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To: Florian Leischner and Melora Shelton, Tacoma Power

From: Steve Winter, Tim Abbe, and Julia Jay
Natural Systems Design

Date: February 7, 2019

Re: Preliminary Geomorphic Assessment Memo
Cowlitz River Geomorphic Assessment

Introduction

Natural Systems Design, Inc. (NSD) has developed a preliminary geomorphic assessment of the Upper Cowlitz River between RM 94 (Lake Scanewa) and RM 132, and of the Cispus River between RM 0 (Lake Scanewa) and RM 22. In general terms, our assessment is focused on the broader alluvial valley upstream of the dam impoundment and does not extend up into the higher slope sediment source and transport reaches.

Tacoma Power has requested a high level geomorphic assessment to investigate geomorphic trends over time with implications for future geomorphic trajectory. We understand this work will be used to support other investigations, including hydraulic and restoration framework development.

We have organized this memo to present our methodology, general background and context, and observations regarding channel morphology; then follow with a discussion based on the following questions:

1. What channel types exist within the study area?
2. What dynamic channel processes are observed over time?
3. What is the current role of large wood in the system?
4. How have changes in land use affected geomorphic processes?
5. What is the geomorphic trajectory of the system?
6. How will ongoing and future geomorphic processes influence restoration planning?

Methodology

Data Sources

a. 1948 Aerials
b. 1994 DOQ aerials
c. 2017 LiDAR
d. 2009 LiDAR
e. 2017 aerials
f. DNR 1:100,000 geology mapping
g. 1910 USGS map of the Upper Cowlitz

h. Past channel traces delineated by GeoEngineers and provided by Lewis County via Interfluve
i. EDT reach scale mapping

Spatial Methodology

a. Visualize existing channel and floodplain topography with a Relative Elevation Map (REM) built using newest available LiDAR.
b. Digitize 2017 unvegetated stream channel
c. Digitize 1994 unvegetated stream channel
d. Digitize 1948 unvegetated stream channel
e. Measure stream parameters (slope, sinuosity)
f. Identify and draw centerlines for side channels
g. Note current wood loading (locations of logjams influencing habitat formation)
h. Note current avulsion risks, particularly with respect to implications to habitat and local human communities.
i. Develop mapbooks of REMS and comparative views of current and past active channels

Background and Context

The Upper Cowlitz and Cispus Rivers drain a varied landscape in the southern Washington Cascades. The northern portion of the Upper Cowlitz drains the southern slopes of Mount Rainier including the Ingrahm and Cowlitz glaciers. Water and sediment contributions from glaciated basins is balanced with drainage from lower elevation tributaries that do not have the characteristically high sediment loads as the glacially fed tributaries. For the Cispus, the basin includes Mount Adams, as well as sharing the lower dividing hills to the Upper Cowlitz.

Hydrology of the basin is also influenced by the varied tributary elevations with snowmelt dominated areas along with rain on snow dominated runoff patterns. The flood event in December 2006 (approximately 42,000 cfs) is the flood of record at the USGS Packwood gauge, which has a record extending back to 1911. The preliminary FEMA Flood Insurance Study (2010) reports a 10 percent chance flood event of 27,300 cfs and 1 percent (100 year flood) chance event at 45,600 cfs at Packwood. The Cispus 1 percent annual chance event is reported at 25,100 cfs, so contributes to significantly greater peak discharges in the mainstem Cowlitz downstream of the confluence.

The valleys here were highly influenced by the glacial history of North America. Local glaciers extended down the valley in each successive glacial advance, leaving a range of deposits (see for example Crandell and Miller 1974). These deposits continue to influence channel form and function, and these deposits continue to delineate the extent of active lateral migration. According to Crandell and Miller, the most recent (Evans) glaciation grounded 24 km west of Randle, and subsequent outwash depositing terraces as much as 7 meters above the current floodplain (Figure 1).

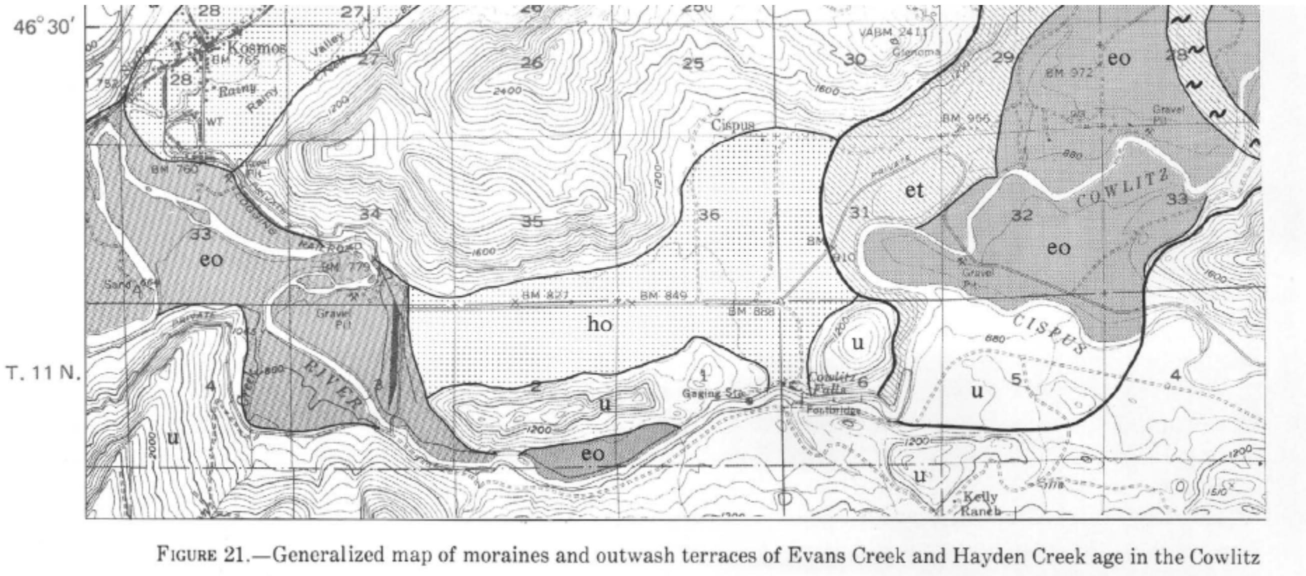


Figure 1. Crandell and Miller Fig 21 - end moraines near the Cowlitz-Cispus confluence. Eo is Evans Creek era outwash (and post glacial alluvium) ho is Hayden Creek era outwash, u is bedrock or undifferentiated deposits, and the wavy lines are the terminal moraine.

Tributary inflows and colluvial inputs to the valley also influence mainstem morphology. Broad alluvial fans such as at Miller Creek in Randle; Silver Creek at Silver Brook; Kilborn Creek, and where Johnson, Smith, and Dry Creeks enter the mainstem near RM 122. These alluvial fans influence the plan form of the mainstem channel, confining the valley in places. Landslides, such as north of the channel near RM 125, also influence the valley floor (Figure 2).

