Because Google Drive works in nearly 'real time,' it was possible for all three team members to view specifics about the data, and to know when it was being edited by another team member. The three left hand columns were used extensively to prevent two (or three) team members from editing the same geodatabase at the same time. When one team member was editing data in a geodatabase, that person (editor) highlighted the columns in the Google Drive document so that the **other** team members knew that it was in 'editing' mode, and therefore to not edit that data until it was uploaded back to Dropbox by the editor. The other users would wait and then subsequently replace their hard drive copy (in their c: drive) with the new (edited) version provided by the editor when they were done. This process worked, we had zero instances of data conflicts. To facilitate future management of the data, we will be providing workflow guides to help guide the Forestry Department in the efficient and effective management of their data moving forward. This process will require two sets of some data, one for ongoing data management (dynamic) and another for cartographic purposes (static).

To facilitate easy data transfer and sharing between sponsor and team partners, each set or group of data is housed in a separate geodatabase. Many smaller geodatabases will be easier to manage and transfer between machines than fewer large geodatabases. All of the data is stored in a single folder named 'HRC_Trailmap' as shown in the graphic below (Figure 3)

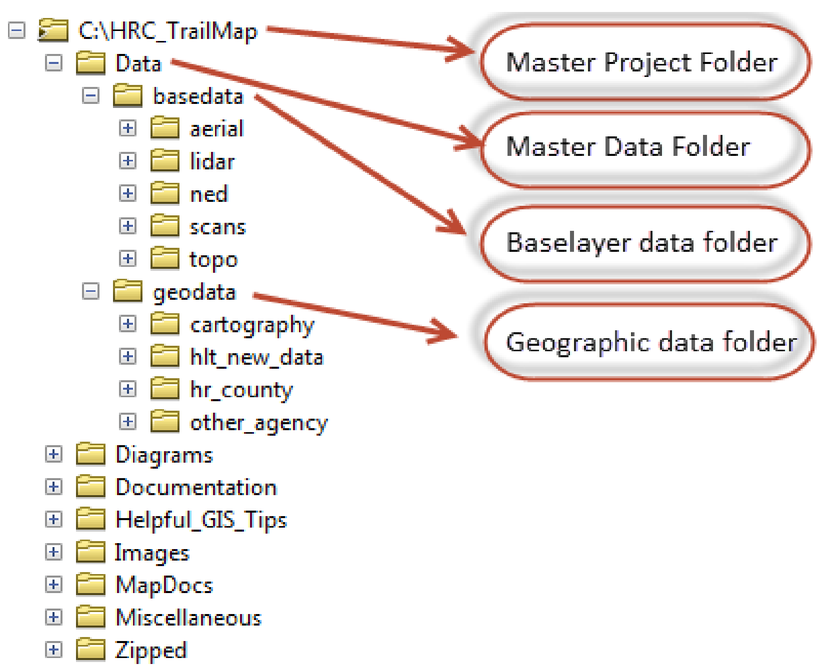


Figure 3: Data Storage Basics

Design Considerations for Sustainability

Sustainability management, ecosystem services, and resilience thinking are components at the core of this project. HRCFD is tasked with serving the public as a land and resource management agency and it is in the best interest of the organization to carry out practices that are environmentally conscious, scientifically sound, socially acceptable, and economically viable. This project, with the support of HRCFD, seeks to design and implement strategies and tangible materials that create a more desirable future condition for the land being managed and the people being served.

Geographic Scale

The focal scale of this project is the 'Northwest Area' of Hood River County's forest lands (Figure 4. Out of all the land areas managed by HRCFD, this area receives the majority of all recreation impacts due to its close proximity to the population centers of the county, and because it is easily accessed by visitors travelling from outside the area. While the three other 'areas' under HRCFD's management are not the primary focus of this project, the considerations developed herein can likely be expanded to these additional areas at a later time. At a regional scale, outside of the areas owned and managed by HRCFD, the landscape has a mix of public and private land that range in type of use and intensity of use. For example, there are areas of dense residential uses, agriculture, timber production, designated wilderness. While interaction between the activities that occur on HRCFD land and other lands in the regional vicinity certainly exist, the focal scale of this project is fairly rigid and has defined boundaries in terms of mapping and data design.

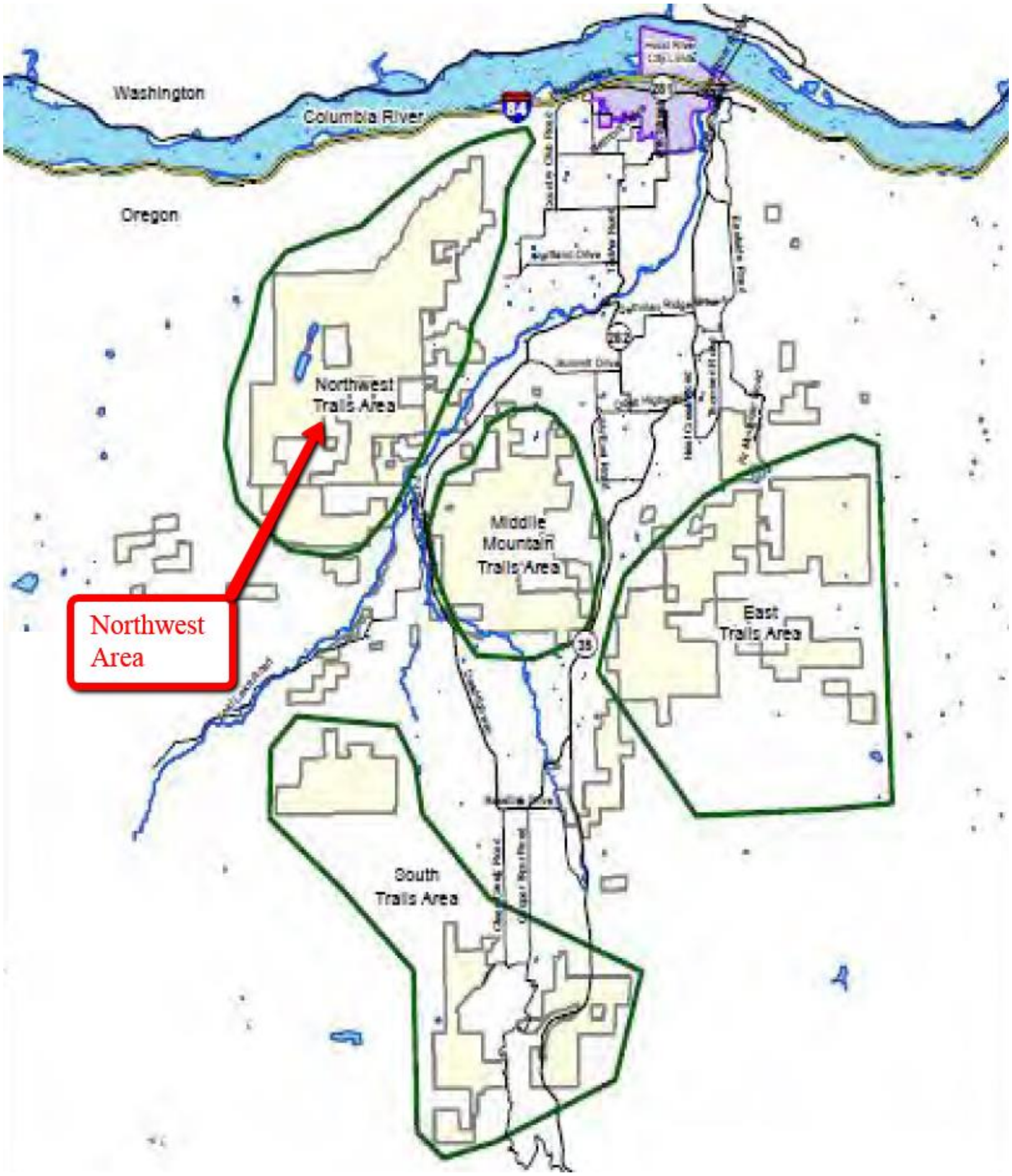


Figure 4: A map of the four distinct areas managed by HRCFD. Map was obtained from the RTMP document (Hood River County, 2010).

Temporal scale

When considering designs that will improve sustainability management, temporal scales have several implications for this project. Consideration should be given to the fact that elements of the project must fit HRCFD's management activities and needs. As such, we considered that management activities may be variable over time. For example, managers of trail systems should not overlook the seasonal influences of weather on trail conditions. Management activities and specific decisions are likely to vary with seasons. Management (and data designers) should also consider the influences of things like the time of day, the day of the week, and the season of the year for how these influence the number of recreational users and the spatial distribution of where those users choose to recreate. To the extent that it is possible, temporal processes should be built into the GIS data during database design in order to establish a means for improved temporal analysis.

Organizational Scale

This project is designed to improve HRCFD's ability to accomplish its mission as a land management agency. It will provide efficiencies for staff within the department. On a larger organizational scale, this project may have additional influences. For example, the GIS Department at HRC, as the division responsible for storing GIS data, may see additional benefits from improved data structure and organization. Trail datasets are currently stored redundantly and with poor consistency of content. Our newly designed data structure, as well as procedures for managing and maintaining that structure, will be a benefit to all data managers and users throughout the organization. Better data will also provide more accurate and current information that can be used by several other departments at HRC.

Alternative Designs

Two important design considerations for this project were establishing the geographic extent, and deciding the primary user for which the maps were meant to benefit. In many ways these two considerations were intertwined. During scoping exercises HRCFD had stated they need updated maps (and data) specifically designed for two user types. These included motorized users and non-motorized users. As an organization HRCFD has distinct reasons for separating these uses. For one, they have a need to provide different information to each user type. They typically produce a separate map for each user because this allows them to tailor the information specific to the use type. Also, they are able to obtain funding to develop materials for motorized trail management, but far less likely to obtain similar funds for non-motorized management. This stems from the availability of grants that are tied to Oregon State gasoline tax dollars. These grants must be utilized in projects promoting or enhancing motorized uses.

Given these considerations, and through consultation with HRCFD as the project sponsor, it was decided that we should focus our project primarily toward non-motorized uses. Because non-motorized users are also allowed to use motorized trail areas, the project geographic extent was established such that it covers both. Additional detail in the maps is focused on areas that are most heavily utilized by non-motorized users.

Design

As with most significant GIS projects, the overall design has been dynamic throughout the process, as we worked towards meeting the Sponsor's required deliverables and GEOG 569 Course Requirements. The Workflow Diagram (Figure 2) details the steps and processes that were completed throughout the eight weeks of the course.

Data Design

A large variety of datasets were used in the development of our map products. In some cases datasets were obtained in a form that was well suited to immediate use, however many other datasets required an extensive amount of editing in order to prepare them for use in our project. Data was managed in many individual file geodatabases with each geodatabase representing a particular data theme (e.g. streams, roads, wilderness, etc.). In many cases we were able to import data from various sources into our geodatabases, manipulate it, and derive additional data projects from it. However, in many cases data needed to be developed entirely by us by reviewing other reference materials, or in some cases, via field reconnaissance. The culmination of our data collection, manipulation, and development efforts was the compilation of a vast amount of data (Figure 5) requiring approximately 20 gigabytes of file storage.

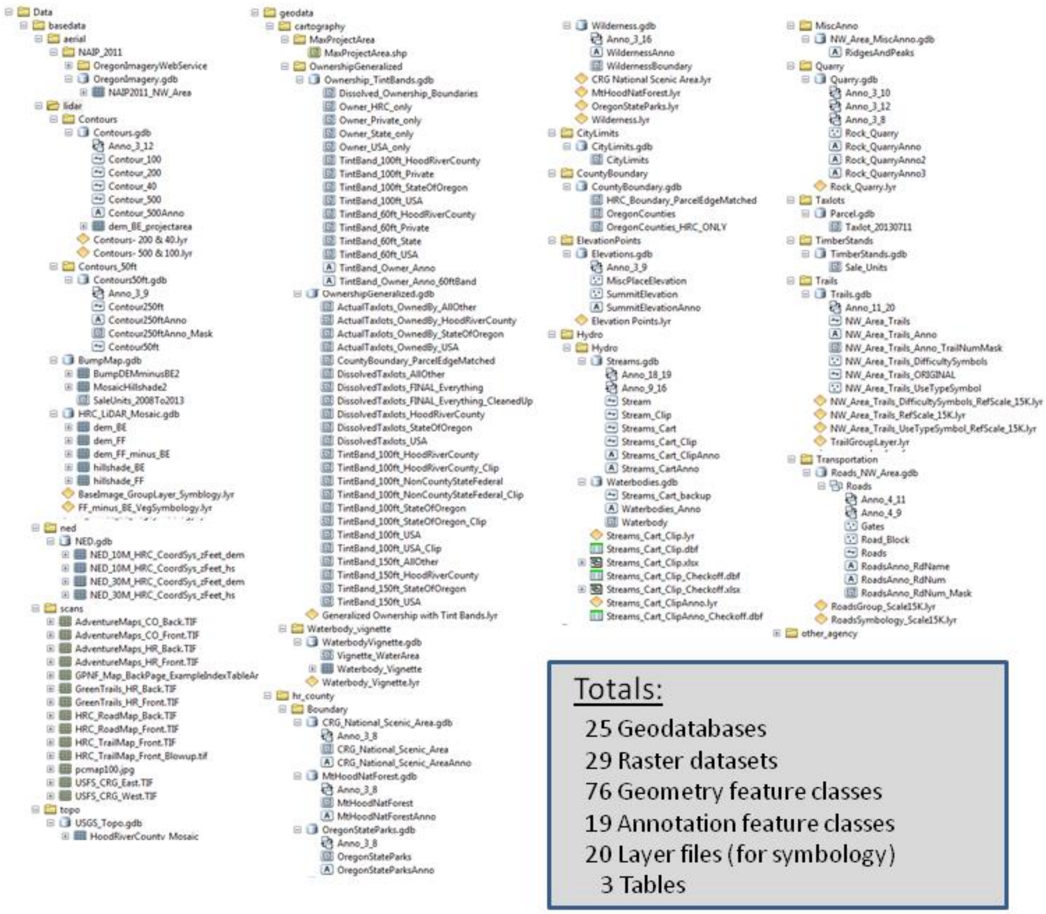


Figure 5: Datasets utilized in the project (screenshots from ArcCatalog)

The large majority of all data we collected and manipulated was solely intended for cartographic representation in our map(s). As part of the cartographic representation we made extensive use of geodatabase annotation to provide the necessary labeling of features in the map(s). Both feature linked and standard annotation were used.

In addition to the data needed for cartographic representation, we also developed an extensive geodatabase design to store trail system data because it will be actively managed by HRCFD at the conclusion of our project. A design was established that will improve HRCFD's ability to manage and maintain the data while reducing attribute redundancy, providing superior quality control measures, and ultimately being more efficient and effective in carrying out their mission. The trail system geodatabase makes use of subtypes, coded value domains, and feature linked annotation (Figure 6). It was also developed with a wide range of improved attributes fields that will be useful for improving both operational and sustainable management. The general use and purpose of each field in the NW_Area_Trails feature class is provided in Table 1. This feature class is the most important data layer in the geodatabase because it includes most of the primary trail attribute information.

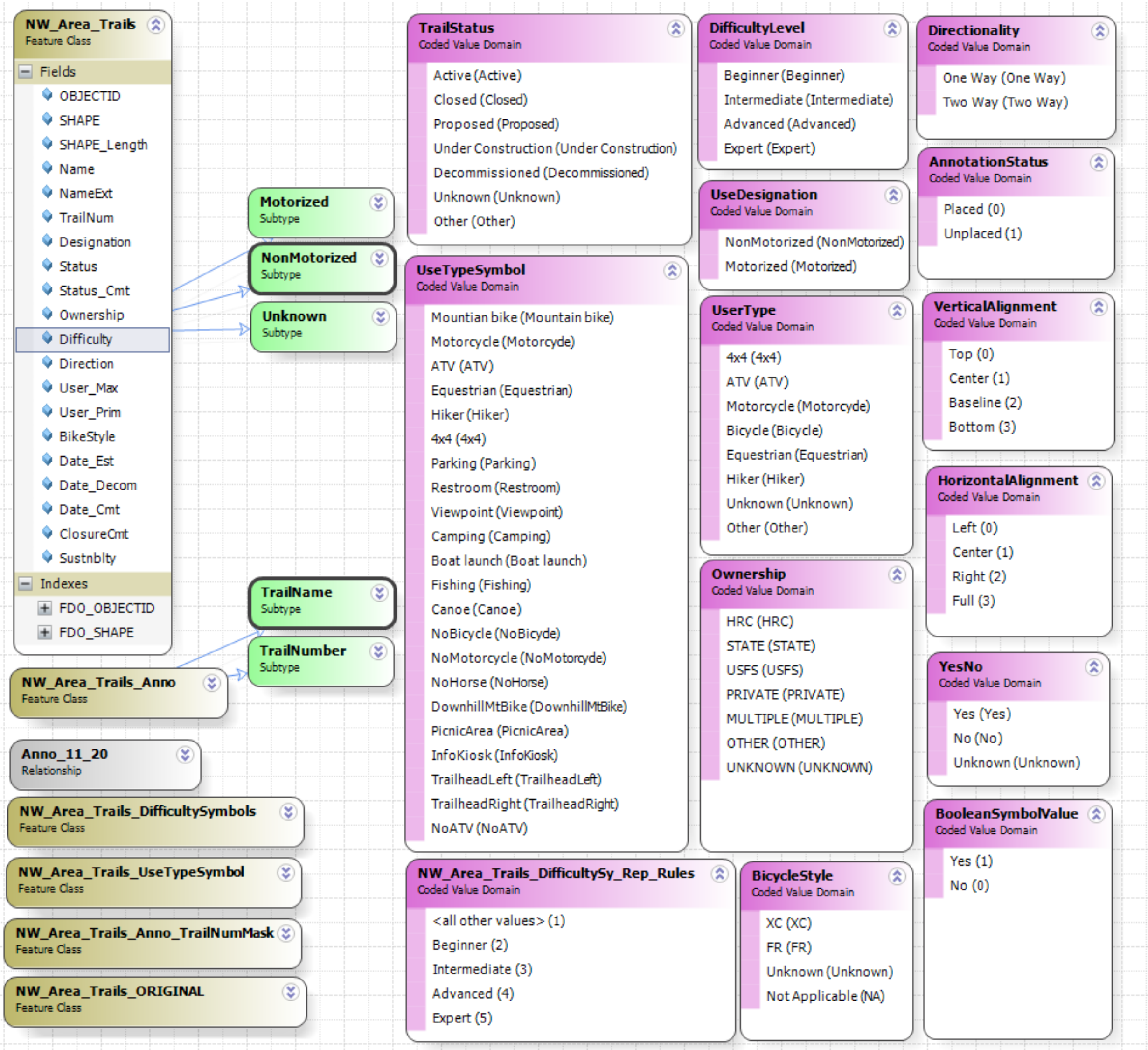


Figure 6: Image of the Trails geodatabase schema (from ArcGIS Diagrammer) showing all feature classes, subtypes, and domain lists.

