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GIS in Water Resources 513

Graduate Final Project Report

3/10/2019

Modeling the Impacts of Reach Scale Stream Restoration on Flooding and Water Storage

Introduction:

This report is part of a larger environmental design project that seeks to decrease wildfire vulnerability and increase ecological resilience on a four-acre property near Alpine, OR. On this property, there is a creek that borders the southwest end of the property and a tract of forest that wildfires would most likely burn through, given predominate weather patterns in the area. This creek could provide a natural firebreak where fire fighters could hold a line in the event of a wildfire. The creek is incised and no longer connected to its floodplain due to a history of timber harvest, grazing, beaver extirpation, and the introduction of invasive species. Doing restoration work to reconnect this creek to its floodplain could serve the duel purpose of creating native species habitat and reducing wildfire risk on the property. Species habitat would potentially be created through the enhancement of aquatic and riparian habitat, while wildfire vulnerability could be reduced by increasing the wetted area surrounding the creek and increasing the water-content of riparian soils and vegetation during the dry season. Evaluating these effects quantitatively using GIS systems before partaking in restoration work is important because there are outbuildings near the creek that could potentially be flooded if restoration were done poorly. Furthermore, measuring changes in water storage is essential in order to predict and avoid potential water rights conflicts with downstream water users. In this light, the specific goals of this project are to estimate the extent to which the addition of five Beaver Dam Analogs (structures intended to imitate natural beaver dams, aggrade sediment, and passively reconnect the creek's channel to its floodplain) would expand the wetted area of the stream reach of interest and store additional water in this system at various flood stages.

Site Description:

The project site is located near the small community of Alpine, roughly halfway between Corvallis and Eugene. The creek of interest is 897ft long from its emergence at a seeping spring to its junction with Larson Creek. It has a flashy hydrograph, discharging upwards of 60CFS in flood state during the winter months and running dry in the summer months, depending on the water year. Approximately 650ft of this creek run through the property and could potentially be enhanced through restoration work. The site sits on the edge of the Coast Range, however, the creek has a relatively low gradient. It is bordered to the northeast by grassy meadow and to the southwest by secondary growth Douglas fir and cedar coniferous forest that is also interspersed with oak, ash, willow, and native, non-native, and invasive riparian shrubs. Beyond this, the site is characteristic of much of the Willamette valley. It is overarchingly cool and rainy in the winter, and warm and dry in the summer. Wildfires in the area are historically infrequent, however, because there is a large amount of fuel present, a wildfire during a particularly dry and hot year could burn aggressively and be difficult to manage. A depiction of the site is shown in figure 1 below.

Figure 1. Project Site with NHD Delineated Streams and Tax Lot Boundary

Data Utilized:

Name	**Vector/Raster**	**Attributes Used**	**Map Projection**
National Hydrography Dataset Plus Flowline	Vector	Length ReachCode	GCS North American 1983
be44123c4 (Bare Earth Lidar) DOGAMI	Raster	Raster Values	NAD 1983 HARN Lambert Conformal Conic
National Water Model Discharge Forecasts (Larson Creek)	Stand Alone Table	Discharge	No Spatial Reference

National Hydrography Dataset HUC 12 basins	Vector	Shape Area	GCS North America 1983

GIS Methods:

Flooded area for the creek of interest was estimated at multiple flood stages for scenarios with and without Beaver Dam Analogs (BDAs) using DOGAMI 3-meter bare earth lidar, National Water Model discharge forecasts, NHD plus flowline and basin data, and ArcHydro GIS analysis tools in ArcGIS Pro. Some calculations were also done in Microsoft Excel.

