Appendix D
Topographic Data Summary

Light Detection and Ranging (LiDAR) topographic data have been collected twice within the Tucannon River basin area since 2010. The comparison of these two datasets provides some insight into how geomorphic change has occurred during the time between flights. However, technological capabilities in LiDAR collection and processing techniques have changed significantly since 2010, and it is therefore necessary to determine what change is geomorphic process, what change is anthropogenic, and what change is simply due to differences in the LiDAR collection. This appendix explains how those determinations were made, how observations of actual geomorphic change were categorized, and the information used in the individual project area assessments in the main report.

LiDAR Comparison

The two datasets were analyzed to quantify physical change within the study area by comparing elevations at coincident locations to determine if topographic change (aggradation, incision, avulsion, or migration) has occurred.

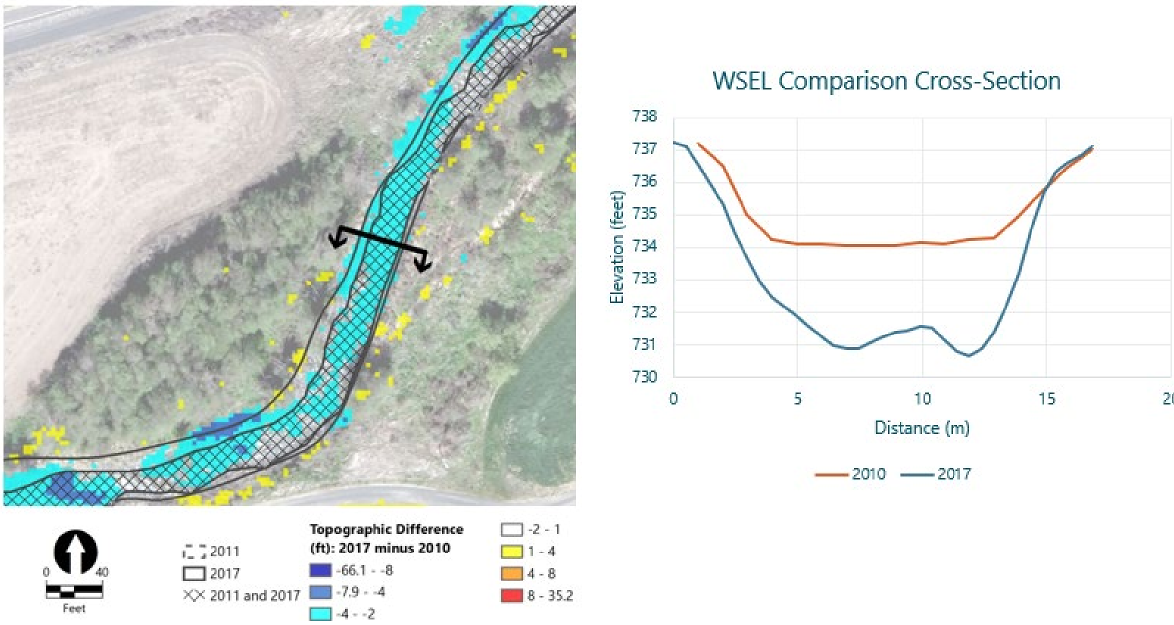
In the spring of 2010, Watershed Sciences, Inc. (WSI) was contracted to collect approximately 16,000 acres of elevation data within the basin. The WSI data measured topographic elevations only, although no bathymetric data were collected. Those data included digital elevation models (DEMs) of both the bare earth conditions and highest hit returns, which include vegetation, structures, etc. Resolution of the DEMs is 1.0 meter and the assessed vertical accuracy was approximately 3.70 centimeters (WSI 2010). Because these are topographic data only, channel bottoms show up at the water surface elevation at the time of the LiDAR flight. It can be assumed that the actual channel bed in 2010 was several feet lower in elevation than appears in the 2010 topographic data. In Figures D-1 to D-4, the range from -2 to 1 foot is shown as no change to better represent this fact. Additionally, it should be noted that change in the area where the 2010 main channel was may be underestimated for aggradation and overestimated for degradation.