Description of the 'NW_Area_Trails' Feature Class Attribute Fields					
Field Name*	**Basic Description**	**Field Type**	**Field Length**	**Domain**	**Purpose and Use Considerations**
Name	Trail name	Text/String	40		The common name for a particular trail (e.g. 'Seven Streams Loop'). This field is used in a feature linked annotation class.
NameExt	Trail name extension	Text/String	20		This field can be used for suffix characters that adjoin to the trail name but are best managed in a separate field.
TrailNum	Trail number	Text/String	20		This field is used for the trail number for administative and map navigation purposes. This field is used in a feature linked annotation class.
Designation	Trail designation	Short integer			The trail designation is the subtype field defining the intended use type for the trail. Subtypes include 'Motorized', 'NonMotorized', and 'Unknown'. Subtype values define default values and behaviors for other fields.
Status	Trail status	Text/String	30	TrailStatus	The trail status is used to define current status. Values are derived from a domain (e.g. Active, Closed, Proposed, Under construction, decommissioned, etc.)
Status_Cmt	Trail status comment	Text/String	70		The trail status comment field is for free form text. It provides a place to enter additional information about the value used in the status field, for example, providing additional detail for why a particular trail has a status of 'Closed'.
Ownership	Ownership	Text/String	20	Ownership	This field is used to define the ownership of the land where the trail is located. In situations where a trail crosses multiple ownerships, the trail should be broken into individual segments for each ownership.
Difficulty	Trail difficulty level	Text/String	20	DifficultyLevel	This field defines the trail difficulty level with one of four levels (i.e. Beginner, Intermediate, Advanced, Expert).
Direction	Trail directionality	Text/String	10	Directionality	This field defines directionality for trails as to whether it is meant to be a one-way or two-way trail.
User_Max	Maximum allowed trail use	Text/String	20	UserType	Trail use types (from domain) are defined in a heirarchy in the following order: 4x4, ATV, Motorcycle, Bicycle, Equestian, and Hiker. The hierarchy establishes the maximum allowed use for any particular trail. A trail is open to its maximum allowed use as well as any lower level uses. For example, a trail designated as 'ATV' is also open to motorcycles, bicycles, equestrians, and hikers. A trail designated as 'Motorcycle' is open to lower level uses, but is NOT open to 'ATV' or '4x4' uses.
User_Primary	Primary trail use	Text/String	20	UserType	This field is used to define the primary trail user type (where applicable). For example, certain trails are specifically designed to be bicycle trails. The value used in this field does not necessarily indicate that other uses are not allowed, however, other uses are less favorable and perhaps not recommended.
BikeStyle	Trail type (Bicycle style)	Text/String	10	BicycleStyle	This field is used to categorize trails based on the bicycle experience provided. Trails are defined as either cross-county (XC) or freeride (FR). Cross-county trails generally provide variations in grade on an mostly obstacle free, smooth surface trail. Freeride trails generally provide more advanced terrain and man-made technical features (stunts). Freeride trails are often designed to be ridden in one primary direction (downhill). This field is used in combination with the Name field in developing the feature linked annotation class for name labels.
Date_Est	Date of trail establishment	Date			This field is used to define the date that a particular trail is established/constructed.
Date_Decom	Date of trail decommissioning	Date			This field is used to define the date that a particular trail is decommissioned (if applicable).
Date_Cmt	Date comment	Text/String	100		This field is used to enter free form text describing the details of the two previous date fields. The field holds enough characters that a running log of events can also be maintained for a particular trail segment.
ClosureCmt	Trail closure comment	Text/String	100		This field serves as a free form text field where trail closure information can be logged. For example, certain trails may be closed to certain uses during the wet season or fire season. This field allows for a description of closure details as applicable.
Sustnblty	Trail sustainability comment	Text/String	50		This is a free form text field that allows the data manager to log any information that is related to the sustainablity of the trail. For example, if sustainability issues are identified such as resource damage or areas needing trail work, they should be described here so they can be addressed.

*Note: The benefit of using short field names in the attribute table is that it keeps the length of overall data paths as short as possible. Also, when converting from geodatabase feature classes to shapefiles, it is beneficial to maintain field names that are 10 characters or less because of the limitation of shapefiles. Fields longer than 10 characters are otherwise truncated when converted to shapefile which can generate data management challenges.

Table 1: A Description of attributes in the trails feature class.

Data Methods

Many advanced data management and data manipulation techniques were used to create specific cartographic representations/effects. Some of these are summarized below and in several cases are supplemented with additional appendix documentation:

<u>Water body vignettes:</u> The purpose of a water body vignette is to subtly symbolize a difference between shallow and deep water for a better cartographic representation. In order to achieve this, a feature class representing large water bodies is converted to a raster with cell values assigned differently based on their distance from shore. Areas closest to shore are assumed to be shallower whereas areas further from shore are deeper. The resulting raster is symbolized with a lighter blue color representing shallow water and a darker blue color representing deeper water (Figure 7). Additional details on how this procedure was performed are provided in Appendix B.

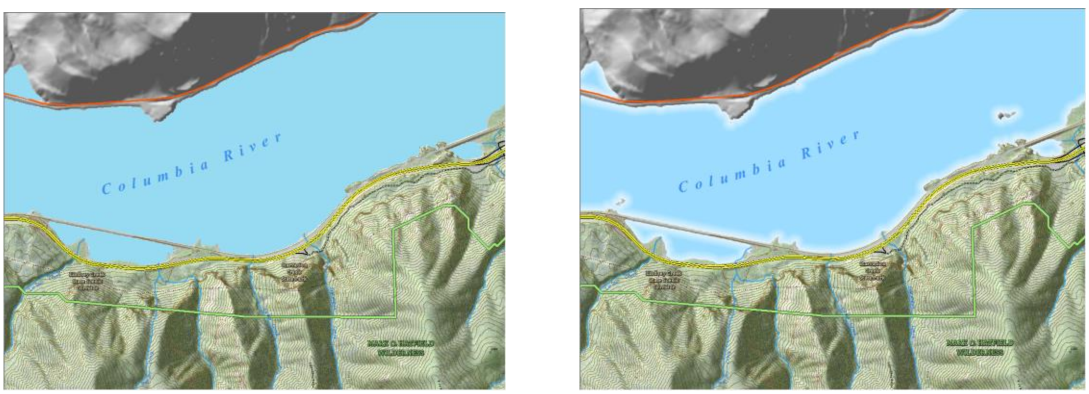
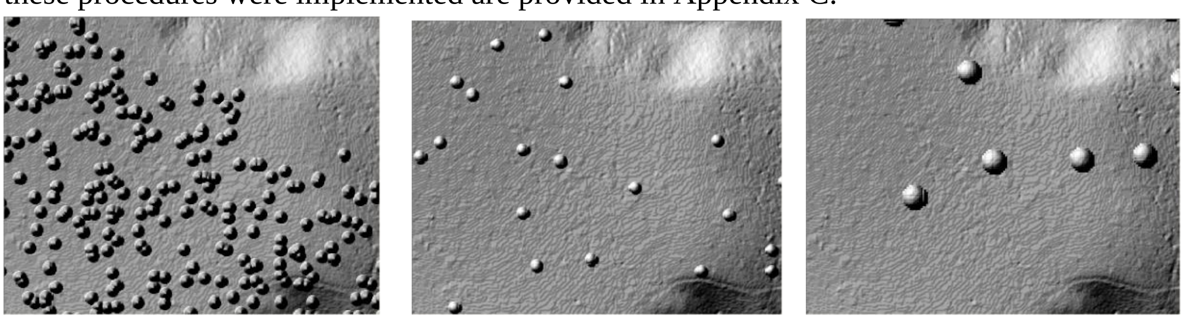


Figure 7: a.) Before vignette b.) After vignette

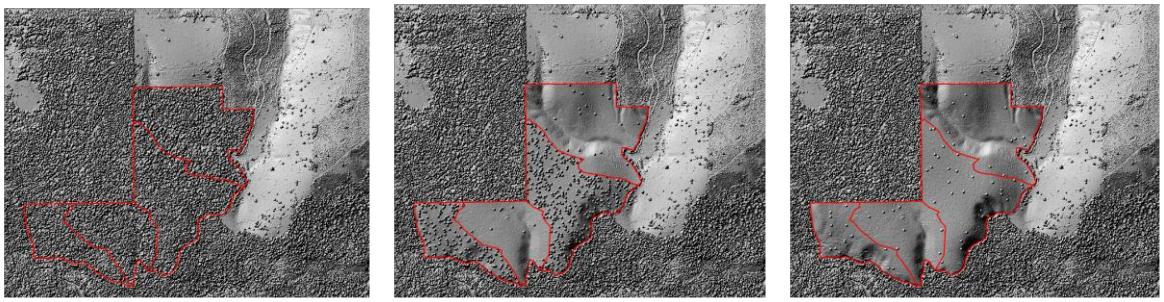
<u>Vegetation simulation from LiDAR:</u> The purpose of simulating vegetation using LiDAR is to enhance the map reader's orientation and understanding of features that are represented on the ground. In order to apply this cartographic technique, a Bare Earth LiDAR digital elevation model is subtracted from the Highest Hit (also known as Full Feature) LiDAR digital elevation model using the Raster Calculator. The resulting (output) raster has cell values representing only the height of vegetation (or other structures like buildings) that are above the ground surface. Next, this raster can be symbolized to represent the difference in height of vegetation (e.g. no color where there is no vegetation, lighter green for shorter vegetation, and darker green for taller vegetation). This raster can be overlaid on a hillshade image derived from Highest Hit LiDAR in order to cartographically represent vegetation height (Figure 8). Additional hillshade rasters, along with various levels of transparency, can also be used to provide cartographic representation of topography to supplement the visual effect.

Figure 8. Vegetation height is simulated through symbology with LiDAR data. Darker green is taller vegetation and lighter green is shorter vegetation.

Bump map techniques: Bump mapping techniques can be used to simulate vegetation through the creation of artificial 'Bumps' in a digital elevation model (and the subsequently derived hillshade image) that represent individual features (e.g. trees, bushes, etc.). The incorporation of bump mapping techniques in this project stemmed from a need to manipulate the appearance of vegetation in locations where our LiDAR-generated vegetation symbology was inaccurate. The problem we identified was that we are mapping an actively managed forest where timber harvests have occurred since LiDAR flights were completed (2008). In other words, our symbology derived from LiDAR was showing forest in areas that had been recently clear-cut or thinned. In order to generate a more accurate map we used bump mapping in these areas to simulate the different silvicultural treatments. Clearcut-areas were essentially manipulated to appear as mostly devoid of trees but having sparsely dispersed 'leave trees' which are required under Forest Practice laws. Thinned areas were manipulated accordingly so that they appear as randomly dispersed trees rather than a dense forest. Bump mapping tools were downloaded from the ESRI Mapping Center Models and Scripts website. The tools run using customizable Python code, which allow for the creation of different tree shapes (e.g. cones and domes) and sizes (Figures 9 a-c), as well as the creation of the desired characteristics for density of tree spacing (Figures 9 d-f). Additional details about how these procedures were implemented are provided in Appendix C.



a. b. c.



d. e. f.

Figure 9: Bump map examples. a.) Cones, b.) Domes, c.) Large size domes, d.) Original LiDAR vegetation, e.) Bump mapping applied with variations in tree density between stands, f.) Additional example of bump map with variation in stand density.

<u>Tint bands:</u> Tint bands can be used as a cartographic technique to form a wide band to symbolize things such as boundaries. In this project, tint bands were used to symbolize boundaries of major land ownership. Property boundary identification is important to Hood River County Forestry Department staff and it is equally important that they convey this information accurately to recreation users and map readers. It is important to make sure recreation activities are consistent with regulations for each ownership type (i.e. County, State, and Federal) as well and restricting infringement on private property.

The process of creating tint bands requires multiple steps but provides a cartographic representation that is not directly available through standard line symbology settings or through development of polygon (i.e. boundary) buffering techniques. The first step in the process was to dissolve property parcels that were owned by one particular landowner. All Hood River County, State of Oregon, and U.S. Forest Service parcels were identified and merged by distinct owner. Also, all privately owned parcels were dissolved into one large multipart polygon. Next, the tint bands were created using techniques that are described in more detail in Appendix D. Developing tint bands of the best width for cartographic purposes required testing of several different widths. A model was developed in ESRI's Model Builder so that small manipulations could be made and the model re-run without having to manually redo all of the geoprocessing tasks with each test (Figure 10). The finished products were tint bands that provide a cartographic representation that can be adjusted with respect to desired color and transparency (Figure 11).

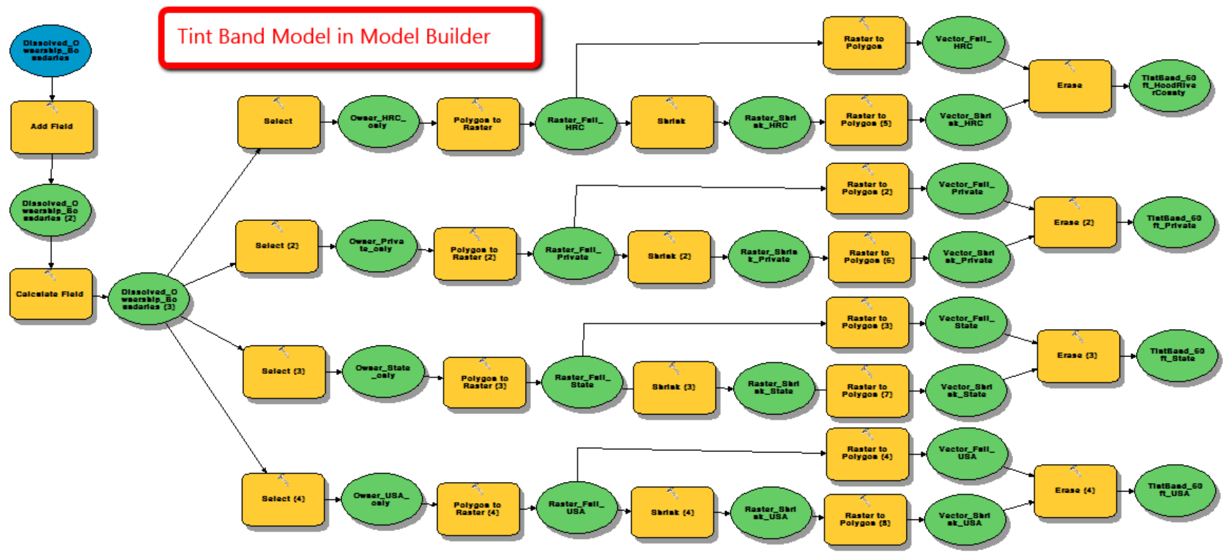


Figure 10: Model Builder image of geoprocessing tasks used to create tint bands

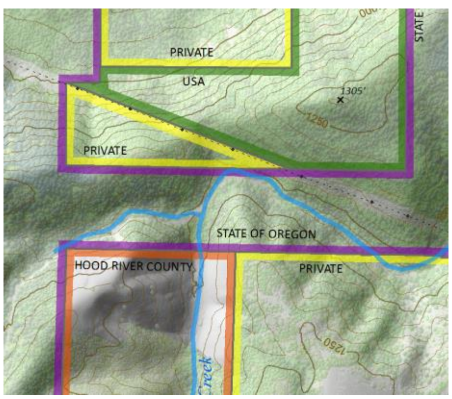
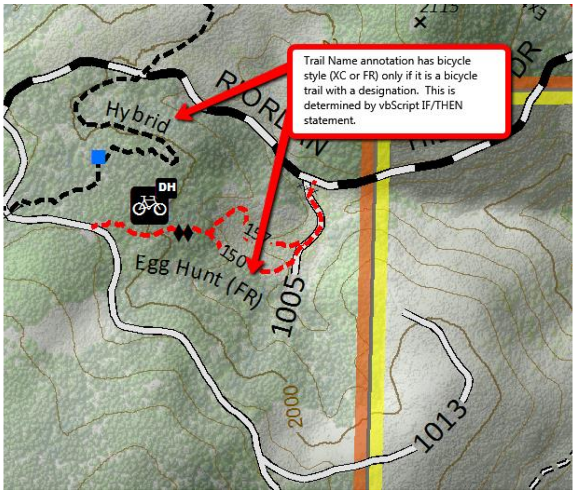


Figure 11: Example of tint bands representing ownership boundaries (shown in yellow, green, purple, and orange).

<u>Feature-linked annotation:</u> Feature-linked annotation feature classes were used to develop map labels/text for several layers. In some cases this required custom vbScript expressions to combine multiple attribute fields into a single text string based on IF/THEN statements. For example, this was used for trail name labels (Figure 12).




```
Function FindLabel ( [Name], [BikeStyle] )
  If  IsNull ([BikeStyle]) Then
    FindLabel = [Name]
  Else
    FindLabel = [Name] & " (" & [BikeStyle] & ")"
  End If
End Function
```

a. b.

Figure 12. Example of custom annotation from vbScript IF/THEN statement as seen a.) in the map, and b.) as a code example.

Creating custom symbols and Style References: Development of custom symbols was necessary for certain cartographic effects (Figure 13). Symbols were compiled into a Style Reference so that they could be easily shared among team members. This ensured consistency in the cartographic representation seen on each member's screen. The procedure used to share Style References is provided in Appendix E.

