Are My Parents in Danger of Flooding?

Final Report Prepared for
Civil and Environmental Engineering
GIS in Water Resources
CEE 6440, Dr. Tarboton
Utah State University

Prepared by
Kade J. Beck

8 December 2017

Introduction

This report summarizes the analysis performed to create inundation maps for the Worm Creek watershed (see Figure 1). Brief information regarding the significance of the location will be presented to provide context for the analysis. The data sources, methods, and results will be outlined. The paper concludes with a comparison between the analysis and available data for an adjacent watershed and a summary of key findings.

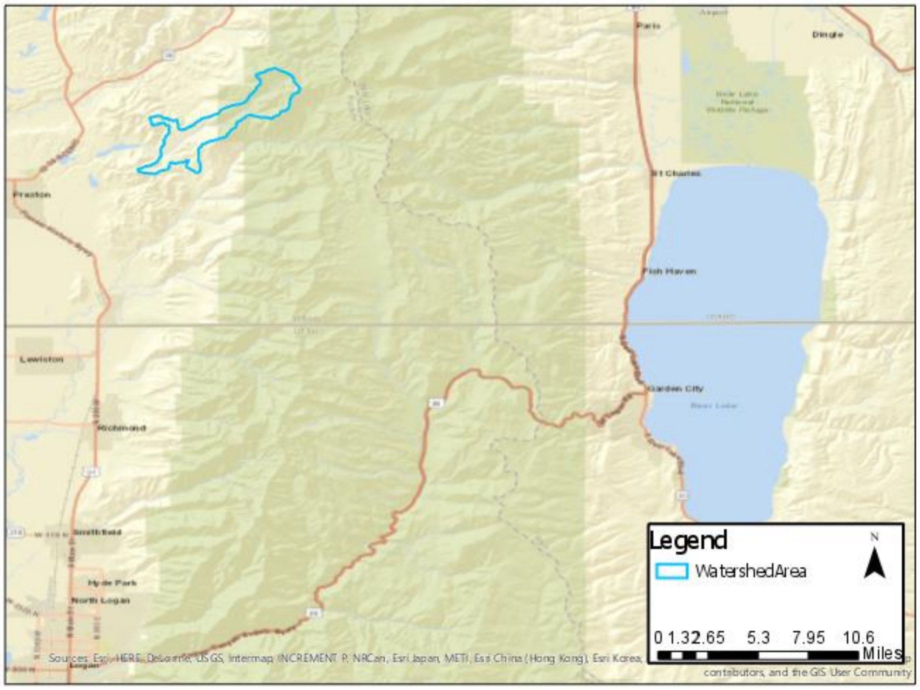

Figure 1. Worm Creek Watershed

Worm Creek is located in southern Idaho's Franklin County and is approximately 30 miles north of Logan, Utah. My parents purchased a farm and moved to this area several years ago. Worm Creek runs through my parents' farm and splits several fields. It was desired to understand the physical effect and corresponding economic impact a flood event would have on my parents' farm.

Table of Contents

Introduction **1**
List of Tables **2**
List of Figures **2**
Statement of Problem **3**
Objectives **3**
Methods **3**
Inundation Maps 3
Economic Impact Assessment 6
Results **6**
Discussion **10**
Conclusion **12**
Citations **13**
Appendix **14**

List of Tables

Table 1. HAND Rating Curve Parameters for Cub River 7
Table 2. HAND Rating Curve Parameters for Worm Creek 8
Table 3. Return Period of Flows for Cub River 14

List of Figures

Figure 1. Worm Creek Watershed 1
Figure 2. Beck Family Farm and Worm Creek 3
Figure 3. Annual Peak Flows for Cub River 4
Figure 4. Removal of Artefacts on Raster 5
Figure 5. Effect of Artefact Removal 5
Figure 6. Cub River HAND Rating Curve 7
Figure 7. Worm Creek HAND Rating Curve 8
Figure 8. Area Influenced by 50-year Flow Event 9
Figure 9. Area Influence by 25-year Flow Event 9
Figure 10. Area of Full Bank 10
Figure 11. HAND vs. USGS Observed Discharge and Stage 11
Figure 12. Stream Comparison 12

Statement of Problem

The purpose of this project was to determine what area of land may be impacted by flooding in the Worm Creek watershed. Several years ago, my parents purchased and moved to a farm in the area. Worm Creek splits several fields as it passes through their farm. Figure 2 displays a map of my parents' farm in the bottom left hand corner. The pink lines represent Worm Creek and its tributaries. The blue line represents the watershed boundary of Worm Creek. It was desired to know whether or not—and to what degree—the fields and outbuildings would be impacted by a flood event. With this information, an economic damage assessment was calculated.