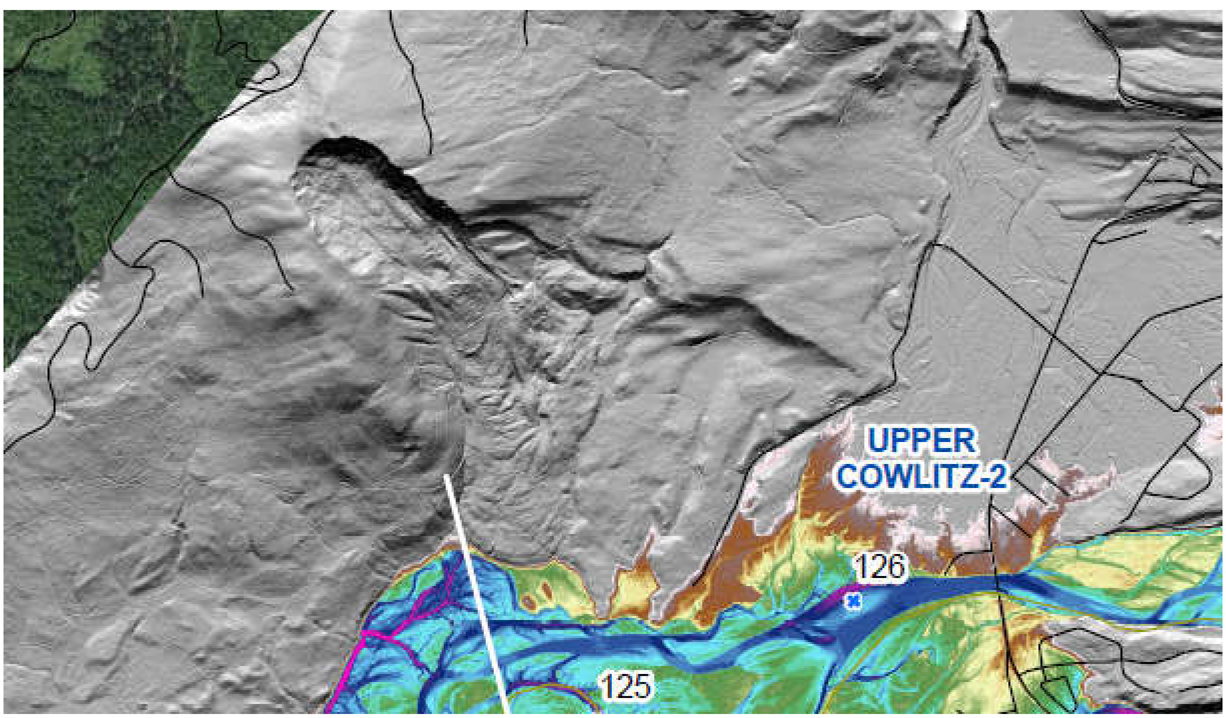


Figure 2. Landslide scarp above the Cowlitz River north of the channel.

While these larger scale landforms influence mainstem morphology, they are typically erodible, so represent a significant sediment source. In general, these landforms complicate the calculation of typical migration rates, as rates of migration into the higher terraces will be lower than the more recent alluvium.

In the broader alluvial valleys, remnants of the floodplain forest suggest that the Upper Cowlitz and Cispus Rivers were anastomosing with multiple perennial channel threads stabilized within a matrix of forested islands (see for example, Figure 3).

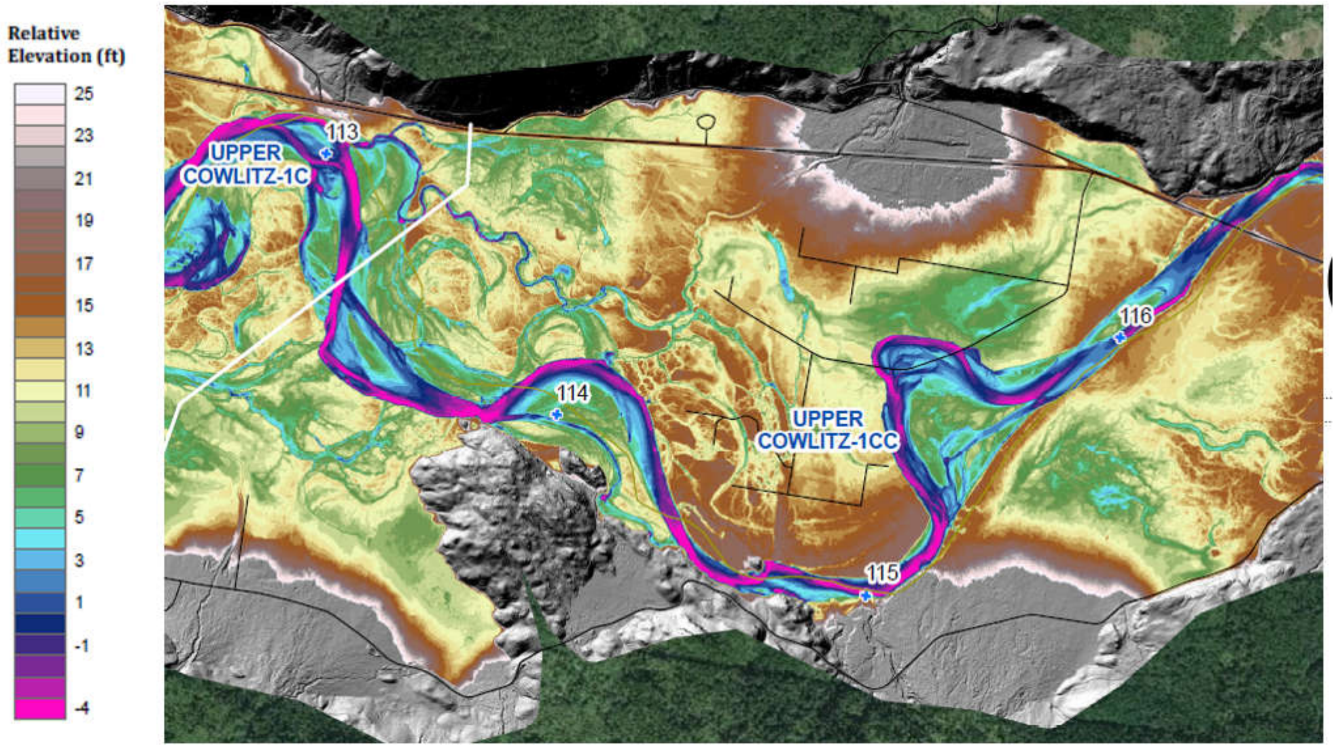


Figure 3. Example Relative Elevation Map showing secondary channels in floodplain

These multiple channels have been shown to be important elements of aquatic habitat, as they act as a multiplier on the length of channel for the same unit of valley length. The anastomosing planform also provides a morphology that diffuses fluvial energy across the landscape. It is not a static configuration, as there will be lateral migration of individual threads and flow splits will adjust over time. However, rates of lateral migration are likely to be lower with the presence of a mature riparian forest.

Observations – Channel Morphology

Our matrix summarizing our reach based metrics is included as Appendix A. In general, we looked for trends in channel morphology throughout the study area both in terms of the range of observed conditions and in how they varied spatially.

Overall channel slopes are modest within the project area, ranging from 0.1 to 0.4 percent above Highway 12, from 0.01 to 0.1 between the lower SR 131 bridge up to Highway 12, and very low slopes in the lowest impoundment influenced reaches below RM 103. Please see Appendix B for a plot of the longitudinal profile.

Channel changes include lateral migration and widening. Bank erosion rates of meander apex bank erosion rates are about 30 ft/yr (RM 108.6). Bank erosion rates at River Miles 128.5-129.5 were found to vary between 2.5 to 79 ft/yr (0.75 to 24 m/yr), averaging 11 ft/yr from 1959 to 1993 (Abbe et al. 1997) (Figure 4). Overall bank erosion and widening is anecdotally noted by NPS geomorphologist Paul Kennard (pers. comm. 2018).

