FloodPlain Mapping of Edgar Ranch, Burnet County

CE394K-GISWR

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1. Introduction

Engineers utilize the floodplain modeling and mapping to predict and prevent the consequence damage of a flood. Computer models help engineers determine the floodplain mapping process in three steps. First, an accurate terrain must be built based on the most accurate land surface information such as location of streams, roads, and buildings. Second, a hydrologic model should be created to determine how much water would flow when the flood happens. Third, a hydraulic model calculates the values of the water elevation at different points along the stream and the computed elevations are plotted on paper maps.

This report focuses on the first step, to produce the most accurate terrain using LiDAR terrain data and HEC-GeoRAS tool in ArcMap to make the input file for hydraulic modeling of the study area that will be explained in the next section. Eventually the best possible floodplain map is provided based on LiDAR data to compare with the current floodplain map issued by FEMA in March 2011 based on USGS data.

To produce an accurate floodplain map, detailed terrain information is needed. To do so, high-accuracy digital elevation data should be collected using laser measurements from aircraft (LiDAR technology), which is enabling creation of relatively more accurate flood inundation maps. Coupling LiDAR terrain data and HEC-GeoRAS could potentially improve the accuracy of floodplain mapping (Cohen, 2007).

3 Study Area

The study area is a property which has been identified as “Edgar Ranch” and is located in northeast Burnet County near the border with Lampasas County. More particularly, it is located at N 31.0293, W 97.9862. Figure 1 shows the location of the Edgar Ranch. This study includes two reaches, Moss Branch and Edgar Draw; both are tributaries of Lampasas River. Figure 2 shows the two reaches and Lampasas river locations.

Figure 1: Edgar Ranch Location

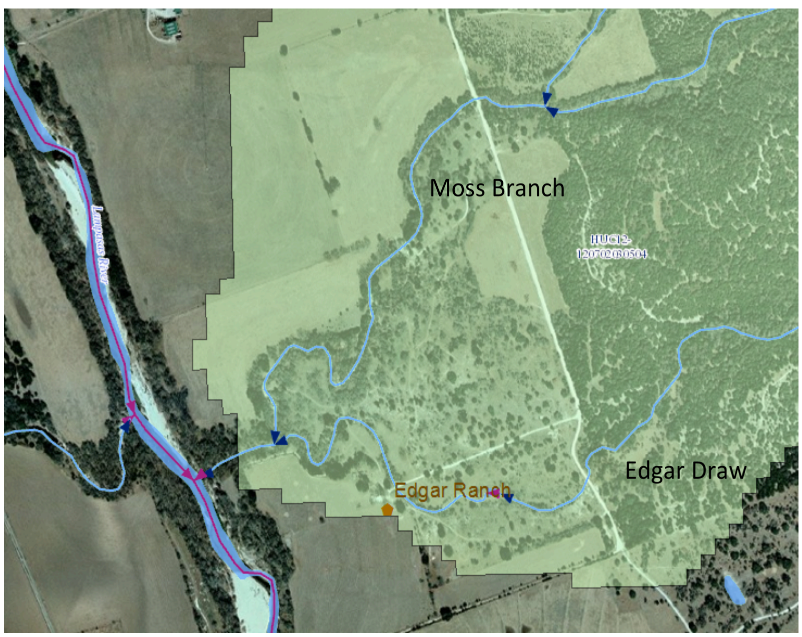

Figure 2: Lampasas River and its two tributaries

In the old floodplain map (Figure 3), the Edgar Ranch was out of the flood region but in the new map which was issued in 2011(Figure 4); it is shown that Edgar Ranch located in Zone "A" floodplain. A Zone "A" floodplain area is subject to inundation by the 100-year flood (1% annual chance) event determined using FEMA prescribed approximate methodologies.

This study includes creating revised floodplain map using LiDAR data and comparing it with the current terrain map issued by FEMA.

Figure 3: old floodplain map showing the Edgar Ranch out of floodplain

Figure 4: Current floodplain map showing Edgar Ranch in the Zone A

2. Methodology

The methodology consists of data collection, preparation and model development using HEC- GeoRAS. HEC-GeoRAS is specifically designed to process geospatial data for use with HEC-RAS (Hydraulic Model). It creates an input file for HEC-RAS containing geometric attribute data from existing complementary data sets. Figure 5 shows the overall procedure to obtain the flood extent. The dash-lined box implies what have been done in this report. Figure 6 shows the detailed procedure of creating a terrain in this report.

