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Delineation of riparian habitats from high resolution LiDAR data: the Willamette River floodplain

Introduction

River floodplains depend upon periodic flooding to maintain ecosystem functions related to disturbance, nutrient cycling, vegetative communities, and fish and wildlife habitat. But in many places floodplains have been altered by regulation of river flows, conversion to agriculture, and development for industrial and urban uses, which has degraded ecosystem processes and services associated with river floodplains. As a result there is increasing interest in restoring physical and ecological processes to floodplains, where possible.

In the Willamette Basin, Oregon government agencies and conservation organizations have identified opportunity areas along the Willamette River for conservation and restoration of physical and ecological processes and services (Floberg 2004, Hulse et al. 2002, ODFW 2006). These conservation opportunity areas (COA) were identified at a regional scale as places where there are good opportunities to conserve high priority habitats and species (ODFW 2006). However, site specific assessments and prescriptions have not been completed for the COAs.

The objectives of this project were to begin to identify and prioritize habitats within the floodplain of the Willamette River between Corvallis and Albany that may be suitable for conservation or restoration. A geographic information system (GIS) was used to analyze topography and vegetation to determine the locations of stream channels and riparian vegetation. The results will contribute to conservation planning by the Greenbelt Land Trust based in Corvallis, Oregon.

Study Area

The study area (Figure 1) is located in the 500-year floodplain of a reach of the Willamette River between Corvallis and Albany, Oregon. It is within the conservation opportunity area identified as WV-04 in the Oregon Conservation Strategy (ODFW 2006) and encompasses 4,438 ha. The mean annual river flow is 4,561 m^3/s as measured by a USGS stream flow gage (14174000) located at the downstream end of the study area near Albany. The drainage area upstream of the gauge is 12,536 square kilometers. There are 9 flood control dams located upstream of the study area that regulate flows through the study reach. Primary land uses include agriculture, sand and gravel mining, rural residences, open space, and recreation. The majority of the land is privately owned with a few parcels along the river owned by the State of Oregon and managed as greenways.

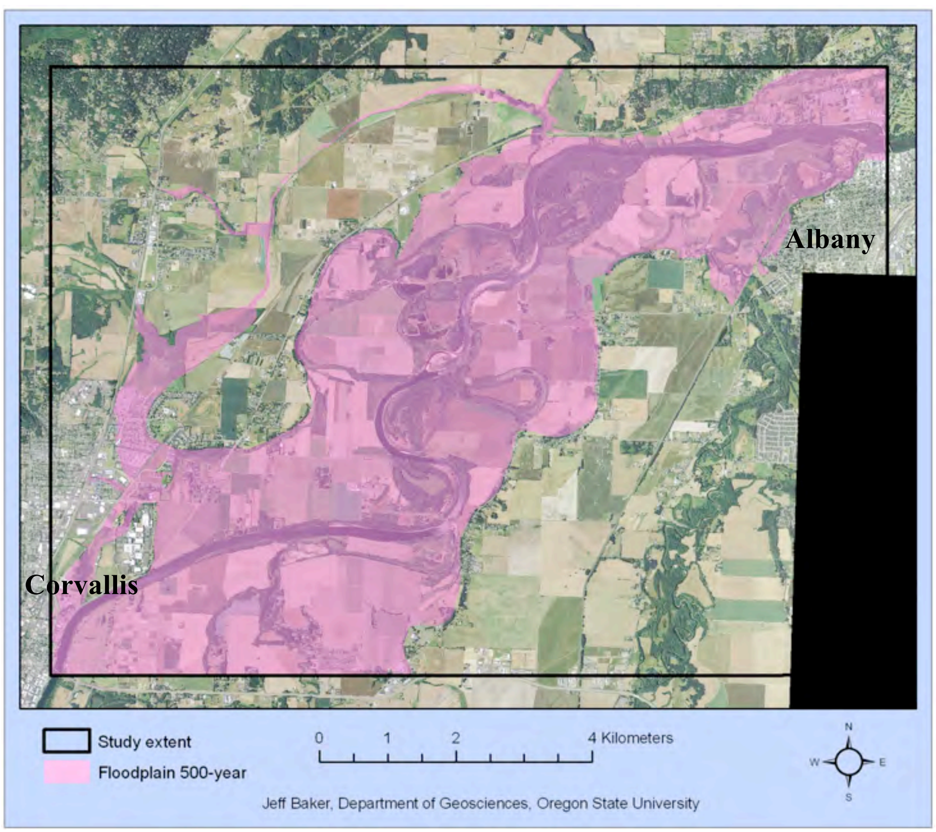

Figure 1. The study area is located within the 500-year floodplain of the Willamette River between Corvallis and Albany, Oregon. The study extent is shown as rectangle as it was used to conduct the initial raster analyses. Imagery is 2009 DOQ from Oregon Geospatial Enterprise Office.