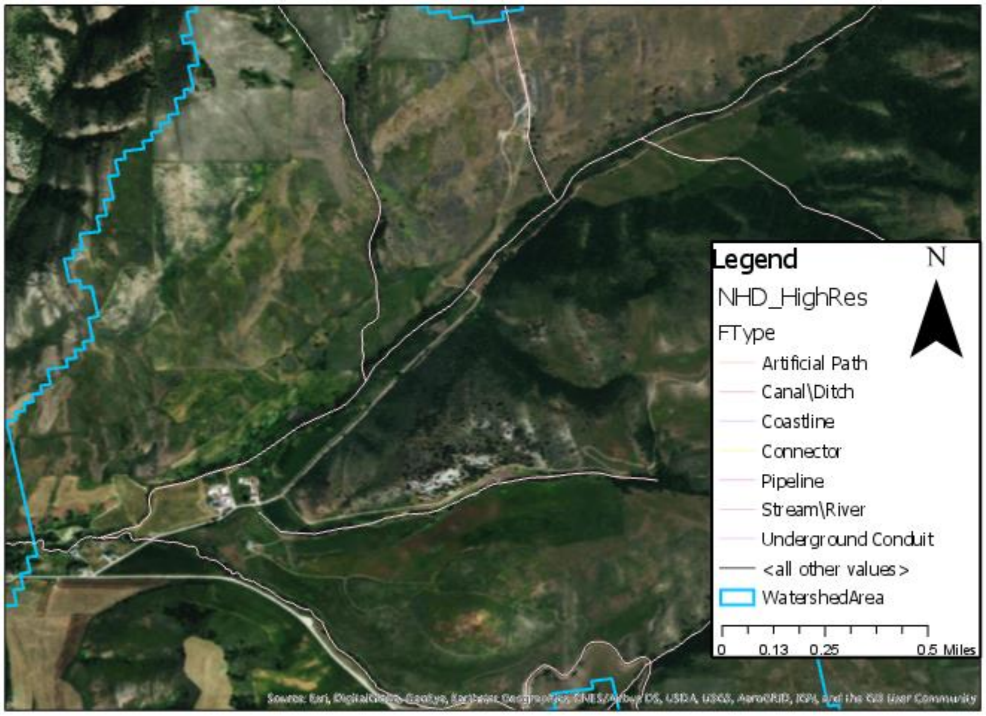

Figure 2. Beck Family Farm and Worm Creek

Objectives

This project had two objectives. First, create an inundation map for a 25-year and 50-year flood event. Second, determine the economic damage of the respective floods.

Methods

The following section explains the methods used to complete the objectives described above.

Inundation Maps

The data required to create the inundation maps included a digital elevation model (DEM) of the Worm Creek and Cub River watersheds and flowlines for those watersheds. This data was obtained from the National Map, which is maintained by the United States Geological Survey (USGS).

As part of validating the inundation maps, stream gage data was obtained for a computational comparison. There is not a USGS stream gage in the Worm Creek watershed. Consequently, an adjacent watershed with a USGS stream gage, the Cub River watershed, was used to compare results.

Using the USGS stream gage for the Cub River, it was determined that all but one of the peak flows on record occurred during the months of May or June (see Figure 2).