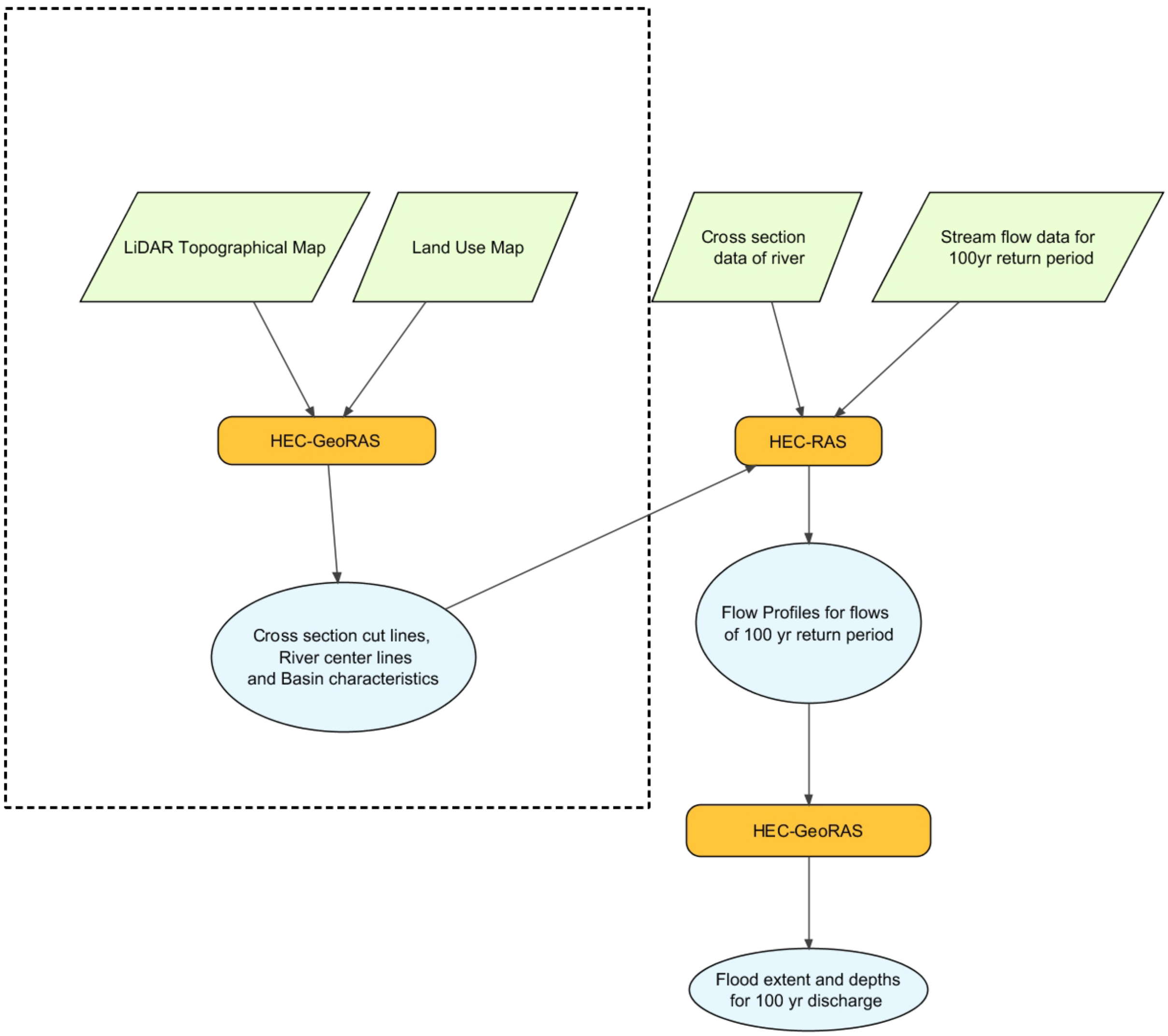

Figure 5: Procedure to Obtain the Flood Extent (Samarasinghe *et al.* 2010)

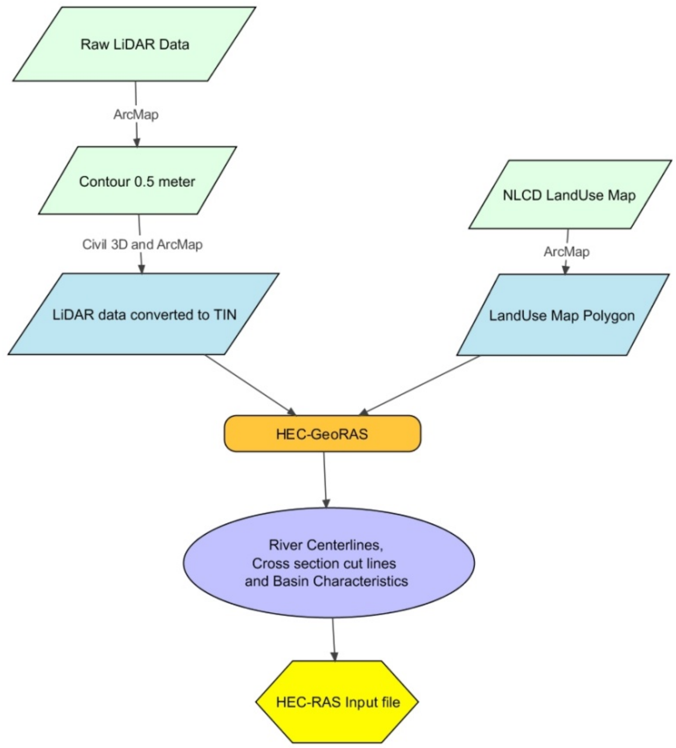

Figure 6: detailed procedure of building a terrain

3.1 LiDAR Topographical Map

The LiDAR data (LAS datasets) used in this study was provided by TNRIS. To save the processing time, all the LAS files merged to one dataset by creating a LAS geodatabase and adding all the LAS files in it. The context menu in ArcCatalog or the ***Catalog*** window provides access to create a LAS dataset. The created LAS dataset can be displayed surface elevation (Figure 7) using the surface display drop-down menu on the ***LAS Dataset*** toolbar. To work with HEC-GeoRAS toolbar, the LAS dataset should be converted to TIN or GRID. Since the conversion tool (from LAS to TIN) has a limitation of point numbers (5,000,000) however the LiDAR dataset for the study area contains almost 2 billion points. A TIN surface constructed from the raw LiDAR dataset represented a good balance between high data resolution and computer processing limitations (Figure 8). However the TIN interpolation at the channel invert produced a flat bottom. This underestimates the flow area, as the lowest channel elevations are not represented. In order to obtain a detailed terrain model to be used for the HEC-RAS hydraulic analysis, contours were extracted from the provided LiDAR data at half meter vertical intervals (Figure 9). By importing the contours into AutoCAD Civil3D and manually drawing a 3D polyline along the channel bottom, a more accurate sloped invert could be produced. The final TIN surface was built within ArcGIS from the combination of the half meter contours and the channel invert polylines (Figure 10).