Methods

Data

High spatial resolution elevation data acquired by light detection and ranging (LiDAR) was used to analyze for stream channels and vegetation heights and patches within the study area. The LiDAR data were collected by Watershed Sciences, Inc. in 2008 and 2009 for the Oregon Department of Geology and Mineral Industries (DOGAMI). Horizontal grid cells measure 0.9144 m by 0.9144 m and mean vertical offsets vary from 0.009 m to 0.033 m as measured by comparing the LiDAR elevations with measured ground-control points (DOGAMI 2009a, DOGAMI 2009b, DOGAMI 2009c). Data were downloaded from the Oregon Geospatial Enterprise Office FTP server at ftp://159.121.106.159/elevation/lidar/WillametteValley_LiDAR/.

Additional GIS layers used for this project included 100 and 500 year floodplains and aerial imagery. The floodplain layer was derived from the Federal Flood Insurance Rate Maps and was downloaded from the Oregon Geospatial Enterprise Office website at http://www.oregon.gov/DAS/EISPD/GEO/sdlibrary.shtml. Aerial imagery flown in 2009 was obtained from the Oregon Geospatial Enterprise Office FTP server ftp://159.121.106.159/imagery/CCM2009/.

All data layers were projected using the NAD 1983 Lambert Conformal Conic coordinate system.

Study Extent and Area

The extent of the study area was defined in the GIS with a rectangle that encompassed the 500 year floodplain between Corvallis and Albany with the east and west boundaries placed at the approximate locations of the Van Buren Street Bridge in Corvallis and the Highway 20 Bridge in Albany. The rectangle study extent was used for clipping and analysis of the raster layers derived from the LiDAR data. The study area was then further refined by clipping results to the boundaries of the 500 year floodplain. The

500 year floodplain was clipped to the study rectangle extent and edited in ArcGIS 9.3.1 to remove tributary floodplains of the Willamette River.

Processing

The LiDAR data were provided as bare earth and highest hit models in raster format in six tiles covering different parts of the study area. For this project the bare earth model is referred to as a digital elevation model (DEM) and the highest hit model is referred to as a digital surface model (DSM). The DEMs and DSMs were clipped to the study area and then a raster mosaic DEM and DSM were created using Model Builder in ArcGIS 9.3.1 (Figure 2).

