



**Use of GIS and Hydrologic Modeling for
Outdoor Recreation in the Bear River Range**

CEE 6440 - GISWR

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Contents

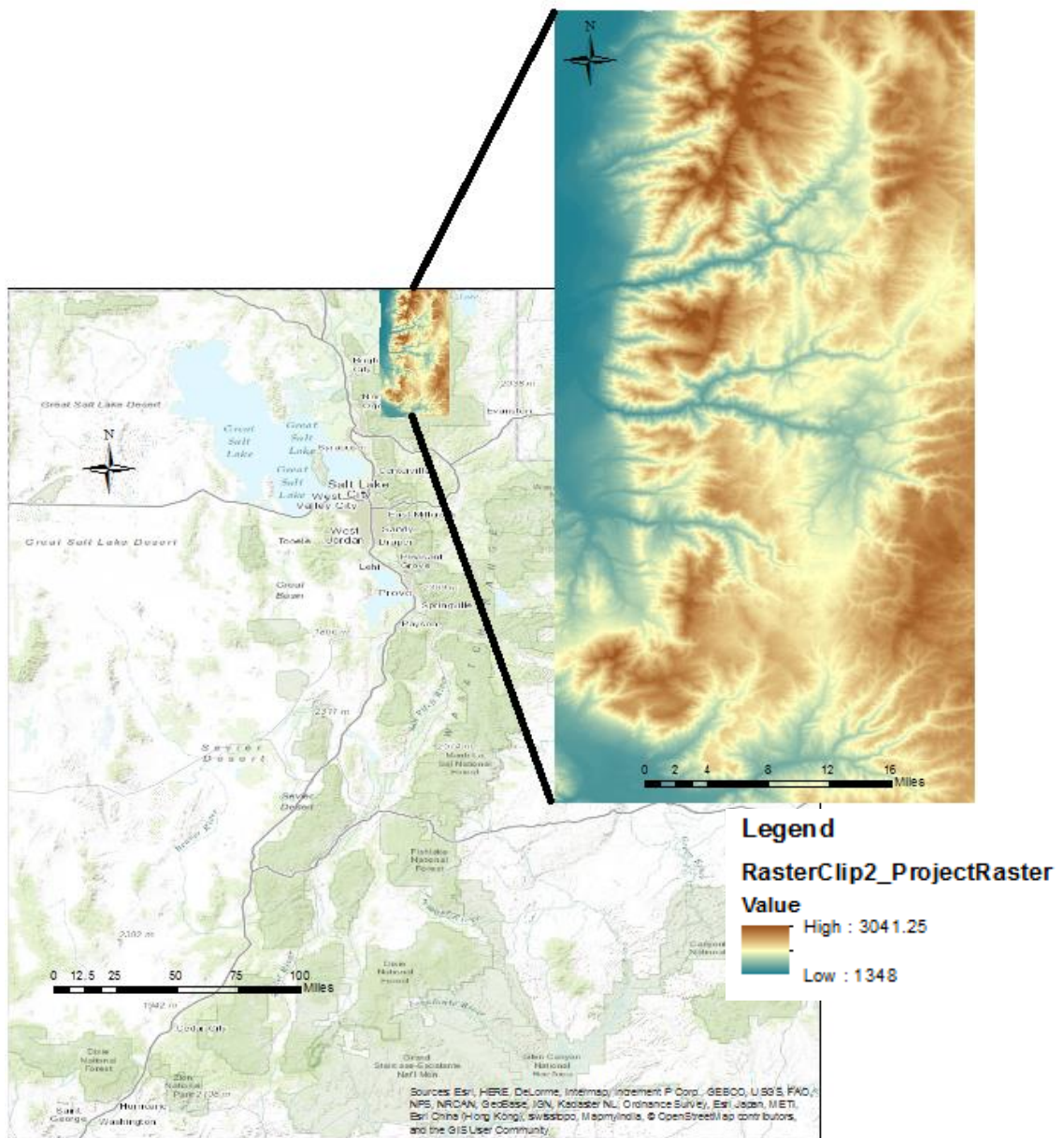
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Introduction

The Bear River Mountain Range is a long range of peaks stretching from the northern part Utah into Idaho. It has rivers, high mountain peaks, glacial cirques, good limestone, and receives a good amount of snow throughout the winter. With all of these factors combined, just about any form of outdoor recreation can be done in the range. There are plenty of sport and traditional rock climbing routes, mountaineering opportunities in the winter and spring, plenty of trails to hike and run and mountain bike on, and powdery peaks and canyons to ski and snowshoe on.

The section that will analyzed in this project will be just the Utah section of the bear River Range between -111.45° E to -111.85° E and from 41.25° N to 42.00° N (pictured below).



Purpose

The purpose of this project was to delineate routes for trail running and cross country skiing in the Bear River range. These routes can either be existing or new, and can incorporate trails or areas without trails. Since there is a lot of land and opportunity for outdoor recreation in the Bear River Range, this project has the purpose of compiling a rough guide with maps for those who want to venture out and explore some of the range's well known and lesser known terrain. The tool that will be used to compile these maps is ArcMap 10.3.1

Methods

The methods that will be used to complete this project are, for the most part, simple and straightforward. Data will be collected from various sources, including ESRI online services, ArcMap generated basemaps, Cache County's GIS department, and NOAA's data services. After collecting the data, the data will be juxtaposed and analyzed using several tools within ArcMap.

Results

The results will be a series of maps that can be used by explorers of any skill level. The level of difficulty can be judged based on criteria that will be presented later on in this report, and will also be displayed with the maps based on the criteria mentioned.

Recreation Quantification

To be able to perform any analysis within this project, the activities discussed needed to be quantified so that different landscapes could be compared numerically. Two sources were found and will be discussed that quantify what kind of terrain is suitable for trail running and cross country skiing.