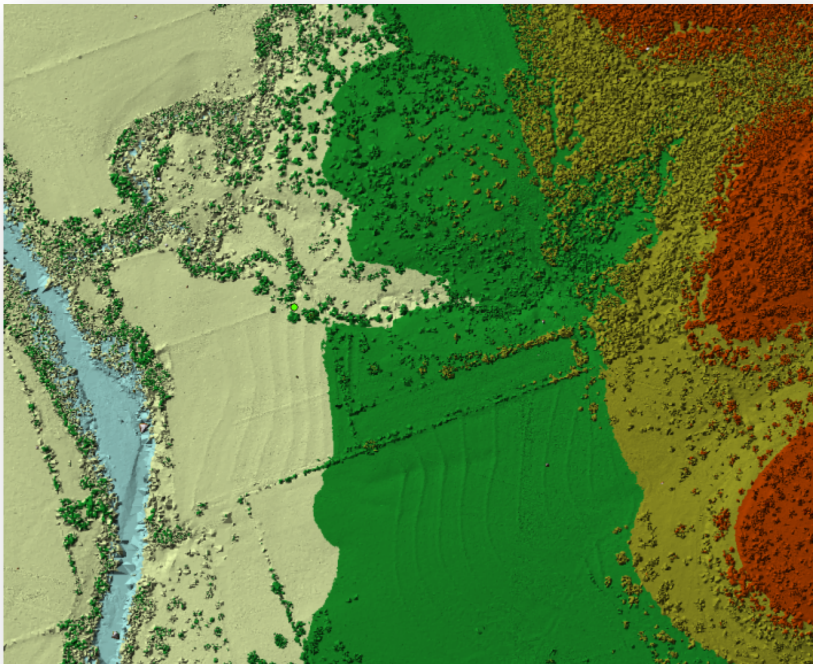

Figure 7: Surface elevation display of LiDAR data using the LAS dataset tool

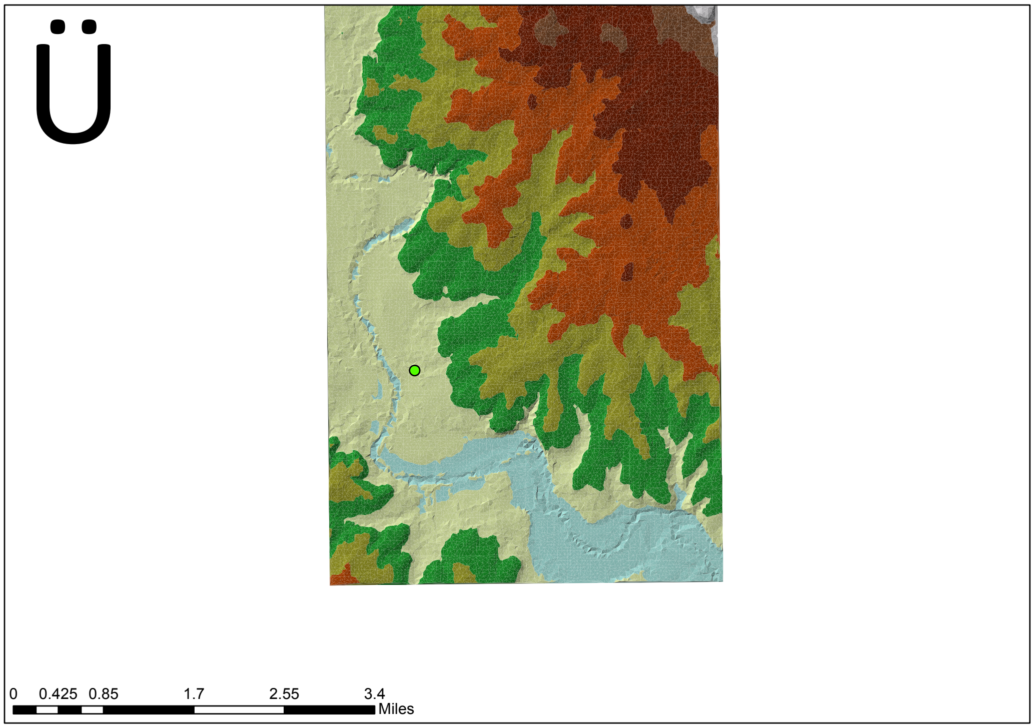

Figure 8: Surface display of TIN converted dataset

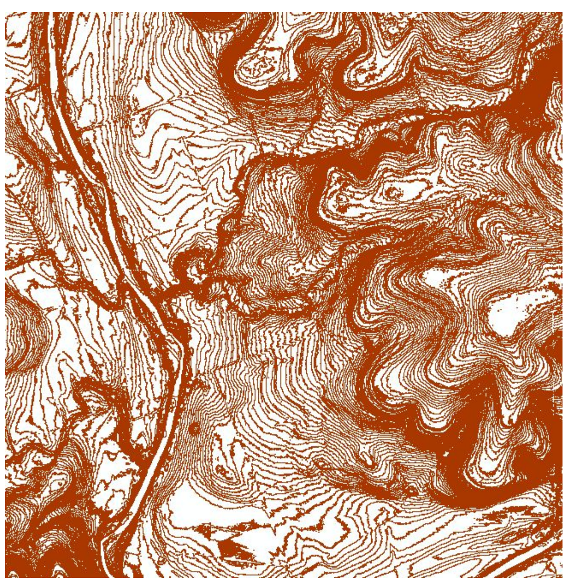

Figure 9: 0.5 meter Contours from LiDAR data

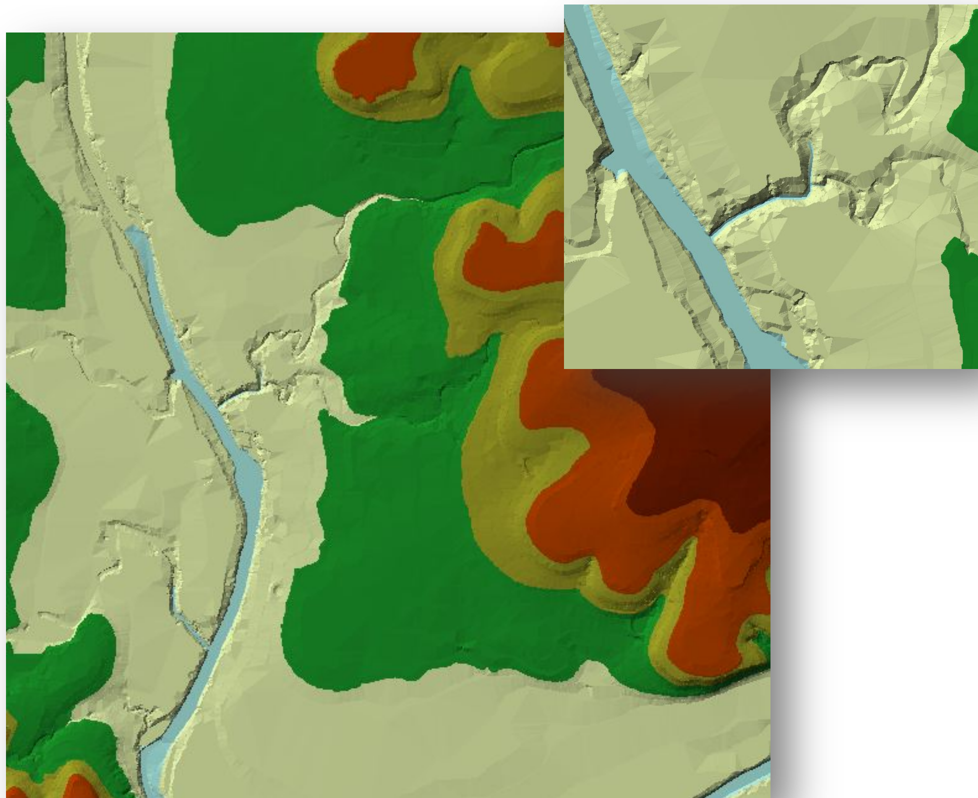

Figure 10: TIN map build based on combination of Contours and 3D polyline sketched in AutoCAD civil 3D

3.2 HEC-GeoRAS Layers

To create floodplain map, a geometry file is needed, contains information on cross sections, hydraulic structures, river banks and other physical attributes of the river channels (Merwade 2010). HEC-GeoRAS model involves creating these attributes in GIS, and then exporting them to the HEC-RAS geometry file. In HEC GeoRAS, each attribute is stored in a separate feature class called as RAS Layer. First the empty RAS layers are created using the RAS Geometry menu on the HEC-GeoRAS toolbar. Then all the needed layers in this project are populated to build the HEC-RAs geometry file. The following subsections are explained how the needed layers are created.

3.2.1 River Centerlines, Banks and Flowpaths

The river centerline is used to establish the river reach network for HEC-RAS (toturial). There are four reaches in this project: Upper Lampasas, Lower Lampasas, Moss Branch and Edgar Draw as shown in Figure 11.