A more recent LiDAR collection effort was conducted by Quantum Spatial, Inc. (QSI) in November 2017 and covered approximately 15,500 acres. QSI used airborne bathymetric sensors, which are capable of some penetration into the water column and depending on depths can resolve the riverbed topography. DEMs delivered by QSI are resolved to approximately 0.5 meter and have an assessed vertical accuracy of approximately 6 centimeters based on the LiDAR report published by QSI (QSI 2018).

While vertical accuracy of the QSI 2017 LiDAR data is slightly reduced from that of the WSI 2010 data, the half-meter resolution provides more channel definition, particularly in smaller off-channel and floodplain areas where channel widths are generally narrower, and the larger pixel size of the

2010 data is unable to represent the feature accurately shown in Figure D-1. This is useful in identifying areas of potential channel avulsion.

Figure D-1
LiDAR Bathymetry Comparison



WSEL: water surface elevation

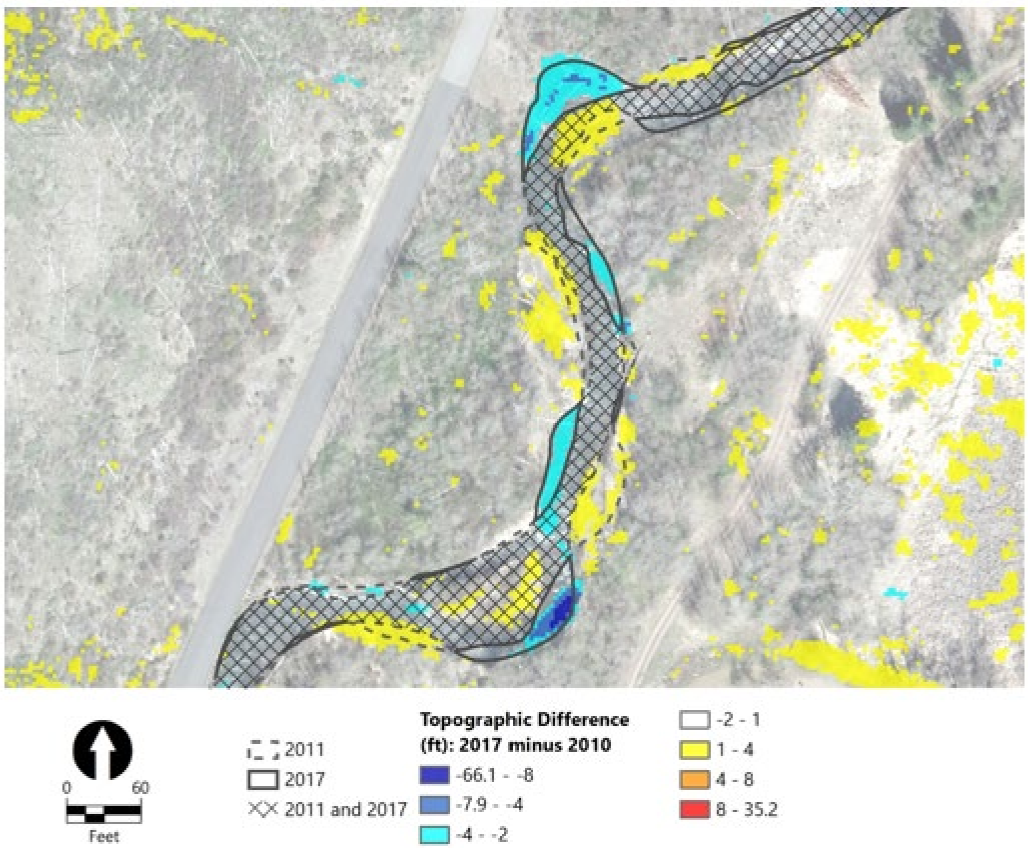
Characterization of Change

Overall change within the basin and subsequent project areas can be quantified by the elevation difference at a given pixel. This analysis is more appropriately applied to off-channel areas as the blue-green bathymetric LiDAR is able to penetrate the water while the topographic LiDAR is reflected from the water surface; thus, a comparison between the two sets of data within the channel is likely to show a lower elevation in the 2017 data relative to the 2010 data, which is an artifact of the two different sensor types rather than a physical change of the river planform. The difference in cell resolution may also result in artificial change when compared to the 2010 data due to being unresolved in the DEM.