First, all layers used were re-projected to the coordinate system of the bare earth lidar DEM raster, NAD 1983 HARN Lambert Conformal Conic. Next, the bare earth lidar layer was masked to the HUC 12 watershed containing the stream of interest. The stream of interest was then “burned” into the bare earth lidar DEM in order to bypass a culvert not accounted for in the DEM that would have disrupted the flow accumulation model described later. This process was done by converting the stream of interest from the NHD flowline layer into a raster file, reclassifying the value of this stream to a depth sufficient to ‘burn’ through the culvert (3ft), and then using the raster calculator to subtract this re-classified layer from the original bare earth lidar DEM. In order to avoid disrupting hydrologic models downstream of the culvert, the stream layer was clipped to the width of the road that the culvert passes beneath before being converted to a raster layer. Once the stream was “burned” into the DEM, “pits” in the DEM were filled using the fill tool in the ArcHydro toolbox. A d8 flow direction was then calculated using the flow direction tool and flow accumulation was calculated using the flow accumulation tool. A conditional raster calculation was then performed to delineate a raster layer depicting streams. This layer was then used along with a “dinfin” flow accumulation to create a Hight Above Nearest Drainage (HAND) model using the flow distance tool. This layer was used as an input for a raster calculation (HAND< “floodstage”) that was used to calculate flooded area within the study site at flood stages of 0.1, 0.2, 0.5, 1, 3, and 5ft flood stages. Raster calculations were then done to estimate inundation depth (“floodstage” -(Hand/ floodarea”)) and slope (SquareRoot(1+ “slope”/100)*(slope/100))/”floodarea”)) at each pixel in the study area. An example of a model builder used to calculate flooded area at a floodstage of 1ft is depicted in figure 2 below.

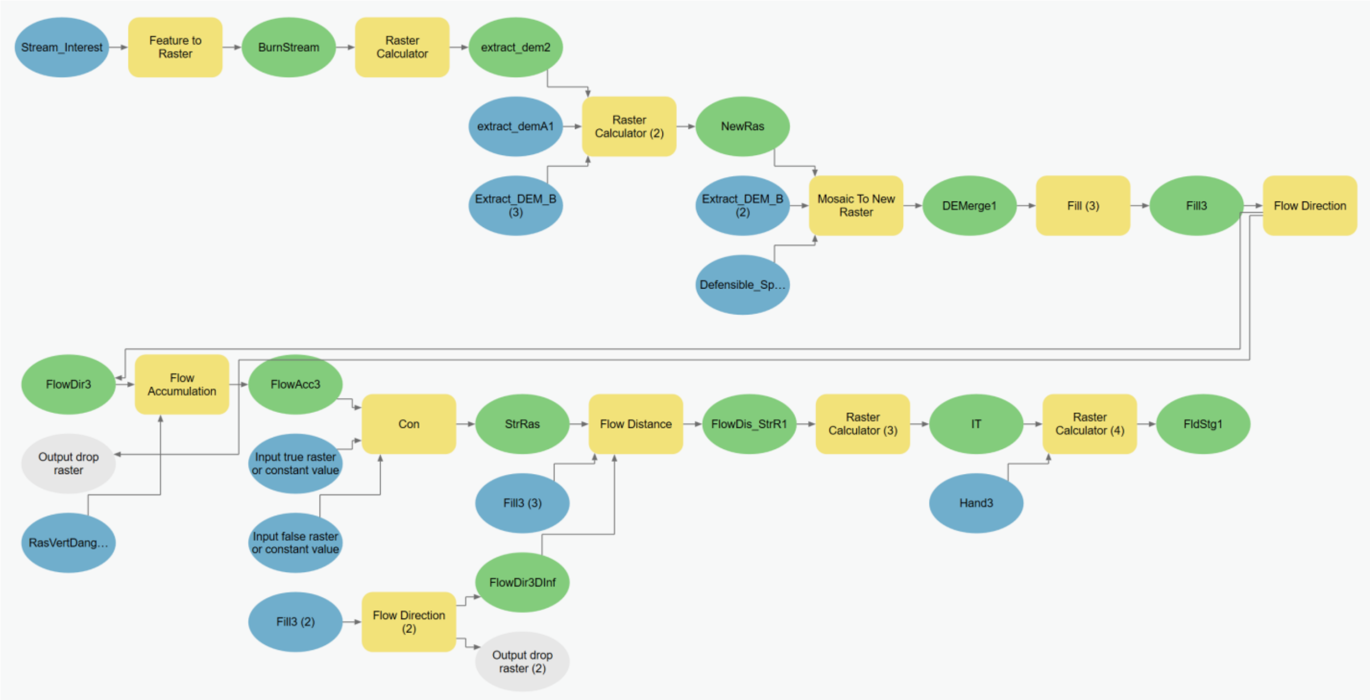
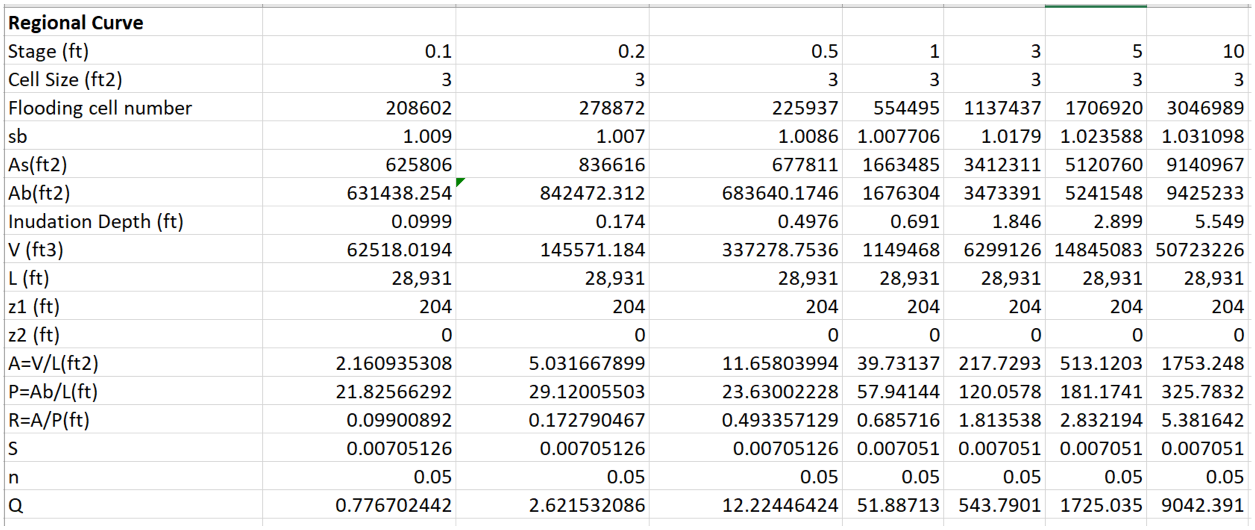