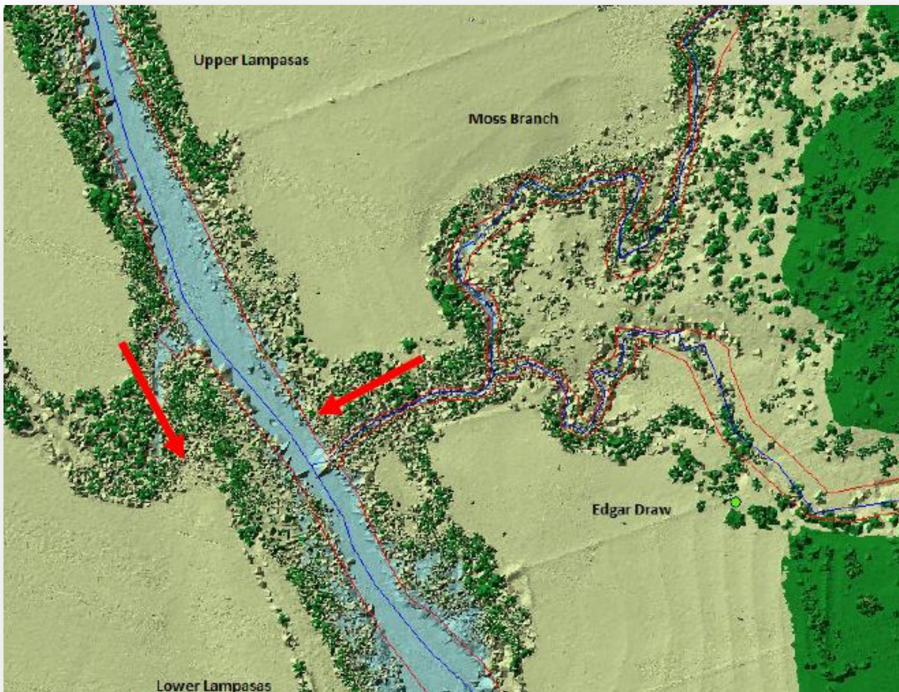

Figure 11: Reaches display

To sketch the river centerlines, first start using editing tools and then chooses Create New Feature as the Task. The river centerlines are digitalized from upstream to downstream. Figure 12 shows the digitalized river centerlines. It is also shown the Edgar Ranch location as the green spot.

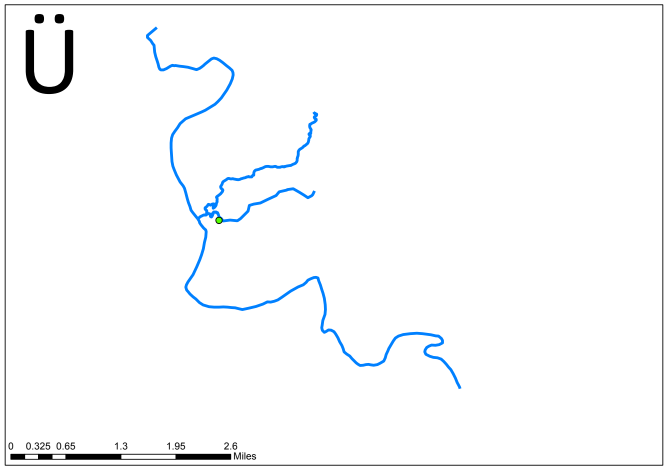

Figure 12: Sketched river centerlines in HEC-GeoRAS

After the reaches are digitalized, the next step is to name them. Each river in HEC-RAS must have a unique river name, and each reach within a river must have a unique reach name (Merwade 2010).

Next step is to create the bank lines of river. Bank lines are used to distinguish the main channel from the overbank floodplain areas. Information related to bank locations is used to assign different properties for cross sections (Merwade 2010). Digitalizing the bank lines is exactly same as river centerlines. To create the channel centerline (in Banks feature class), start editing, and choose Create New Feature as the Task, and Banks. Figure 13 shows the sketched bank lines for the study area.

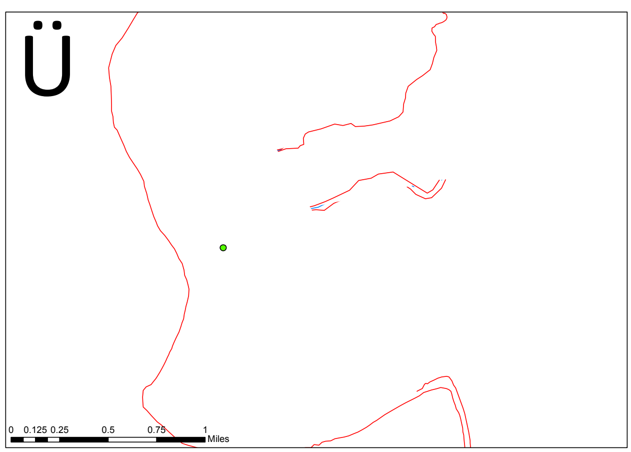

Figure 13: Sketched bank lines for the study area

The flowpath layer contains three types of lines: centerline, left overbank, and right overbank. The flowpath lines are used to determine the downstream reach lengths between cross-sections in the main channel and over bank areas (Merwade 2010). In this study, the river centerline that was created earlier was considered as the flowpath centerline. The left overbank and right overbank were digitalized same as the previous steps. Figure 14 shows the sketched flowpaths. The last step of this section is to label all flow paths, and confirm this by opening the attribute table of the Flowpaths feature class.

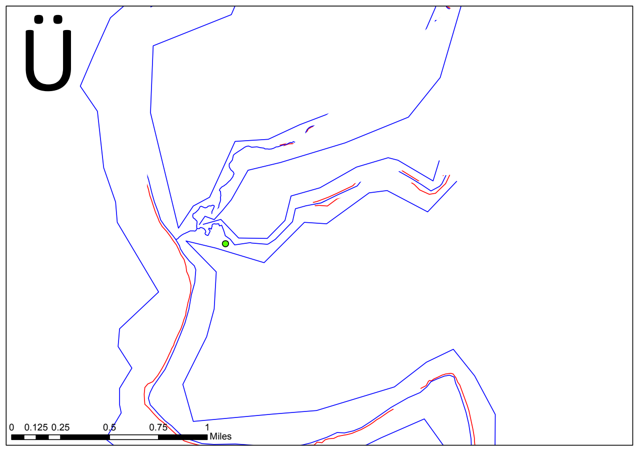

Figure 14: Sketched left overbank and right overbank

3.2.2 Cross Section cutlines

Cross-section cutlines are used to extract the elevation data from the terrain to create a ground profile across channel flow using HEC-RAS. The intersection of cutlines with other RAS layers such as centerline and flow path lines are used to compute HEC-RAS attributes such as bank stations, downstream reach lengths and Manning's n. Therefore, it is critical to create adequate number of cross-sections to produce a good representation of channel bed and floodplain (Merwade 2010).

To create cross-section cutlines (in XSCutlines feature class), first started editing, and then choosing Create New Feature as the Task, and XSCutlines and digitalized using sketch tools. Cutlines are sketched from downstream to upstream. After digitalizing the cutlines, the river/reach should be named and also the station numbers should be assigned.