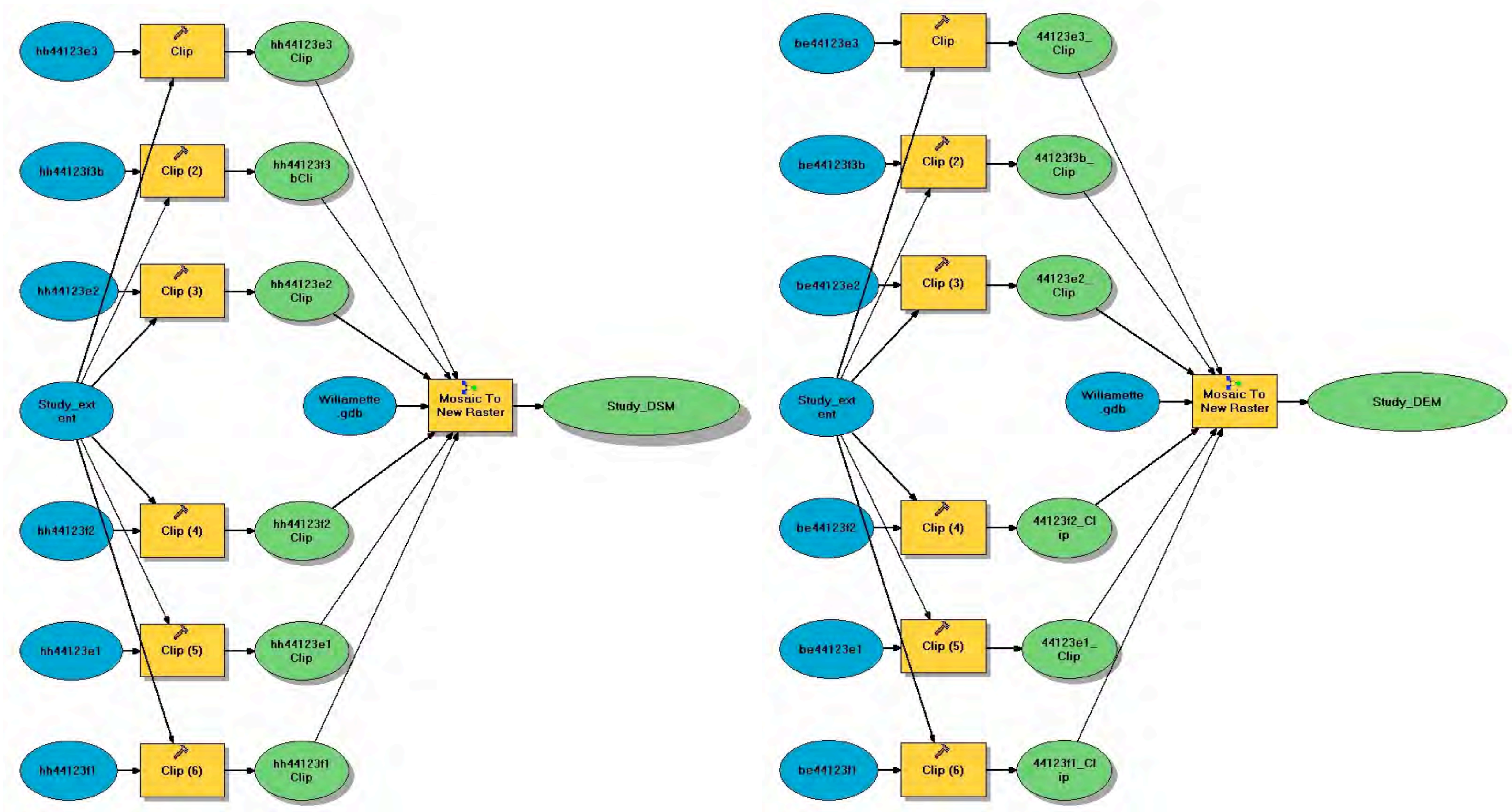

Figure 2. This flowchart shows the process of creating a DSM and DEM for the study extent. Blue ovals represent input data, yellow rectangles represent the operation performed, and green ovals are the output data with the final output being the Study DSM and Study DEM.

Analysis

After processing the DEM and DSM to the study extent, stream channels and vegetation were derived and an intersection overlay was completed to determine where stream channels are vegetated. All analysis operations were performed in ArcGIS 9.3.1 using Model Builder.

Stream channels were derived from the study DEM using the Watershed Delineation Model that is part of the Watershed Delineation Toolbox available for download from ESRI at http://support.esri.com/index.cfm?fa=downloads.geoprocessing.filteredGateway&GPID=16. The steps for deriving the stream channels are shown in Figure 3. The threshold for contributing area in order for a stream to be created was >=10,000 cells or 9,144 m^2. Streams were output as a vector line file.