From the Northern Arizona University Recreation Facility and Area Planning program, the following aspects of a suitable cross country skiing trail were taken:

“Percent Grade ... Desired: 0-5%, Maximum: 10% (sustained), 15-25% (shorter than 50 yards), 25-40% (shorter than 50 yards, experts only)” (NAU 2001)

From the Trail Run Project, a collaboration of trail runners and mapping professionals from around the country, the following excerpt was taken:

“Getting into the nitty gritty, any section that is <5% grade is considered 100% runnable. Sections above 5% grade can be anywhere from 25% to 100% runnable, on a sliding scale. So, for example, let's say that we're looking at a 10 mile run with 3 gps nodes |--5---|---5--|. That first section is <5% grade and is therefore 100% runnable. The second section is somewhere >5% and we calculated its runnability as 50%. 100% of the first section is runnable, so that's 5mi/10mi that's runnable. The second section is 50% runnable, so that's 2.5mi/10mi that's runnable (5mi/2). To assign the entire run a % runnability, we just take the mileage that's runnable and divide it by the total mileage. So, for this example, it's 7.5/10 or 75% runnable.” (TRP 2015)

So these two sources show similar traits between trail running and cross country skiing - 0-5 percent grade is the preferable, but higher slopes are acceptable depending on the duration of the stretch and how much of the total distance is above that acceptable slope. With trail running, it is technically even less important that the slope be less than 5% however, since there is no danger in having steep slopes while trail running (you simply stop running and hike steep sections). In cross country skiing, it can be dangerous if you run into a steep slope in deep snow, as it is difficult to ski steep slopes on cross country skis, and removing them can often result in potentially dangerous post holing (if you run into really deep snow).

Data Collection

Although it is not analyzable and may not seem like data in some senses, the Topographic Basemap within ArcMap 10.3.1 was one of the most instrumental tools in the analysis for this project. Topographic maps are essential in determining suitable spots for outdoor recreation, at least in my mind. These maps offer a wide variety of things to base an initial determination of a suitable spot off of, including stream and other water body locations, elevation changes, locations of ridges and cliffs, and a rough visual estimate of the steepness of terrain. However, this basemap was used only as a tool to determine roughly what spots might be suitable, and then other data were overlaid on the basemap to give a more clear depiction of suitability.

The NED 10 meter DEM data was also collected to be able to perform an integral part of the analysis done in this project. A picture of this DEM can be seen in Figure 1, pictured above.

NHDPlus data was also used to determine the location and magnitude of streams and streamflow. Using the Identify tool, the streams shown on NHDPlus data within ArcMap can be identified as either perennial or intermittent, and mean annual flows can also be determined to see if a site is suitable for an activity based on how often one would have to cross a stream, or if one would have to cross one at all during certain times of year. It is much more likely that an intermittent stream will get filled in and covered with snow, which makes things much easier for cross country skiing (because usually the streambed is the feature in the landscape with the lowest slope, which is good for skiing)

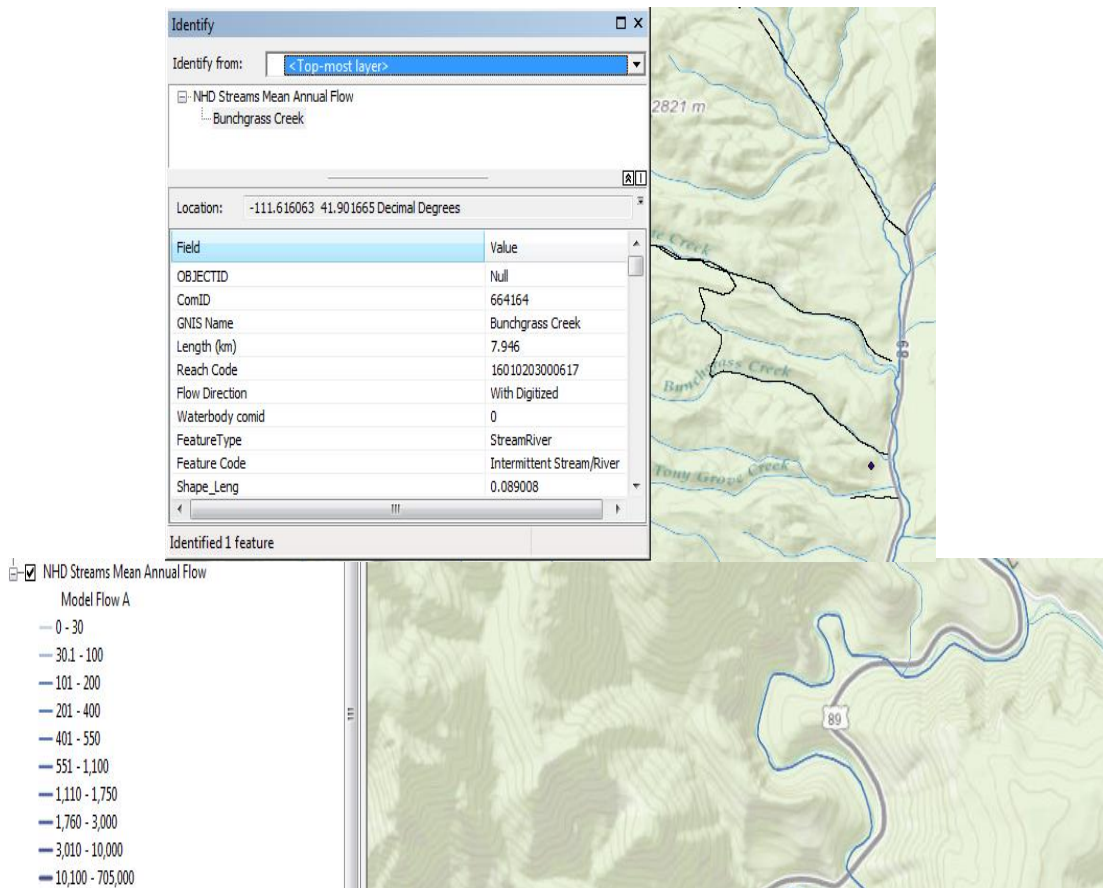


FIGURE 2 - NHDPLUS MAP VIEW AND USAGE WITH THE IDENTIFY TOOL

NOAA precipitation data was also incorporated into this project to be able to determine which areas receive snow, and at what elevations the most snow falls. The data that was mostly used was the Total Snow Depth data from Snotel Sites throughout the Bear River Range, which was used more of an indicator than anything as to which places get snow and which places do not throughout the range. The data that was included in this analysis was the monthly maximum snow depth ranging

from January 2000 to January 2015, as this was determined to be sufficiently characteristic of current snowfall conditions.