In this study, two cross sections were made before and after each culvert. For the rest of streams, based on the width of rivers the cross section widths are different. It was tried to have cross sections as many as possible. Along the Lampasas river (Upper and Lower reaches) the cross sections width is considered very wide, average of 900 meters, to make sure that it covers the whole floodplain extent. For Moss Branch and Edgar Draw, the cross sections were sketched more close but less wide, average of 400 m. the cross sections spacing is different for different parts. Figure 15 shows the sketched cross sections in the study area.

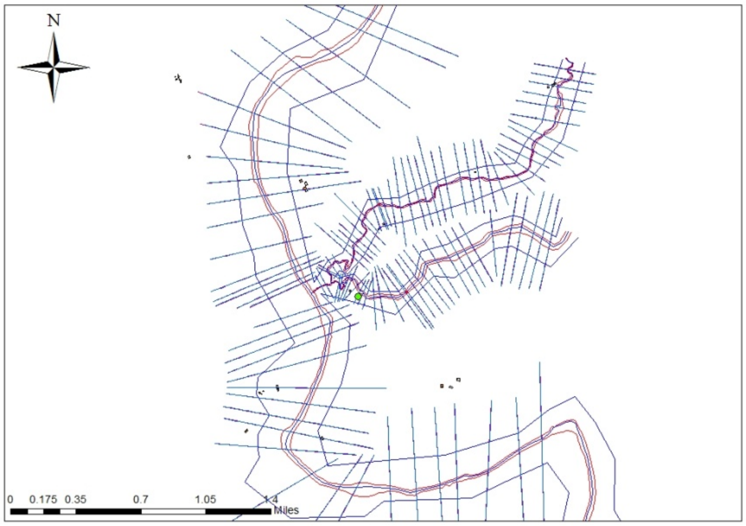

Figure 15: XS Cutlines along the four reaches

3.2.3 Culverts/Bridges

After creating cross-sections, the next step is to define bridges, culverts and other structure along the river. A bridge or culvert is treated similar to a cross-section so the same criteria used for creating cross-sections must be used for bridge/culverts (Merwade 2010). There is no bridge in the study area but there are two culverts, one in the intersection of Moss Branch with the road and the other in the intersection of Edgar Draw and the road. In Figure 16 the culverts location are shown. After digitalizing the culverts, next step is to assign he name and station numbers for reaches.

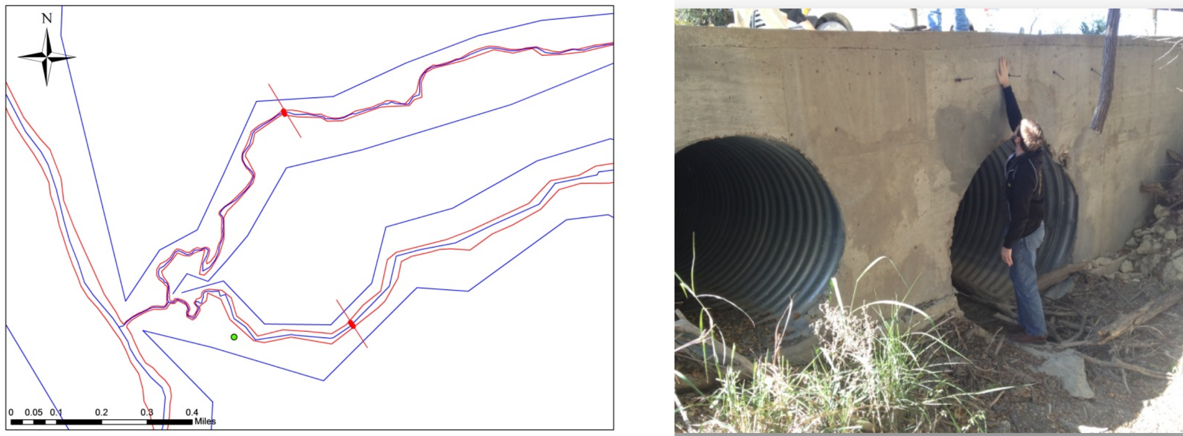

Figure 16: Culverts location along the Moss Branch and Edgar Draw

3.2.4 Obstructions

Obstructions represent blocked flow areas (areas with no water and no flow). For example, buildings in the floodplain are considered obstructions. In this study building locations were added as blocked obstructions. In Figure 17 the buildings location as the blocked obstructions are shown in small spots.

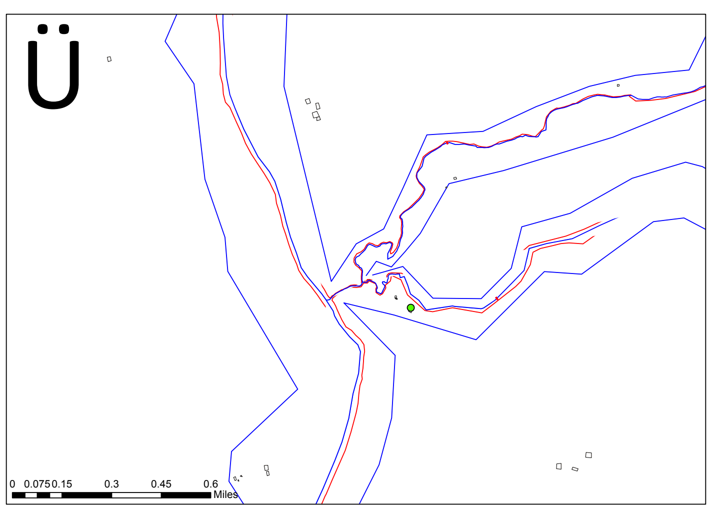

Figure 17: Blocked obstructions location

3.2.5 Basin Characteristics

The final task is to assign the manning values. It is accomplished by using a land use feature class with Manning's n stored for different land use types. In addition, HEC-GeoRAS requires the land use polygons to be non multi-part features (Merwade 2010). NLCD Land-use map was used to extract the Manning's n value in this section is shown in Figure 18.