Figure 2. Example of model builder used to map flooded area at a 1ft flood stage

In order to estimate flooded area at likely flood stages, a regional curve was developed for the HUC12 basin that the stream of interest falls within. For this calculation, length was estimated using the longest serious of continues drainage lines in the HUC12 basin containing the stream of interest. Calculations used to estimate discharge and develop the regional curve used to estimate flooded area at various flood stages is depicted in Figure 3. The regional curve itself is depicted in figure 4.



Regional Curve							
Stage (ft)	0.1	0.2	0.5	1	3	5	10
Cell Size (ft2)	3	3	3	3	3	3	3
Flooding cell number	208602	278872	225937	554495	1137437	1706920	3046989
sb	1.009	1.007	1.0086	1.007706	1.0179	1.023588	1.031098
As(ft2)	625806	836616	677811	1663485	3412311	5120760	9140967
Ab(ft2)	631438.254	842472.312	683640.1746	1676304	3473391	5241548	9425233
Inudation Depth (ft)	0.0999	0.174	0.4976	0.691	1.846	2.899	5.549
V (ft3)	62518.0194	145571.184	337278.7536	1149468	6299126	14845083	50723226
L (ft)	28,931	28,931	28,931	28,931	28,931	28,931	28,931
z1 (ft)	204	204	204	204	204	204	204
z2 (ft)	0	0	0	0	0	0	0
A=V/L(ft2)	2.160935308	5.031667899	11.65803994	39.73137	217.7293	513.1203	1753.248
P=Ab/L(ft)	21.82566292	29.12005503	23.63002228	57.94144	120.0578	181.1741	325.7832
R=A/P(ft)	0.09900892	0.172790467	0.493357129	0.685716	1.813538	2.832194	5.381642
S	0.00705126	0.00705126	0.00705126	0.007051	0.007051	0.007051	0.007051
n	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Q	0.776702442	2.621532086	12.22446424	51.88713	543.7901	1725.035	9042.391