Quantifying physical change on a small scale can be difficult when using only the topographic change DEM created from the LiDAR data due to the previously discussed limitations. However, when looked at discrete areas/reaches and with ancillary lines of evidence (e.g., aerial photographs, channel traces, field observations, local knowledge) the topographic change analysis can be useful in identifying and quantifying localized and reach-scale geomorphic processes (e.g., avulsions, head-cutting and associated downstream deposition, channel migration, and activation/deactivation).

Within the Tucannon River study area, the topographic change data resolves multiple geomorphic processes and features. These geomorphic processes include channel migration, avulsion, aggradation, incision, bar building, and bank erosion, among others. Channel migration is characterized by several alternating areas where the 2017 LiDAR elevation is deeper than the 2010 elevation was on either side of the channel. This effectively increases the number of meanders and sinuosity of a reach and is often seen in unconfined higher energy areas, as shown in Figure D-2.

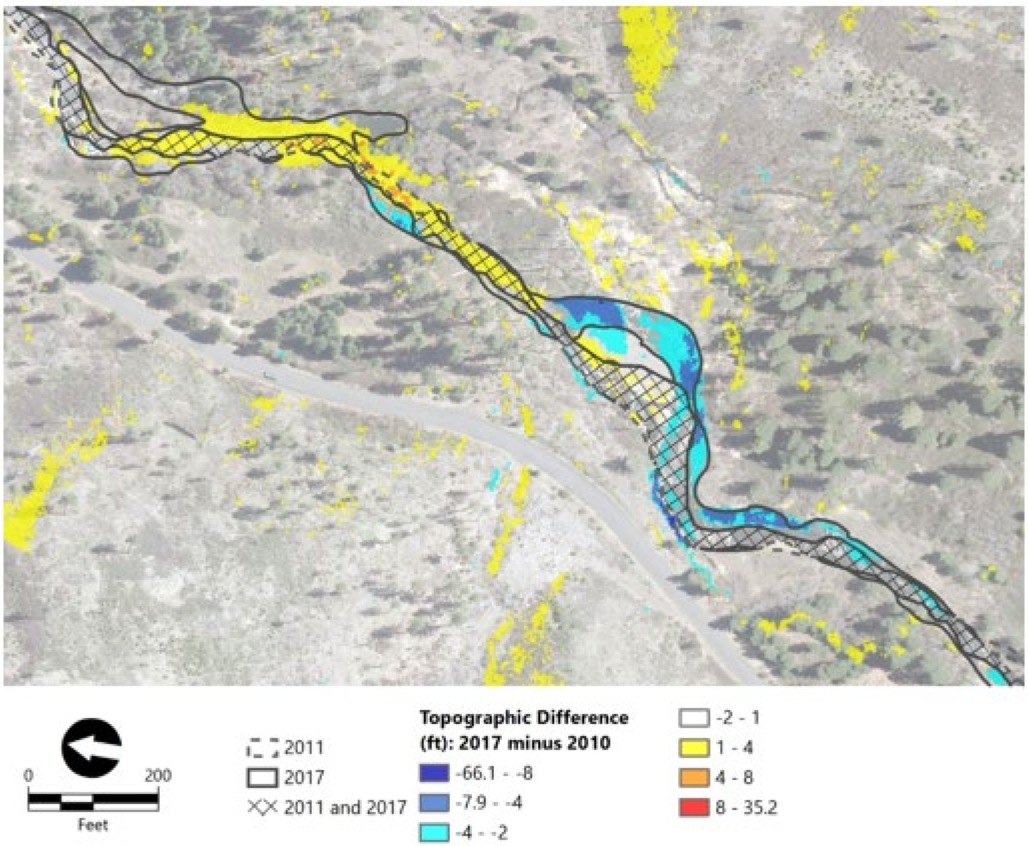
Figure D-2
Channel Migration



Project Area 11

Several large-scale avulsions were observed in this change analysis. Avulsions are characterized by whole reaches of river moving completely outside of the banks of the 2010 location. Figure D-3 shows where the river has migrated towards the right bank and eventually avulsed outside of the 2010 channel completely. Often, avulsions cause a large amount of floodplain material to be mobilized. Depending on how long ago these avulsions occurred, they are often associated with bed aggradation just downstream, as shown in Figure