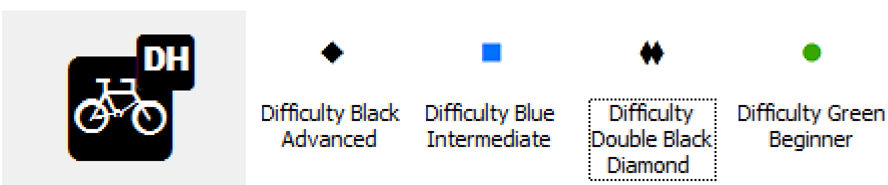
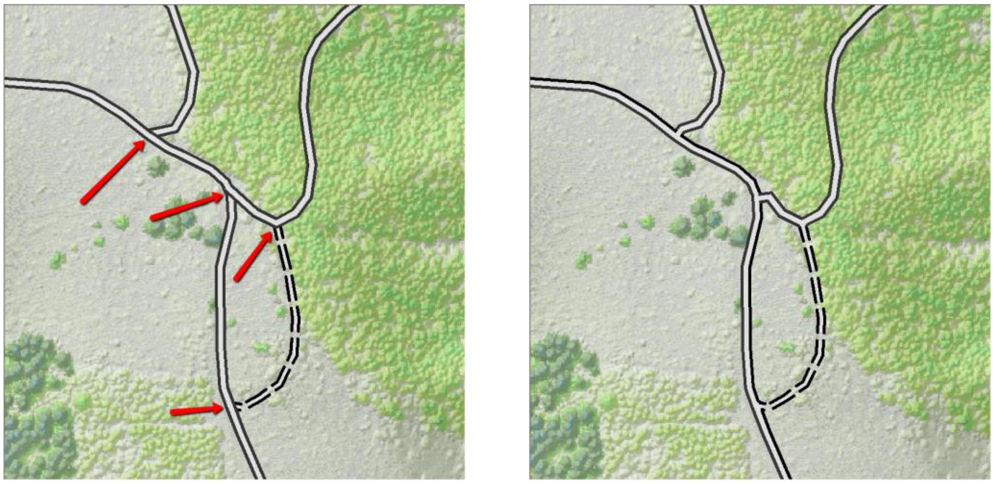


Figure 13: Examples of custom symbols that were created and stored in a custom Style Reference.

Representations: In some cases, feature class representations were required to generate the desired cartographic effect. Representations allow fine tuning of the cartographic 'representation' of features to obtain a desired visual effect without actually modifying the underlying feature class data in the geodatabase. This is ideal when you need to manually adjust the placement of specific features or their draw order, but do not want to change the data itself (Figure 14, a and b).



a. b.

Figure 14: Example of using representation for a desired cartographic effect as seen in the before image (a) and the after image (b).

<u>Variable depth masking to improve annotation display:</u> Variable depth masking is a technique that uses a mask layer that is essentially a polygon generated around each piece of annotation. The user defines the layers that will be 'masked' (i.e. visually obscured) by the mask polygon. This technique was used with annotation in layers such as roads, trails, and contours (Figure 15).

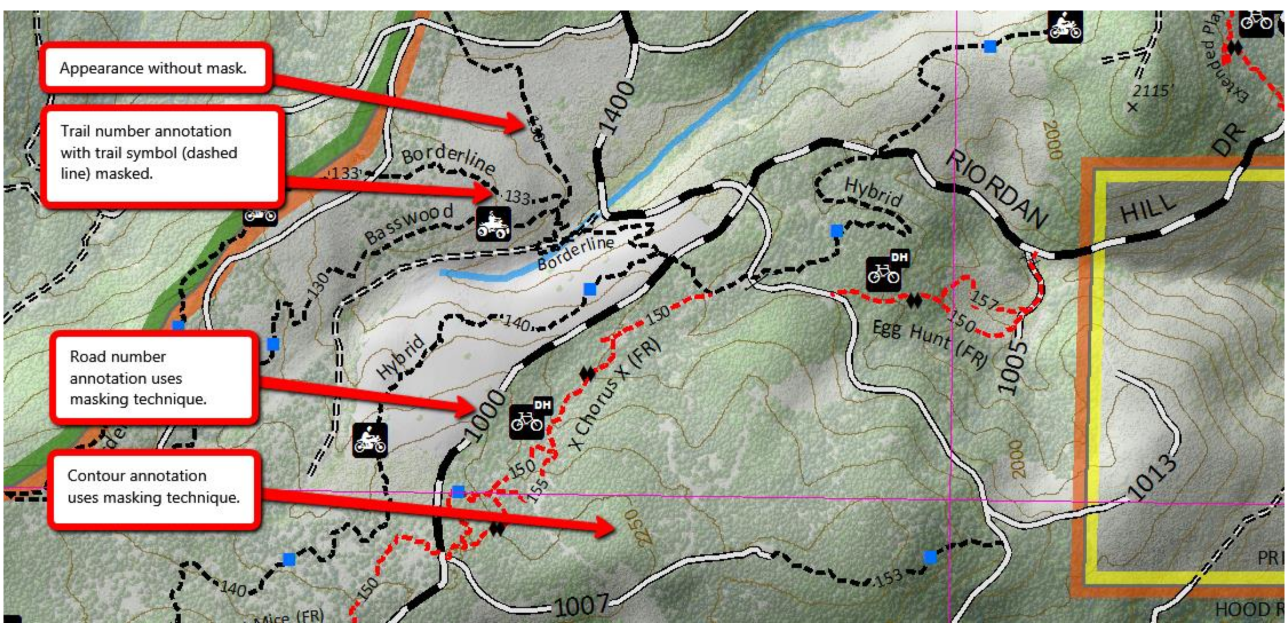


Figure 15: Examples of variable depth masking in combination with annotation.

<u>Use of reference grids:</u> Reference grids can be used by the map reader for orientation, particularly when used in concert with GPS coordinates while in the field. Two separate reference grids were used in the map, including a latitude/longitude grid and a UTM grid (Figure 16).

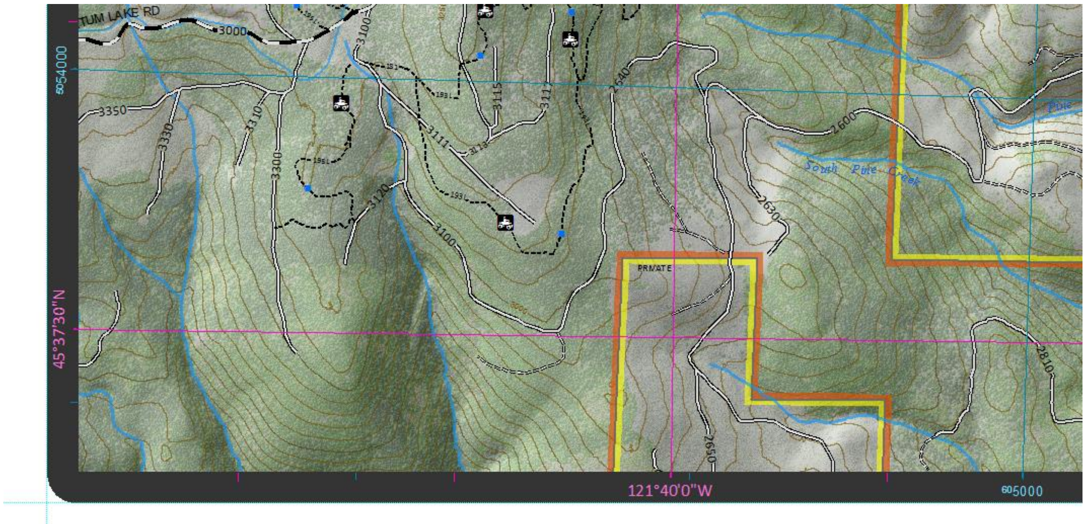
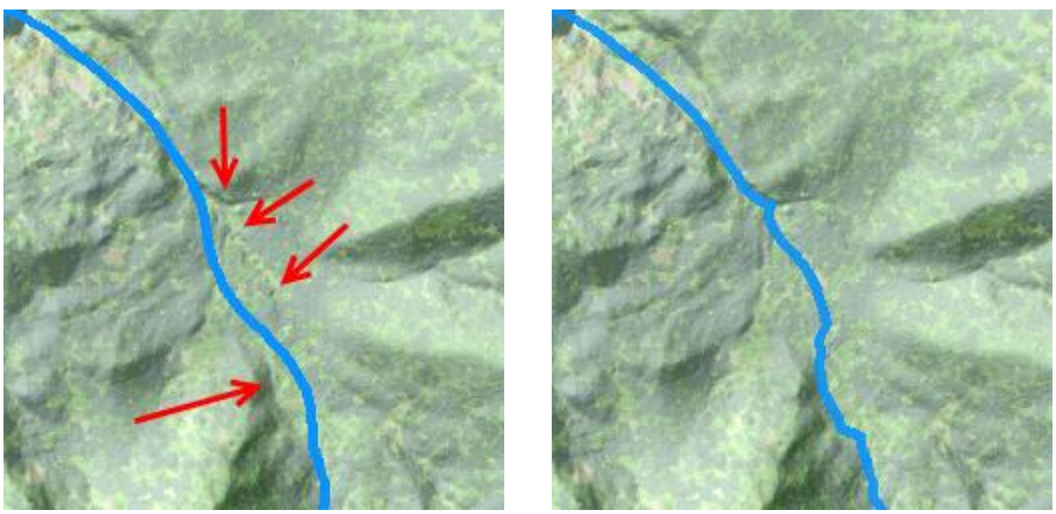


Figure 16: Reference grids for Lat/Long (pink) and UTM (blue) along with their respective grid labels along the map border.

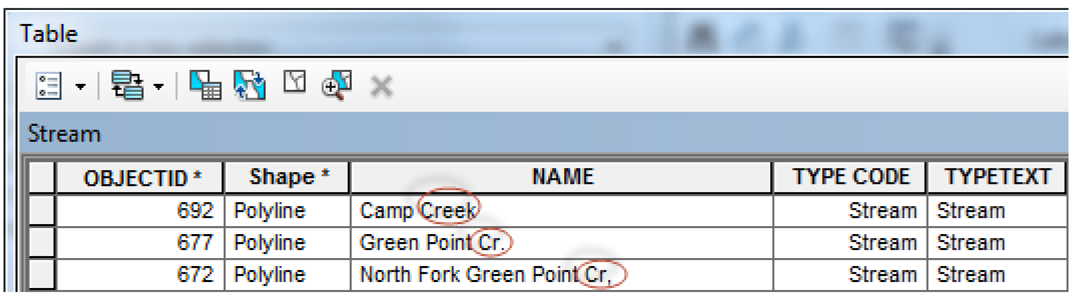
<u>Stream Symbology and Labeling</u>**:** The stream file began as a Hood River County layer with 839 features that was first clipped to just beyond our extent, resulting in 128 features. Once the streams phenomena was viewed in the map in relation to the other data, it was clear that they did not line up with some of the base layer data as shown in Figure 17a and Figure 17b. In Figure 17b, the stream has been edited to 'follow' the LiDAR elevation data.



a. b.

Figure 17 (a and b): Stream Not Edited and Stream Edited to match LiDAR data.

The streams initially lined up with one of the hillshades because they too were created from NED 10 meter DEM. The NED 10 meter DEM (and therefore its hillshade) was the best available digital elevation model for generating stream centerlines on the regional scale. That is, when someone at the State of Oregon created a stream centerline dataset, they took the best available DEM (the USGS NED 10-meter resolution DEM) and produced stream centerlines for the State of Oregon that were subsequently adopted by Hood River County. This scenario is similar for Washington and many other states since the 10-meter DEM is the best available complete DEM for the continental USA. However, LiDAR is now available but only in certain areas. It is not available for the entire state. This means it is impossible to use it to create an improved statewide hydro dataset(s). The LiDAR is 3 ft resolution compared to the roughly 32.8 foot (i.e.10 meter) DEM resolution. If necessary and time allowed, the LiDAR data could be used to perform hydro modeling and to develop very accurate location of the centerlines (where LiDAR is available). It was logical that the streams lined up with the NED DEM (hillshade) because they were both derived from the same dataset. This creates a visual problem. To resolve this issue, a table was exported from the clipped streams layer to use as a physical (paper and pencil) 'check-off' sheet as each stream was edited within the geodatabase to match the visualization of the LiDAR data. As each stream was edited, it was checked off as completed. Another issue with the stream layer was instances of labels such as '<Name of Stream> Cr.' '<Name of Stream> Cr,' and '<Name of Stream> Creek' for creeks as shown in Figure 18.



Table

Stream

OBJECTID *	Shape *	NAME	TYPE CODE	TYPETEXT
692	Polyline	Camp Creek	Stream	Stream
677	Polyline	Green Point Cr.	Stream	Stream
672	Polyline	North Fork Green Point Cr,	Stream	Stream

Figure 18: 'Creek', 'Cr,' and 'Cr.' issue.

A new text field was created, to which 'NAME' was copied. Through a series of selections and short python code (!NAME!.replace("Cr,","Creek" for example)) all instances of 'Cr,' and 'Cr.' were changed to 'Creek' for consistency. It should be noted that this issue should have been resolved at data entry. Upon completion of stream editing, Maplex was selected as the label editing engine and labels were placed for each part. While this produced far more labels than necessary, it provided a good choice from which to choose appropriate labels. In addition, using Maplex the Label Repetition was utilized so that even more labels were created. During final editing, extra labels were deleted. Labels were placed using 'River Placement' (Curved), 'Offset' from the line (stream) by 1 point and allowed to overrun the feature. The minimum feature size for labeling was two inches; labels were NOT allowed to 'stack' and were set to 'Follow' the feature for easier placement and editing. The labels were converted to annotation that was stored within the Stream Geodatabase. This is important to note because ArcGIS Desktop Standard is the minimum requirement for editing feature-linked annotation or other types of relationship classes. Every stream label required a placement modification so that it was not overlapping another important feature. During final editing (when all features and feature labels/annotation are on the map), it is likely that minor modifications will be necessary to create a high quality document.

Testing & Results

For our project, we tested different trail database designs, various map layouts, and online map products. Through these processes we determined what would be the best approach for Hood River County to implement.

Trail Database Design

Trail geodatabase development occurred through a process of design and testing. The first step was to scope the needs of HRCFD in terms of their trail data and map needs. With this complete, we were able to start conceptualizing ideas about necessary database elements (Figure 19). Next, we proceeded to build the geodatabase and define its properties in ArcCatalog. A subtype field was applied and several attribute domains were developed to improve consistency and quality control during data entry. A benefit of using subtypes is that it allows default behaviors to be established for each field in the attribute table based on a particular subtype. This generally decreases the amount of time required during data entry and therefore will provide workflow efficiencies for the HRCFD personnel. After a significant amount of data scrubbing and cleanup of the HRCFD's existing trail shapefile(s), we were able to import the data into our new trail feature class. The geodatabase feature classes were edited in test mode (i.e. with backup copies) to ensure that subtype, domains, and default behaviors were working as intended. As we continued to work with the geodatabase there were several instances where additional fields needed to be added and assigned accordingly for default behaviors. There were also several instances where we use ArcToolbox geoprocessing tools to modify domain value lists to either add or remove values from the lists.

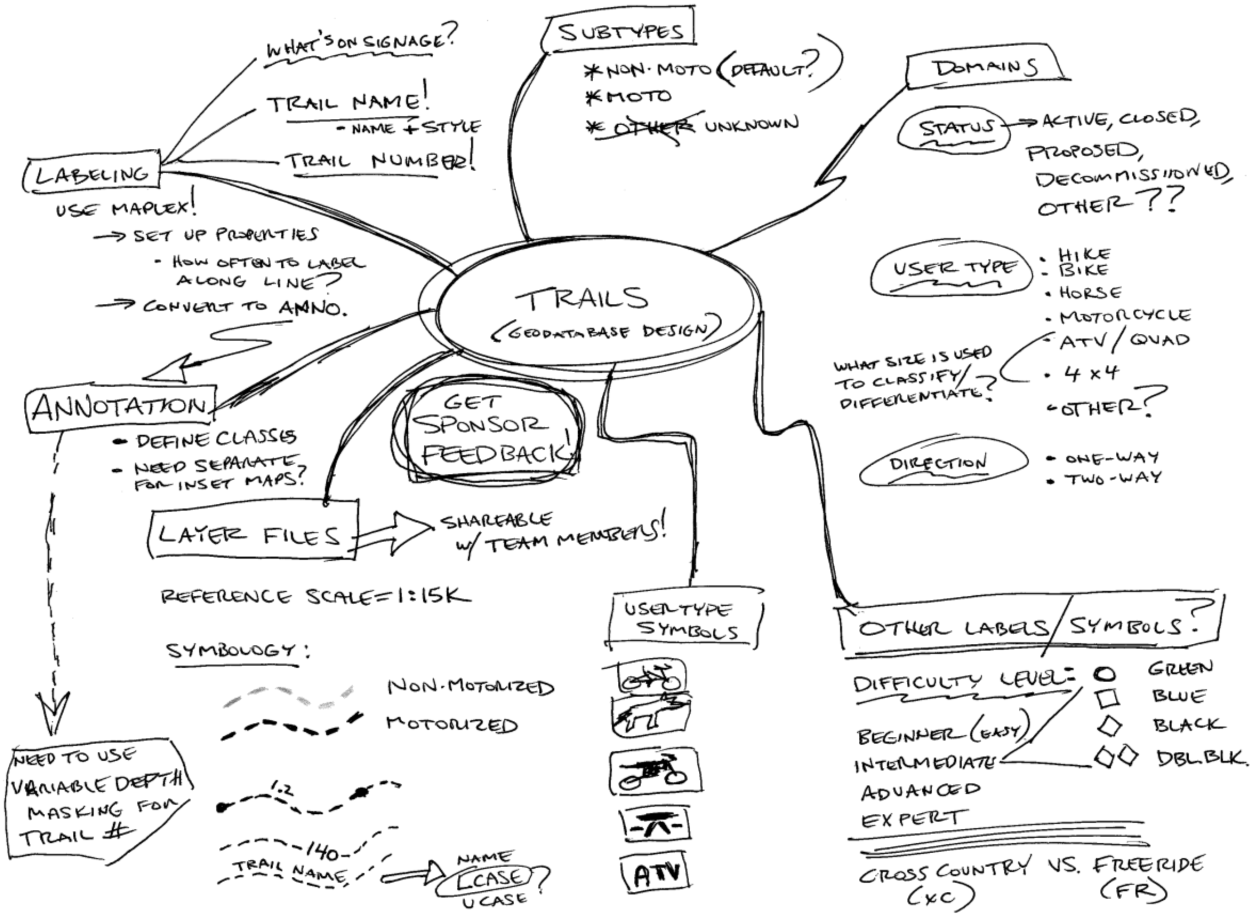


Figure 19: Brainstorming of geodatabase design elements

Trail Map

During the creation of our map products we used a strategy of dividing up data development activities. Each team member took responsibility for one particular data theme at a time, be it trails, roads, contour lines, streams, water bodies, boundaries (of ownership, wilderness, scenic areas), etc. As each dataset was prepared for representation, feature-linked annotation was created and meticulously edited to place labels following cartographic best practices and with visual appeal and readability in mind. As dataset packages were finished and shared back among team members, minor adjustments were sometimes needed to fix overlaps (such as annotation overlaps) between datasets or other small manipulations to improve cartographic representation.