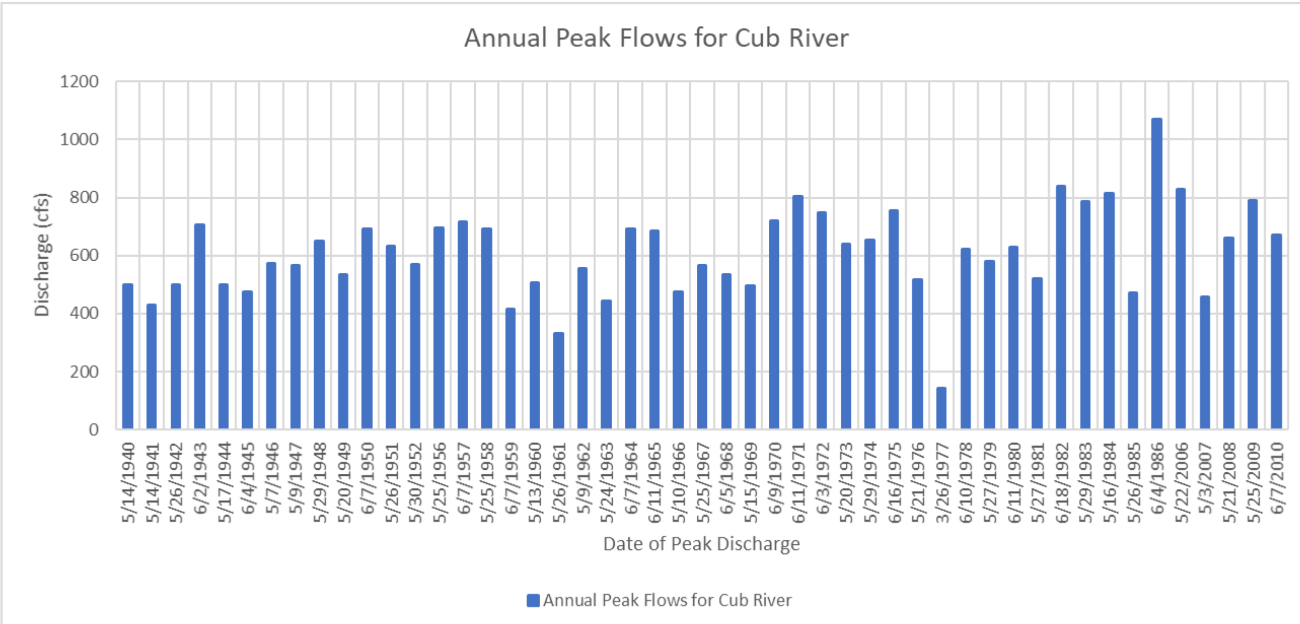

Figure 3. Annual Peak Flows for Cub River

The timing of peak flows indicates the peak flows for both the Worm Creek and Cub River watersheds are snowmelt driven. Consequently, the peak flows used to determine the impact of flooding were based upon the USGS data.

The USGS published the process used for determining monthly and annual streamflow at ungagged sites in Idaho. The process for determining ungagged streamflow statistics was used to project the results of the Cub River watershed onto the Worm Creek watershed. This method was also compared with a simple areal scaling from the Cub River watershed to the Worm Creek watershed.

The DEMs used for the analysis had a resolution of 10 x 10 meters. It was thought a resolution of 3 x 3 meters could be obtained from the 3D Elevation Program. However, 3 meter DEMs were not available for the Worm Creek and Cub River watersheds.

As discussed by Zheng et al. (2017), the DEM must be hydrologically conditioned prior to the height above the nearest drainage (HAND) analysis. This process includes filling pits and removing artefacts, such as rail crossings and bridges, that do not allow the DEM to accurately reflect the actual flow path of the stream. Removing pits fills the elevation of the cell to allow the cell to drain downstream. Removing artefacts burns or lowers the elevation of the cell to better represent the elevation of the stream (see Figure 4) (Tarboton, 2017). After the pits are filled and artefacts are removed, the flow direction tool is run to ensure the flow directions for each cell represent the conditioned DEM.

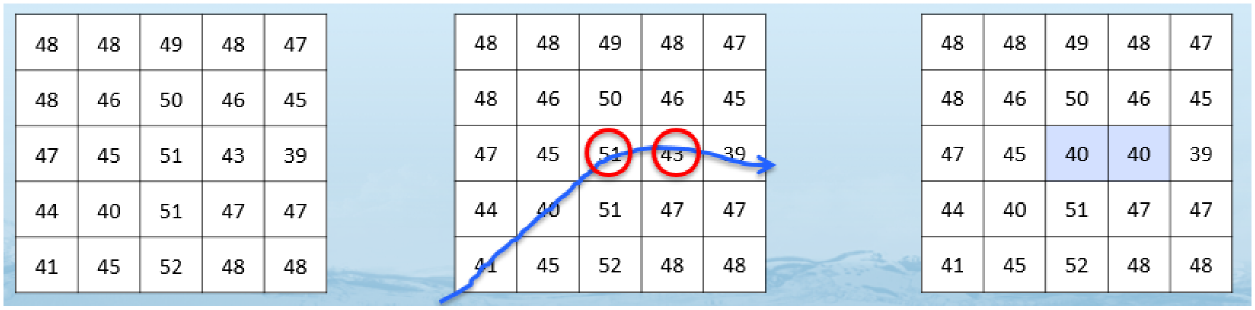

Figure 4. Removal of Artefacts on Raster

Figure 5 (Tarboton, 2017) displays a comparison of a HAND analysis with and without artefact removal. It is clear the results of any model are dependent upon the representative accuracy of the data used for the model. For this reason, the DEMs in this analysis were hydrologically conditioned to ensure the most accurate results possible.