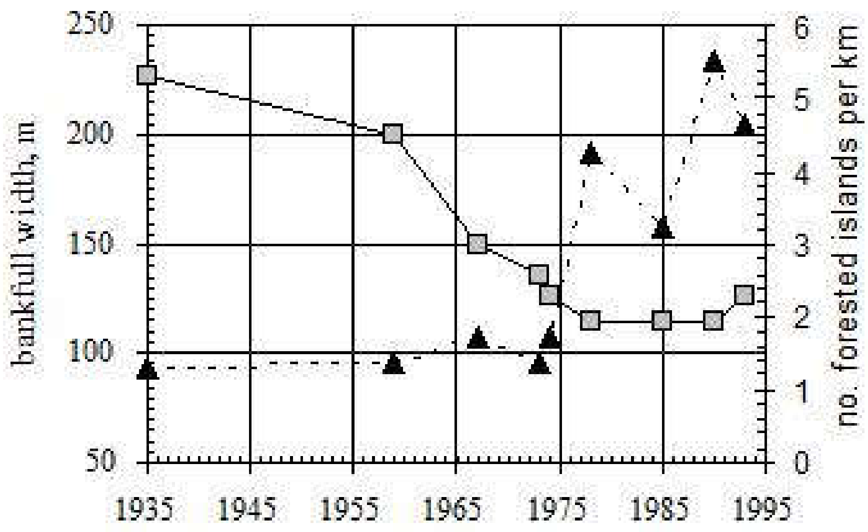


Figure 4. Plot showing expansion of unvegetated channel width (depicted with triangles) and loss of forested islands (depicted with squares) in Upper Cowlitz from 1935 to 1993. River Miles 128.5 to 129.5, upstream of Packwood (Abbe et al. 1997).

We used georeferenced aerial photos to extend the previous analysis into example reaches of each of our three channel types (Figure 5 to Figure 6). For each reach, channel width was found by averaging the active channel width measured at 4 evenly spaced points along the reach. Forested islands were counted visually as any areas vegetated with trees that were surrounded on all sides by water. No aerial image was available earlier than 1948; however, a USGS survey map showing a channel polygon was used to estimate channel width.

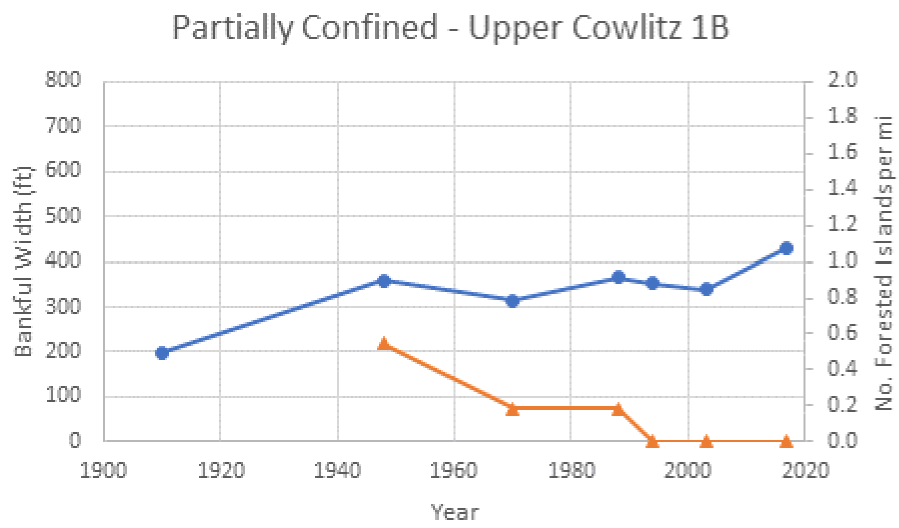


Figure 5. Forested islands (orange with triangles) and bankfull width (blue with circles) over time in a partially confined reach.

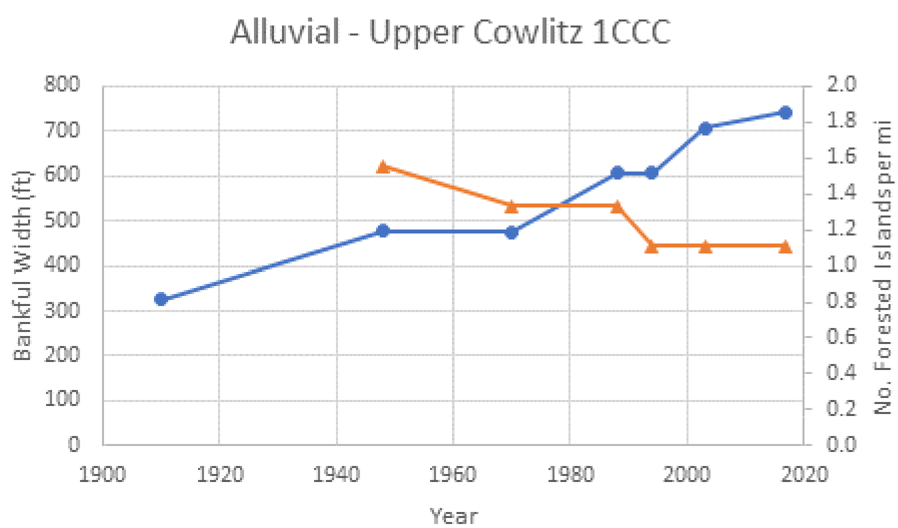


Figure 6. Forested islands (orange with triangles) and bankfull width (blue with circles) over time in an alluvial reach.

These examples generally corroborate the overall trends of increasing channel width and reduction in forested islands over time. The Partially Confined reaches appear to be more susceptible to loss of complexity as the relative change is similar to Alluvial, but results in a complete loss of forested islands.

Side channels can provide significant aquatic habitat, and have historically been present in the alluvial and partially confined reaches of the Cowlitz/Cispus. Using reach metrics, we note that the length of side channels scales to reach length and to the degree of confinement. Secondary channels are also much more likely to occur in unconfined reaches (Figure 7).