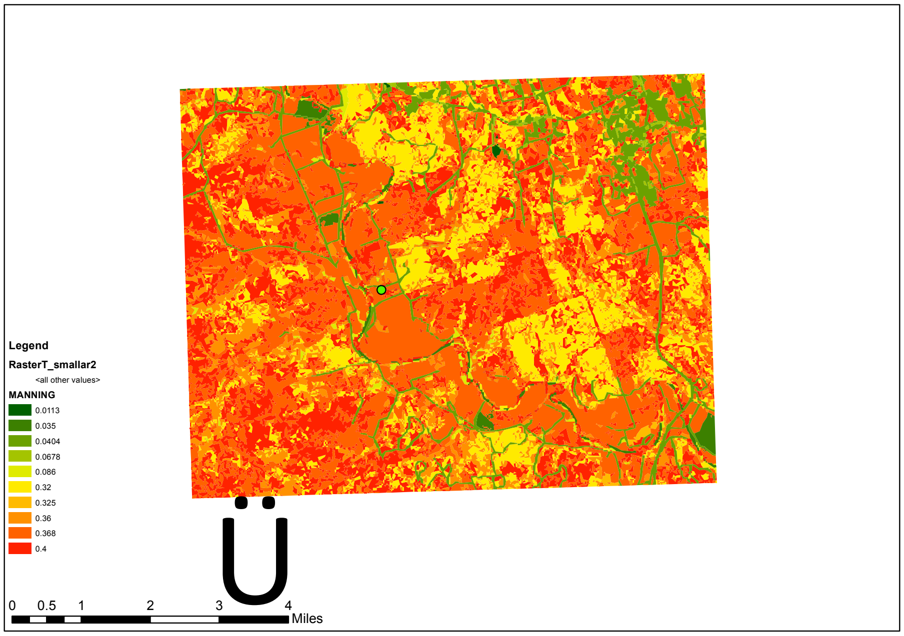

Figure 18: NLCD LandUse Map

Manning's value depends on different factors such as, vegetation, channel irregularities, shape of the channel and etc (Samarasinghe *et al*. 2010). The Manning's values used for NLCD map are as shown in Table 1. The following Manning's values should be added to the Land Use attribute table.

Table 1: NLCD Mannings' Values (Kalayanapu *et al.* 2009)

Land Cover	Description	Manning's n
21	Developed, open space	0.0404
22	Developed, low intensity	0.0678
23	Developed, medium intensity	0.0678
24	Developed, high intensity	0.0404
31	Barren land	0.0113
41	Deciduous forest	0.36
42	Evergreen forest	0.32
43	Mixed forest	0.40
52	Shrub/scrub	0.40
71	Grassland/herbaceous	0.368
81	Pasture/Hay	0.325
90	Woody wetlands	0.086
95	Emergent herbaceous wetlands	0.1825

The HEC-GeoRAS model is done at this step. Now the model is ready to be exported to HEC-RAS for hydraulic modeling steps.

4 Discussion

4.1 Compare LiDAR data and USGS data accuracy

As mentioned earlier, LiDAR data is more accurate than USGS data. The following pictures show the USGS data display (Figure 19), the LiDAR data display (Figure 20).

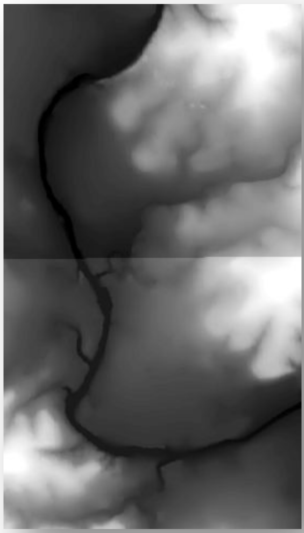

Figure 19: USGS data

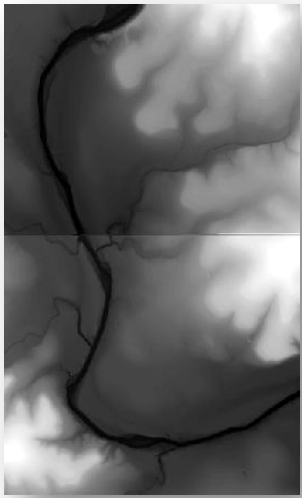

Figure 20: LiDAR data

Using raster calculator tool in ArcGIS the actual difference between the USGS and LiDAR elevations were calculated (Figure 21). The areas shown in red and blue have the highest difference value. Figure 22 shows the absolute value of difference between USGS and LiDAR elevations. As shown in these pictures, the USGS data is approximately 5% different from LiDAR in some areas along the river especially in the area around the Edgar Ranch. Since in this study the LiDAR elevations, which are more accurate than the USGS, were used; the more accurate cross sections were made and consequently the more accurate floodplain map will be produced.

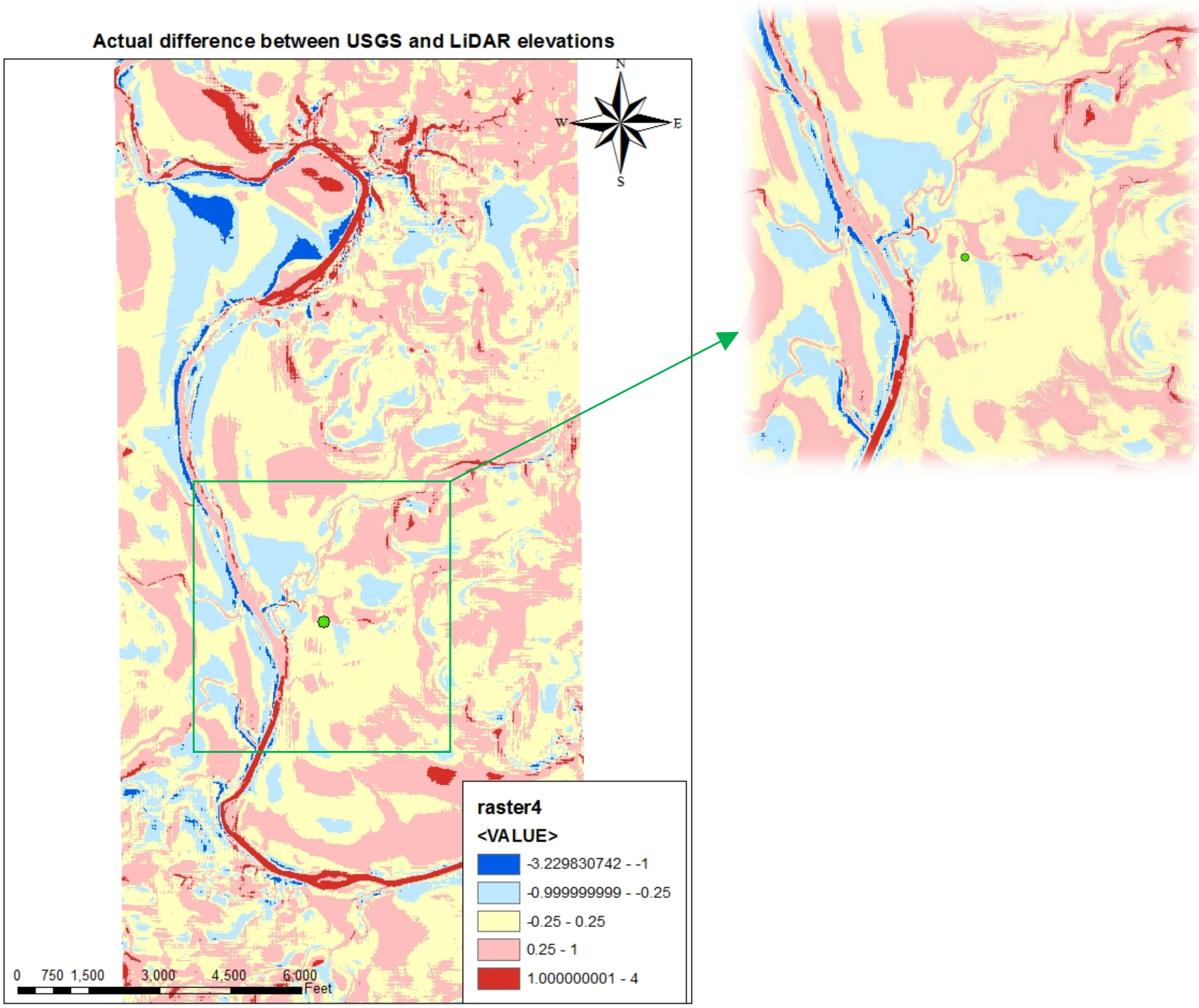

Figure 21: Actual difference between USGS and LiDAR data (feet)