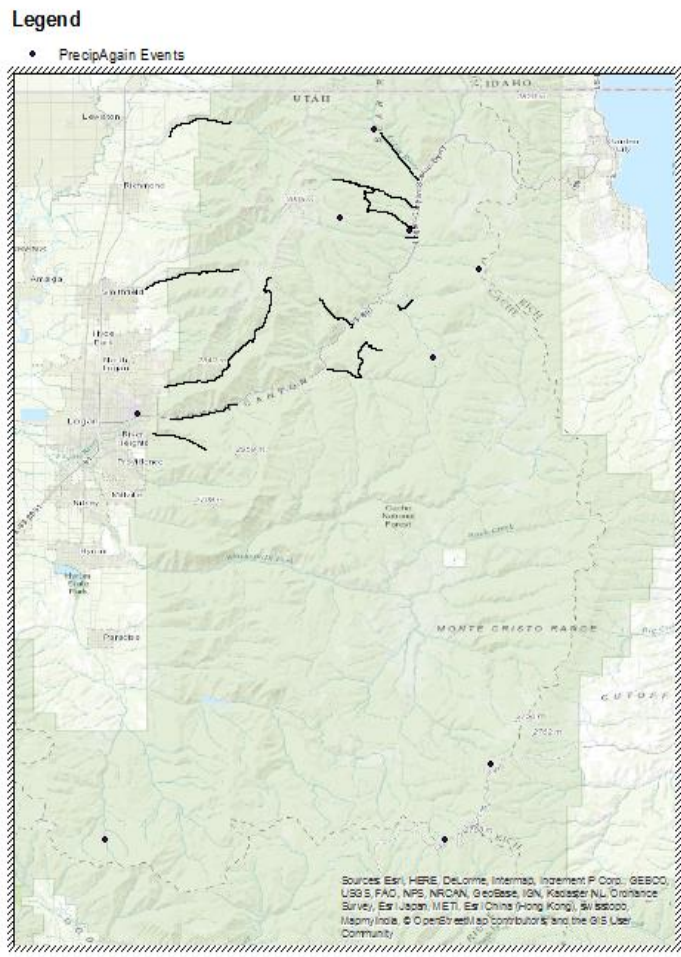


FIGURE 3 - VARIOUS NOAA PRECIPITATION DATA COLLECTION LOCATIONS IN THE BEAR RIVER RANGE

Private/Public property data was also collected and incorporated into the maps. The Cache County GIS department kindly sent a geodatabase that included all of the current data of this sort so that within ArcMap the Identify tool could be used to identify which land boundaries were for private land

and which parcels were publically owned so that the user could determine whether a trailhead was owned privately or publically.

National Land Cover Data (2011) was also used to determine whether a certain area was covered in thick forest or smaller vegetation to determine whether a spot was suitable for skiing or

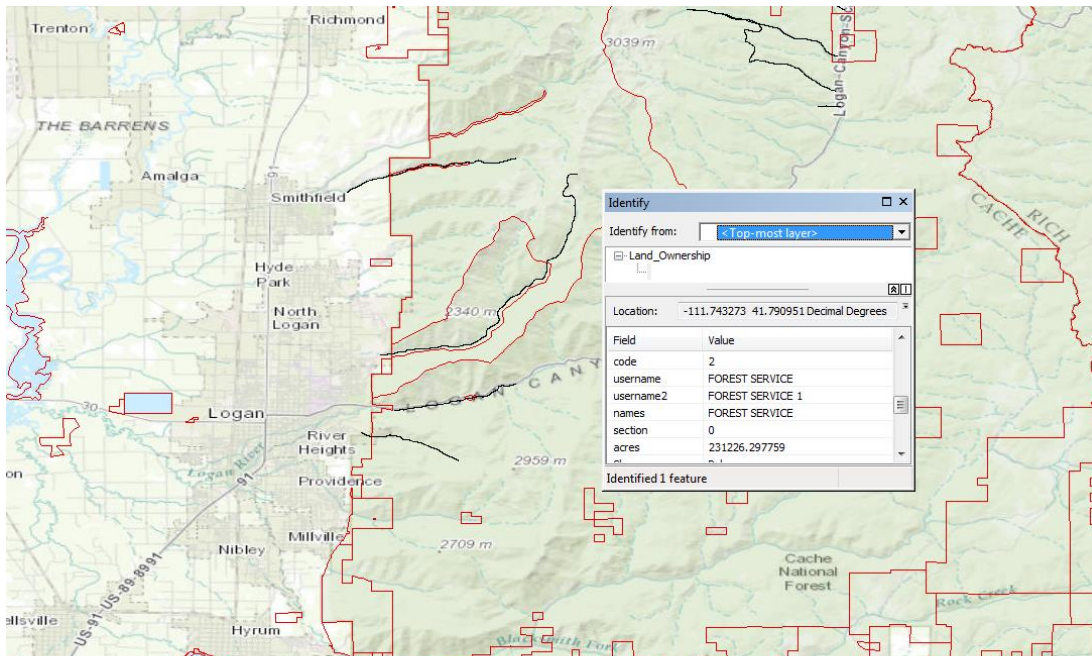


FIGURE 4 - A SECTION OF THE PRIVATE/PUBLIC PROPERTY MAP WITH THE IDENTIFY TOOL INFORMATION BOX SHOWN

trail

running as well. It is not enjoyable (and can be dangerous, in the case of skiing) to be traveling over deadfall that is characteristic of most dense forests. During the winter, snow will often cover up completely the shrubs and scrub vegetation that is characteristic of many parts of the Bear River Range.

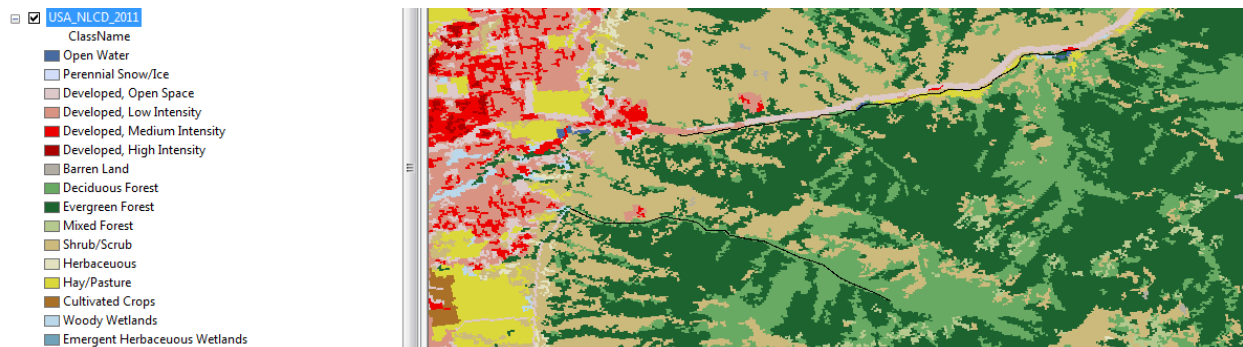


FIGURE 5 - A DEPICTION OF THE NLCD DATA AT THE MOUTH OF LOGAN CANYON, AND ITS KEY TO THE LEFT

Analysis of Data

The tools used in the analysis data were specific to several purposes of the project. The tools that were used were the identify tool, the transparency tool, the slope tool and the Spline Interpolation tool within the spatial analyst toolbox, the Interpolate Line tool and Profile Graph tool within 3D analyst toolbox.