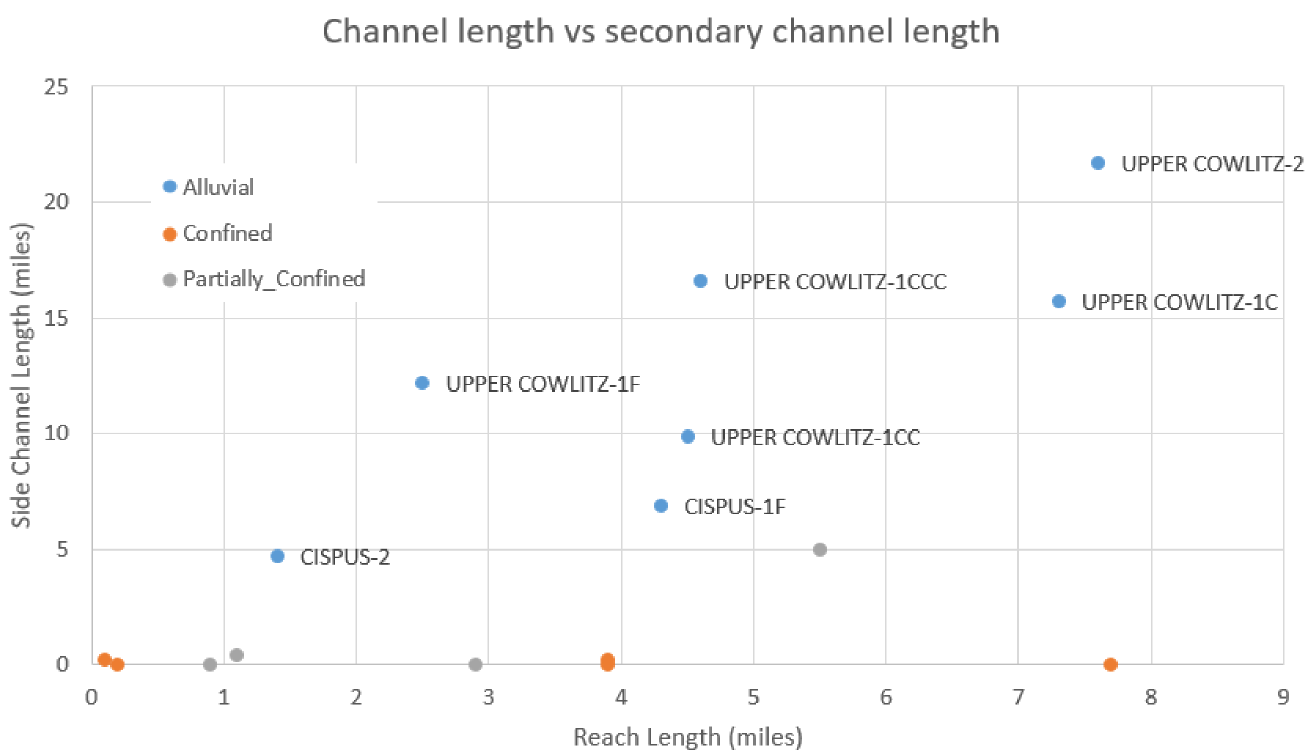


Figure 7. Plot of side channel length vs reach length, organized by reach type.

The degree of vertical channel change is unknown. It is likely that systemic incision is continuing as the channel reworks the vast amount of glacial sediments but this process is slow due to the incoming sediment load from glaciers, tributaries, and hillslopes.

To investigate trends in channel capacity near Packwood (located at the Skate Creek Road Bridge, we downloaded the USGS (14226500) field discharge measurements from the gauge and plotted them by era (Figure 8).

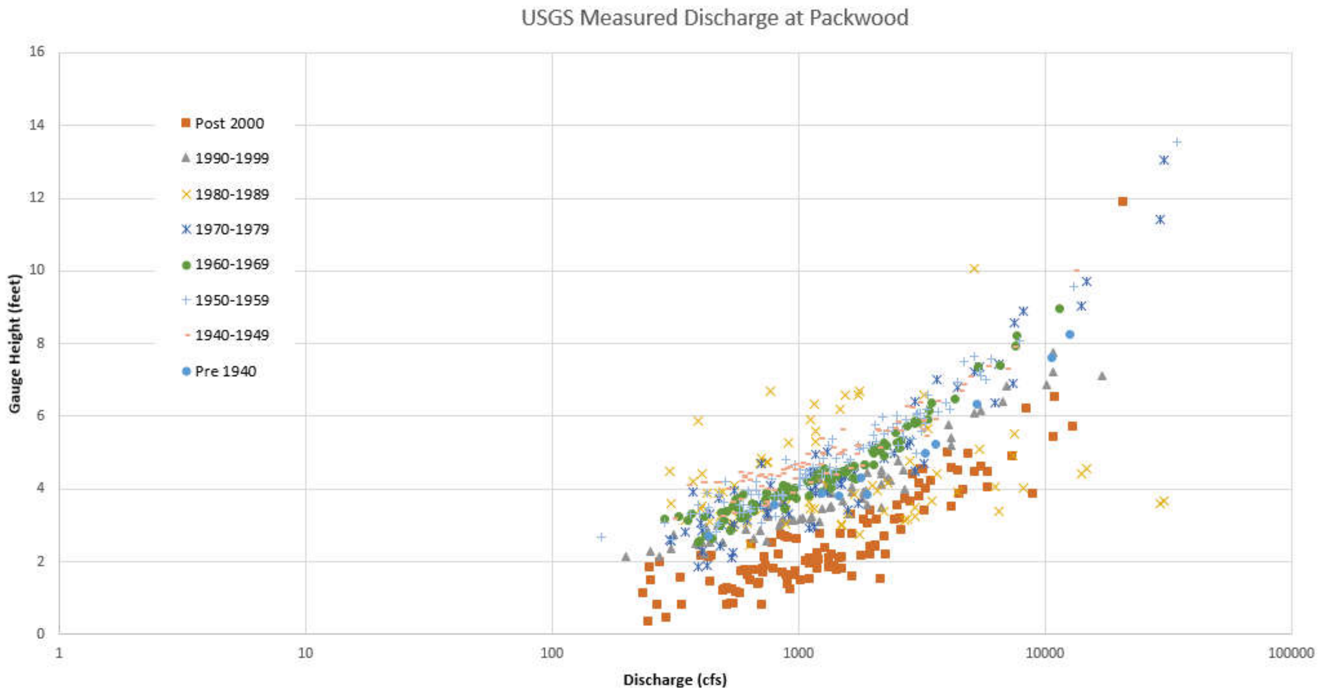


Figure 8. USGS field discharge measurements comparing gauge height and discharge (semi log plot) and labeled by era

Scatter in stage-discharge curves is typical, as it represents hysteresis (differences in discharge on the rising and falling limbs of the hydrograph). Here, however, it is interesting that the last 18 years of data plot below the majority of the scatter from measurements from the previous 90 years. Plotting lower and to the right means that there is more discharge for a given gauge height, so channel capacity is increasing. The gauge is located at a bridge with fixed abutments, so incision is the most likely adjustment. Incision at the Packwood gauge is consistent with Czuba et al 2010 who performed a similar analysis and found that the gauge showed "Pronounced Incision."

There may be methodological changes at the gauge, and the gauge reach is influenced by the bridge and associated abutments so we do not want to overemphasize this information, but it does suggest that the channel is not aggrading in this reach, which is often the case in glacially fed rivers. Overall incision was also noted by Interfluve in field work in the Cowlitz mainstem.

Geomorphic Questions

What channel types are present in the study area?

There are three general classes of channel configuration in terms of the degree of valley confinement:

1. Laterally confined reaches – very little active floodplain area (much of valley can be inundated in very large floods), little evidence of lateral migration post-glaciation

2. Partially confined reaches – reaches that have alluvial surfaces but confined between higher alluvial fans or terrace deposits

3. Alluvial reaches – channel occupation extends to each valley wall.

What dynamic channel processes are observed over time?

The main channel has reduced in overall length, increased in typical width, and continued to migrate laterally. From a systems perspective, the channel appears to be still reworking glacial sediments that covered the valley in the most recent glaciation (Evans).

We suspect that the channel has at least locally incised. The gauge records at Packwood, field observations by Interfluve and the National Park service, and past USGS reports suggest that incision has occurred, at least in places. Incision is a likely outcome given the observed lateral changes. Where channel meanders have cut off, the significant increase in local slope is likely to result in local scour. Further, the main channel is likely adjusting to local sediment inputs at alluvial fans and landslide deposits which will drive incision in these locations.

Lateral migration has been dramatic in places, requiring stabilization measures to protect infrastructure (Figure 9).