The process of developing all of the map elements including the feature symbols, annotation, layouts, and a host of other map elements, required constant testing and refinement. As the cartographers we were responsible for determining appropriate symbol types, colors, sizes, fonts, positioning, classification schemes, brightness, contrast, transparencies, etc. On many occasions drafts of the map were exported to digital copies for review and/or printed to ensure that the desired visual effect was being achieved. After developing a conceptual layout for the map (Figure 20), we were able to make decisions about paper size, project area, and the appropriate scales of the main map and any inset maps. Many of these decisions required careful consideration and conversations with the project sponsor to determine their interests (e.g. discussing printing costs when considering different paper sizes). We experimented with several different prototypes before reaching the final size, configurations, and layout. The finished map provides the best balance on many cartographic best practices and decisions (Appendix F).

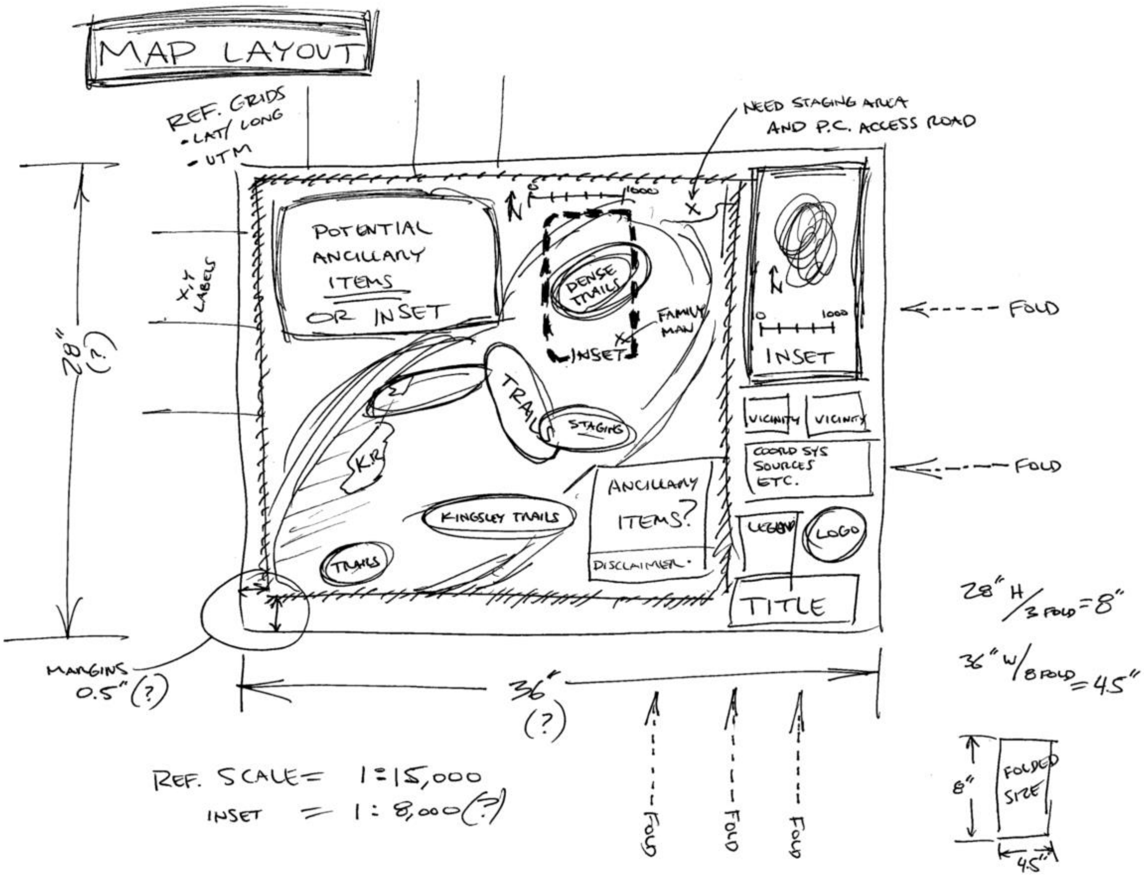


Figure 20: Conceptual map layout

ArcGIS Online Prototypes

In our attempts to provide suggestions for further study and analysis for a sustainable trail management system, we experimented with two approaches to web mapping. For the first web map, we tried publishing and hosting a feature service using a shapefile. For the second web map, we instead tried publishing and hosting a feature service using an ArcMap document. Both methods have their benefits and drawbacks. Choosing a method to implement will depend on what is considered to be the most important and the most feasible.

ArcGIS Online Map - Publishing a web map using a shapefile or CSV file:
Shapefiles or CSV files can be uploaded to ArcGIS.com and hosted as services in the cloud. This can be done without ArcGIS products locally installed on the machine. All you need to do is have a zipped shapefile that is saved to your computer. Then in ArcGIS.com the zipped shapefile can be uploaded by adding it as an item. While a web map with a shapefile is very easy to create, it has limited capabilities. Publishing a hosted feature service from ArcGIS.com using a shapefile, can only support files that are smaller than 10 MB meaning only small .zip shapefiles and CSV files containing less than 1,000 features can be added to the web map. The zipped shapefiles are easy when you only want to display a simple and small feature on the map (Figure 21).

Figure 21: Example Trail Web Map with a Shapefile

ArcGIS Online Map - Publishing a web map using an ArcMap document:
An ArcMap document can be published as a feature service and hosted in the cloud using ArcGIS.com. To publish an ArcMap document, first create the map document (.mxd) with the layers displayed how you would like them to be shown in the web map (Figure 22). Scale and symbolize the layers accordingly. Even though a basemap will be used in the final ArcGIS.com map, it cannot be published as a map service with an ArcGIS.com basemap in the map document.

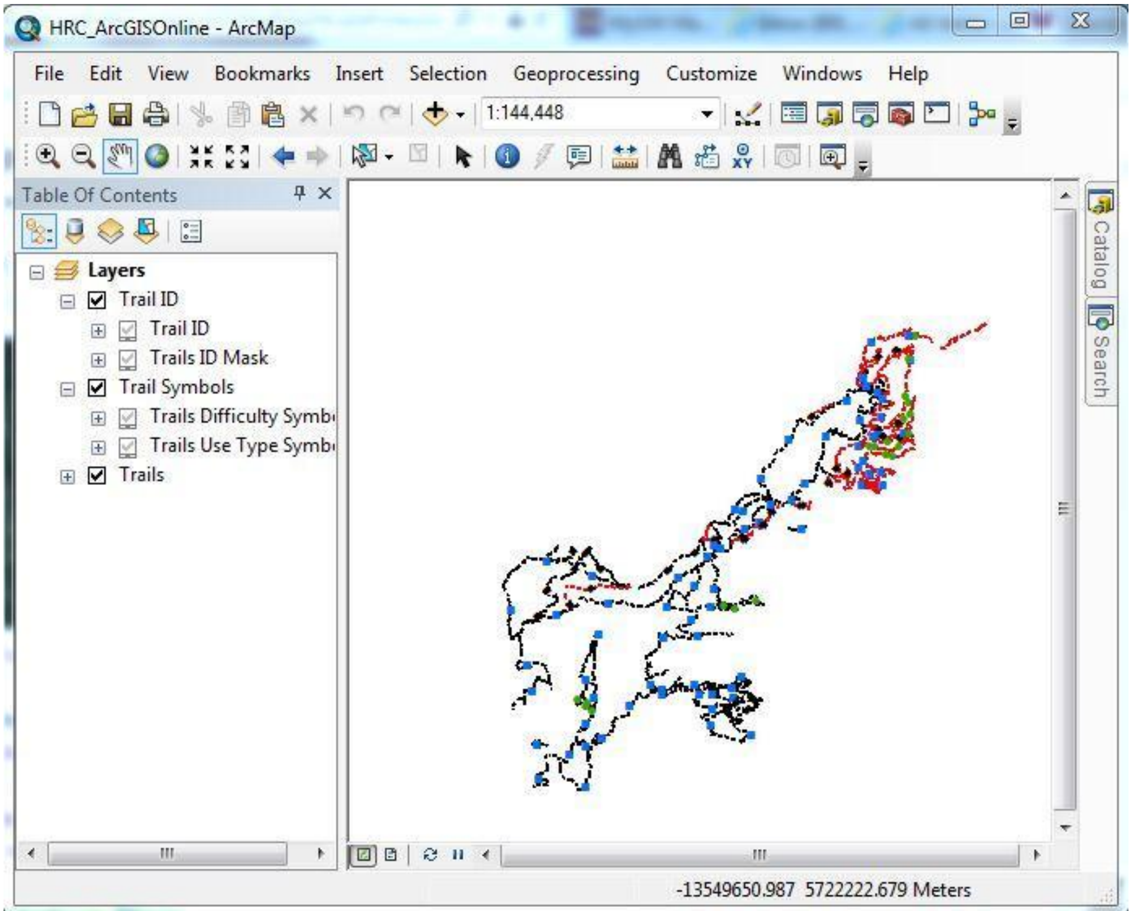


Figure 22: ArcMap Document to be published as a Map Service

Once the map document contains all of the desired web map layers, it must be 'Analyzed' to see if the map can be published as a service (File > Analyze Data…). Analyzing the map examines drawing errors, warnings, and messages that could potentially impact the drawing performance. For example, an error appears if the data layers are not in the correct coordinate system for ArcGIS.com (WGS_1984_Web_Mercator_Auxiliary_Sphere). Other errors can occur if the symbology is not supported in ArcGIS.com. If errors exist, error messages will appear in a new window. Right-clicking on an error will explain the conflict and provide ways to resolve the issue. If there are errors they will need to be examined and fixed before the map can be published as a service. Once the errors have been fixed, the map can be shared as a map service on the University of Washington Department of Geography server. In ArcGIS.com, the map service can be loaded with all of the layers that were previously in the map document (Figure 23). The layers in the web map will be symbolized and shown exactly how they were specified. The map service created from an ArcMap document supports larger datasets, feature classes, and annotation feature classes. While this approach provides a lot more interactive and design capabilities, an ArcGIS Server is needed in order to create a map service.

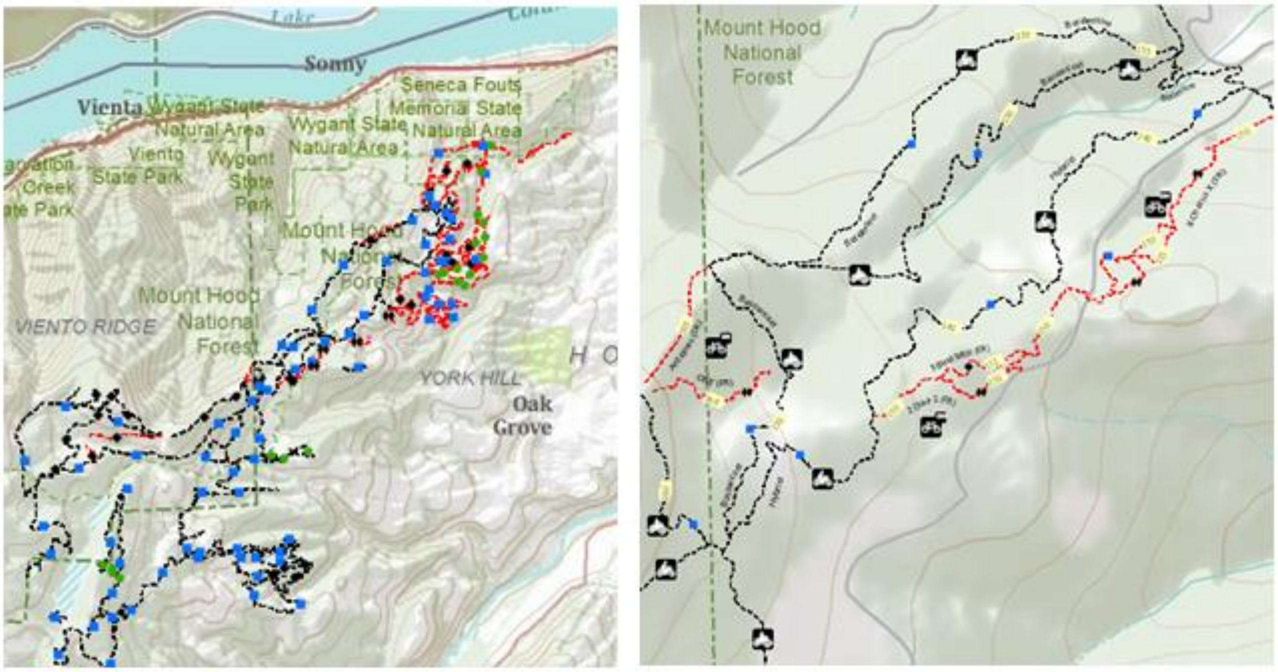


Figure 23: A Zoomed Out and Zoomed In View of the ArcGIS Online Trail Map

Implementation Plan

This project is unique in that there is one specific deliverable (an updated cartographic representation of the HRC Recreational Trail System) and a recommended plan of further action (Figure 24) for the County to more effectively maintain their system of sustainable logging areas which double as a recreational area.

A cartographic representation has been presented to HRCFD, and is currently under review in a process that will outlast the length of GEOG 569. It should be noted that the project team has committed to Mr. Buckalew that we will work with him and the County to make any and all necessary edits to the document as the review process moves forward. The project team has developed a completed hard copy map (still in draft form) with the updated data that has been received to date from the project sponsors.

For HRC to implement the cartographic representation (Print the Map), the map should be edited to satisfaction by the HRCFD staff and then sent out to ‘people of the place’ to provide input. While the county would have final say, it is important to hear from community groups, recreational trail users, businesses and other entities involved with the HRC Trail System Master Plan. To implement the final recommended version of our design, we will plan to take the elements from the map layout brainstorm and put them into the final hardcopy map. While the data maintenance and cartographic representation have been very time consuming and tedious, the project sponsors will benefit from having an updated non-motorized trail map, an updated trail database, and a map document that can be used as a template for future updates.

In order for the project sponsors to implement the recommended trail design for the future, we plan to provide the project sponsors with all of the necessary databases and map documents that were used to create the final product. For maintaining the trail database, it would be helpful to have someone who can take ownership of it in order to make sure that it gets updated accurately. It would be recommended for the HRCFD to train the staff on how to add, maintain, or delete data according to the trail database design. It would be very beneficial and recommended for the trail data to be updated on a regular basis, and as it gets updated via field work. This will prevent the trail database from getting outdated and will make it easier to update the non-motorized trail map in the future.

For implementing the web map using a shapefile, the HRCFD could simply create and export a zipped shapefile or CSV file, store it on a hard drive and upload it to an ArcGIS Online map. If the HRCFD decided to implement the proposed web maps created with a map document, it would be recommended for the county to invest in an ArcGIS Server. The decisions involved in this portion are beyond the scope of the project, specifically because we were asked to focus on creating a print ready map and to provide suggestions for data management and future map development. However it is included because of our suggestion for further study and it is something for them to consider.

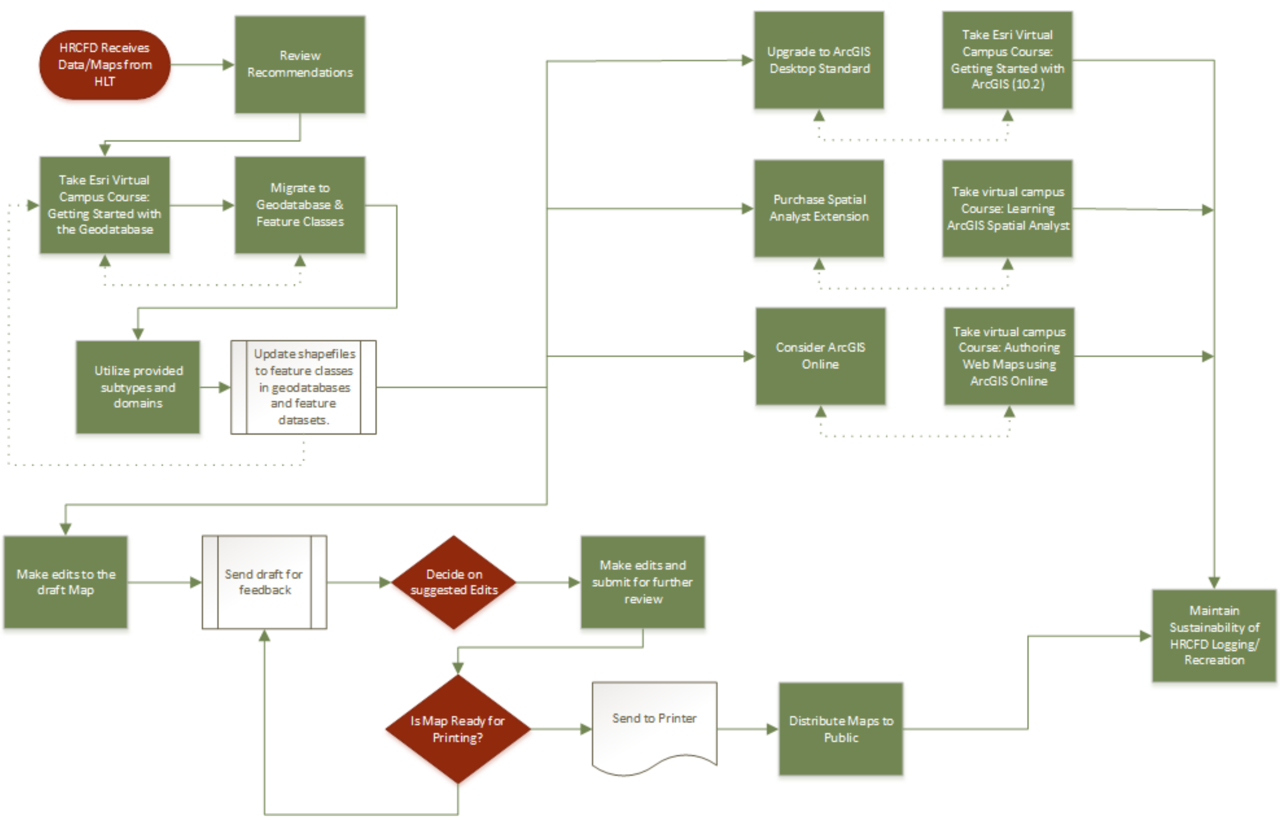


Figure 24: Implementation workflow diagram

The GIS data management aspect of the project was focused on a business process improvement for HRC. By definition, a 'business process improvement' is a situation in which business processes are tuned or modified to increase performance using incremental and continuous changes to process where modifications happen more slowly but continuously and frequently (McKibben & Pacatte, 2003). We set out to provide a series of recommendations to help improve the HRCFD workflow. Harmon states: "the first phase of any process change project is to define the project itself, consider possible solutions and then make a recommendation about what level of effort and budget will be needed to solve the problem (Harmon, 2007). In addition, this is not a bottom up methodology; there is full involvement and support from the 'Senior Management' (project Sponsor– Mr. Buckalew) (McKibben & Pacatte, 2003). As such, with the support of Mr. Buckalew we have developed a list of suggestions in order to implement our trail design as well as sustainable management ideas.