D-3. The area in the channel just downstream of the avulsion is 1 to 4 feet higher in 2017 than the water surface elevation was in 2010, indicating that much of the material from this avulsion has been deposited here at least temporarily. Areas of aggradation are not always associated with avulsions, and the source of the sediment for aggradation may be unclear. Unlike erosion within the channel, it is unlikely that areas of channel bed aggradation are false positives because the 2017 LiDAR should always register deeper channel elevation, as discussed previously. It can also be noted in Figure D-3 that aggradation downstream from the avulsion area resulted in split flow conditions and likely greatly improved floodplain connectivity. Thus, the process of avulsion and aggradation can improve habitat conditions and promote a reach-scale trend toward natural habitat creation and maintenance over time.

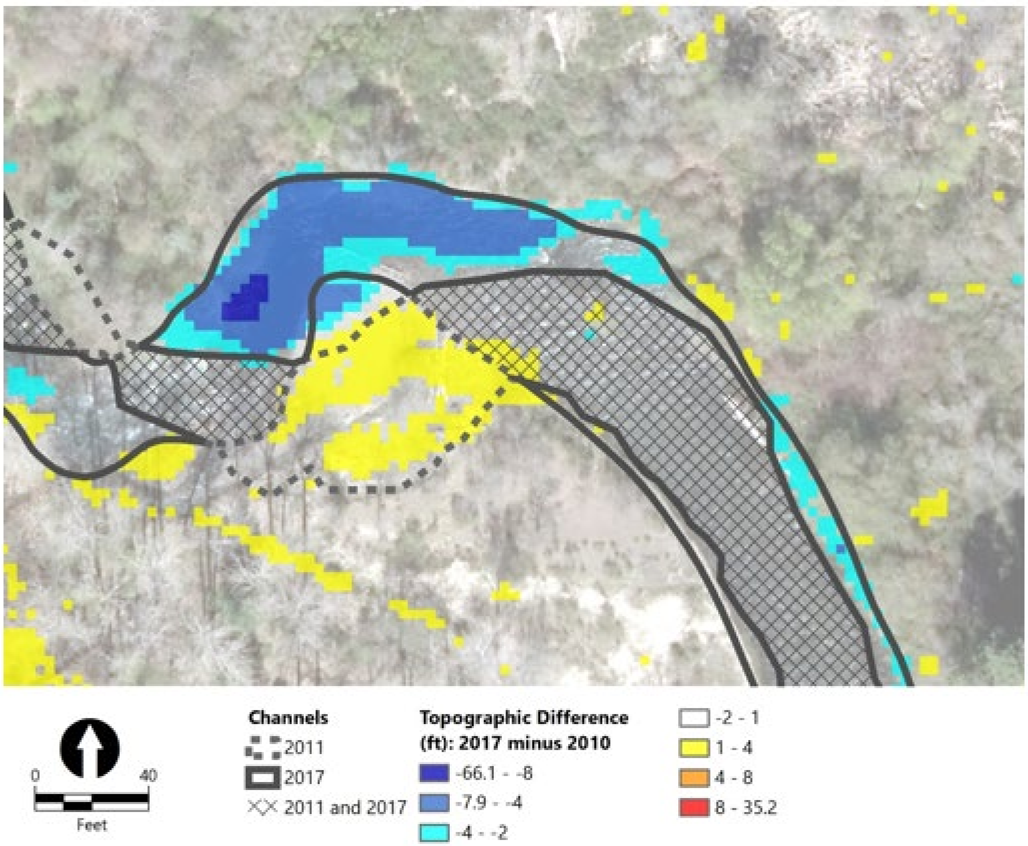
Figure D-3
Avulsion and Aggradation



Project Area 10

Finally, a commonly seen geomorphic change in the basin is the process of bar building and bank erosion. Figure D-4 shows an example of this geomorphic process. Bar building and bank erosion happen on a relatively small spatial scale compared to other geomorphic processes and can either be a localized event or part of a larger geomorphic process such as channel migration, as shown in Figure D-2. However, bar building and particularly bank erosion can often threaten critical infrastructure, possibly prompting actions such as emergency riprap placement, which could have negative effects on the natural processes of sediment transport and channel migration. Therefore, these areas were identified and special attention was paid to the surrounding landscape.