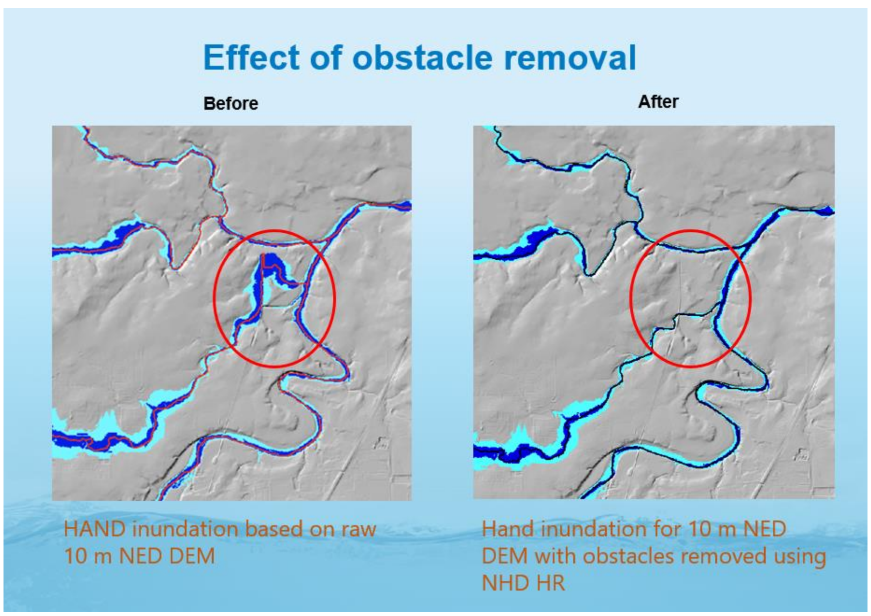

Figure 5. Effect of Artefact Removal

After the DEM is hydrologically conditioned, the stream raster is prepared by using the National Hydrography Dataset (NHD) flowlines and converting the start points of the flowlines to a raster. These start points are then used to delineate a stream network using the DEM. This ensures a stream raster consistent with DEM flow directions. The remaining raster analysis followed the steps outlined in Exercise 5.

Two methods were used to determine the 25-year and 50-year flows in Worm Creek. The first method used an area only based factor to scale the 25-year and 50-year flow from the USGS Cub River gage (see Equation 1).

$$Scale\ Factor = \frac{Area\ of\ Worm\ Creek\ watershed}{Area\ of\ Cub\ River\ watershed} \qquad \text{Equation 1}$$

The second method was based on the USGS report titled, "Estimating Monthly and Annual Streamflow Statistics at Ungaged Sites in Idaho" (Hortness and Berenbrock, 2001). In this report, the USGS divided Idaho into different basins and determined key factors influencing annual flow and used multiple-regression analysis to determine equations for calculating annual flow and monthly flow for each region. StreamStats uses this method to provide a mean annual flow when delineating a basin. Both the Worm Creek and Cub River watersheds were delineated in StreamStats. Equation 2 shows how the second scale factor was calculated.

$$Scale\ Factor = \frac{Mean\ Annual\ Flow\ Estimate\ of\ Worm\ Creek}{Mean\ Annual\ Flow\ Estimate\ of\ Cub\ River} \qquad \text{Equation 2}$$

By using the output of StreamStats multiple regression analysis, the second scale factor accounts for the same parameters as the USGS report.

The 25-year and 50-year flows for Cub River were determined to be the two highest flows in the 49-year period of record of the Cub River stream gage. By ranking the 49 years of data from highest discharge to lowest, an exceedance probability was assigned to each value (see Appendix, Table 5).

Economic Impact Assessment

The following values used for economic impact assessment were determined in personal conversations with my father and using GIS. The key elements were to determine the average yield of barley in bushels per acre, the total acreage damaged due to flooding, and the average selling price per bushel of barley. These values were used to calculate a monetary loss.

The economic impact assessment included the following assumption. The timing of the peak flows would damage the entire inundated area because the plants may not have germinated yet and may be washed away. Additionally, this eliminated the need for address points, or an equivalent reference, to perform a raster calculation subtracting the HAND values from the inundation depth. By using this assumption, the worst case was evaluated.

Results

This section presents the results of the HAND analysis and the inundation maps created for the 25-year and 50-year flows. Tables 1 and 2 display the parameters used to create the rating curves shown in Figures 6 and 7 respectively.

Table 1. HAND Rating Curve Parameters for Cub River

Cub River				
Stage h (m)	0.1	0.5	0.75	1
Number of flooded cells	47	49	71	181
slope	1.002595707	1.003025247	1.0024776	1.00259571
A_s (m^2)	3702.281438	3859.825329	5592.8081	14257.7221
A_b (m^2)	3711.9	3871.5	5606.7	14294.7
Average inundation depth (m)	0.097942987	0.485816371	0.5533872	0.75748662
V (m^3)	362.6125022	1875.166334	3094.9883	10800.0337
L (m)	337.2	337.2	337.2	337.2
A = V/L (m^2)	1.075363293	5.560991501	9.1784944	32.0285697
$P=A_b/L$ (m)	11.0	11.5	16.6	42.4
R=A/P (m)	0.10	0.48	0.55	0.76
S_o	0.033411153	0.033411153	0.0334112	0.03341115
n	0.05	0.05	0.05	0.05
Q=1/n AR^(2/3) S_o^(1/2) (m^3/s)	0.8	12.5	22.6	97.1
Q (ft^3/s) = Q (m^3/s) x 35.3	29	443	797	3429