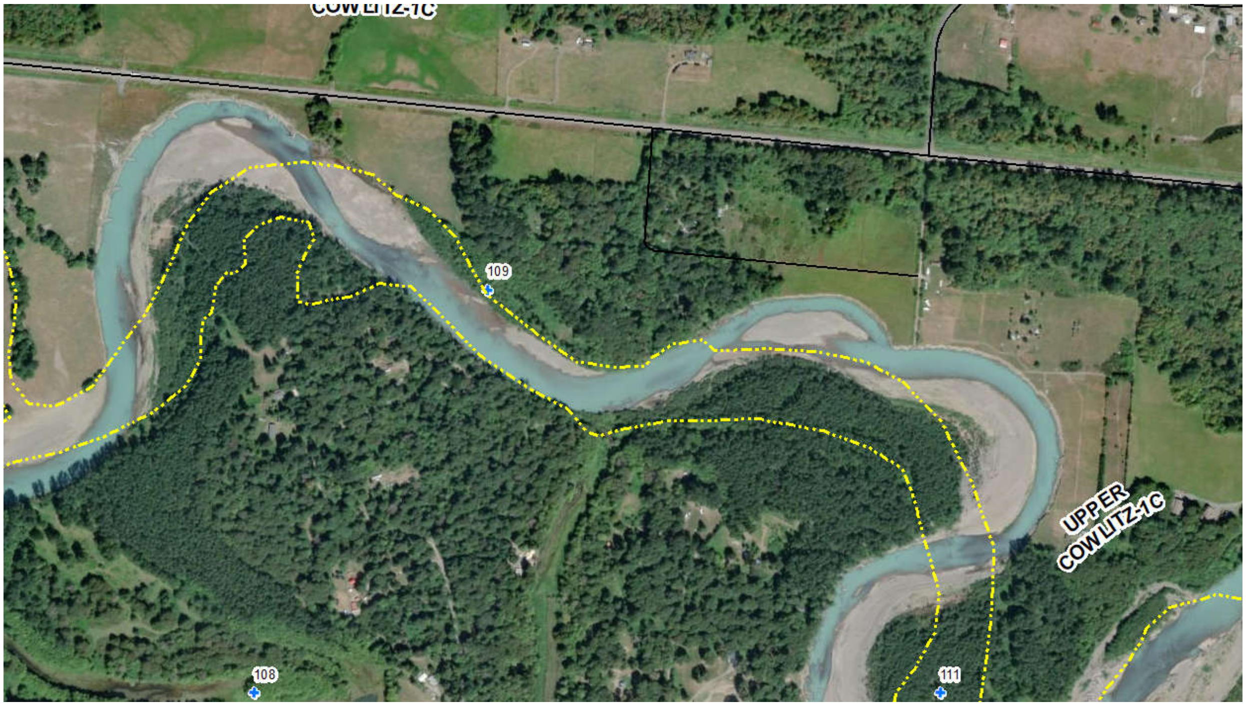


Figure 9. Current aerial photograph with 1994 unvegetated channel trace shown in yellow. Bank protection has been installed where the channel has migrated toward the highway.

In other places, lateral migration has increased sinuosity and complexity in locations where the channel had been straight in the past 80+ years (Figure 10). Lateral erosion and avulsions present significant risk in much of the study area, where development has occurred within the floodplain and channel migration zone.

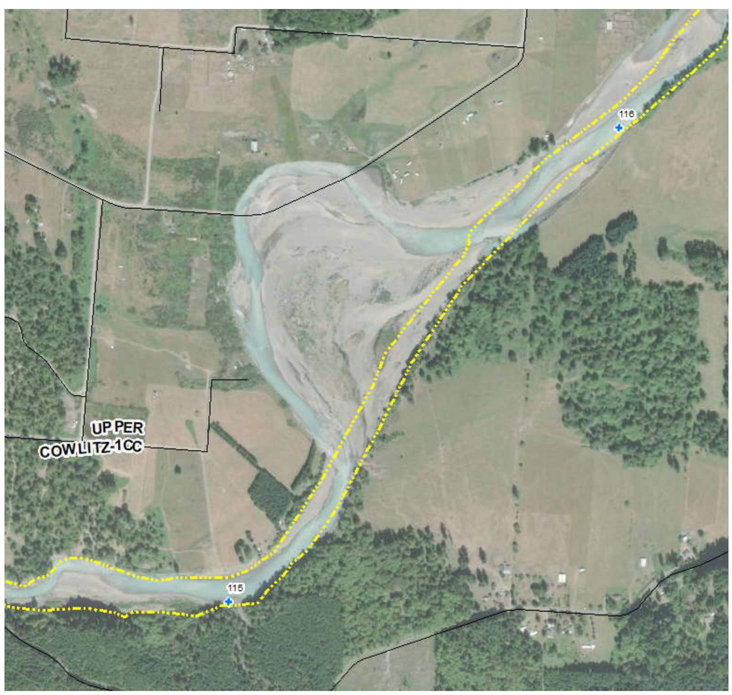


Figure 10. Upper Cowlitz RM 115 to 116 below SR 12 bridge where recent lateral migration has covered over 2,500 lateral feet. Yellow lines are 1994 unvegetated channel.

What is the current role of large wood in the system?

Large wood is lacking throughout the study area, but there are reaches where logjams still occur. We noted accumulations in Upper Cowlitz Reaches 1C, 1CC, and 1CCC. The current structure of the riparian forest is not generating the largest logs that used to occur in the system. The reduction of large wood source, paired with the very powerful and laterally active channels mean that even the largest wood available is mobile (Figure 11).

Figure 11. Cispus River near RM 19 facing downstream showing mobile wood (2014).

How have changes in land use affected geomorphic processes?

The primary change has been the reduction in riparian forest, particularly on the main channel banks. The reduction in cover and rootmass has changed the typical cross-section of the channel. Banks will erode more rapidly, so the equilibrium width will shift to a wider typical morphology.

Secondary changes include:

1. Changed hydrology and sediment loading from forest harvest zones.
2. Removal of large wood from the channel
3. Development and associated channel armoring within the channel migration zone.

Together, these changes result in an overall simplification of the channel system. As noted above, the channel has widened over time and lost forested islands where they once existed.

What is the geomorphic trajectory of the system?

Trends within the project reach are highly varied. For areas with great levels of channel armoring and channelization, the trend of simplification and widening is likely to continue. In these areas, meander cut-off events will continue, but additional channel length will not develop as the system is locked into place by development.

For example, on the Cispus River, a meander cutoff has resulted in half as much main channel length, effectively doubling local bed slope (Figure 12).