1. Upgrade the current software (2 licenses) from ArcView 10.0 to a concurrent license of ArcGIS Desktop Standard 10.2 (formerly known as "ArcEditor" in versions prior to 10.1) that can be used by both Mr. Buckalew and the Forestry Office Manager. There are multiple benefits in upgrading to this version that will facilitate data management and editing. At the ArcGIS Desktop Basic license level (formerly known as "ArcView"), users are able to edit annotation stored in a map document (.mxd), or view annotation stored in a geodatabase, but are restricted from editing geodatabase annotation. Because there are many benefits to storing and managing annotation in a geodatabase, and because all of the annotation developed for this project is stored this way, we are recommending the upgrade to the higher license level so that staff has the ability to edit annotation as needed for future map projects. With an upgrade to any of the ArcGIS license levels that are version 10.1 or newer, users gain access to the Maplex labeling extension. This extension was previously only available at no cost at the ArcGIS Desktop Advanced license level (formerly known as ArcInfo), or through an additional purchase of the extension for $2500. The Maplex extension provides a sophisticated labeling engine that improves the ability to generate labels and new annotation. The approximate initial cost for the upgrade to ArcGIS Desktop Standard is $7000 with a $1500 per year maintenance fee.
2. Add a concurrent license of the Spatial Analyst Extension from Esri. Spatial Analyst will provide a plethora of tools that are useful for analysis and generation of additional datasets. Spatial Analyst includes tools that are required to perform the 'Bump Mapping' techniques used in this project. Spatial Analyst also provides tools for generating hillshades, contours, and a host of other datasets and would be useful to HRCFD when used in concert with their LiDAR data. The initial cost for this extension is $2500, and there is a $500 per year maintenance fee.
3. Instead of using shapefiles, it is recommended that HRCFD begin using feature classes stored within geodatabases and perhaps organized within feature datasets. Files are being returned to HRCFD in many separate geodatabases so that they can be easily edited and

maintained as necessary. There are only slight procedural changes between feature classes and shapefiles, and the benefits outweigh the short learning curve.

4. A significant reduction in data entry time will be achieved if HRDFD utilizes the subtypes and domains that have been developed for several data sets. It is also recommended that HRCFD create subtypes and domains in new datasets as appropriate. The use of these items will also reduce data entry error (thus saving additional time that would have been required to 'fix' the errors).
5. Moving forward, it is suggested that HRCFD maintain one dynamic dataset for each specific phenomena, rather than create duplicate shapefiles or feature classes for each new task. With domains and subtypes, data quality can be maintained with less chance of corruption.
6. Back-up copies of all data should be housed off location, perhaps on a server and/or in the cloud. Data should be backed up daily.

Financial Analysis

As noted by Mr. Buckalew, the county has very limited staff and financial resources that they can devote to recreation management. The use of GIS has already eased some of the burden in terms of managing an inventory of the trail system. The importance of a quality map product was emphasized because of how many people use it. Mr. Buckalew noted that the map is "heavily used by our own Forestry staff and recreationists." HRCFD provides maps to users via the county office, outdoor retailers, as well as in the forest at some of the staging areas. Recreation tourism is an important component of HRC economy, and promoting sustainable trail recreation serves many social, economic and health benefits within the community. Mr. Buckalew noted that the ability to wisely and sustainably manage the trail system starts with having a good inventory of trails and a good map. In creating a quality map, HRC would be more likely to be awarded in-kind matches toward grants that HRCFD manages for recreation trail improvement projects. While the reasoning behind the production of a new map and improved workflows seem obvious from the Project Questionnaire and in speaking with Mr. Buckalew, it is important to complete a thorough financial analysis of the proposed GIS improvements and creation of the cartographic deliverable to the County to determine if the changes are financially beneficial.

The development of this 'top-down - business process improvement' stipulates only minimal financial outlays. However, it is imperative to consider and document whether there will be any significant costs incurred with the advent of the suggested changes and if the costs will be offset by the business process improvements in the form of streamlined (more efficient) workflows, increased revenue and other monetary advantages. Nancy Lerner's 'Business Process Analysis/Modeling for Defining GIS Applications and Uses' was utilized as a template and guide to analyze the financial aspects of the proposed business process improvements. We utilized the 'Future 5 Years.xls' template provided by Lerner based on the assumption that GIS technology is rapidly changing over time and it is very likely that in five years there will be technology in place that would require additional financial analysis. We saved the file in the most recent .xlsx format in MS Excel 10 and proceeded with the instructions. There are only 4 internal and zero external positions involved in this project, as HRC Forestry Department is very small and this is not a county wide analysis.

Many assumptions were made in an attempt to complete a general financial analysis without going outside of the original scope of the project. Unfortunately, there wasn't an opportunity to consult with the HRC Financial and Human Resources departments. Following the directions in Appendix A of Lerner's publication, variables were entered in the Project Setup Sheet as indicated in Table 2 below (Lerner & Technology Association, 2007).

Project Name:	Hood River County GIS Improvement Project (HRC-GIS)				
Date Analyzed:	8/3/2013				
Net Present Value (Net Benefits):	$308,977				
Annualized Return on Investment:	242.04%				
Breakeven Point:	2013				
Payback Period (in Years):	0				
Inflation Rate:	2.47%				
Opportunity Cost of Capital:	5.00%				
Project Year Labels:	**2013**	**2014**	**2015**	**2016**	**2017**
Project Life (Number of Years):	5				

Method for Determining Future Years' Cost of Labor:
Derived by Applying Inflation Rate to Current Costs

Notes and Other Assumptions:
Project will be implemented in year one (2013) and continue for five years.

Table 2: Project Setup Sheet

While some of the values are entered automatically from other sheets in the excel document, some were entered manually:

- Inflation 2.47% (based on the average inflation over the past 10 years as reported on the http://data.bls.gov website) (D. o. L. United States, 2013).
- Opportunity Cost of Capital: 5% (as suggested by the spreadsheet/directions)
- Project year labels 2013 – 2017
- Method for Determining Future Years' cost of Labor: Derived by Applying Inflation Rate to Current costs (as recommended by the spreadsheet/directions)

NPV (Net Present Value) was chosen (as opposed to ROI) as the key metric in this analysis. NPV is more straightforward, ROI can be somewhat deceptive and cannot be used in comparing mutually exclusive investments (Gardner, Gould, & Jumawan, 2012). Because we are going under the assumption that NPV is the more acceptable metric, we decided to not treat any of our internal labor costs as a negative productivity benefit (Lerner & Technology Association, 2007).
The 'Financial Analysis' sheet will be discussed later in this document because the values herein are based on twelve other sheets in the file.

Four types of Job Categories were entered into the Labor Rates worksheet. Trails Program Coordinator/Forest Technician II (Mr. Buckalew), Forestry Office Coordinator, part time Forestry Technicians and GIS Director, with approximated salary values as shown below in Table 3.

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Job Category	Current Average Hourly Rate ($/Hour)	Fringe	Burdened Hourly Rate	Average Annual Regular Hours	Average Annual Cost Before Overtime	Average Annual Overtime Hours	Average Overtime Multiplier	Average Annual Cost of Position
Trails Coordinator/Forestry Tecn	$40.00	33.00%	$53.20	2080	$110,709.20	0		$110,709.20
Foresty Office Coordinator	$20.00	33.00%	$26.60	2080	$55,354.60	0		$55,354.60
Forestry Technician I's	$12.00	33.00%	$15.96	2080	$33,212.76	0		$33,212.76
GIS Director	$60.00	33.00%	$79.80	2080	$166,063.80	0		$166,063.80

Table 3: Labor Rates Worksheet

Approximate wages and fringe were entered, and because overtime is not currently authorized within the county, it was not included in this analysis. Fringe (a wage multiplier that covers the cost of taxes, insurance, and related overhead items that contribute to the cost of each employee) was set at 33% for all positions to replicate the Lerner example (Lerner & Technology Association, 2007). All other work on the trail system is volunteer work.

In the 'Labor Cost Multipliers' worksheet, (Table 4) 'per hour' was selected as the default basis for labor costs, nothing else was changed in this worksheet.

Method for Determining Future Years' Cost of Labor:			**Derived by Applying Inflation Rate to Current Costs**					
Job Category	**Current Hourly Rate**	**Current Cost/FTE**	**Valuation Method**	**2013 Labor Cost**	**2014 Labor Cost**	**2015 Labor Cost**	**2016 Labor Cost**	**2017 Labor Cost**
Trails Coordinator/Forestry Tecnician II	$53.20	$110,709.20	*per Hour*	$53.20	$54.51	$55.86	$57.24	$58.65
Foresty Office Coordinator	$26.60	$55,354.60	*per Hour*	$26.60	$27.26	$27.93	$28.62	$29.33
Forestry Technician I's	$15.96	$33,212.76	*per Hour*	$15.96	$16.35	$16.76	$17.17	$17.60
GIS Director	$79.80	$166,063.80	*per Hour*	$79.80	$81.77	$83.79	$85.86	$87.98

Valuation Method Options	***Description***
per Hour	*Labor cost reflects averge cost per hour worked*
per FTE	*Labor cost reflects average annual cost of one full time position*

Table 4: Labor Cost Multipliers

In the 'Internal Labor Usage' worksheet, the nature of the work was entered as well as the total of all labor hours for the category was entered in the corresponding years. It is estimated that fifty hours will be required on the part of Mr. Buckalew, one hundred hours by the Office Manager, and zero hours by the part-time Forestry Technicians and ten hours by the Hood River County's GIS Director. The reasoning behind this is there are not many **new** tasks **nor** many drastic changes to the workflow, **and** all changes will be beneficial to productivity. Once the change in workflow is adopted and the map product is produced, there will be no additional work time to implement the suggested changes. The expected hours required for the implementation of the recommendations are documented in 'Internal Labor Usage' worksheet (Table 5) below.

Job Category	**Valuation Method**	**Nature of Work**	**2013 Hrs or FTEs**	**2014 Hrs or FTEs**	**2015 Hrs or FTEs**	**2016 Hrs or FTEs**	**2017 Hrs or FTEs**
Trails Coordinator/Forestry Tecnician II	*per Hour*	Managing the Project, Data work	50.00				
Foresty Office Coordinator	*per Hour*	Data Entry	100.00				
Forestry Technician I's	*per Hour*	Data Collection	0.00				
GIS Director	*per Hour*	GIS Upgrades and Conversion	10.00				

Table 5: Internal Labor Usage.

The hours listed above result in the costs shown from the 'Internal Labor Costs' worksheet (Table 6). A total of $6,118 dollars of internal labor costs will be required for the workflow implementations.

(in future year dollars)	**$2,013**	**$2,014**	**$2,015**	**$2,016**	**$2,017**
Job Category	**Labor Cost**	**Labor Cost**	**Labor Cost**	**Labor Cost**	**Labor Cost**
Trails Coordinator/Forestry Tecnician II	$2,660	$0	$0	$0	$0
Foresty Office Coordinator	$2,660	$0	$0	$0	$0
Forestry Technician I's	$0	$0	$0	$0	$0
GIS Director	$798	$0	$0	$0	$0
Total Internal Labor Costs	$6,118	$0	$0	$0	$0
Total Iternal Labor Investment	**$6,118**				

Table 6: Internal Labor Costs

The 'Contract and Procurement Costs' worksheet (Table 7) was used to record all one-time and ongoing project costs in each of the respective categories. The recommendations included upgrading from two ArcView (ArcGIS Desktop Basic) licenses to either two ArcEditor (ArcGIS Desktop Standard) licenses or a concurrent license. It is also recommended that the HRCFD purchase the Spatial Analyst extension so that they have the capability to perform complex analysis (BumpMaps) in the future on their own. It is also recommended that the Maintenance Agreement be maintained for all ArcGIS software throughout the five years. The printing of the maps was not included because the costs will be fully covered by an existing grant and the document will have a 5 year lifespan (the time designated for this financial analysis).

(in future year dollars)	**2013**	**2014**	**2015**	**2016**	**2017**
Staff development and training					
Esri Virtual Campus: Spatial Analyst ($160 each)	$320.00				
Esri Virtual Campus: Getting Started with the Geodatabase ($32 each)	$64.00				
Esri Virtual Campus: Using ArcGIS Online (Free)	$0.00				
Esri Virtual Campus: Getting Started with ArcGIS (Free)	$0.00				
Esri Virtual Campus: Preparing to implement an ArcGIS online Subscription (Free)	$0.00				
New software					
Upgrade to ArcEditor (ArcGIS Desktop - Standard) Concurrent	$7,000.00				
Spatial Analyst	$2,500.00				
Software maintenance fees					
ArcEditor (Standard) Maintenance (Concurrent)	$1,500.00	$1,500.00	$1,500.00	$1,500.00	$1,500.00
Spatial Analyst Maintenance (Concurrent)	$500.00	$500.00	$500.00	$500.00	$500.00
Total External Costs	$11,884	$2,000	$2,000	$2,000	$2,000
Total External Investment	**$19,884**				

Table 7: Contract and Procurement Costs

The 'Productivity Benefits' worksheet (Table 8) was for review purposes only, nothing was entered directly. The sheet is a summary, calculated as a result of the 'Productivity Benefit Detail' worksheets 1-4 (Tables 9, 10, 11, and 12). 'Productivity Benefit Detail' sheets one through four were completed based on a realistic analysis of the benefits that the deliverables for this project have produced. Deliverables are the enhanced GIS data management and workflow modification and the state of the art, marketable map that will be sold to thousands of visitors per year.

(in future year dollars) **Job Category**	**Valuation Method**	**2013 Savings**	**2014 Savings**	**2015 Savings**	**2016 Savings**	**2017 Savings**
Trails Coordinator/Forestry Tecnician II	*per Hour*	$30,058	$30,800	$31,561	$32,341	$33,140
Foresty Office Coordinator	*per Hour*	$12,768	$13,083	$13,407	$13,738	$14,077
Forestry Technician I's	*per Hour*	$0	$8,439	$8,647	$8,861	$9,080
GIS Director	*per Hour*	$3,192	$3,271	$3,352	$3,434	$3,519
Total Productivity Benefits		$46,018	$55,593	$56,967	$58,374	$59,815

Table 8: Productivity Benefits

Job Category: Trails Coordinator/Forestry Tecnician II **Specific Productivity Benefits**	**2013 Hours**	**2014 Hours**	**2015 Hours**	**2016 Hours**	**2017 Hours**
Reduction in Data entry error fixes (domains/subtypes), less redundancy of datasets etc.	50.00	50.00	50.00	50.00	50.00
Reduce the amount of time required to perform data analysis	100.00	100.00	100.00	100.00	100.00
Improve productivity by reducing travel time to investigate problems	100.00	100.00	100.00	100.00	100.00
Enhanced management of routine tasks, rather than 'putting out brush-fires' day after day	50.00	50.00	50.00	50.00	50.00
Reduction in trail review processes	50.00	50.00	50.00	50.00	50.00
Improved tracking of trail adopters	20.00	20.00	20.00	20.00	20.00
More efficient Grant Application submissions	25.00	25.00	25.00	25.00	25.00
Enhanced management of Law Enforcement Personell	20.00	20.00	20.00	20.00	20.00
Reduction of time required for effective and efficient Contract Operations: silvicultrual operations (thinning), logging, trail work, planing operations, road and culvert maintenance	100.00	100.00	100.00	100.00	100.00
Customer Service efficiency	50.00	50.00	50.00	50.00	50.00
Total Hours Saved for this Job Category	565.00	565.00	565.00	565.00	565.00

Table 9: Productivity Benefit Detail-1

Job Category: Foresty Office Coordinator	2013	2014	2015	2016	2017
Specific Productivity Benefits	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**
Reduction in staff training time required (simpler, more efficient and less error during data entry)	100.00	100.00	100.00	100.00	100.00
More efficient and accurate 'mini' 'upon request' map making	100.00	100.00	100.00	100.00	100.00
Reduction in management time required for: field crews: GPS, timber cruisers, planting crews, restroom cleaning/maintenance/garbage removal	30.00	30.00	30.00	30.00	30.00
Customer Service (Walk ins) Efficiency, 5 hours per week	250.00	250.00	250.00	250.00	250.00
Total Hours Saved for this Job Category	480.00	480.00	480.00	480.00	480.00

Table 10: Productivity Benefit Detail-2

Job Category: Forestry Technician I's	2013	2014	2015	2016	2017
Specific Productivity Benefits	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**
Enhanced (more efficient) data collection.		416.00	416.00	416.00	416.00
Enhanced management of Forestry Technicians time		100.00	100.00	100.00	100.00
Total Hours Saved for this Job Category	0.00	516.00	516.00	516.00	516.00

Table 11: Productivity Benefit Detail-3

Job Category: GIS Director	2013	2014	2015	2016	2017
Specific Productivity Benefits	**Hours**	**Hours**	**Hours**	**Hours**	**Hours**
Performing advanced Analysis, not previously available due to the limited license.	20.00	20.00	20.00	20.00	20.00
Reduced tasks involving Repairing 'problems' resulting from non-GIS Users	20.00	20.00	20.00	20.00	20.00
Total Hours Saved for this Job Category	40.00	40.00	40.00	40.00	40.00

Table 12: Productivity Benefit Detail-4

The ‘Other Benefits’ worksheet (Table 13) was completed with the expected non-productivity benefits. Non-productivity benefits are minute in comparison to the productivity benefits for this project because the project is, as noted earlier, a small business process improvement that facilitates productivity benefits and the development of a state of the art, marketable map.