The identify tool has already been mentioned as being used for two purposes - the identification of stream properties within the NHDPlus data, and also for the use within the Public/Private Property data. This is a useful tool in determining characteristics of an area before determining whether it is suitable for an activity or not.

The slope tool was used to calculate the percent slope of all of the 10 meter DEM cells. This information was integral in determining whether a spot was suitable for activity or not, especially when used in conjunction with the 3D Analyst's Interpolate Polyline tool.

This Interpolate Line tool was used to delineate the routes that would be followed by the recreationist. When used with the Slope raster, a Profile Graph could be drawn by the 3D analyst to show the local slopes of every DEM cell that the polyline crossed, and then also a median slope could be determined to see if the sustained slope over the entire reach exceeded the values that were previously discussed to be acceptable.

The spline interpolation tool was used to interpolate a maximum snow depth surface throughout the Bear River range based on the NOAA data that was gathered.

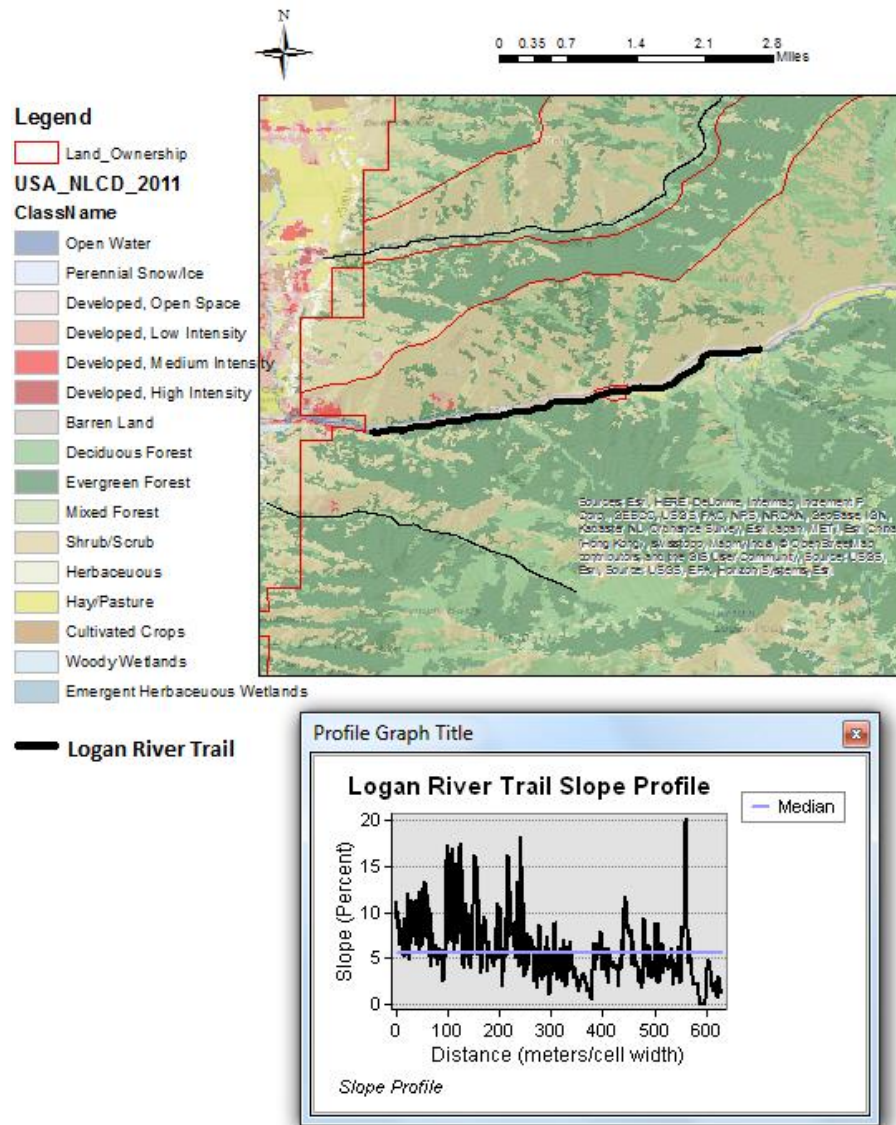
The transparency tool was used with several of the datasets. By using different transparencies with different layers, several layers could be juxtaposed to be able to analyze a route based on several characteristics at the same time (including slope, land cover data, property lines, etc.).

Recommended Recreation Areas

After completing maps of several areas throughout the Bear River Range, I selected a few that were suitable for differing levels of experience with the different activities discussed in this paper.

For beginning trail runners, the Logan River Trail was chosen as a suitable introduction to the sport. The distance is displayed as about 630 meters/cell width (with the cell width being 9 meters) which equates to 5.7 km, or about 3.5 miles, one way (which corresponds well with measurements

that I have taken of the distance of this trail, and could be easily shortened for those who want to run a shorter distance).