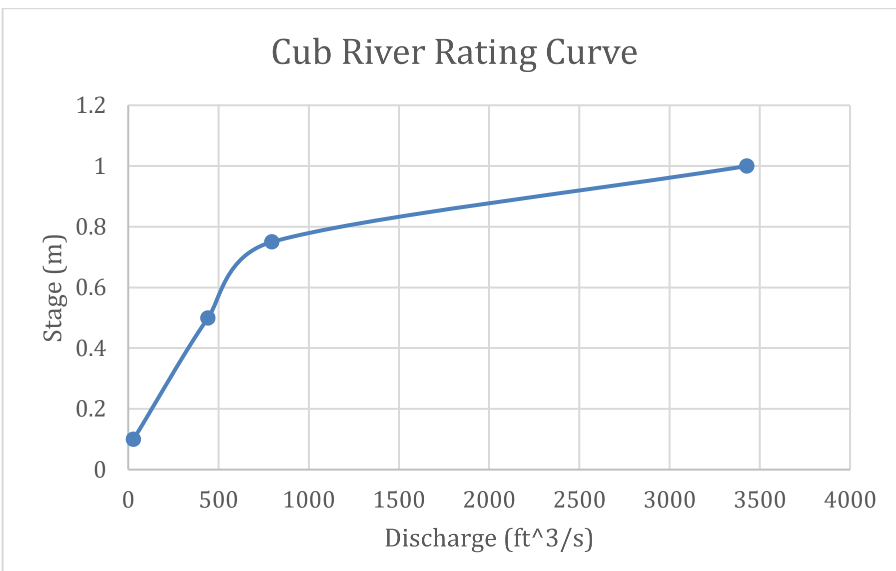

Figure 6. Cub River HAND Rating Curve

Table 2. HAND Rating Curve Parameters for Worm Creek

Worm Creek				
Stage h (m)	0.1	0.25	0.5	1
Number of flooded cells	237	372	594	1024
slope	1.000241463	1.000202636	1.0002832	1.0005022
A_s (m^2)	18668.95108	29303.16372	46790.536	80662.4722
A_b (m^2)	18673.5	29309.1	46803.8	80703.0
Average inundation depth (m)	0.089690638	0.176839457	0.3117616	0.57794363
V (m^3)	1674.430125	5181.955563	14587.494	46618.3621
L (m)	1815	1815	1815	1815
A = V/L (m^2)	0.922551033	2.855071936	8.0371866	25.685048
$P=A_b/L$ (m)	10.3	16.1	25.8	44.5
R=A/P (m)	0.09	0.18	0.31	0.58
S_o	0.017204523	0.017204523	0.0172045	0.01720452
n	0.05	0.05	0.05	0.05
Q=1/n AR^(2/3) S_o^(1/2) (m^3/s)	0.5	2.4	9.7	46.7
Q (ft^3/s) = Q (m^3/s) x 35.3	17	83	342	1650

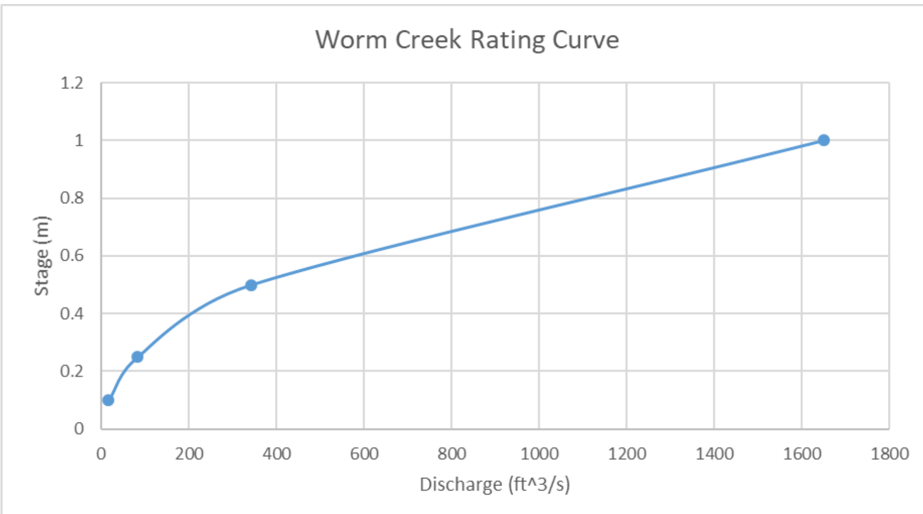

Figure 7. Worm Creek HAND Rating Curve

Figures 8 and 9 show the area of land that would be inundated for the 25-year and 50-year flows respectively. Figure 10 shows the polygon and raster that were created to determine the portion of the total area that was not field area. The area of this raster was subtracted from both the 25-year and 50-year inundated rasters to determine only the area of the fields damaged. Each inundation map is represented by two colors that correspond with two numbers. The cells displaying the color referencing a value of one, indicate inundated area. Whereas the cells displaying the color referencing zero indicate no inundation. Tables 3 and 4 show the calculations for determining the economic impact of each flood event.