(in future year dollars)	2013	2014	2015	2016	2017
Specific Other Benefits	**Benefits**	**Benefits**	**Benefits**	**Benefits**	**Benefits**
Sale of New Maps to visitors (1000 per year at $15.00 each over the life of the map (approx. 5 years))	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$15,000.00
Total Other Benefits	$15,000	$15,000	$15,000	$15,000	$15,000

Table 13: Other Benefits

As shown in Table 14 below, the results from this financial analysis provide a strong case for pursuing the project recommendations. In 2017, the Net Present Value (chosen metric) is calculated to be $310,434.

	2013	2014	2015	2016	2017
Future Cash Flows					
Internal Labor Costs	($6,118)	$0	$0	$0	$0
Contract/Procurement Costs	($11,884)	($2,000)	($2,000)	($2,000)	($2,000)
Productivity Benefits	$46,018	$55,593	$56,967	$58,374	$59,815
Other Benefits	$15,000	$15,000	$15,000	$15,000	$15,000
Present Value Multiplier:	*100.0%*	*97.6%*	*95.2%*	*92.9%*	*90.7%*
Present Values					
Internal Labor Costs	($6,118)	$0	$0	$0	$0
Contract/Procurement Costs	($11,884)	($1,952)	($1,905)	($1,859)	($1,814)
Total Annual Costs	*($18,002)*	*($1,952)*	*($1,905)*	*($1,859)*	*($1,814)*
Cumulative Costs	*($18,002)*	*($19,954)*	*($21,859)*	*($23,717)*	*($25,532)*
Productivity Benefits	$46,018	$54,254	$54,254	$54,255	$54,255
Other Benefits	$15,000	$14,639	$14,286	$13,942	$13,606
Total Annual Benefits	*$61,018*	*$68,892*	*$68,540*	*$68,197*	*$67,861*
Cumulative Benefits	*$61,018*	*$129,910*	*$198,451*	*$266,647*	*$334,508*
Cumulative Net Benefits	**$43,016**	**$109,957**	**$176,592**	**$242,930**	**$308,977**

Breakeven Year:	2013	
Payback Period (in Years):	0	
Net Present Value:	$308,977	
Present Value of Costs:	$25,532	
Return on Investment:	242.04%	*(Annualized)*

Table 14: Financial Analysis

The costs in this analysis consisted of labor, software updates and maintenance during the first year. No further expenditures are expected (beyond the maintenance agreements, as indicated above). An indirect and currently unquantifiable benefit is the enhanced interest in the trail system, resulting in more than expected maps being purchased as well as increased volunteer hours and commitment from possible corporate sponsors of the trail.

The breakeven year is 2013, and even if half of the projected benefits do not come to fruition, there will still be a net present value of over $100,000. The numbers used in the analysis were of course hypothetical, however, they were completed conservatively so as to not inflate or skew the results. Additionally, it should be noted that this analysis was completed in just four days based on the HLT team assumptions. Clearly, the small outlay of expenses and staff time is worthy of such significant gains in productivity and revenue.

Recommendations for Future Study & Analysis

For the future, we would like to recommend several ideas that could be used to help improve trail design and sustainability management. In addition to hardcopy paper maps, we would recommend further investigation of interactive web maps created on ArcGIS.com that can be hosted in the cloud. While paper maps will always serve a distinct and necessary purpose, web maps have the potential to provide users with information that far exceeds that which is typically available in a paper map. For example, the ability to 'point-and-click' to select features in the map to access stored information provides many additional benefits. Web maps also have the potential to provide more current information since they can be continuously updated.

It is suggested that if the development, hosting, and maintenance of a web map is beyond the scope of projects that HRCFD plans to implement, that HRCFD consider working with an outside organization that may be interested in this type of endeavor. Purely for the sake of example, HRCFD could partner with an organization such as the local non-profit Hood River Area Trail Stewards (HRATS). This is an organization that may have a fitting organizational mission and perhaps the funding mechanisms available to host a web map of the Hood River area trail system(s) on its website. Some benefits of hosting this type of web service are that a map administrator could keep the map up-to-date with current trail status and condition information. Users of the web map could obtain additional information from the map through a point-and-click procedure. For example, trail segments, when clicked, could provide contact information for the Trail Adopter that is responsible for its maintenance. Or, information could be provided about its current status and condition. The map could be used as a means to post new trail system developments or changes while encouraging feedback from the public audience. The map could also be used as a platform to seek funding for necessary improvements.

It is suggested that HRC create a sign inventory complete with subtypes and domains as a first simple run of using the newer technology. It will help with management of the sign inventory, and the trail system data as a whole in the GIS. It will also help with rescues and trail maintenance if/when these are needed. As new trails are built more signs will be placed and then added to the GIS data inventory.

It would behoove future researchers to incorporate research by Jeremy Wimpey who has investigated the relationship that trail slope has to sustainability (Wimpey, 2006). Additional Research by Wimpey is purported to expand on his Master's Thesis, utilizing LiDAR data and advanced (yet to be developed) scripts, models and tools (Wimpey, 2013). While Wimpey's Master's Thesis discovered that the USGS and NED DEMs at 10m and 30m were insufficient to estimate the trail characteristics with any certainty (r^2 below .5), future research with LiDAR data has proved promising (Wimpey, 2013). He and his co-workers are looking to hire a programmer to build some custom tools that will streamline and automate the process (Wimpey, 2013).

Unfortunately Dr. Wimpey was traveling when we first contacted him and we were unable to obtain any further information.

All of these ideas proposed to the HRCFD are meant to help them improve and enhance their trail management system in order to make it more sustainable for future use.

Conclusion

This project proposes and implements database design improvements. That will help HRCFD more efficiently manage GIS Datasets while emphasizing sustainability at several operational levels. This project also developed a new paper map design using professional cartography, and multiple ArcGIS.com maps to demonstrate the benefits of new mapping technologies that leverage the intent to expand upon capabilities of the static paper map. While all of the implemented items are considered to be works-in-progress at this time, we believe they provide significant progress toward items that will help HRCFD achieve its sustainability management goals.

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APPENDICES

Appendix A - Data Sources Spreadsheet

Flag			Data Sources					
By Rick	By Greg	By Alyssa	data type	File Location	File Name (as stored in data directory)	Type of File	Agency name	GIS data website location or direct source
			base	C:\HRC_TrailMap\Data\basedata				
			base	C:\HRC_TrailMap\Data\basedata\aerial\NAIP_2011\OregonImageryWebService\	NAIP_2011_NAIP_2011_SL.lyr	Layer File	State of OR / Oregon State University	http://oregonexplorer.info/IMAGERY/home_imagery
			base	C:\HRC_TrailMap\Data\basedata\aerial\NAIP_2011\OregonImageryWebService\	NAIP_2011_NAIP_2011_WM.lyr	Layer File	" (Same as above)	http://oregonexplorer.info/IMAGERY/home_imagery
			base	C:\HRC_TrailMap\Data\basedata\aerial\NAIP_2011	\OregonImagery.gdb	Geodatabase	" (Same as above)	http://oregonexplorer.info/IMAGERY/home_imagery
			base	C:\HRC_TrailMap\Data\basedata\aerial\NAIP_2011\OregonImagery.gdb\	NAIP2011_NW_Area	Raster	" (Same as above)	http://oregonexplorer.info/IMAGERY/home_imagery
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours		Folder		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours.gdb	Contours.gdb	Geodatabase		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours.gdb\Contour_100	Contour_100	Feature Class		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours.gdb\Contour_500	Contour_500	Feature Class		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours.gdb\Contour_500	Contour_500Anno	Feature Class		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours.gdb\dem_BE_projectarea	dem_BE_projectarea	Raster		
			base	C:\HRC_TrailMap\Data\basedata\lidar\Contours\Contours- 500 & 100.lyr	Contours- 500 & 100.lyr	Layer File		
			base	C:\HRC_TrailMap\Data\basedata\lidar\BumpMap.gdb	BumpMap.gdb	Geodatabase		
			base	C:\HRC_TrailMap\Data\basedata\lidar\BumpMap.gdb\BumpDEMminusBE2	BumpDEMminusBE2	Raster		
			base	C:\HRC_TrailMap\Data\basedata\lidar\BumpMap.gdb\MosaicHillshade2	MosaicHillshade2	Raster		
			base	C:\HRC_TrailMap\Data\basedata\lidar\BumpMap.gdb\SaleUnits_2008To2013	SaleUnits_2008To2013	Feature Class		
			base	C:\HRC_TrailMap\Data\basedata\lidar\	HRC_LiDAR_Mosaic.gdb	Geodatabase	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\HRC_LiDAR_Mosaic.gdb\	dem_BE	Raster	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\HRC_LiDAR_Mosaic.gdb\	dem_FF	Raster	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\HRC_LiDAR_Mosaic.gdb\	dem_FF_minus_BE	Raster	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\HRC_LiDAR_Mosaic.gdb\	hillshade_BE	Raster	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\HRC_LiDAR_Mosaic.gdb\	hillshade_FF	Raster	Hood River County	Obtained directly from agency
			base	C:\HRC_TrailMap\Data\basedata\lidar\	FF_minus_BE_VegSymbology.lyr	Layer File	Created	
			base	C:\HRC_TrailMap\Data\basedata\ned\	NED.gdb	Geodatabase	USGS NED	http://ned.usgs.gov/
			base	C:\HRC_TrailMap\Data\basedata\ned\NED.gdb\	NED_10M_HRC_CoordSys_zFeet_dem	Raster	USGS NED	http://ned.usgs.gov/
			base	C:\HRC_TrailMap\Data\basedata\ned\NED.gdb\	NED_10M_HRC_CoordSys_zFeet_hs	Raster	USGS NED	http://ned.usgs.gov/
			base	C:\HRC_TrailMap\Data\basedata\ned\NED.gdb\	NED_30M_HRC_CoordSys_zFeet_dem	Raster	USGS NED	http://ned.usgs.gov/
			base	C:\HRC_TrailMap\Data\basedata\ned\NED.gdb\	NED_30M_HRC_CoordSys_zFeet_hs	Raster	USGS NED	http://ned.usgs.gov/
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			base	C:\HRC_TrailMap\Data\basedata\scans\	AdventureMaps_CO_Front.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	AdventureMaps_HR_Back.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	AdventureMaps_HR_Front.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	GPNF_Map_BackPage_ExampleIndexTableAndIndexMap.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	GreenTrails_HR_Back.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	GreenTrails_HR_Front.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	HRC_RoadMap_Back.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	HRC_RoadMap_Front.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	HRC_TrailMap_Front.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	HRC_TrailMap_Front_Blowup.tif	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	USFS_CRG_East.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\scans\	USFS_CRG_West.TIF	Raster	Created / Scanned	
			base	C:\HRC_TrailMap\Data\basedata\topo\	USGS_Topo.gdb	Geodatabase	USGS via Skamania County	Obtained from Skamania County but originally downloaded from a currently unknown source website.
			base	C:\HRC_TrailMap\Data\basedata\topo\USGS_Topo.gdb\	HoodRiverCounty_Mosaic	Raster	USGS via Skamania County	" (Same as Above) "

Flag			Data Sources					
By Rick	By Greg	By Alyssa	data type	File Location	File Name (as stored in data directory)	Type of File	Agency name	GIS data website location or direct source
			geo	C:\HRC_TrailMap\Data\geodata				
			geo	C:\HRC_TrailMap\Data\geodata\cartography\	Clip_Rectangle.shp	Shapefile	Created	
			geo	C:\HRC_TrailMap\Data\geodata\cartography\MaxProjectArea	MaxProjectArea.shp	Shapefile	Created	
			geo	C:\HRC_TrailMap\Data\geodata\cartography\OwnershipGeneralized	OwnershipGeneralized.gdb	Geodatabase	Created	
			geo	C:\HRC_TrailMap\Data\geodata\cartography\Waterbody_vignette	WaterbodyVignette.gdb	Geodatabase	Created	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary		Folder		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\CRG National Scenic Area.lyr	CRG National Scenic Area.lyr	Layer File		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\CRG_National_Scenic_Area.gdb	CRG_National_Scenic_Area.gdb	Geodatabase	Alyssa Created	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\CRG_National_Scenic_Area.gdb\CRG_National_Scenic_Area	CRG_National_Scenic_Area	Feature Class	Alyssa Created from NSA_Boundary_As Line	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\CRG_National_Scenic_Area.gdb\CRG_National_Scenic_AreaAnno	CRG_National_Scenic_AreaAnno	Feature Class	Alyssa Created	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\MtHoodNatForest.lyr	MtHoodNatForest.lyr	Layer File		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\MtHoodNatForest.gdb	MtHoodNatForest.gdb	Geodatabase		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\MtHoodNatForest.gdb/MtHoodNatForest	MtHoodNatForest	Feature Class		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\MtHoodNatForest.gdb\MtHoodNatForestAnno	MtHoodNatForestAnno	Feature Class		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\OregonStateParks.lyr	OregonStateParks.lyr	Layer File		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\OregonStateParks.gdb	OregonStateParks.gdb	Geodatabase		
			geo	C:HRC_TrailMap\Data\geodata\hr_county\Boundary\OregonStateParks.gdb\OregonStateParks	OregonStateParks	Feature Class		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\OregonStateParks.gdb\OregonStateParksAnno	OregonStateParksAnno	Feature Class		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\Wilderness.lyr	Wilderness.lyr	Layer File		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\Wilderness.gdb	Wilderness.gdb	Geodatabase	Alyssa Created	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\Wilderness.gdb\WildernessAnno	WildernessAnno	Feature Class	Alyssa Created	
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Boundary\Wilderness.gdb\WildernessBoundary	WildernessBoundary	Feature Class		
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CityLimits		Folder	Hood River County	Obtained directly from agency
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CityLimits\CityLimits.gdb	CityLimits.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CityLimits\CityLimits.gdb\CityLimits	CityLimits	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CountyBoundary		Folder	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CountyBoundary\CountyBoundary.gdb	CountyBoundary.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CountyBoundary\CountyBoundary.gdb\HRC_Boundary_ParcelEdgeMatched	HRC_Boundary_ParcelEdgeMatched	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CountyBoundary\CountyBoundary.gdb\OregonCounties	OregonCounties	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\CountyBoundary\CountyBoundary.gdb\OregonCounties_HRC_ONLY	OregonCounties_HRC_ONLY	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro		Folder	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Streams.gdb	Streams.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Streams.gdb\Stream	Stream	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro	Stream	Shapefile	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro	Stream_Clip.lyr	Layer File	Hood River County	" (Same as Above) "

Flag			**Data Sources**					
By Rick	By Greg	By Alyssa	data type	File Location	File Name (as stored in data directory)	Type of File	Agency name	GIS data website location or direct source
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			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Streams.gdb\Stream__Cart_Clip	Stream_Cart_Clip	Shapefile	Hood River County	Created from above
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Streams.gdb\Stream_Cart_ClipAnno	Stream_Cart_ClipAnno	Other	Created by Greg	Created from above
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Stream_Cart_Clip.lyr	Streams_Cart_Clip.lyr	Other	Created by Greg	Created from above
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Stream_Cart_ClipAnno.lyr	Streams_Cart_ClipAnno.lyr	Other	Created by Greg	Created from above
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Waterbodies.gdb	Waterbodies.gdb	Geodatabase	Hood River County	Obtained directly from agency
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Hydro\Waterbodies.gdb\Waterbody	Waterbody	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Quarry		Folder	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Quarry\Quarry.gdb	Quarry.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Quarry\Quarry.gdb\Rock_Quarry	Rock_Quarry	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Taxlots		Folder	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Taxlots\Parcel.gdb	Parcel.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Taxlots\Parcel.gdb\Taxlot_20130711	Taxlot_20130711	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Timber Stands		Folder	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Timber Stands\TimberStands.gdb	TimberStands.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Timber Stands\TimberStands.gdb\Sale_Units	Sale_Units	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Trails			Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Trails\Trails.gdb	Trails.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Trails\Trails.gdb\NW_Area_Trails	NW_Area_Trails	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Trails\Trails.gdb\NW_Area_Trails_ORIGINAL	NW_Area_Trails_ORIGINAL	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Transportation			Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Transportation\Roads.gdb	Roads.gdb	Geodatabase	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Transportation\Roads.gdb\Gates	Gates	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Transportation\Roads.gdb\HRC_Forest_Roads	HRC_Forest_Roads	Feature Class	Hood River County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\hr_county\Transportation\Roads.gdb\Roads	Roads	Feature Class	Hood River County	" (Same as Above) "
			geo					
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\crgc\	NSA_Boundary.shp	Shapefile	Columbia River Gorge Commission	http://www.gorgecommission.org/GIS-files.cfm
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\crgc\	NSA_Boundary_AsLine.shp	Shapefile	Columbia River Gorge Commission	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\crgc\	Urban_Areas.shp	Shapefile	Columbia River Gorge Commission	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\crgc\	Urban_Areas_AsLine.shp	Shapefile	Columbia River Gorge Commission	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\hwynet2007\	hwynet2007.lyr	Layer File	ODOT via Skamania County	Obtained from Skamania County but originally downloaded from a currently unknown source website of ODOT.
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\hwynet2007\	hwynet2007.shp	Shapefile	ODOT via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\hwynet2007\	mileposts_2007.lyr	Layer File	ODOT via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\hwynet2007\	mileposts_2007.shp	Shapefile	ODOT via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\	OR_Trans_Public_2012.gdb	Geodatabase	ODOT via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\odot\	OR_Trans_Public_2012.gdb\OR_Trans_Public	Feature Class	ODOT via Skamania County	" (Same as Above) "