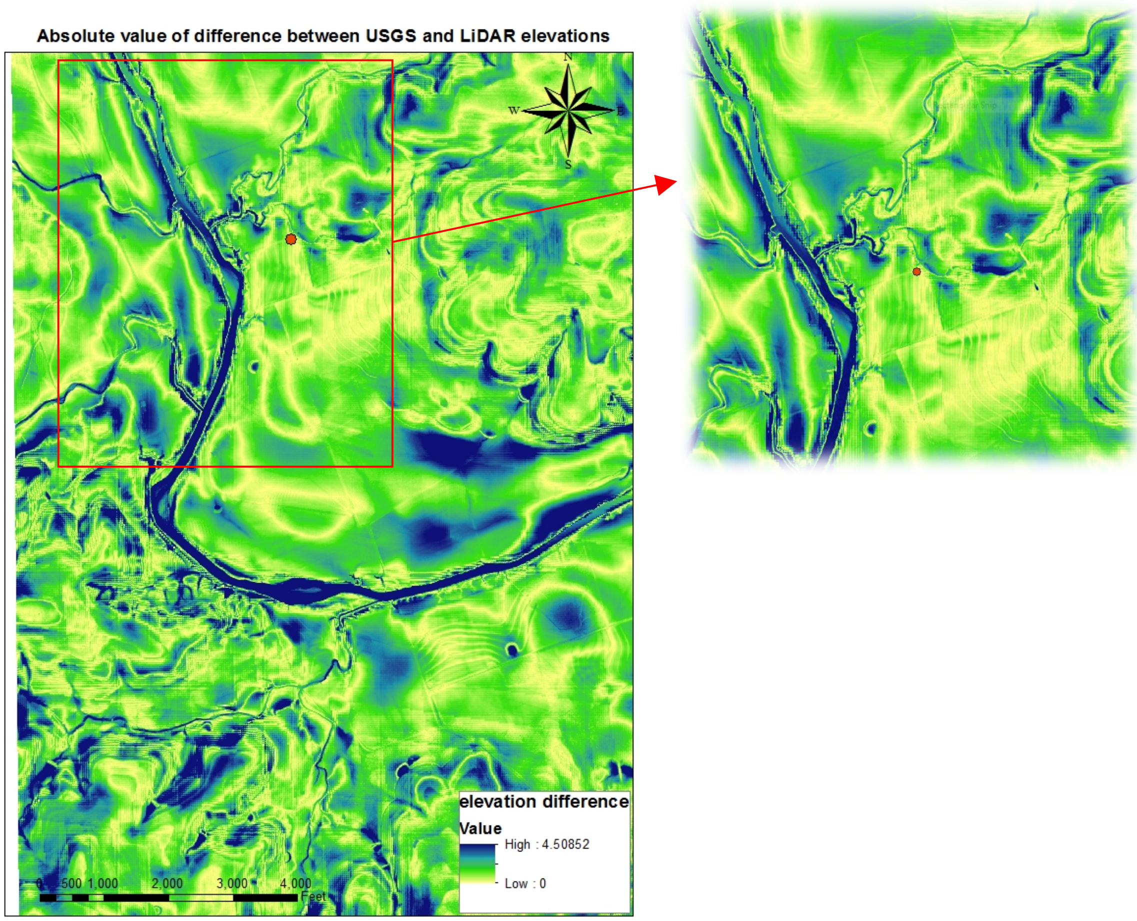

Figure 22: Absolute difference between USGS and LiDAR elevations (feet)

This difference can also be shown in the contour display of USGS data and LiDAR data. Figure 23 shows the USGS contours and Figure 24 shows the LiDAR contours. It is clearly visible that the LiDAR contours are more accurate than USGS contours.

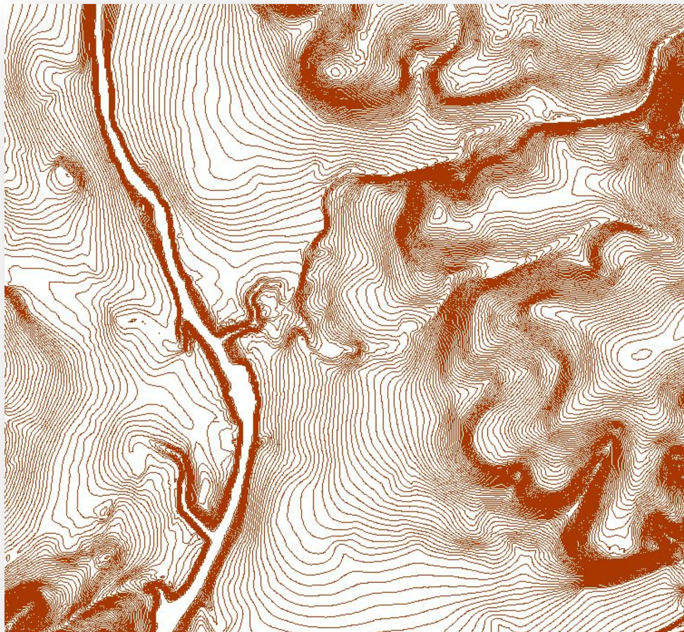

Figure 23: USGS contours (0.5 meter)

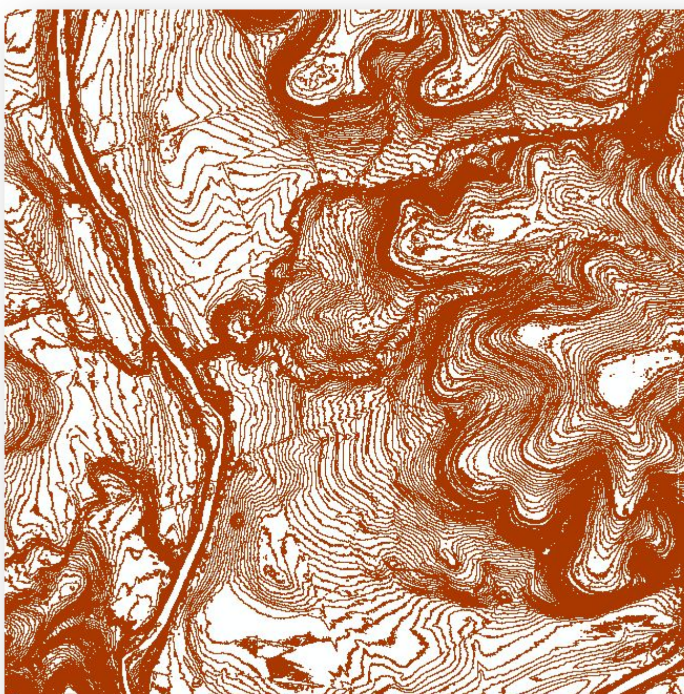

Figure 24: LiDAR contours (0.5 meter)

Figure 25 and Figure 26 show the TIN terrain display of USGS and LiDAR data and the low accuracy of USGS data in comparison with LiDAR data is clearly visible. As shown in Figure 25, even Moss Branch and Edgar Draw are not shown clearly. However Figure 26 shows the elevations very clear and accurate.