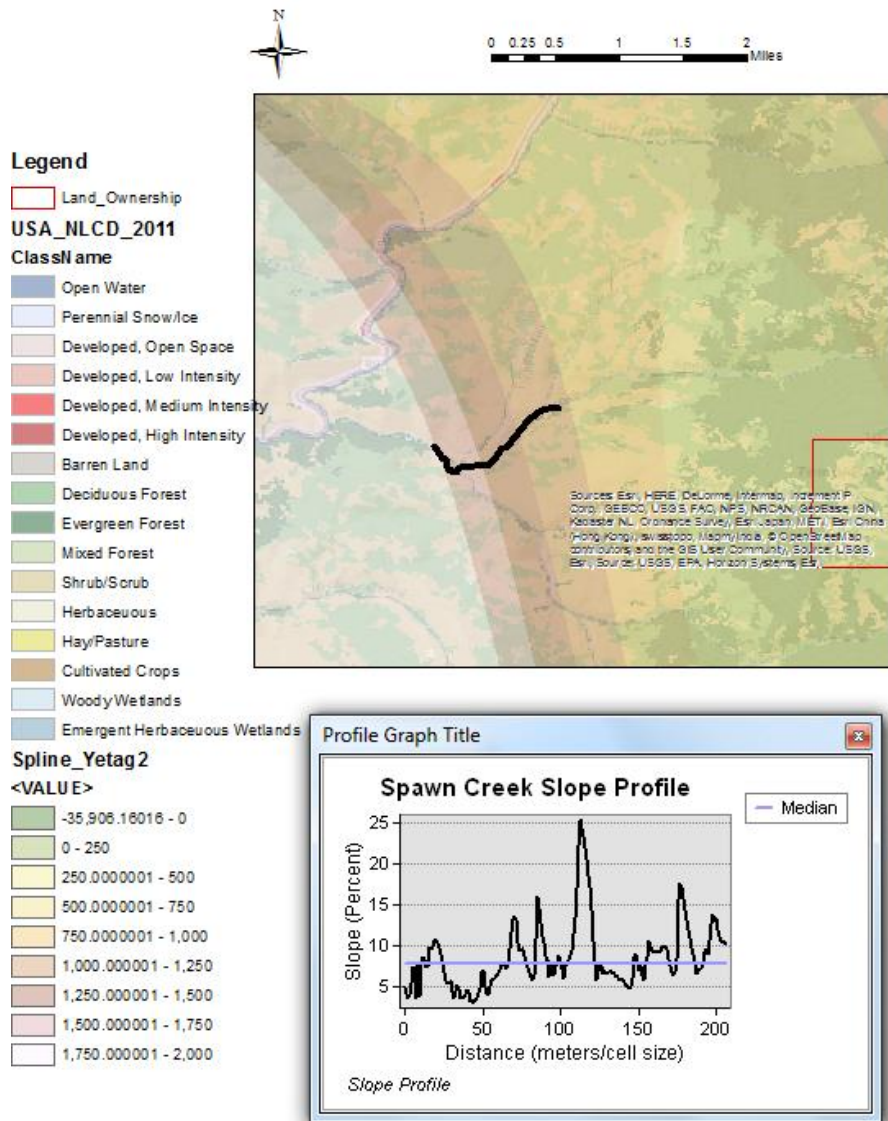


It also shows that the maximum grade never exceeds 20 percent, and that the average grade of the trail is just over 5 percent. This grade is somewhat higher than the estimated grade of the trail based on the elevation gained over the course of the trail (which estimates the grade to be about 3 percent), but the reason for this will be explained later on in this paper. This trail never needs to cross the river (and it would be difficult in most cases to cross this river anyway due to the average Gage Adjusted Flow of 230 cfs). The land cover along this trail includes mostly shrub/scrub, herbaceous

FIGURE 6 - LOGAN RIVER TRAIL MAP/PROFILE

land, and some interspersed sections of hay/pasture, deciduous forest and evergreen forest. The forest sections are short (never greater than 90 consecutive meters, and the forest sections cover less than 10 percent of the total trail distance) and therefore shouldn't cause a large problem with running. The entirety of the trail is also on Forest Service Land except for a small section (that can be seen in the middle of the map, surrounded by a cell with red boundaries). This is private property, which could potentially pose a problem if I were only using GIS based knowledge, but I know from experience that this trail is open the public throughout the span that has been delineated on the preceding map.

For beginning cross country skiers, the Spawn Creek trail would be an almost ideal introduction (amongst the areas in the Bear River Range, anyway). The trail delineated ends up being



about 220 meters/cell size long, or about 2 km (1.2 miles) one way, which is an easy distance for beginners, and the slope averages about 8 percent, never exceeding 25 percent (and normally never exceeding 15 percent, except in three short sections). This corresponds well with previous measurements of the slope of this area. Also, none of the trail is on private land (it is all owned by the U.S. Forest Service (USFS)). The land cover is all either shrub/scrub or developed (which means in this case that the trail or road was picked up by the NED 10m DEM). According to the snow spline interpolation, this spot also receives enough snow depth to support cross

FIGURE 7 - SPAWN CREEK MAP/PROFILE AND NHDPLUS STREAM DATA ON RIGHT

country skiing (between 1-1.5 meters on average, which is greater than the required 8 inches). The NHDPlus data shows that the route will cross the creek twice, and that Spawn Creek is a perennial stream, but the mean average flow is only 7.3 cfs, with the value definitely being lower in the winter which should allow for freezing of the creek and covering with snow.

Field	Value
Feature Code	Perennial Stream/River
FeatureDetailURL	Null
FeatureType	StreamRiver
FISH CONSUMPTION ADVISORY	Null
FLOW ALTERATION(S)	Null
Flow Direction	With Digitized
Flow Loss for Catchment	0.018
From Measure	0
From Node	800000087
Gage Adjusted Flow E	7.334
GNIS Name	Spawn Creek
HABITAT ALTERATIONS	Null
Impairments_Number	Null
Impairments_String	Null

For intermediate level trail runners, an amazing area is the Cottonwood Canyon area (and the trail was just renovated this year!). The trail delineated measures a little over 4 km, or about 2.5 miles one way with an average slope of about 16 percent and rarely exceeding 30 percent slope, and just