Flag			Data Sources					
By Rick	By Greg	By Alyssa	data type	File Location	File Name (as stored in data directory)	Type of File	Agency name	GIS data website location or direct source
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\oregon_geospatial_library\citylim_2007\	citylim_2007.lyr	Layer File	Oregon Geospatial Data Clearinghouse	http://spatialdata.oregonexplorer.info/geoportal/catalog/main/home.page
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\oregon_geospatial_library\citylim_2007\	citylim_2007.shp	Shapefile	Oregon Geospatial Data Clearinghouse	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\oregon_geospatial_library\orcnty24\	orcnty24.shp	Shapefile	Oregon Geospatial Data Clearinghouse	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\oregon_geospatial_library\ORStateParks\	OregonStateParks.shp	Shapefile	Oregon Geospatial Data Clearinghouse	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\skamania_county\ColumbiaRiverShoreline\	ColumbiaRiverShoreline.gdb	Geodatabase	Skamania County	Obtained directly from agency
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\skamania_county\ColumbiaRiverShoreline\ColumbiaRiverShoreline.gdb\	ColumbiaRiver_Shoreline_line	Feature Class	Skamania County	Obtained directly from agency
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\skamania_county\ColumbiaRiverShoreline\ColumbiaRiverShoreline.gdb\	ColumbiaRiver_Shoreline_polygon	Feature Class	Skamania County	Obtained directly from agency
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\orhydro_24k\geo_gis\hydro\Hydro 2006\water_courses0907	***MANY TABLES, Too many to list individually	Table	State of Oregon via Skamania County	Obtained from Skamania County but originally downloaded from a currently unknown source website of the State of Oregon.
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\orhydro_24k\	wb_oregon.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\orhydro_24k\	wc_oregon.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	orrivers.pdf	Other	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	orrivers_epa250k_Clip.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	orrivers_rr100k_Clip.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	orrivers_usgs2000k_Clip.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	PRJdevelopment.pdf	Other	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\hydro\	rivers.pdf	Other	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\plss\	plss_or.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\plss\	PRJdevelopment.pdf	Other	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\state_or\plss\	township_range_or.shp	Shapefile	State of Oregon via Skamania County	" (Same as Above) "
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\NatlForestBoundary\	NatlForestBoundary_Proclaimed.shp	Shapefile	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\RecreationSites\	rec_site_pt.shp	Shapefile	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\	Transportation.gdb	Geodatabase	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	RoadEvent	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	Trail	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	TrailEvent	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	Transportation	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	TravelManagementArea	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Transportation\Transportation.gdb\	TravelRoute_ln	Feature Class	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\	Waterbody\waterbody.shp	Shapefile	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/
			geo	C:\HRC_TrailMap\Data\geodata\other_agency\usfs\MtHood_NF\Wilderness_20110517\	Wilderness.shp	Shapefile	USFS Mt Hood NF	http://www.fs.fed.us/r6/data-library/gis/mthood/

Appendix B - Developing a Water body vignette

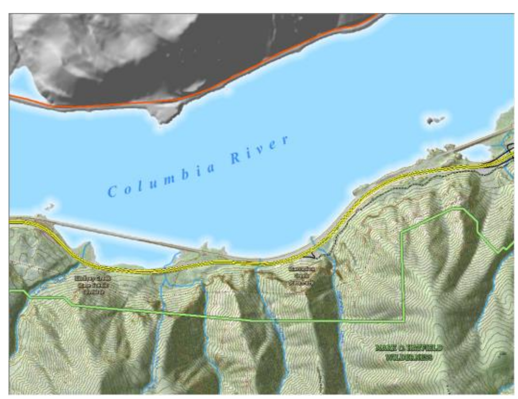
Steps to create the Columbia River shoreline vignette using techniques in:

http://downloads.esri.com/support/whitepapers/ao_/CoastalVignettes_031505.pdf
http://blogs.esri.com/esri/arcgis/2009/03/05/symbolizing-shorelines/
http://support.esri.com/en/knowledgebase/techarticles/detail/28823

Using the raster Euclidean distance tool method (Spatial Analyst>Distance>EuclideanDistance)

1. Create a polygon representing the land area of the shoreline.
    a. Since I started with only a polygon layer of the water of the Columbia River, I made a new polygon that loosely encompassed the entire boundary of the Columbia River dataset. Then I used the Erase tool to remove the area of water from the polygon. What remains is a polygon representing the shorelines and area of land around borders of the Columbia River.
    b. Make sure to deal with areas of islands appropriately.
2. Use the Euclidean distance tool to create a raster of this shoreline polygon dataset. Set the output cell size to something appropriate (I used 10 ft). Leave everything else as default.
3. Once the Euclidean distance raster is created, use the Extract by Mask tool (Spat. Analyst>Extraction>Extract by Mask) to extract only the area of the raster that is the Columbia River. In other words, use the Columbia River polygon as the mask boundary.
4. The final raster is now what you want.
5. Symbolize it using light blue to darker blue (shallow to deep water).
6. In the symbology tab in the Histogram dialog you can drag the graph up and to the left (ie add vertices). This makes the area of light color along the shoreline thinner.
7. Set transparency as desired.

Before



After

Appendix C: Bump map techniques

Bump Map:

A methodology for creating a visual appearance of scattered vegetation for areas where Lidar vegetation needs to be 'removed' to more accurately represent a clear cut or other timber harvest while also having some randomly dispersed trees.

- Note – You could create a fairly similar result without using Bump Mapping at all if all you want is to remove areas of vegetation. You can just create a mask of the areas desired, then use that mask to 'clip' just those areas from your copy of the Bare Earth dem (and/or hillshade) and then use that to represent areas of clear cuts. The only difference is that these areas will be entirely clear of all vegetation (bare earth) and may not look as realistic as if Bump Mapping is completed.
- If you want to make a representation that has some randomly dispersed trees (perhaps looking more realistic), then proceed with the following directions.

***Note – Requires Spatial Analyst extension!**

- Read the following blog post about Bump Mapping: http://blogs.esri.com/esri/arcgis/2010/01/21/introducing-the-arcgis-bump-map-tools/
- As described in the blog, you can download the Bump Map tools (which includes the Toolbox for ArcMap) from the following locatioin: http://mappingcenter.esri.com/index.cfm?fa=arcgisResources.modelsScripts
- Follow the directions in the blog and Resources page to add the 'Bump Map Tools' toolbar to ArcToolbox in ArcMap

What you need:

A DEM (in our case we use the Lidar BE DEM for tool operation). We are also using a FF lidar dem and hillshade as part of the intent of this work and for visualization.

A polygon layer representing stands that have been cut

Spatial Analyst Extension

1. Create a polygon layer of treated timber stands in the project area:
    a. In our case we use the Sale_Units feature class and select only those stands that we want.
        i. These are stands harvested after the lidar flight date (based on available metadata, the flight for Hood River/Gorge Area was flown between May 18 and July 26, 2008)
        ii. Select all units (polygons) harvested (clear cut or other silvicultural treatment) from 2008 to the present.
        iii. Also make sure the selection is only the stand polygons in the project area. Bump mapping requires a significant amount of processing. You want to minimize the area to only the practical area.
        iv. Export the selected stands to a new feature class.

    b. As an added step, use the most current available aerial photo to cross-check the accuracy of the 'clear cut' areas as represented by the polygon layer. Personal knowledge or a site inspection may be required if new aerials are not available. Edit the polygons if necessary so they are an accurate representation of what has actually been clear cut. Be particularly careful to make the polygons accurately reflect for areas that are not actually cut (e.g. riparian buffers, etc.)

    c. Separate polygons can also be created to represent different vegetation types if desired.
        - For example you could treat areas differently based on conifers (cones) or hardwoods (domes) in the bump map tools.
        - Perhaps some stands are clearcut and some are thinned and therefore you will create different Bump Map settings for each (e.g. tree spacing, tree radius, tree heights can be created differently for different areas, if desired).
    d. If you are developing separate vegetation types then each different type should be its own polygon feature class (e.g. a feature class of clearcut polygons, another feature class of thinned stand polygons, a feature class of areas that will be hardwood areas (domes) separate from a feature class that will have conifers(cones) etc.)
    e. Split polygons if necessary to ensure each polygon really only represents one variety of vegetation.
    f. Create a new field in the attribute table of the feature class.
        i. Call it something like: 'RastValue'. Use short integer type.
        ii. Use field calculator to add a unique value to each record in this field based on unique vegetation variety.
            1. For example: 1 = Clearcut, 2 = Thinned stand, 3 = unique riparian area, etc.
            2. Each different vegetation area can be constructed to have different styles of vegetation (tree type [cone or dome], tree spacing, radius, height)
2. Convert the 'stands' polygon layer to a raster
    a. Use the Polygon To Raster tool (ConversionTools>To Raster> Polygon to Raster)
        i. In the tool parameters, set the Value field to be the field in the polygon dataset that you created and populated previously (e.g. 'RastValue') so that the output raster will have cell values based on the values for each different polygon of stand types.
        ii. Set the cell size to be identical to the BE DEM dataset (use the browse dialog to browse to that dataset)
        iii. IMPORTANT: Set the environment settings
            1. Set it to Snap To the BE DEM
            2. Set the processing extent to 'Same as' the polygon input. Otherwise it will use a larger processing area and it will take a long time.

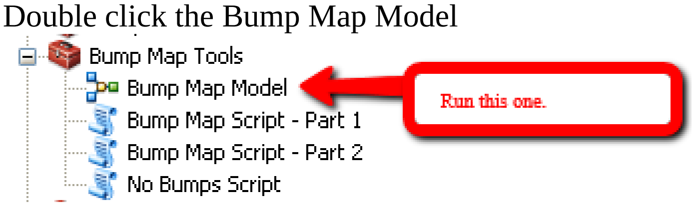
        iv. The output will be a raster representing cell values derived from individual polygons.
        v. For the sake of these directions, let's say we named the output raster "StandsAsRaster"
3. Use the Extract by Mask tool to extract the areas of the BE DEM that we need
    a. Use Extract by Mask tool (Spatial Analyst Tools>Extraction>Extract by Mask)
        i. Use the BE DEM as input
        ii. Use the raster you previously created as the mask (i.e. "StandAsRaster")
        iii. Define the output name.
        iv. IMPORTANT: Set the environment settings

1. Set it to snap to BE DEM
2. Set the processing extent to 'Same as" the previous raster (ie. the one used as a mask which is "StandAsRaster"

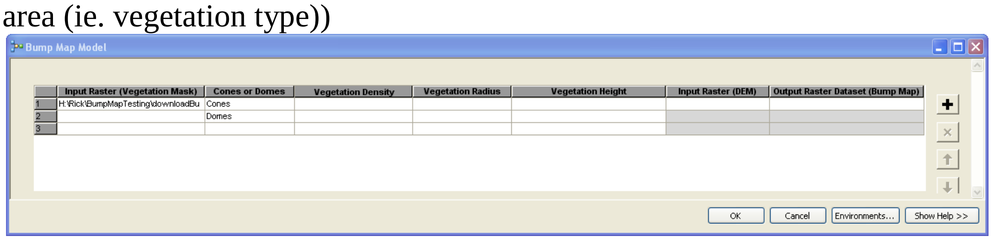
b. The output will be the BE DEM for only the stands that we care about.

4. Use Extract by Attributes (Analyst Tools>Extraction>Extract by Attributes)
   a. Use this to create individual rasters of stands for each of the different stand types.
      i. The input raster in this example is "StandAsRaster"
      ii. For the 'Where clause', enter a SQL statement such as *"Value" = 1*, or *"Value" = 2*, etc.
      iii. Run the tool for each different stand type that you need for your individual mask rasters (stands that will be bump mapped differently).
   b. These will be used individually as mask rasters in the Bump Map Tool since a separate mask raster is necessary for each different vegetation type to be created (i.e bump mapped differently).

5. Start running the Bump Map tool.
   a. Double click the Bump Map Model



   b. This runs in batch mode so you can enter many lines (one for each different mask area (ie. vegetation type))



   c. Based on the Bump Map documentation, the tool (python code) creates bumps with an equation that uses the diameter of the bump divided by 11 when developing the resolution of the cells used as part of the bump (to make smooth looking bumps). If the diameter entered (it is actually entered as a radius so you must multiply be 2) in the calculation divided by 11 creates a resolution smaller than the cell size of the DEM then resampling to a higher resolution will occur for the entire DEM (this takes longer). In other words, since our DEM has a resolution is 3 feet, if we enter a radius of 16 (i.e. diameter of 32) we have 32/11 = 2.9090 so the tool will force resampling. If we enter a radius of 17 (i.e. diameter of 34) we have 34/11 = 3.0909 so it is more than the resolution of the DEM and therefore the tool will not do resampling and will keep the output cell size at the initial size (i.e. 3).
   d. Sizes for cones that I found to work well were:
      i. For a clearcut but having a few scattered 'leave trees'
         1. Use 'Cones'
         2. Use Vegetation Density = 100 (i.e. one tree every 100 ft randomly dispersed)

3. Use Vegetation Radius = 17 (no resampling will occur)
4. Use Vegetation Height = 90

ii. For a thinned area having many more scattered trees

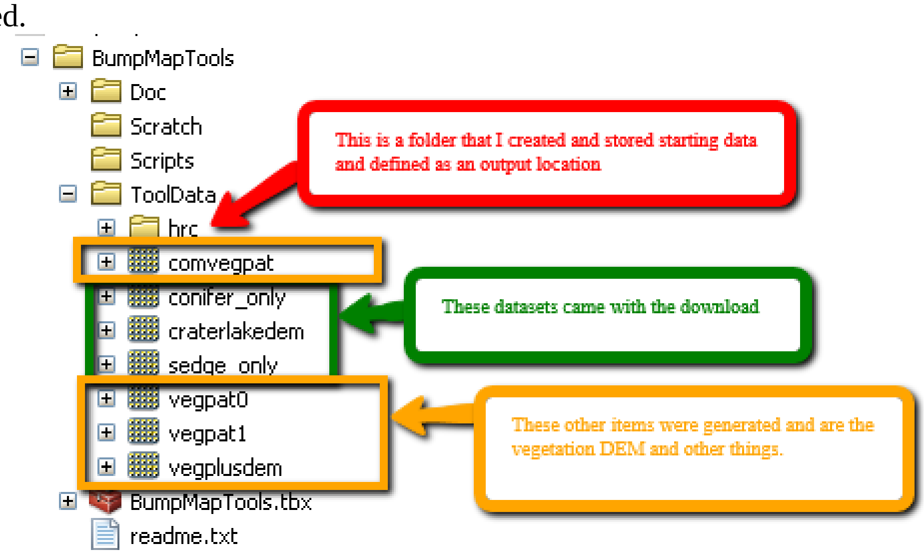
1. Use the settings as above, except for change Vegetation Density
2. I used a Vegetation Density of 25

iii. Use Domes if desired

1. Xx
2. Xx

iv. Xx

e. Output (a hillshade image) is added to the map and saved wherever you set for the output location. In addition to the hillshade you can access the other intermediately developed layers by going in to the Tool Data folder in the location where the tools are installed.



i. It appears that a coordinate system is not assigned to these datasets by default, however they are positioned appropriately so the user should be able to assign the existing coordinate system to them.

ii. The name of the output items (shown in above image in orange) represent some of the intermediate outputs that are generated in order to make the finished hillshade. These are described as follows:

1. vegpat0 (veg pattern 0) is the pattern of just the trees generated for the first 'stand' type entered in the tool.
2. vegpat1 (veg pattern 1) is the pattern of just the trees generated for the second 'stand' type entered in the tool
3. comvegpat (complete veg pattern) is all of the vegetation patterns combined.
4. vegplusdem (veg plus DEM) is everything combined and is used as the input for the hillshade process.

iii. IMPORTANT: Note that the above described outputs ARE DELETED BY THE SCRIPT EACH TIME YOU RUN IT so save a copy of them before re-running the tool if you want to have them for later!

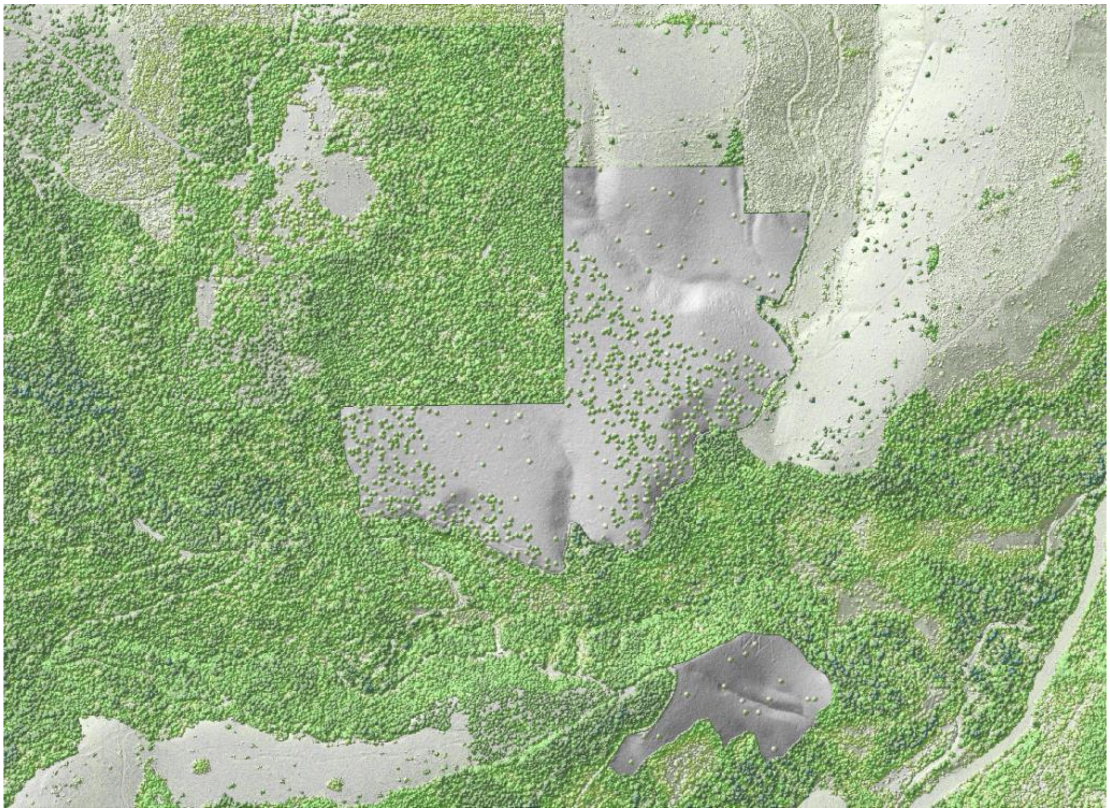
6. You can only create one vegetation type (style and specifics of the cone, dome, density, size, etc.) for each stand type when you run the tool. However, you can do several iterations of the same areas (e.g. one with cones and the next one with domes) and then combine the

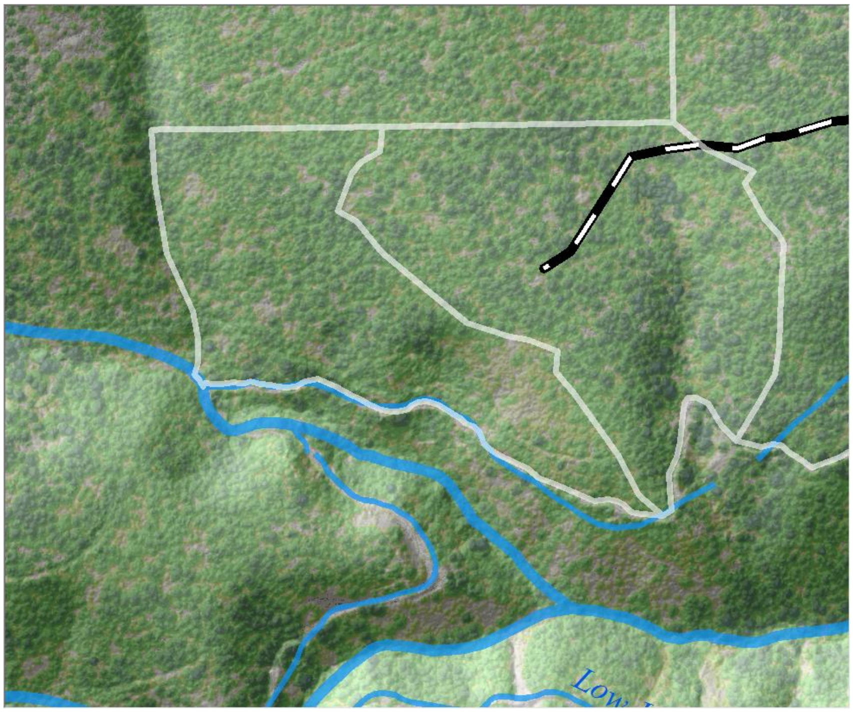
DEM rasters and take only the HIGHEST value from each raster. This will keep ALL vegetation (cones and domes).

   a. To do this use the Cell Statistics Tool (Spatial Analyst Tools>Local Toolset> Cell Statistics)
   b. Use the MAXIMUM parameter. This will determine the largest value of the inputs on a cell-by-cell basis. This should accurately give the cell values for Bare Earth locations as well as values for vegetation.