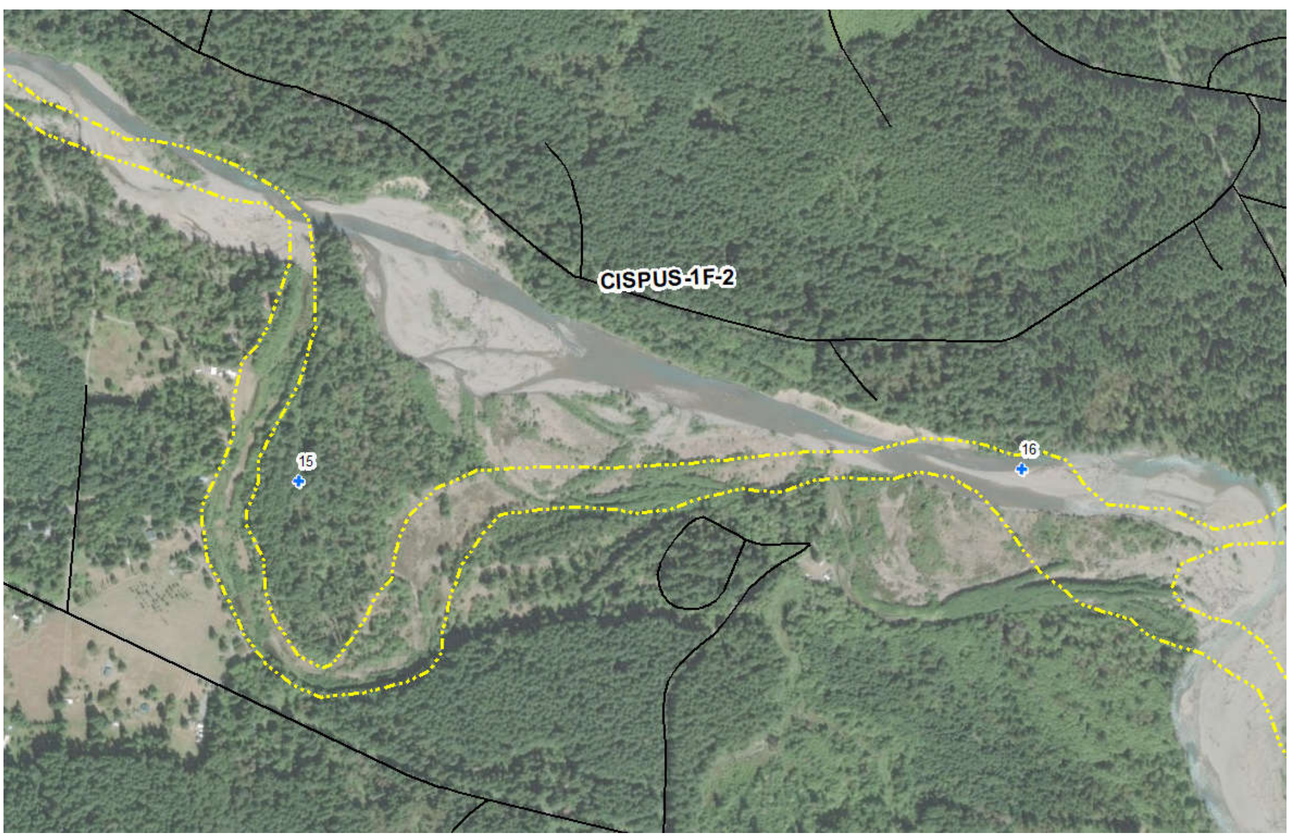


Figure 12. Cispus River migration showing an overall simplification of the channel system.

However, lateral migration will continue to occur as noted above in Figure 9 and Figure 10. In these locations, migration can be rapid averaging 10s of feet per year in places.

How will ongoing and future geomorphic processes influence restoration planning?

Restoration efforts along the mainstem Cowlitz and Cispus will need to balance reconnection of processes with protection of infrastructure. The Cowlitz and Cispus systems are both large, powerful, rivers so efforts to engage and enhance process will need to be scaled accordingly. Restoration projects will need to be broad in scope to have an appreciable influence on physical processes on both rivers.

Therefore, different strategies will be appropriate where development overlaps the lowland floodplain. Strategies are likely to include:

- Prioritizing acquisition efforts to help people who are at high risk from channel migration.
- Stabilization of banks in areas that threaten critical infrastructure in ways that enhance local habitat
- Adding complexity to the mainstem. Focus instream efforts in locations where wood accumulations are more likely to be stable, where existing systems of secondary channels can be re-engaged, and where the floodplain is more accessible.

From a habitat enhancement perspective, focusing on engaging perennial side channels at a reach scale is likely to be the most effective way of substantially increasing available instream habitat. The scale of the Cowlitz/Cispus River system and the magnitude of the geomorphic processes that occur mean that restoration will need to occur at a reach scale and will need to take substantial steps to influence form and function of the system.

References

Abbe T., Montgomery D.R. and Petroff, C. 1997. Design of stable in-channel wood debris structures for bank protection and habitat restoration: An example from the Cowlitz River, WA. In Wang S.S.Y., Langendoen E.J. and Shields F.D. Jr. (Editors), Proceedings, Management of Landscapes Disturbed by Channel Incision, pp. 809-816.

Crandell, D.R. and R.D. Miller. 1974. Quaternary Stratigraphy and Extent of Glaciation in the Mount Rainier Region, Washington. Geological Survey Professional Paper 847.

Czuba, J.A, Czuba, C.R, Magril, C.S., and Voss, F. D. 2010. Channel-conveyance capacity, channel change, and sediment transport in the lower Puyallup, White, and Carbon Rivers, western Washington: U.S. Geological Survey Scientific Investigations Report 2010-5240. 104 p.