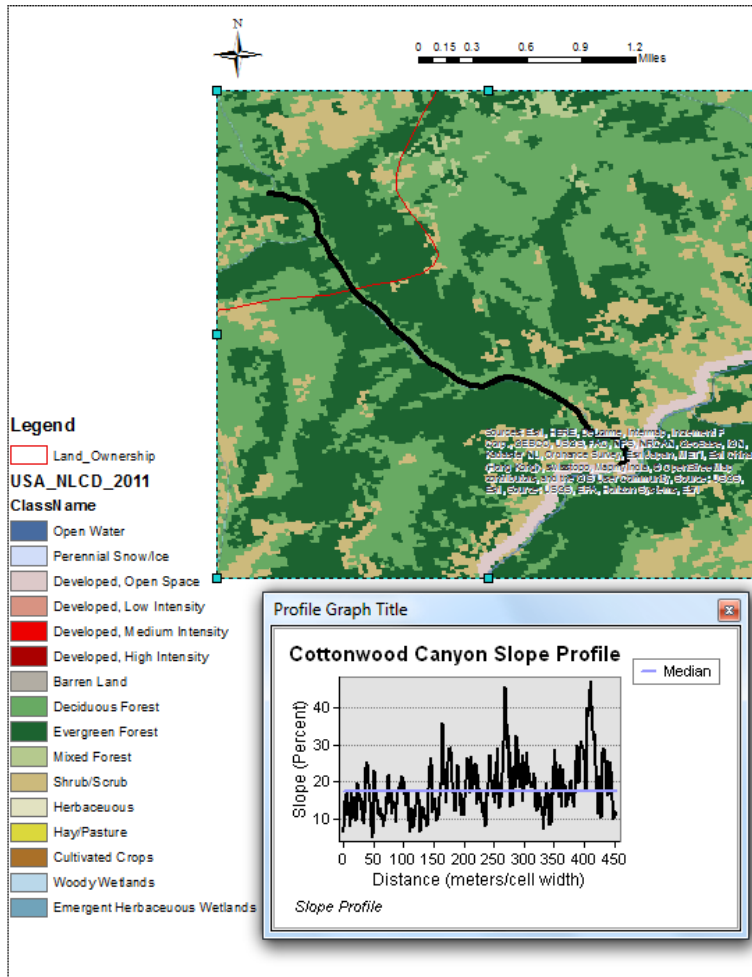


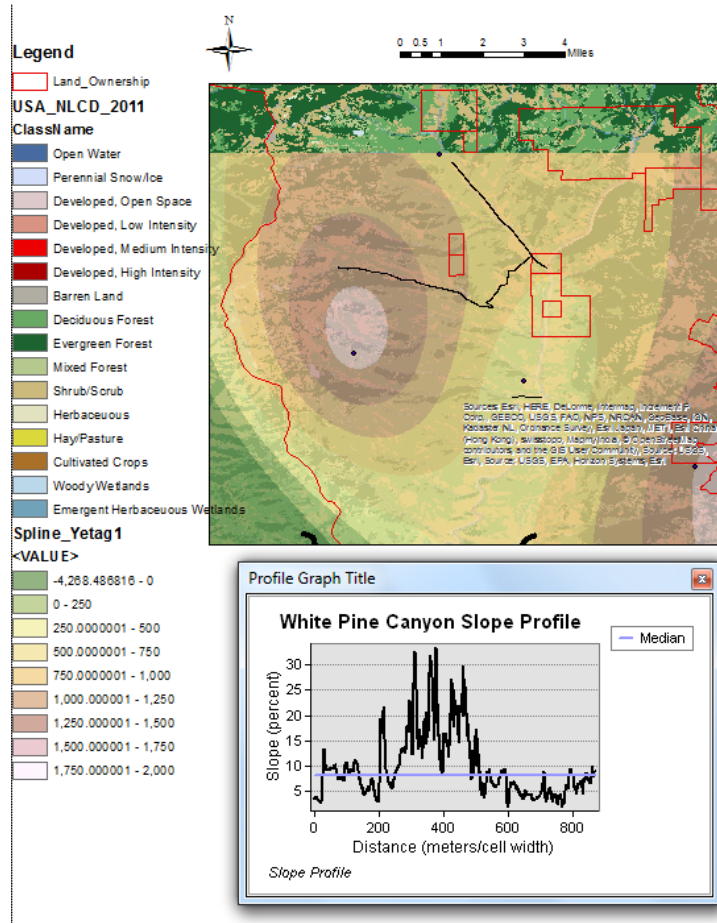
FIGURE 8 - COTTONWOOD CANYON MAP/PROFILE AND NHDPLUS STREAM DATA ON RIGHT

not have included this trail in my project had I not known previously that a trail had been cleared through this space. I mostly included this trail because it really is a gem within the Bear River Range that many people do not know about, and even fewer people know that the trail was renovated just this year. There are several stream crossings, but the discharge of the stream is intermittent and has an average of 16.5 cfs. This is an easily crossable stream (although your feet might get wet) when there is water, but during the summer and fall when trail running are most popular, it is likely that the stream will not even be running. The property boundary marked on the map simply marks the boundary between USFS land and the Mount Naomi Wilderness Area boundary, which is also public land so all of the land is public.

for short sections. This slope estimate is, however, high due to the nature of Cottonwood Canyon and the limitation of this slope profile method. The canyon bottom is very narrow, and therefore many of the canyon bottom DEM cells record a slope that is actually mostly from the walls of the canyon, which leads to a much higher estimate of percent rise over the course of the trail. By doing rise over run, the trail gains about 1000 feet over the 2.5 miles and therefore should have an average slope closer to 8 percent. The land cover data was almost 100 percent deciduous forest, which would normally be a problem for running unless a trail has been cleared. I would

Field	Value
Enabled	True
ESRI_Key	Null
Feature Code	Intermittent Stream/River
FeatureDetailURL	Null
FeatureType	Stream/River
FISH CONSUMPTION ADVISORY	Null
FLOW ALTERATION(S)	Null
Flow Direction	With Digitized
Flow Loss for Catchment	0.051
From Measure	0
From Node	80000094
Gage Adjusted Flow E	16.574
GNIS Name	
HABITAT ALTERATIONS	Null

For intermediate cross country skiers, the White Pine Canyon area would be a great choice. It starts out gradually as the route leaves Franklin Basin, and then steepens as the trail ascends into a glacial valley and then flattens out as it gets into the wide bottomed valley and follows along near the creek up towards White Pine Lake. The route delineated doesn't go all the way to the lake because



the route steepens slightly as it gets close to the lake, so it was determined that the slope would be too high for most intermediate cross country skiers. The slope, as delineated, has an average of about 8 percent, and the section where the route is ascending into the glacial valley has a sustained portion of about a mile of slopes higher than 10 percent (this is why it is considered for intermediate users). The distance ends up being 7.5 km or 4.5 miles one way, with an elevation gain of about 1000 feet. The land cover is mostly shrub/scrub, especially at the beginning and once the trail has gotten into the glacial valley. There are some sections of deciduous and evergreen forest, but they account for less than 20 percent of the area covered by the trail, and there are long stretches of just

FIGURE 9 - WHITE PINE CANYON MAP/PROFILE AND NHDPLUS STREAM DATA ON RIGHT

shrub/scrub that will be covered by snow during skiing season that will allow for great sections of XC skiing. The average maximum snow depth, according to the spline, should be sufficient (.75m-1.25m) for skiing. The route does cross the creek once, which could be problematic as White Pine Creek is a perennial stream, but the discharge is only 13.3 cfs, and therefore should also freeze in winter and get covered in snow to allow for easy crossing. If it does not freeze, it is possible to stay on the north side of the creek throughout the whole canyon as well, to avoid crossing the creek.