Field Area Influenced by 50-year Flow Event

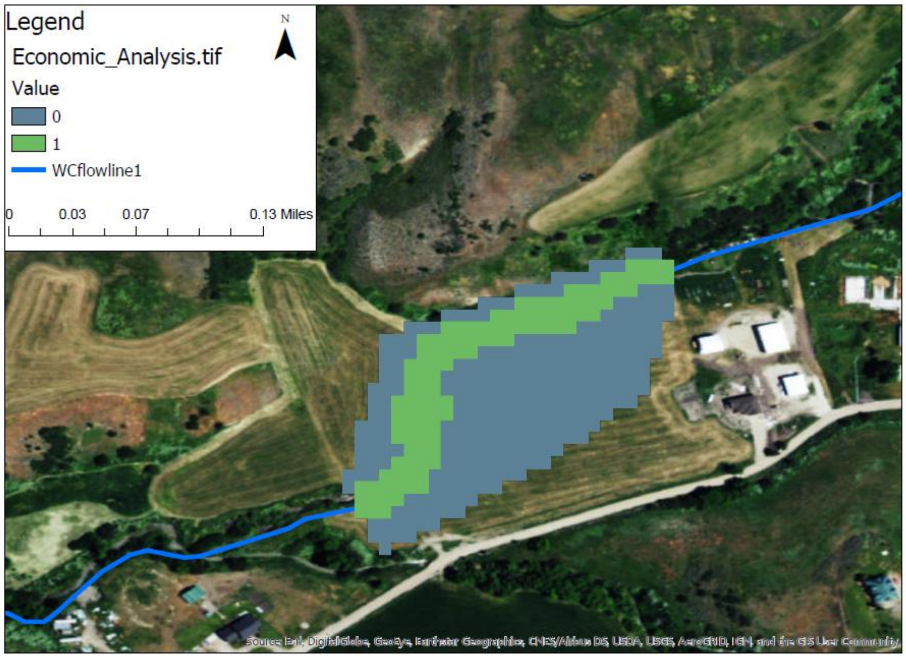

Figure 8. Area Influenced by 50-year Flow Event

Field Area Influenced by 25-year Flow Event

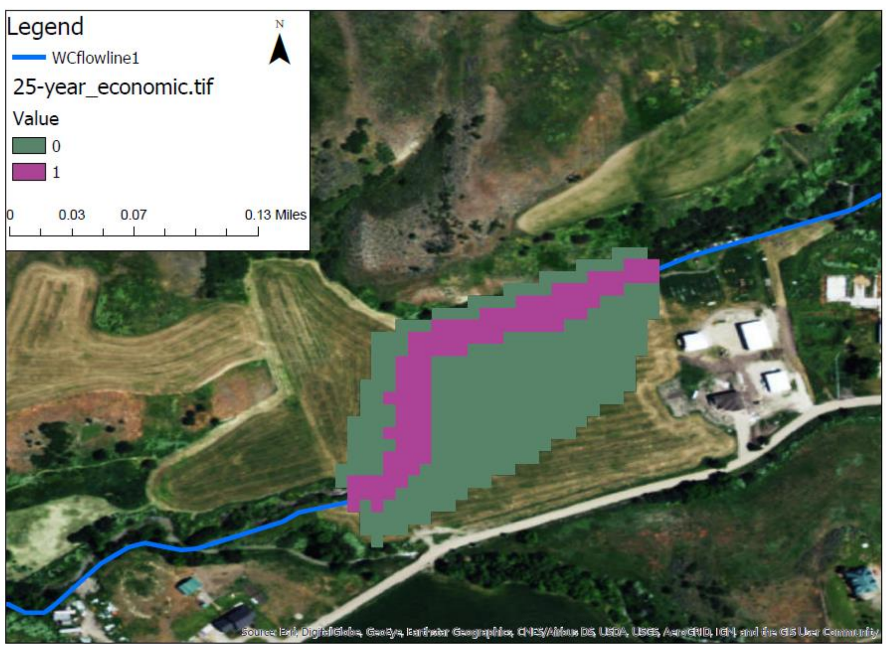

Figure 9. Area Influence by 25-year Flow Event

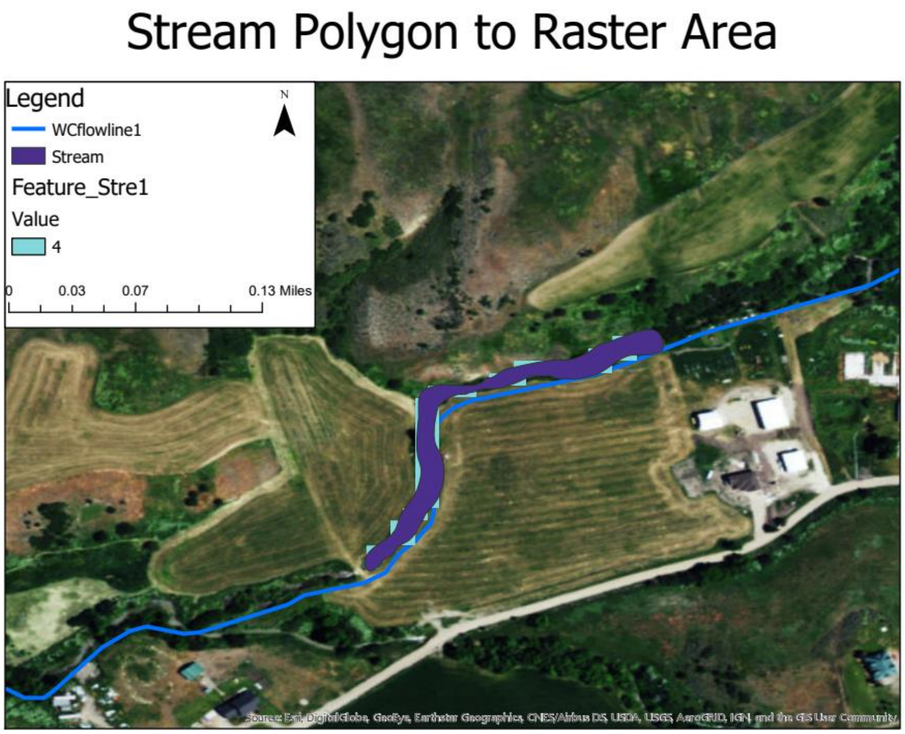

Figure 10. Area of Full Bank

Table 3. 50-year Flood Impact Analysis

50-Year Flood Economic Impact Analysis	
Average Yield Barley in Bushel/Acre	70
Total Acreage Damaged Due to Flooding	1.15
Average Selling Price/Bushel of Barley	$ 3.00
Total Monetary Loss	$ 241.17

Table 4. 25-year Flood Impact Analysis

25-Year Flood Economic Impact Analysis	
Average Yield Barley in Bushel/Acre	70
Total Acreage Damaged Due to Flooding	0.95
Average Selling Price/Bushel of Barley	$ 3.00
Total Monetary Loss	$ 200.29

Discussion

As with many models, the validity of the results is dependent upon the data used. Even though the most accurate data available was used in the analysis, there are several limitations that ought to be considered when interpreting the results. This section outlines those limitations.