Appendices

A. Reach Matrix

B. Longitudinal Profile

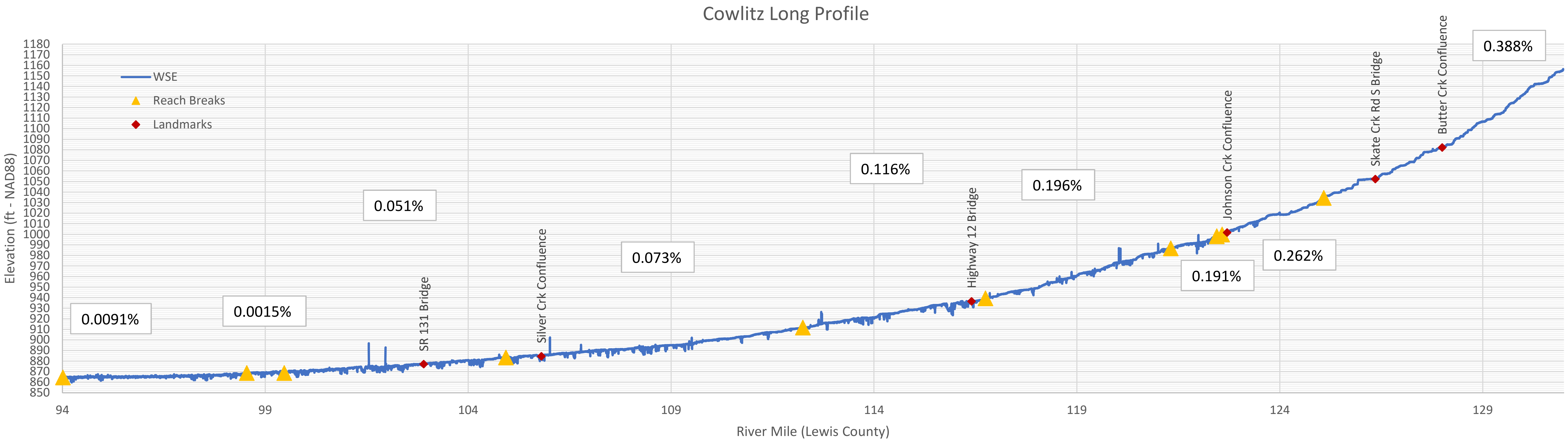
C. REM Map Book

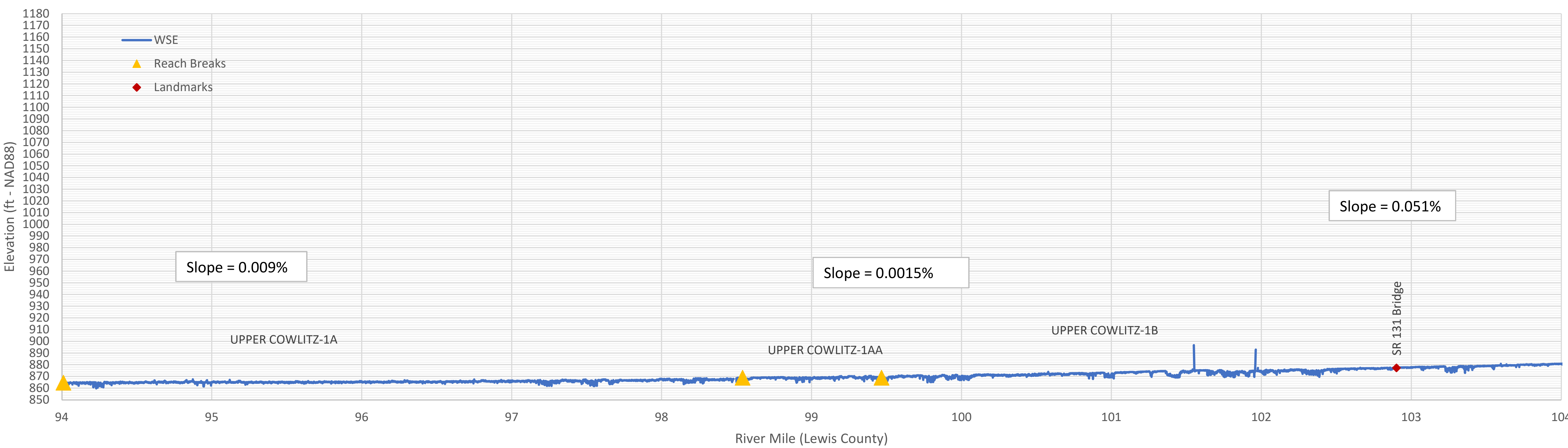
D. Active Channel Comparison Map Book

APPENDIX A. REACH MATRIX

REACH	CATEGORY	CHANNEL LENGTH	VALLEY LENGTH	SINUOSITY	TOTAL SIDE CHANNEL LENGTH	SIDE CHANNEL LENGTH/VALLEY LENGTH	SLOPE	NOTABLE WOOD ACCUMULATIONS
		mi	mi		mi		ft/ft	
CISPUS-1B	Partially Confined	2.9	2	1.42	0	NA	0.489%	
CISPUS-1C	Confined	0.2	0.2	1.11	0	NA	0.656%	
CISPUS-1D	Confined	3.9	3.3	1.21	0	NA	0.583%	
CISPUS-1E	Confined	3.9	3.3	1.18	0.2	0.07	0.427%	
CISPUS-1F	Alluvial	4.3	3.7	1.16	6.9	1.89	0.469%	
CISPUS-2	Alluvial	1.4	2.4	0.57	4.7	1.93	0.477%	
UPPER COWLITZ-1A	Confined	7.7	5.8	1.32	0	NA	0.009%	
UPPER COWLITZ-1AA	Partially Confined	0.9	0.3	3.1	0	NA	0.002%	
UPPER COWLITZ-1B	Partially Confined	5.5	2.5	2.16	5	1.96	0.051%	
UPPER COWLITZ-1C	Alluvial	7.3	4.1	1.81	15.7	3.85	0.073%	Yes
UPPER COWLITZ-1CC	Alluvial	4.5	2.8	1.61	9.9	3.58	0.116%	Yes
UPPER COWLITZ-1CCC	Alluvial	4.6	3.5	1.3	16.6	4.75	0.196%	Yes
UPPER COWLITZ-1D	Partially Confined	1.1	1.1	1.04	0.4	0.38	0.191%	
UPPER COWLITZ-1E	Confined	0.1	0.1	0.92	0.2	1.48	0.261%	
UPPER COWLITZ-1F	Alluvial	2.5	1.6	1.58	12.2	7.62	0.262%	Yes
UPPER COWLITZ-2	Alluvial	7.6	6	1.26	21.7	3.62	0.388%	Yes

Appendix B - Longitudinal Profile





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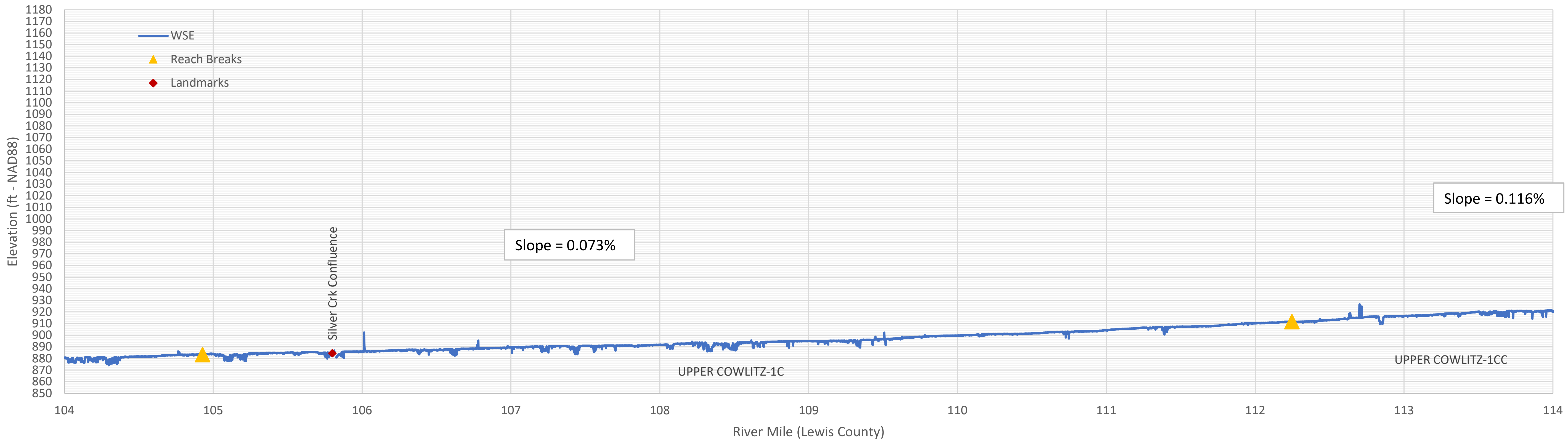