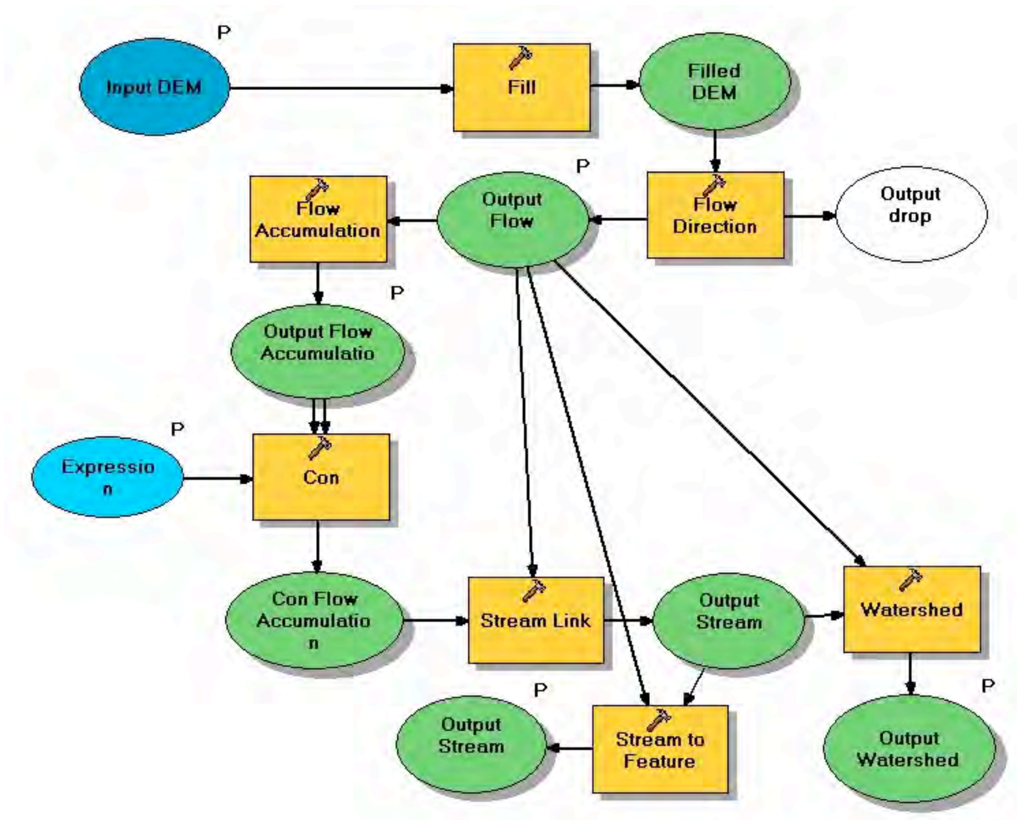

Figure 3. This flowchart shows the steps to derive stream channels from the DEM.

Vegetation was derived by subtracting the DEM from the DSM and then reclassifying the results based on height. Vegetation was classed as heights < or > 3.048 m. Vegetation < 3.048 m was assumed to be agricultural crops while vegetation >3.048 m was assumed to be natural or mostly native vegetation. The reclassified vegetation raster was converted to a polygon feature class and then natural vegetation features were selected and output as a separate feature class. The steps for deriving vegetation are shown in Figure 4.

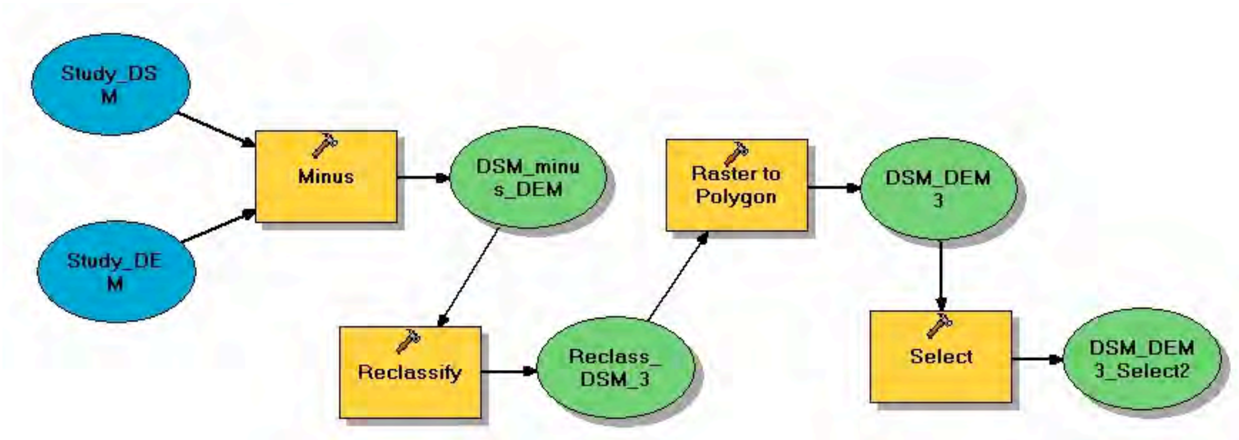

Figure 4. This flowchart shows the steps used to derive vegetation from the DSM and DEM.