Field	Value
Feature Code	Perennial Stream/River
FeatureDetailURL	Null
FeatureType	Stream/River
FISH CONSUMPTION ADVISORY	Null
FLOW ALTERATION(S)	Null
Flow Direction	With Digitized
Flow Loss for Catchment	0.049
From Measure	0
From Node	80000066
Gage Adjusted Flow E	13.313
GNIS Name	White Pine Creek
HABITAT ALTERATIONS	Null
Impairments_Number	Null
Impairments_String	Null

For expert trail runners, running up to Mount Elmer from Green Canyon is a great challenge. The route gains over 3500 vertical feet in a little over 5 miles, which equates to an average grade of 13 percent throughout the entire run. According to the profile that was delineated, the average slope is over 20 percent, but this is most likely due to the canyon effect that was discussed with the Cottonwood Canyon profile. The slope when getting up to the actual peak is almost 100 percent for a short section of scrambling, but some scrambling is often expected for expert alpine trail runners. The entire route is on public property, crossing from USFS land into the Naomi Wilderness Area but never onto private property. The stream that the trail crosses is intermittent, and has a mean flow of 8 cfs (and honestly I've never seen it flowing and I've been up there in early June before, when it should really have been flowing).

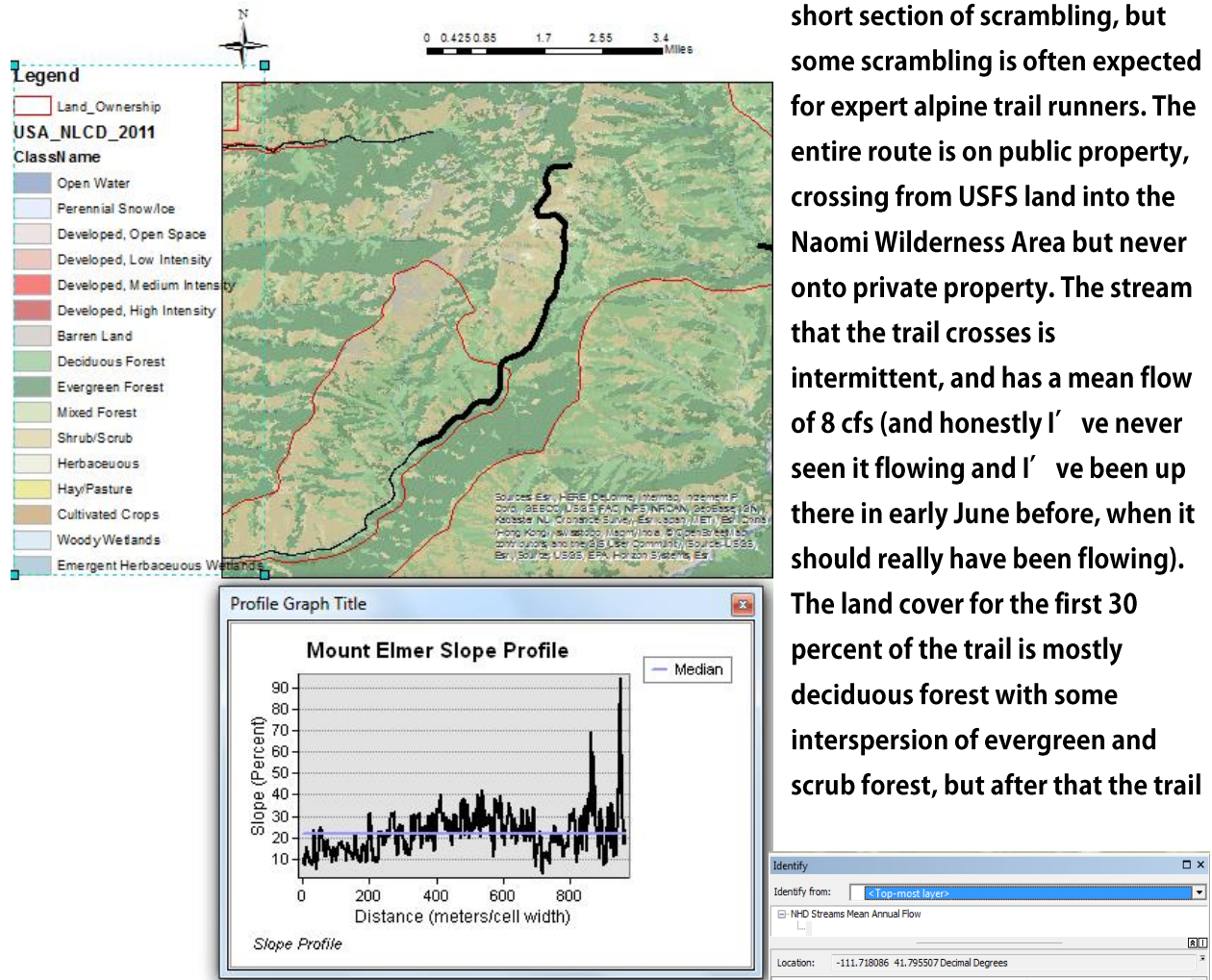
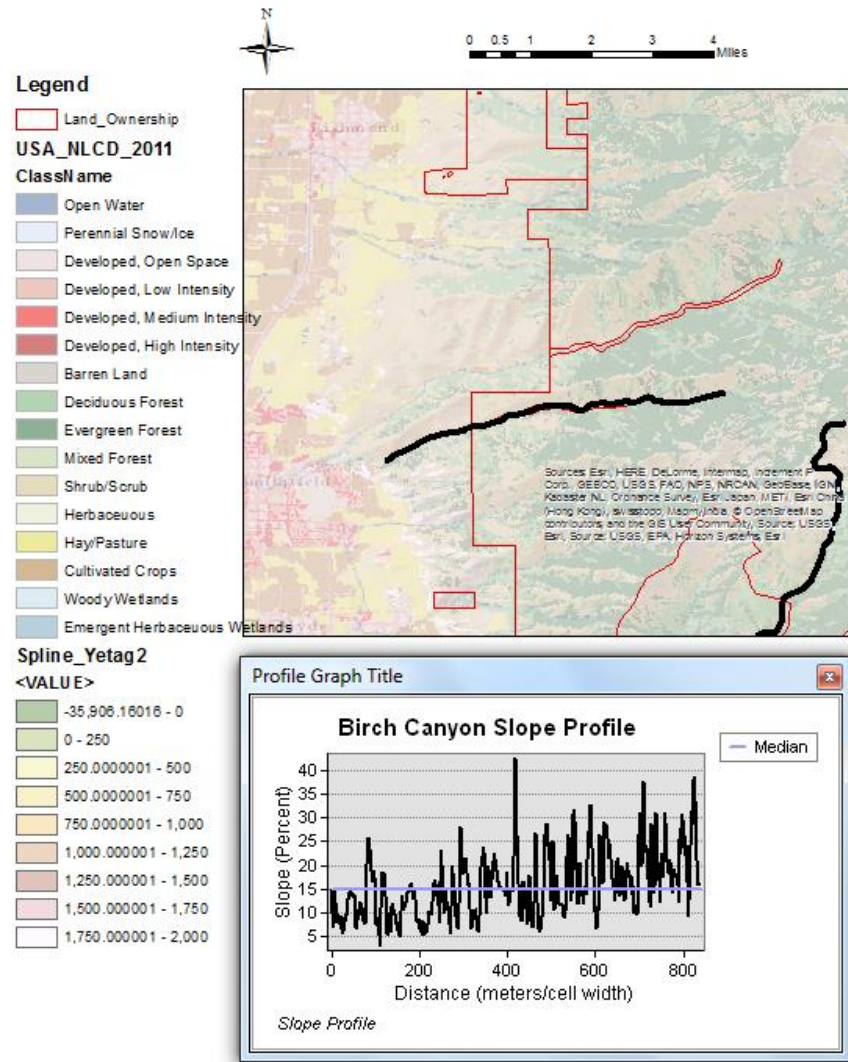