Figure 3. Data and calculations used to develop a regional curve for HUC 12 basin containing stream of interest

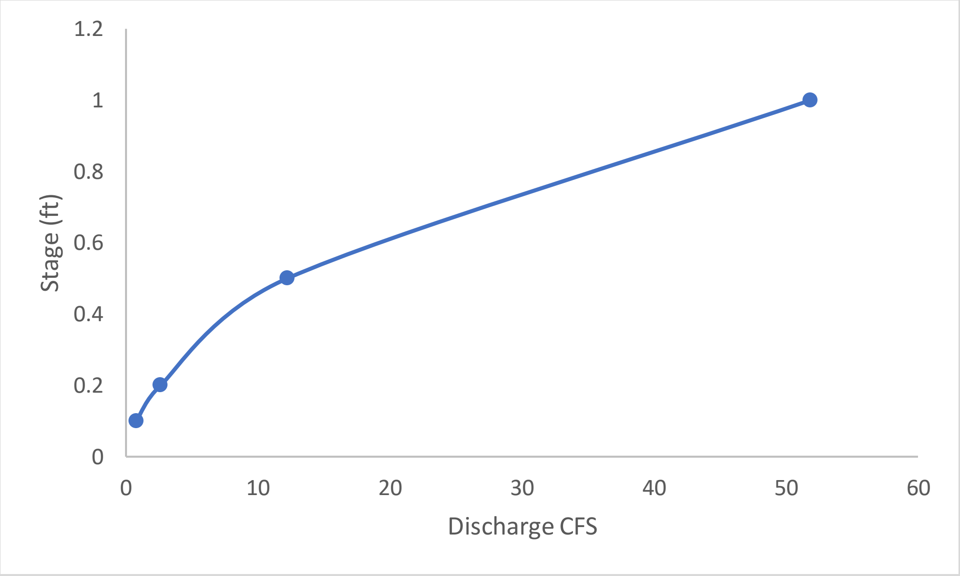


Figure 4. Regional curve for HUC 12 basin containing stream of interest

To model BDAs on the landscape a vector feature class was first created and lines representing proposed BDA placements were drawn using the edit toolbar. This vector line layer was then converted into a raster file and then reclassified so that the elevation of each “BDA” was at the height of bank-full for each placement location. A conditional raster calculation was then performed to create a new DEM layer with proposed BDAs integrated into the landscape. This layer was then mosaiced into the original masked bare earth lidar raster. This process is depicted in figure 4. “Pits” in this raster were then filled and flooded area was again estimated using the process depicted in figure 2.