After deriving stream channels and vegetation an intersection overlay was performed to determine where vegetation and stream channels intersected. Only vegetation > 3.048 m was used in this analysis because it was assumed to be natural vegetation and not agricultural crops. This model was constructed to output both stream lines that intersect with vegetation polygons and vegetation polygons that intersect with stream lines, so that both could be viewed simultaneously in resulting maps. Figure 5 shows the steps used for the intersection overlay.

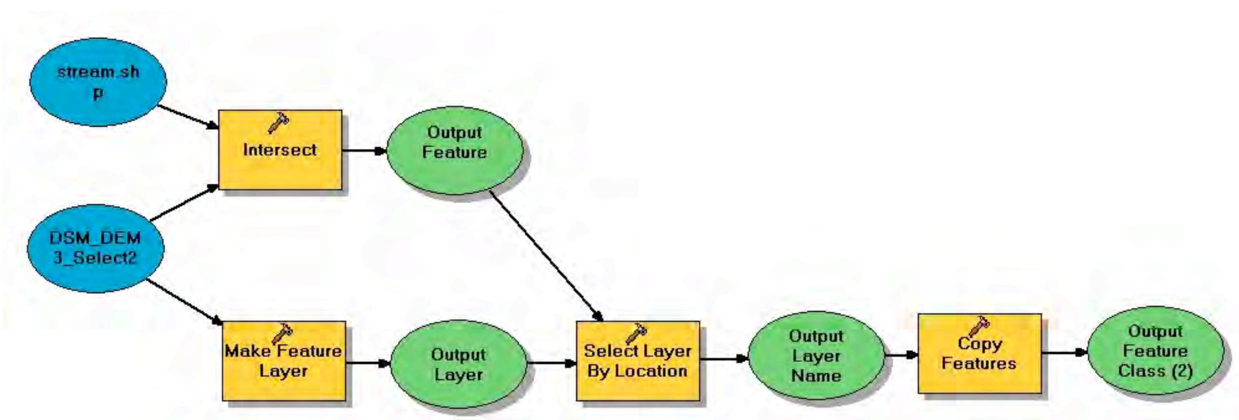

Figure 5. This flowchart shows an intersection overlay of streams and vegetation.

Results

The results indicate that there are approximately 884 hectares of riparian vegetation and 110 kilometers of vegetated stream in the floodplain study area (Table 1, Figures 6, 7, and 8).

Table 1. The length and area of stream and vegetation features in the study area.

feature	length (m)	area (ha)	% of total
riparian vegetation		883.64	85%
non-riparian vegetation		154.13	15%
vegetated streams	110,573.40		25%
unvegetated streams	331,477.37		75%