Figure D-4
Bar Building/Bank Erosion



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Uses of Topographic Data

The analyses described in this assessment use a combination of water surface information and DEMs to determine geomorphic conditions. Water surface elevations in turn were determined from a combination of 1-dimensional (1D) and 2-dimensional (2D) hydraulic models as well as directly from LiDAR results. Several relevant flow events were selected for the analyses and are described in Table D-1 along with one of three methods used to obtain them. The low-winter flow data raster was taken from the LiDAR output of water surface elevation and clipped to only include the main channel. The LiDAR was taken on November 11, 2017, when the flow at the Starbuck gage was approximately 130 cubic feet per second (cfs) and was used as the representative “low-winter flow” for this analysis. Lower flows may occur in the Tucannon River; however, these are likely to be episodic and only periodic.

Table D-1
Geomorphic Flows

Flow Significance	Flow at Starbuck	Method	Analyses Used In
Low-Winter Flow	130	2017 LiDAR Digital Elevation Model	River Complexity, Pool Frequency
Mean-Winter Flow	300	2D Hydraulic Model	River Complexity
1-Year Event (yearly high)	552	2D Hydraulic Model	River Complexity
2-Year Event	1,435	1D Hydraulic Model and Relative Elevation Map	Floodplain Connectivity, Stream Power
5-Year Event	2,528	1D Hydraulic Model and Relative Elevation Map	Floodplain Connectivity

The hydraulic model development is the largest data processes operation performed for this assessment. However, several smaller processes were used to obtain critical pieces of information as well. Both methods are based either on the LiDAR survey or the aerial photographs taken shortly afterwards.

Aerial photographs taken in April of 2018 (QSI 2018) were used to estimate roughness values for the HEC-RAS model as well as define rough channel extents. Channel extents were used to help characterize the change in LiDAR described previously. Additionally, major features such as roads, levees, floodplain lakes, and structures were digitized based on these aerial photographs.

It should be noted that the aerial photographs were taken at a different date than the LiDAR (April 2018 vs. November 2017) and therefore represent different flow conditions. The flow on the date of the aerial photographs is estimated at 320 cfs at the Starbuck gage, which corresponds to the flow analyzed for “mean-winter flow” in Table D-1. The flow rate during the LiDAR flight was 130 cfs at the Starbuck gage, which more closely represents the “low-winter flow” in Table D-1. Finally, the

Tucannon River basin experienced one of the highest flows since the previous geomorphic assessment on March 16, 2017, at 1,790 cfs (USGS 2018), just before the LiDAR imagery and aerial photographs were taken. There may be significant channel or floodplain changes shown in the aerial photographs that are not reflected in the LiDAR.

In addition to aerial photograph digitization, relative elevation maps (REMs) were developed for a variety of situations. REMs show the floodplain elevation relative to a point along the river channel. Typically, the thalweg elevation is used as the point of reference and the resulting REM displays floodplain elevations as they relate to the lowest point in the channel. However, for this assessment REMs were also created based on several different water surface elevations obtained from the modeling results. The effect is a REM that shows the floodplain as it relates to the water surface, quickly identifying areas that would be inundated at a given flow.

References

QSI (Quantum Spatial, Inc.), 2018. Topobathymetric LiDAR Technical Data Report: Tucannon River.

USGS (U.S. Geological Survey), 2018. Monitoring Location 13344500, Tucannon River Near Starbuck, Washington. Accessed November 2018. Available at: https://waterdata.usgs.gov/monitoring-location/13344500/.

WSI (Watershed Sciences, Inc.), 2010. LiDAR Remote Sensing Data Collection: Tucannon River, Tucannon Headwaters, and Cummings Creek, WA. Prepared for Columbia Conservation District, City of Dayton, CTUIR, and USFS Pomeroy Ranger District.