First, it is important to note the USGS stage height given for the Cub River 50-year flow differs with the HAND rating curve for Cub River by approximately one and a half feet (1 ½-feet). Figure 11 shows the 50-year flow as measured by the USGS stream gage as an orange dot and the blue curve represents the Cub River rating curved computed using the HAND method. There are several reasons that could account for this discrepancy. One reason may be the coarseness of the DEM for such a small river. It could also be due to the fact that the HAND method creates one rating curve for the entire reach of interest. Whereas the USGS gage uses a rating curve based on the location of the stream gage only. Additionally, the HAND method assumes uniform flow for Manning's equation where in fact the flow may not be uniform.

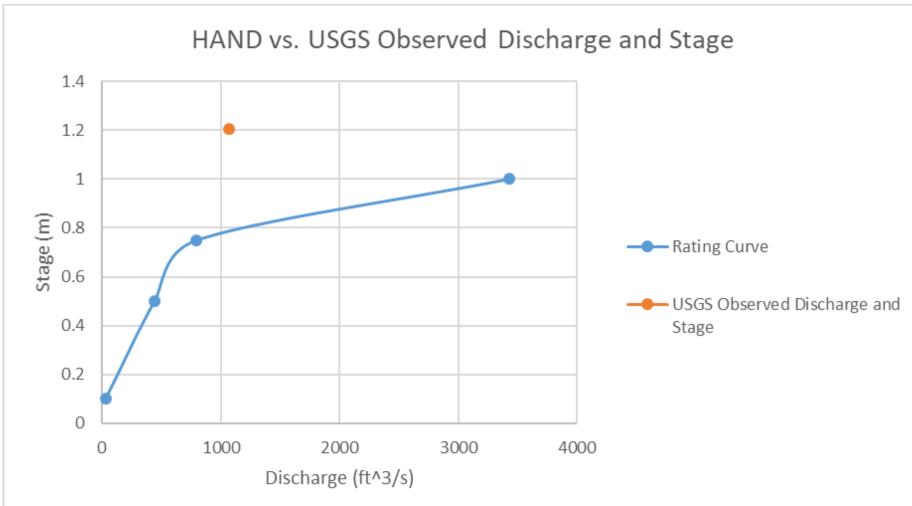

Figure 11. HAND vs. USGS Observed Discharge and Stage

A second critical element is shown in Figure 12. The WCFlowline1 does not appear to line up with Worm Creeks actual location as shown in the basemap imagery. This may be due to the inconsistency of the imagery projection. The imagery spatial reference is different from the rasters' spatial reference. To account for this, a polygon was drawn by hand and converted to a raster to determine the area of Worm Creek and subtracted from the inundation area as noted earlier.