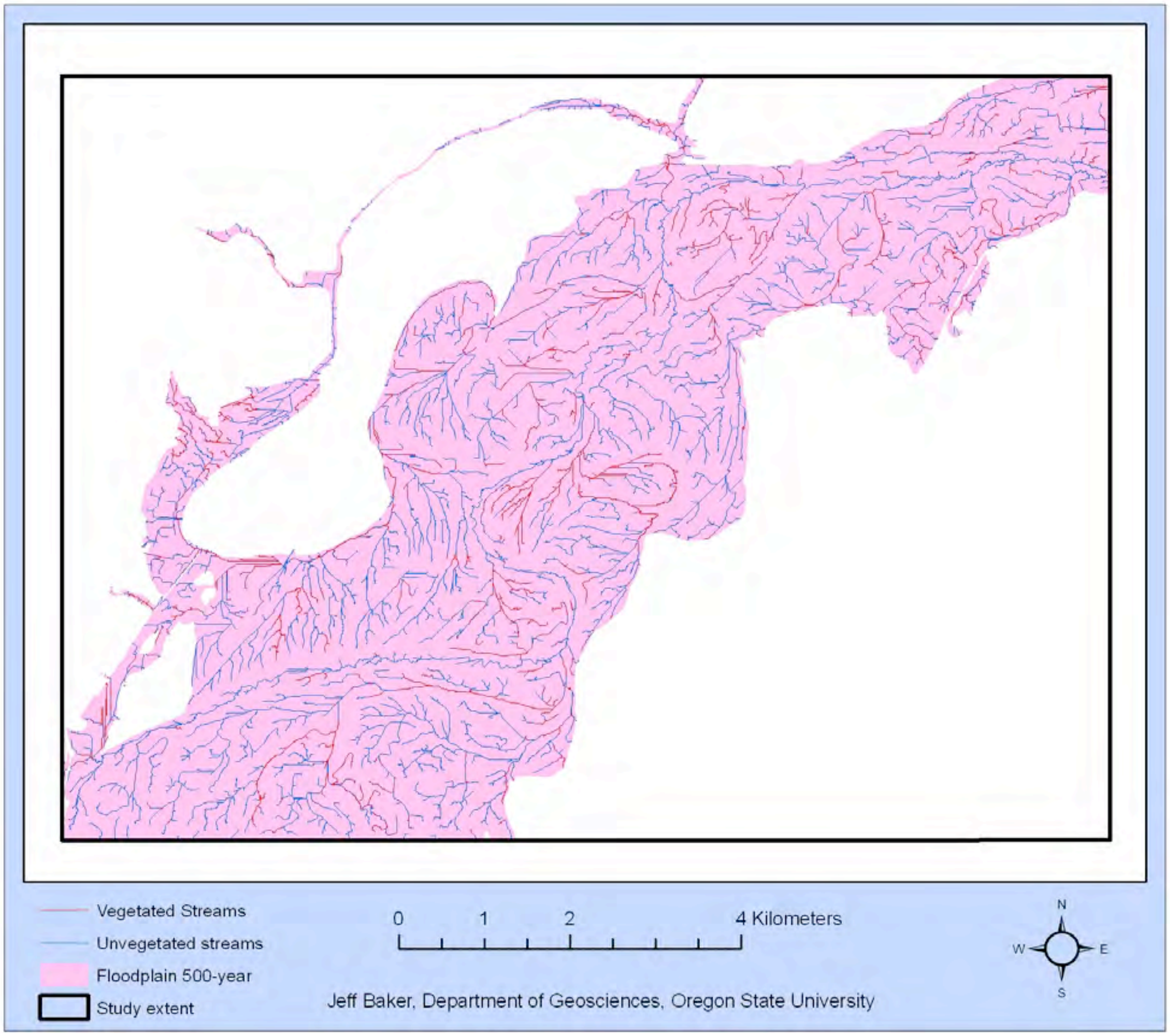

Figure 6. Vegetated and unvegetated streams delineated from a 0.9144 m digital elevation model.