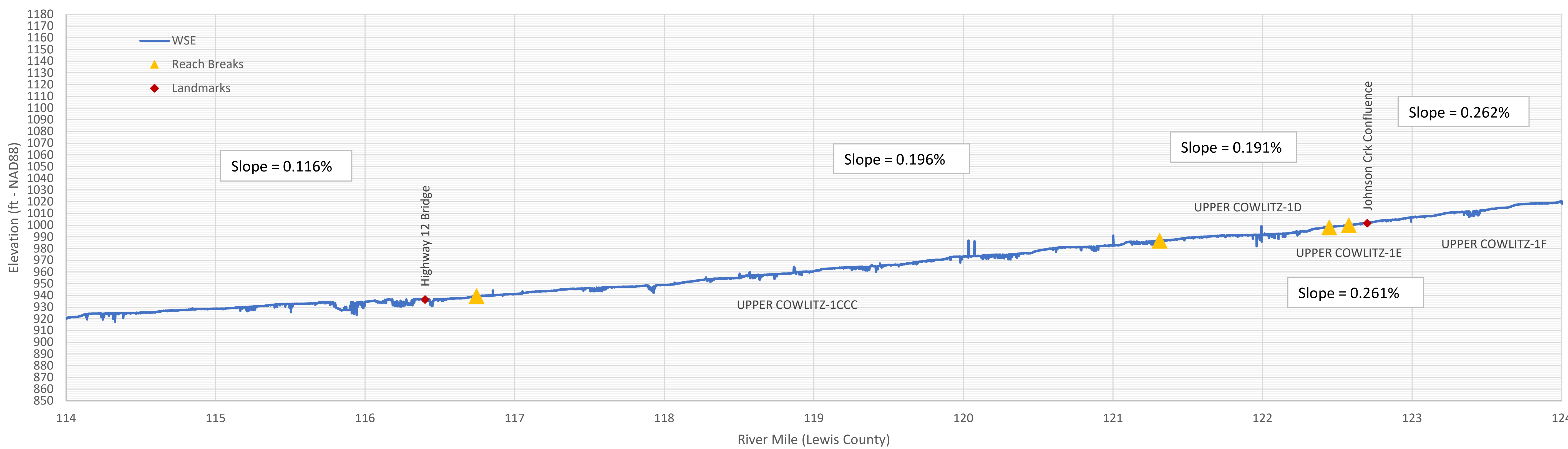

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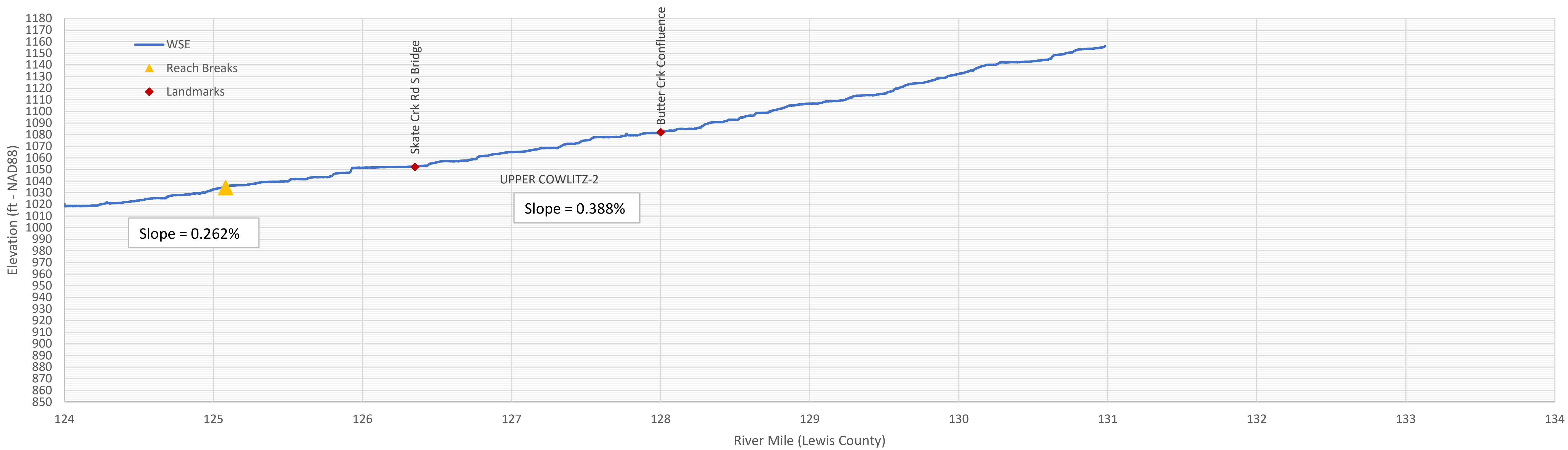

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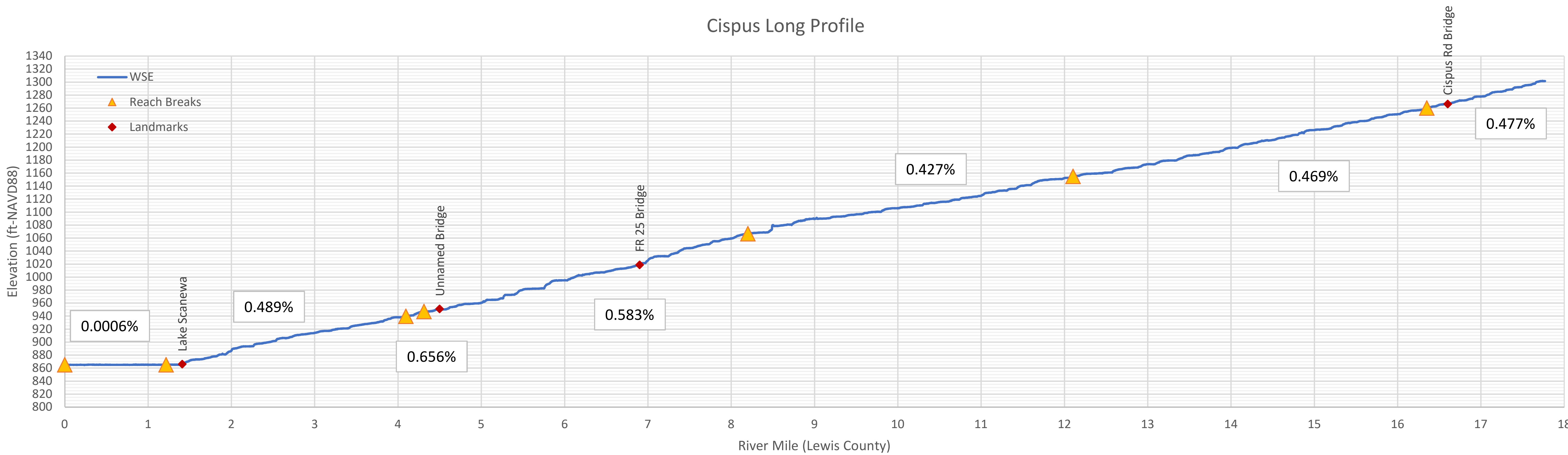

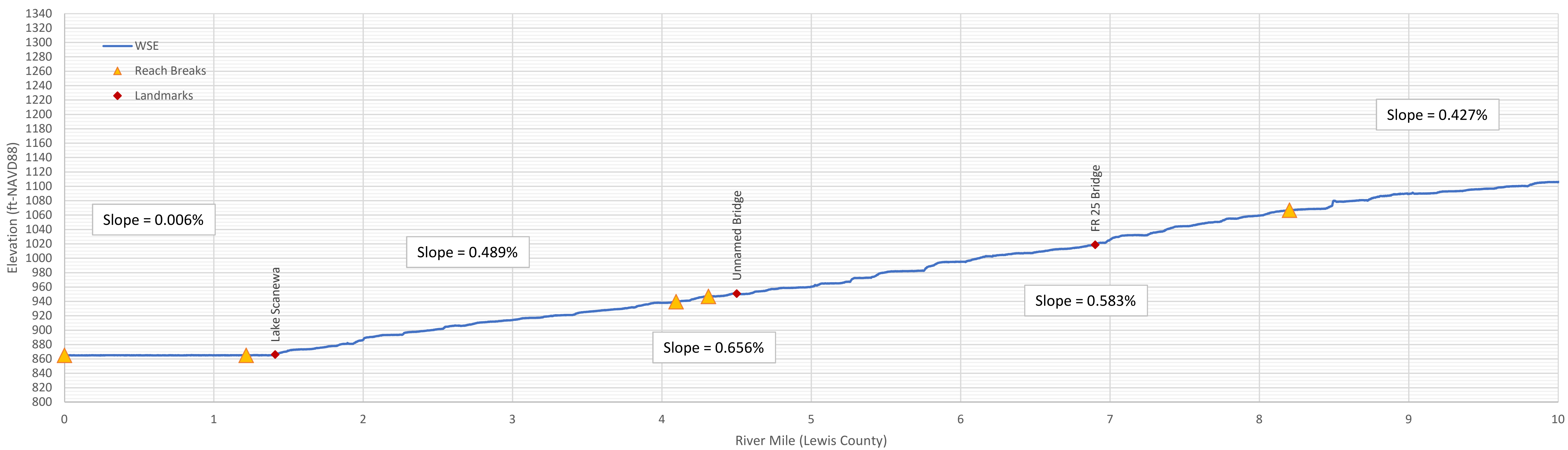

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