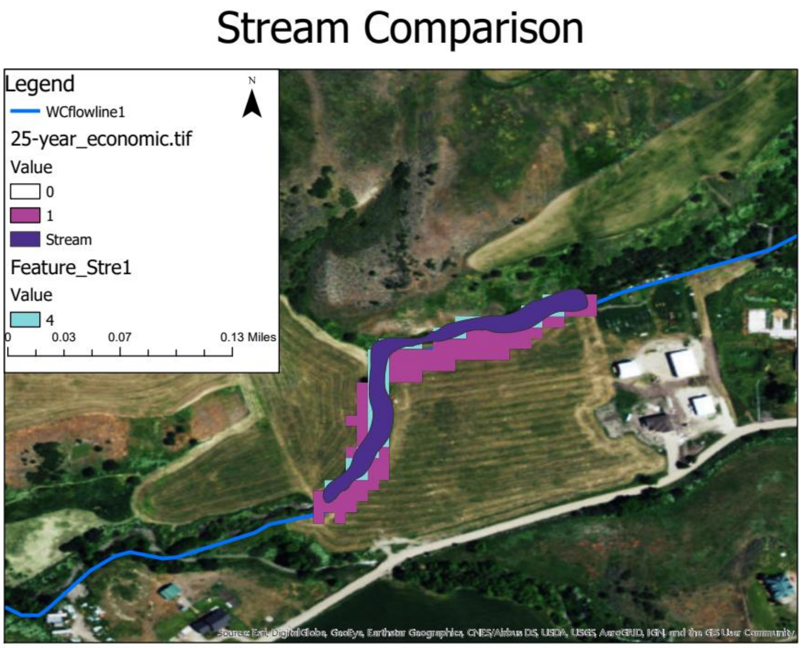

Figure 12. Stream Comparison

Another limitation that ought to be considered is the coarseness of the DEM for the entire Worm Creek watershed. Worm Creek would be more accurately represented by a finer resolution DEM. For this reason, it is uncertain how accurate the HAND method represents the actual flooding that would occur for a 25-year and 50-year flow in the Worm Creek watershed.

Conclusion

Data was obtained and analyzed to determine the economic impact of a 25-year and 50-year flow event for the Worm Creek watershed. The methods used in the analysis were limited by the accuracy and resolution of the data available. Although there may be some uncertainty in the results of the inundation map and corresponding economic impact, the results do provide some valuable conclusions.

First, according to the analysis conducted, none of my parents' outbuildings will be damaged from a 25-year and 50-year flow event. Second, the results suggest that the fields will not experience an irrecoverable loss. Finally, problems of personal interest can be evaluated and provide valuable information that would not otherwise be available to help inform decisions.

Citations

Hortness, J. E., Berenbrock, C. (2001). "Estimating Monthly and Annual Streamflow Statistics at Ungaged Sites in Idaho." <https://pubs.usgs.gov/wri/2001/4093/report.pdf> (November 17, 2017).

Tarboton, D. G. (2017). "GIS in Water Resources, HAND Lecture" <http://hydrology.usu.edu/dtarb/giswr/2017/> (November 21, 2017).

Zheng, X., Tarboton, D. G., Maidment, D. R., Liu, Y. Y., Passalacqua, P. "River Channel Geometry and Rating Curve Estimation Using Height Above the Nearest Drainage." <http://hydrology.usu.edu/dtarb/Zheng_JAWRA_May2017_AuthorSubmitted.pdf> (November 21, 2017).

Appendix

The table below displays the ranked values of flow for the Cub River, exceedance probability, and return period.

Table 5. Return Period of Flows for Cub River

Exceedance Probability	Flow (cfs)	Return Period (yrs)
0.02	1070	50.00
0.04	840	25.00
0.06	828	16.67
0.08	813	12.50
0.1	803	10.00
0.12	789	8.33
0.14	787	7.14
0.16	753	6.25
0.18	747	5.56
0.2	719	5.00
0.22	715	4.55
0.24	705	4.17
0.26	695	3.85
0.28	692	3.57
0.3	692	3.33
0.32	692	3.13
0.34	686	2.94
0.36	671	2.78
0.38	661	2.63
0.4	654	2.50
0.42	650	2.38
0.44	640	2.27
0.46	633	2.17
0.48	628	2.08
0.5	621	2.00
0.52	579	1.92
0.54	574	1.85
0.56	571	1.79
0.58	566	1.72
0.6	565	1.67
0.62	555	1.61
0.64	534	1.56
0.66	533	1.52
0.68	520	1.47
0.7	516	1.43
0.72	505	1.39
0.74	499	1.35
0.76	498	1.32
0.78	498	1.28
0.8	495	1.25
0.82	475	1.22
0.84	474	1.19
0.86	473	1.16
0.88	456	1.14
0.9	442	1.11
0.92	431	1.09
0.94	415	1.06
0.96	331	1.04
0.98	144	1.02