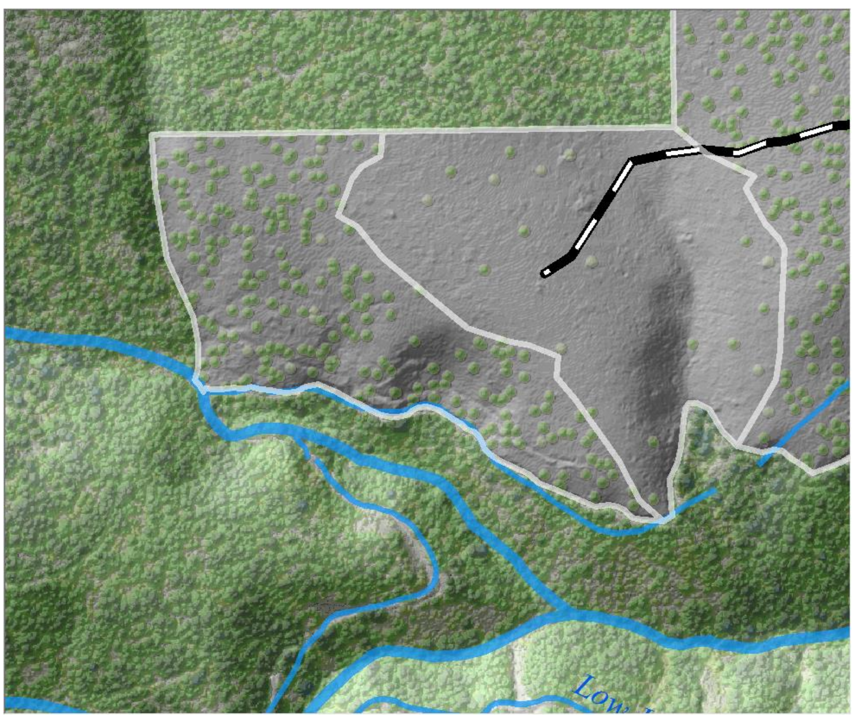
7. Once you have a Hillshade and DEM that you are happy with, the next step is to merge it into the original dataset(s) for final display in the map.
8. Use the Raster to Mosaic tool to mosiac the original Lidar FF DEM with the generated Bump Map (FF) DEM. Make sure the Bump Map is set as the one that takes precedence for areas of overlap. Once you generate a new DEM that includes both, then you can create a hillshade for the final layer. You will also need to do a Raster Calculator operation to subtract the finished the original BE DEM from the finished FF DEM (which is a combination of the Lidar FF and the BumpMap FF DEMs). This provides you with the final raster that has only the values of the height of things that are above the ground (i.e. vegetation). Use this as a transparent overlay to give color to the vegetation.

EXAMPLES:





BEFORE. Showing the LiDAR derived vegetation.



AFTER. Using Bump Mapping with two different spacing densities.

Appendix D: Tint band techniques

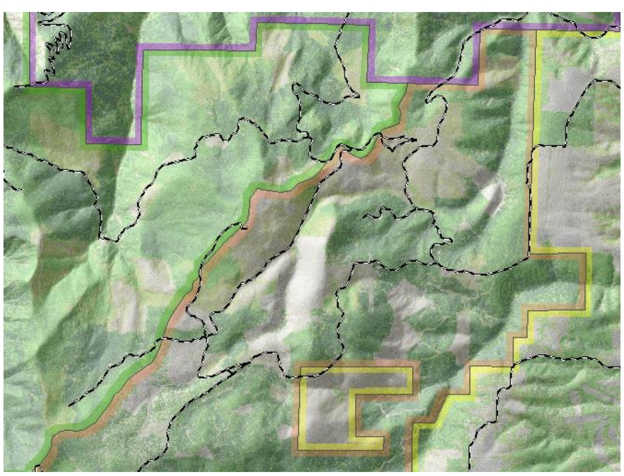
<u>How to Produce Tint Bands for Boundaries:</u>

This methodology comes from:
http://blogs.esri.com/esri/arcgis/2007/04/17/how-to-produce-tint-bands-for-boundaries/

Steps:

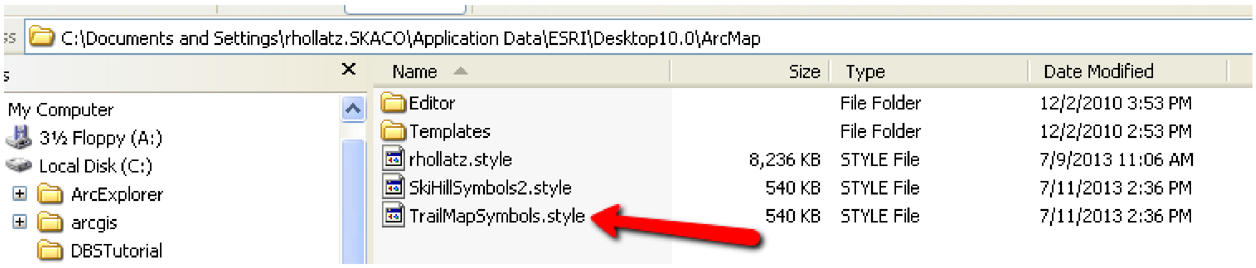
1. Identify the boundary layer (polygon) that you want to create a tint boundary for.
2. Convert the polygon to a raster using Conversion Tools>To Raster > Feature to Raster. You will need a field in the polygon feature class that you set at the field value that each cell will be set to in the new raster. For example, you can create a new field and use Field Calculator to assign a '1' to all records. Then each cell of the developed raster will have a value of '1'. The number used, and therefore the value assigned to each cell, is irrelevant. You just have to have something to assign to each cell.
3. Use the shrink tool on the raster. This is in Spatial Analyst Tools > Generalization > Shrink.
4. In the shrink tool set the 'Zone values' to whatever is assigned to all cells (e.g. '1')
5. This outputs a new raster that has been shrunk around the edges by the amount (of cells) specified.
6. Convert the full sized raster and the shrunken raster back into polygons (Conversion Tools> From Raster > Raster to Polygon).
7. Use the erase tool to erase the shrunken polygon from the full sized polygon. What remains will be the polygon representing the tint band.
8. Symbolize and set transparency as desired.

An example of tint bands (In this case used to differentiate ownership....County, State, Federal, Private)



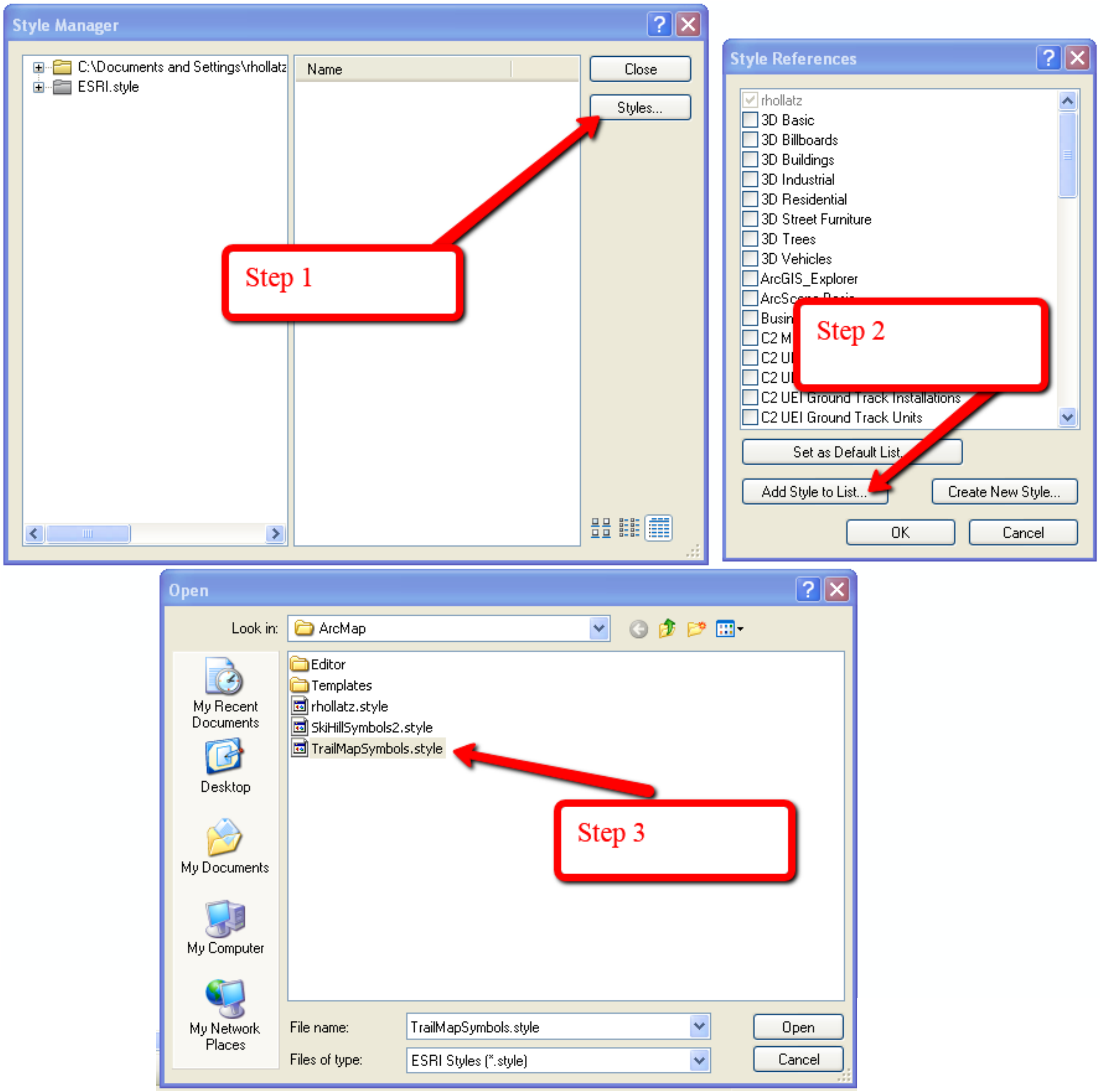
Appendix E: Style Reference techniques
Add a new Style Reference to the Style Manager:

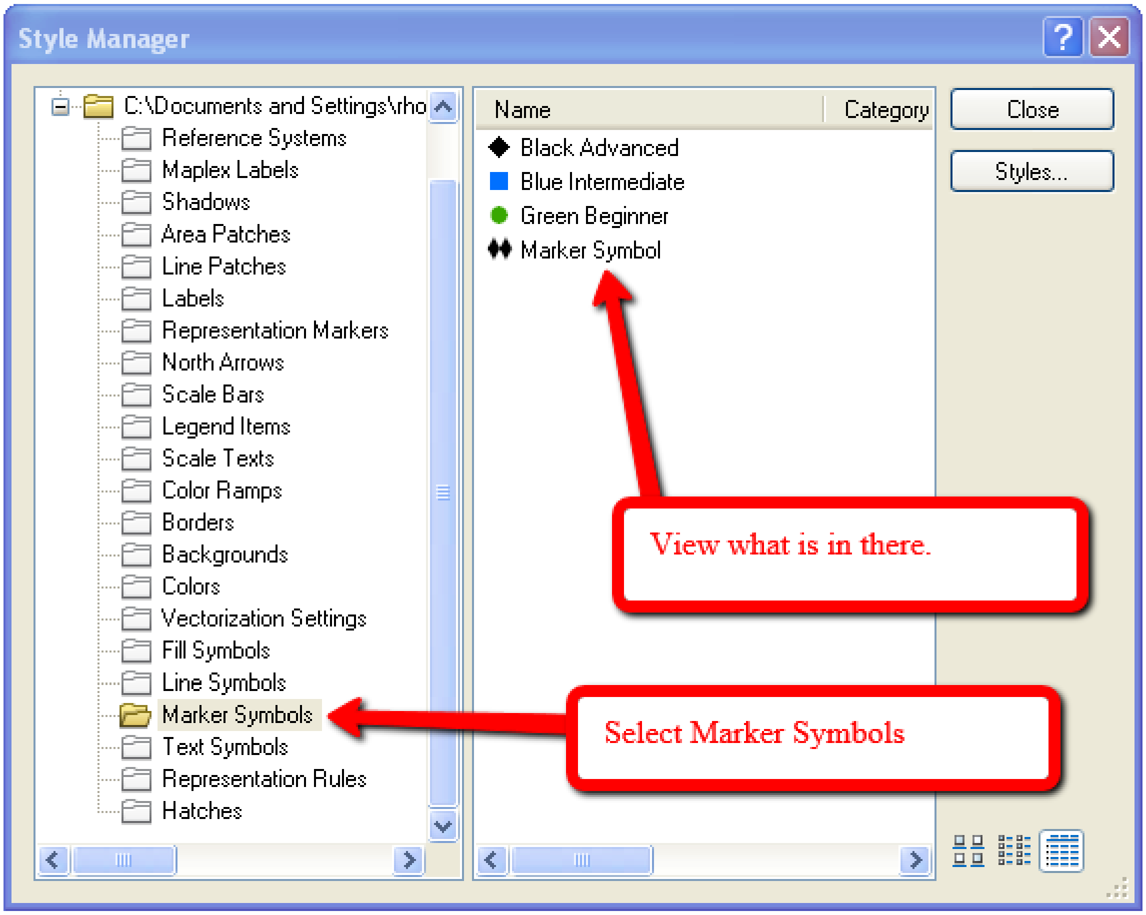
The default location on my machine where the styles are stored is here:
C:\Documents and Settings\rhollatz.SKACO\Application Data\ESRI\Desktop10.0\ArcMap
*(Yellow being your user profile)



You can copy the .style file to this location on your machine (or store it elseswhere)
Next, in ArcMap, open the 'Customize' menu and choose 'Style Manager…'
As depicted in the drawing below:
Step 1:
Click the 'Styles…' button.
Step 2:
Click the 'Add Style to List…' button.
Step 3:
Navigate to the location where the .style file is and select it. Click 'Open'. And 'Ok' on the Style Reference Dialog.

You can now select the style in the Style Manager and look at its contents. This one has some custom items in the 'Marker Symbols'.
Now, back in ArcMap, if you open the Symbol Selector to edit any symbols you will have access to these symbols.


Style Manager
C:\Documents and Settings\rhollatz
ESRI.style
Name
Close
Styles...
Step 1
Style References
rhollatz
3D Basic
3D Billboards
3D Buildings
3D Industrial
3D Residential
3D Street Furniture
3D Trees
3D Vehicles
ArcGIS_Explorer
C2 UEI Ground Track Installations
C2 UEI Ground Track Units
Step 2
Set as Default List
Add Style to List...
Create New Style...
OK
Cancel
Open
Look in:
ArcMap
Editor
Templates
rhollatz.style
SkiHillSymbols2.style
TrailMapSymbols.style
Step 3
My Recent Documents
Desktop
My Documents
My Computer
My Network Places
File name:
TrailMapSymbols.style
Files of type:
ESRI Styles (*.style)
Open
Cancel



Style Manager
C:\Documents and Settings\rho
Reference Systems
Maplex Labels
Shadows
Area Patches
Line Patches
Labels
Representation Markers
North Arrows
Scale Bars
Legend Items
Scale Texts
Color Ramps
Borders
Backgrounds
Colors
Vectorization Settings
Fill Symbols
Line Symbols
Marker Symbols
Text Symbols
Representation Rules
Hatches
Name
Category
Black Advanced
Blue Intermediate
Green Beginner
Marker Symbol
Close
Styles...
View what is in there.
Select Marker Symbols

Appendix F: Draft Map*

*Provided here as a very low resolution image. A high resolution image of the full size 28”x 36” image will be submitted with our report. Its file size is large (in excess of 120 MB).