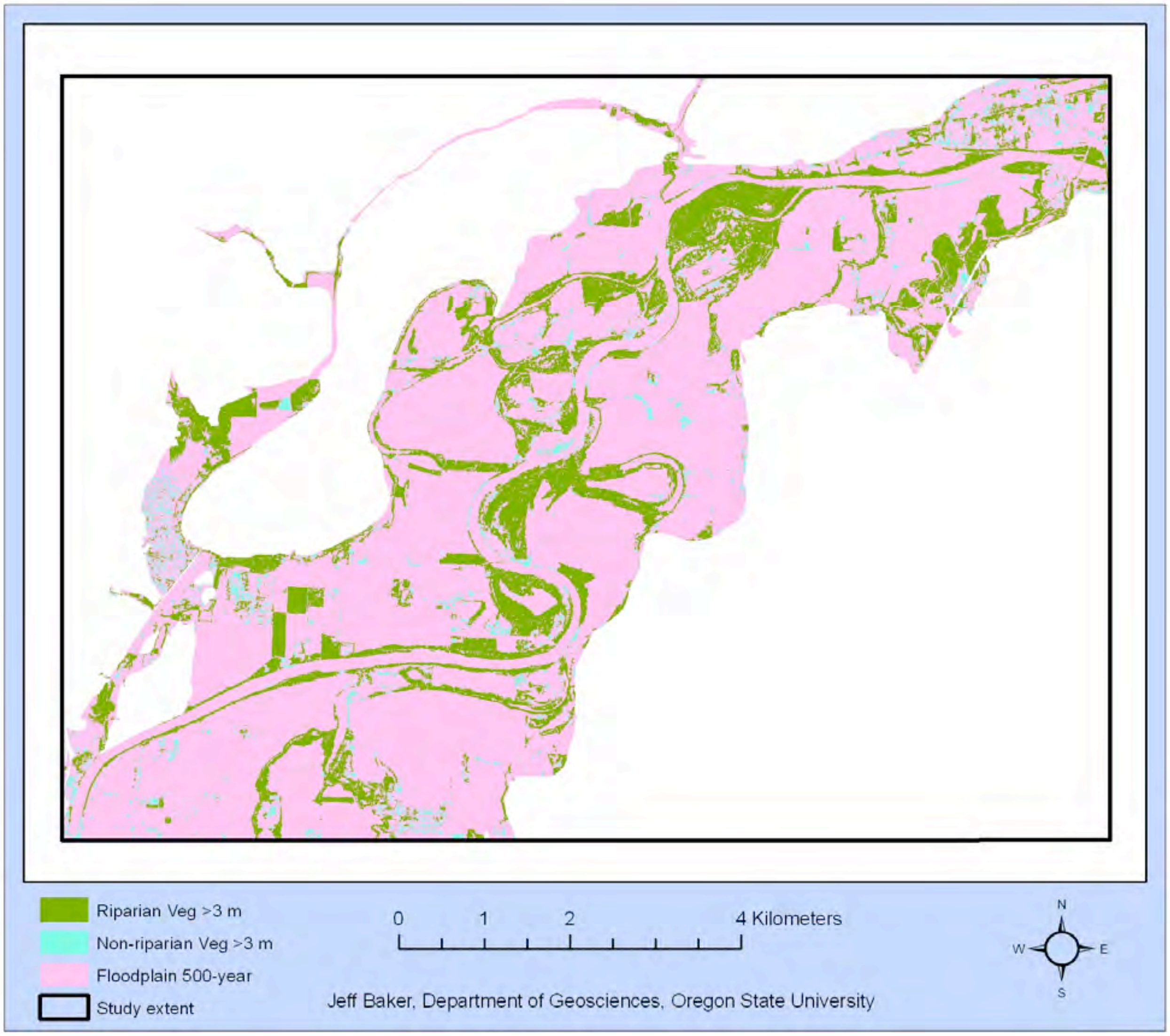

Figure 7. Riparian and non-riparian vegetation derived from 0.9144 m digital elevation and digital surface models.