FIGURE 10 - MOUNT ELMER MAP/PROFILE WITH NHDPLUS STREAM DATA ON RIGHT

becomes mostly scrub/shrub land cover, which makes this route great for running.

The route that was chosen for expert cross country skiers was the Birch Canyon area from the west side of the Bear River Range. This was chosen for experts because even though the route gains



1800 feet in 4.5 miles, most of this gain occurs in the last half of the route (you can see on the graph how the slope trends upward in the last half of the route). So even though the average slope would be calculated as about 8 percent, the slope in the last half of the route would exceed 10 percent sustained (as is shown - the method used calculated a 15 percent slope average throughout the route). Also, there are several stream crossings that increase the difficulty, although the discharge of this creek is only 9.6 cfs on average and therefore the stream crossings are mild. The maximum snow depth, according to the spline interpolation, is between 1.75-2 meters, which is more than sufficient for skiing.

FIGURE 11 - BIRCH CANYON MAP/PROFILE WITH NHDPLUS STREAM DATA ON RIGHT

The land cover is almost 100 percent deciduous forest, with some interspersions of scrub/shrub land cover. This also increases the difficulty of the route. The route crosses a property boundary from private into public land, but the route is all on public land or private land that has been opened for public recreational use (hiking, skiing, etc.)

Field	Value
Enabled	True
ESRI_Key	UT16010202-005_00<<=>>2010
Feature Code	Perennial Stream/River
FeatureDetailURL	http://ofmpub.epa.gov/waters10/s
FeatureType	StreamRiver
FISH CONSUMPTION ADVISORY	
FLOW ALTERATION(S)	
Flow Direction	With Digitized
Flow Loss for Catchment	0.177
From Measure	0
From Node	800007326
Gage Adjusted Flow E	9.591
GNIS Name	

Problems with Analysis

One of the main problems with the method for delineating recreational routes in this project is the resolution of the elevation data that was available at the time of the project. NED 10m DEM is a great resolution for many purposes, and is a great upgrade from the 30m DEM alternative, but the resolution was not quite high enough to capture the roads and existing trails in the area, which would have been very useful in mapping out routes and determining slopes of the routes. Also, in some areas like Cottonwood Canyon the shallowest slope was right inside of the creekbed, which is a terrible place to go running in reality. If 1m LIDAR data could have been used for the route making, it would have been much easier to get a more realistic slope and picture of what the route would have looked like.

Also, along with the resolution of elevation data, land cover data could have had a higher resolution. There is no way to really get a good idea of what the terrain is like with 30m land cover data, as a section going through a forest might have a trail or some other natural path that would allow activity to occur there that might otherwise be disqualified due to the nature of the landcover.

The number of precipitation gaging stations was also a problem when it came time to interpolate the snow depth surface throughout the entire range. Since there were only a few sites scattered through the middle of the range, and none really on the outsides to be able to interpolate a good surface, many large sections of the range were measured as having little or no snow that in reality get lots of snow throughout the winter. If there were more snotel sites, especially on the west side of the range, it would be easier to interpolate a more accurate surface.

Future Work

Because of the amount of time it takes to create each map and delineate new routes, the guide will finish as shown above, with 1 basic route for each sport for each level of expertise. The project could easily be expanded to include more routes and eventually other areas outside of the Bear River Range if it were found to be an acceptable method and worthwhile.

Although most of these routes have been mapped with GPS and traveled by many, there is not a lot of documentation about them, especially with Cross Country Skiing (it is very hard to find any information at all about XC skiing in the Bear River Range, except for groomed trails like Green Canyon and some places near Beaver Mountain). It would be interesting to continue this research, and physically confirm the acceptability of these routes by exploring them on foot or ski to create a full brochure or guide to cross country skiing and trail running in the Bear River Range.

It also would be very interesting to determine acceptability values for backcountry skiing and other activities to determine great spots throughout the range for all kinds of activities, and create guides for these sports as well.

Summary

In the end, a pretty accurate depiction of several routes throughout the Bear River Range was presented to guide people who are either new to cross country skiing or trail running or new to the area can use to start exploring the wonders of this beautiful mountain range. This was accomplished by using various sources of data, including: NED 10m DEM elevation data for slopes of the routes that were chosen, precipitation data interpolated using a spline to determine if these routes received enough snow to be skied on, private property boundaries to determine if a trailhead could be used or not, NHDPlus stream data to determine if a route would cross streams, and if so, how large the streams would be, and NLCD 2011 data to determine what kind of land cover was characteristic of the area where a route would go through. These data were analyzed using tools within ArcMap 10.3.1 to determine if routes would be acceptable for the activities chosen or not, and then presented in map form with the help of the Transparency tool that allowed several layers to be juxtaposed and analyzed simultaneously.

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< <https://www.trailrunproject.com/forum/read.php?4,1733,1733#msg-1733>>