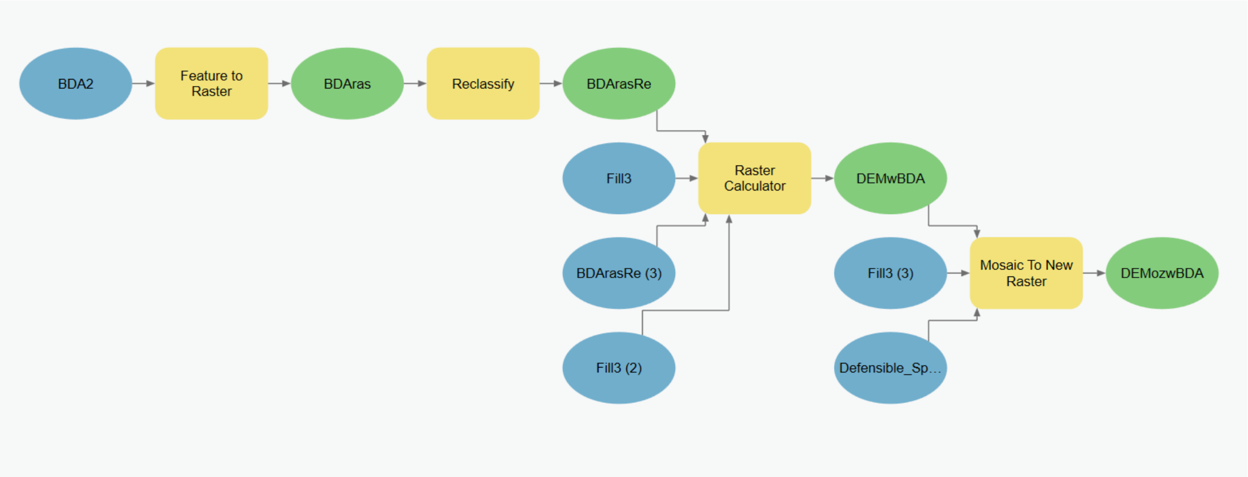


Figure 5. Model representing method used for altering DEM to model Beaver Dam Analogs on landscape

Changes in water storage at different flood stages were assessed by taking the difference in volume of water in the stream of interest at different flood stages, modeled without and with BDAS on the landscape. Volume was calculated using the method depicted in figure3.

Outcomes, Results, and Conclusions:

In this model, when five BDAs are added to the landscape flooded area increases at all flood stages. Figure 6 visually depicts changes in flooded area at a stage of 0.1ft (estimated baseflow) while Figure 7 visually depicts changes in flooded area at a stage of 3ft (estimated 100yr flood). Estimates of baseflows and 100yr floods were taken from National Water Model Discharge Forecasts. As might be expected, these models depict water pooling behind the BDAs and spreading onto the floodplain before continuing to flow downstream. During a floodstage of 0.1ft there is a 561ft^2 change in flooded area. At a stage of 3ft there is a 4818ft^2 change in flooded area.

Figure 6. Estimated Flooded Area Without (yellow) and With (Pink) BDAs on the Landscape at 0.1ft floodstage

Figure 7. Estimated Flooded Area Without (purple) and With (green) BDAs on the Landscape at 3ft floodstage

Like flooded area, water storage also increases at each flood stage when BDAs are added to the modeled landscape. At a flood stage of 0.1ft storage increased by 561ft^3 and at a flood stage of 3ft by 4818ft^3.

These results are to be expected: when BDAs are added, flooded area and water storage increases at all flood stages. While this model makes some things clear, such as the fact that potential restoration work would not cause immediate damaging to the outbuildings on the property, some effects of restoration are still unclear. More sophisticated models could yield more precise results and answer some of these unknowns. These are discussed below.

This model only provides a snapshot of flooded areas and water storage at different flood stages. It does not speak to the long-term effects of increased water storage. From experience, it is reasonable to believe that the BDAs would help increase channel floodplain connectivity, increase the moisture content in riparian plants which could help reduce wildfire risk, and store water later into the hydrologic year (Lee, 2017; Charnley 2018; Palmer, 2006). The water storage question poses the largest unknown from a legal standpoint. The effects of changing water delivery due to stream alteration could create a legal issue in the form of a water rights conflict as higher order streams downstream of the stream of interest are diverted for irrigation. While it is likely that the water stored behind 5 BDAs in a relatively short headwater stream would likely not be enough to significantly change water delivery downstream, more sophisticated hydrologic time serious models would need to be run in order to approximate long-term water storage if water transactions were to occur.

Along with running a more sophisticated time series model, this project could be improved by ground truthing. While bare earth lidar is highly accurate, the study would be greatly improved by uploading potential BDA sites from GPS coordinates instead of drawing them in ArcGIS. Furthermore, modeling soil moisture and changes in evapotranspiration could also help to prove the theoretical idea that stream restoration can help reduce wildfire vulnerability. Work of this nature would greatly benefit from long term monitoring before and after stream restoration.

Works Cited:

Charnley, S. (2018). Beavers, landowners, and watershed restoration: experimenting with beaver dam analogues in the Scott River basin, California.

Lee, A. A. (2017). Leave it to Beavers: Evaluating the Potential for Incised Stream Restoration using Natural and Analog Beaver Dams.

Palmer, M. A., & Bernhardt, E. S. (2006). Hydroecology and river restoration: Ripe for research and synthesis. *Water Resources Research*, *42*(3).