Figure 25: USGS TIN display

Figure 26: LiDAR TIN display

4.2 Compare the USGS cross-sections with LiDAR cross-sections

As the LiDAR elevations are more accurate than USGS elevations, the cross-sections based on LiDAR data should be more reliable than USGS cross-sections. Figure 27 and Figure 28 show the cross-sections of LiDAR and USGS data for the two cross-sections before and after the Edgar Ranch.

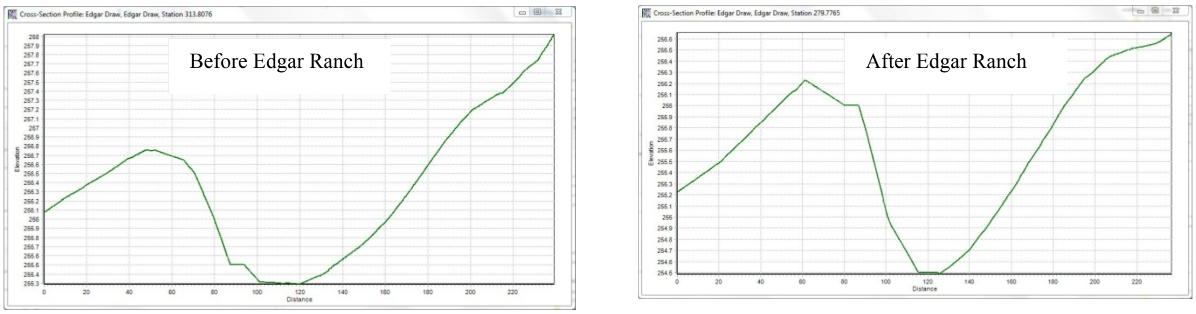

Figure 27: cross-section before and after Edgar Ranch along the Edgar Draw, based on USGS data

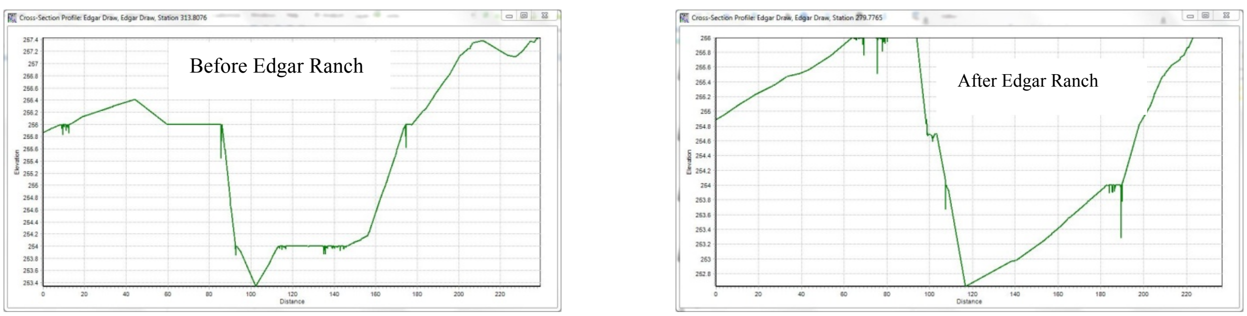

Figure 28: cross-section before and after Edgar Ranch along the Edgar Draw, based on LiDAR data

4.3 LandUse-based Surface Roughness

Kalyanapu et al. (2009) has done a study on effects of land use-based surface roughness on hydrological model output. They calculated the Manning's value by visual inspection and compared it with the NLCD Manning's value and found that there is a significant difference between them, especially in urban areas. Table 2 shows what Kalyanapu et al. (2009) found in their study.

Table 2: statistics of Manning's per NLCD class

NLCD Class Description	No. of cells*	Avg. NLCD n	Avg. Base n	Difference (NLCD-Base)	% Relative error	Weighted % Relative error
Open water	18	0.0010	0.0260	-0.0250	-96.2	-0.1
Developed, Open space	3663	0.0404	0.1720	-0.1316	-76.5	-12.3
Developed, Low Intensity	4488	0.0678	0.1366	-0.0688	-50.4	-9.9
Developed, Medium Intensity	5798	0.0678	0.0803	-0.0125	-15.6	-4.0
Developed, High Intensity	3238	0.0404	0.0501	-0.0097	-19.4	-2.8
Barren land	24	0.0113	0.1227	-0.1114	-90.8	-0.1
Deciduous Forest	1063	0.36	0.2083	0.1517	72.8	3.4
Evergreen Forest	2475	0.32	0.2901	0.0299	10.3	1.1
Mixed Forest	388	0.40	0.2309	0.1691	73.3	1.3
Shrub/Scrub	214	0.40	0.1810	0.2190	121.0	1.1
Grassland/Herbaceous	351	0.368	0.1665	0.2015	121.0	1.9
Pasture/Hay	697	0.325	0.1727	0.1523	88.2	2.7
Woody Wetlands	316	0.086	0.3350	-0.2490	-74.3	-1.0
Emergent Herbaceous Wetlands	29	0.1825	0.1586	0.0239	15.1	<0.1

* cell size = 30 m

Now the question is that if these differences in Manning's can cause the similar differences in hydrologic and hydraulic model. One approach to answer this question is to test the variability of the hydraulic and hydrology model with the visual inspection values and the NLCD values. This might be considered as a future work for this study.

5 Conclusion

- Since the LiDAR elevations are more accurate than USGS data, and the cross sections based on LiDAR data are more reliable than the ones based on USGS data. So the floodplain map based on the LiDAR terrain produced a different flood extent than FEMA maps show. Figure 29 shows the new floodplain map based on the LiDAR data and compares it with the FEMA flood extent which is shown in red line. As can be seen the Edgar's house locates out of the flood zone in the new floodplain map.

Figure 29: New floodplain map based on the LiDAR terrain (comparing with the FEMA flood extent)

6 References

1. Alfred J. Kalyanapu, Steven J. Burian, and Timothy N. McPherson, Effect of land use-based surface roughness on hydrologic model output, Journal of Spatial Hydrology, Vol.9, No.2 Fall 2009.
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