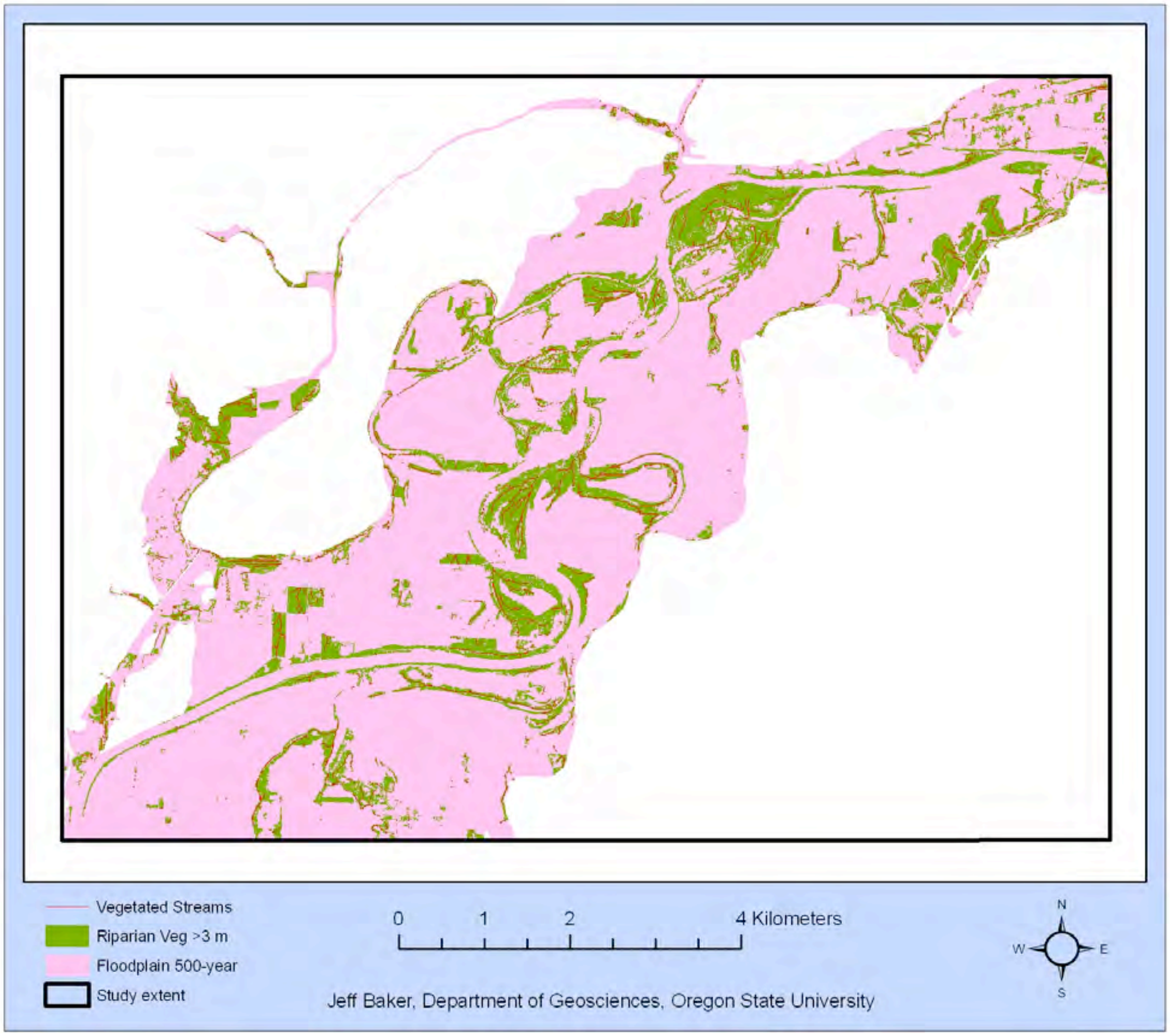

Figure 8. Riparian vegetation that intersects with stream channels totals 884 hectares. These areas may be the most suitable for conserving floodplain ecological processes.

Discussion

The results indicate that much of the taller vegetation (> 3.048 m) in the floodplain is associated with stream channels (~85%), which for the purposes of this project is considered to be riparian communities. These areas, shown in Figure 8, would be the highest priority for conservation because they contain stream channels and intact vegetative communities. Streams without vegetation and vegetation without polygons would be considered a lower priority because the aquatic and vegetative features do not intersect. The remaining area of the floodplain that does not have vegetation > 3.048 m or aquatic features would be the lowest priority for conservation because it has less valuable ecological features present and would require the greatest level of restoration. These areas are typically in agricultural production.

There are several assumptions and caveats that should be considered with this analysis. The stream channels delineated were done so at a relatively fine scale using high resolution elevation data so that subtle differences in topography resulted in streams showing in areas that are not typically considered to be streams. In some cases it might be better to consider the stream network as drainage patterns. For this analysis it has been assumed that any vegetation > 3.048 m is natural vegetation and is of conservation interest. However, further analysis may show that some polygons contain something other than natural, mostly native vegetation. One last important caveat is that no ground truthing has been conducted and little editing has been done to remove features from the analysis that may not be of interest, such as telephone poles.

Sources of error in the study could include misclassification of vegetation, incorrect delineation of the stream network, or errors in the raw LiDAR data. There are obvious locations where vegetation polygons along the edge of the Willamette River should be classified as riparian but were not due to how the river was delineated. The river was delineated as a line that meandered between the river banks so that in some places there was no intersection of vegetation and stream channels when there should have been. Essentially, the river is much wider than the line that was delineated. There could be vertical or horizontal errors associated with the LiDAR data however the LiDAR data had extensive quality control analysis and the vertical error reported in the methods section above appears to be acceptable.

Additional work should focus on improving the accuracy of results generated by this project, adding additional analysis, and prioritizing with additional parameters. Editing of some stream channels and reclassifying some vegetation polygons (e.g. the river edge boundary and adjacent vegetation) using aerial photos or field visits would improve accuracy. Additional analysis should look at inundation levels and frequencies using satellite imagery or hydrologic models such as HEC-RAS (Ackerman et al. 2009) and add additional feature classes such as soil types, permanent water bodies, and historic vegetation types to help further identify ecologically important features to conserve or restore. Adding a private versus public ownership layer would identify already protected areas to use as core conservation areas. Editing and improving the results and adding further analysis would contribute towards additional prioritization so that conservation investments can be optimized.

Conclusion

The use of LiDAR data to analyze stream channels and riparian vegetation in the Willamette River floodplain revealed complex drainage patterns as well as the location and heights of vegetation. With this new information over 800 hectares of floodplain has been identified as potentially suitable for restoring ecological and physical processes in the Willamette River floodplain. Further analysis should help to narrow the focus to the very best areas in which to invest limited conservation resources.

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