The Puyallup River's Response to Setback Levees

By Kiersten Wilbur

Abstract

Levees containing the Puyallup River (PR) were set back after 1996. The purpose of this study was to measure the river's response to the setback from 1990-2021. This was measured using Google Earth and three different parameters; sinuosity, width, and the River Channel Complexity Ratio. The increased almost becoming a wandering river, the width varied widely, and the channel became more 1.7 times as complex. Ultimately, Puyallup River's complexity increased, vegetation may play a larger role than originally thought, and the methods could be improved with more images during different discharge per year.

Guiding Question

How does the complexity of the Puyallup River (PR) change after the levees containing it were set back?

Introduction

Understanding how the complexity of the PR changes is important because:

- Sediment transport is altered by confining the bounds of a river.[1]
- Infrastructure near the river is at risk if flooding occurs.[2]
- Salmon rely on aspects of an unrestrained river for habitat.[3][4]

The timeline:

- 1990, original levees still in place around PR.[4]
- 1996, major flood event broke/destroyed levees on PR.[5]
- 1997, new levees installed further from PR.[5]
- 1997-2021, PR's response to levee setback.

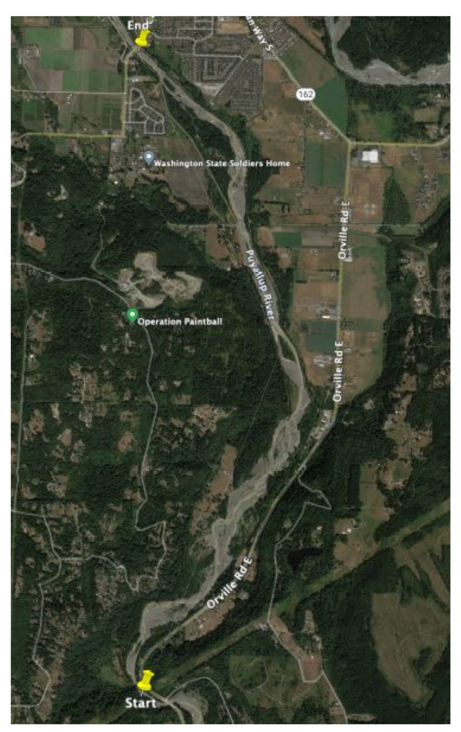


Fig. 1 Study area in relation to Washington. The red dot shows the approximate location of PR section. Pushpins show start and end points of the river.

Expectations for how PR - a straight to meandering, alluvial river - will behave:

- Levees set back: Normal flow velocity, free to meander, gravel bars form and deform through the channel altering the flow velocity.[6]
- Original levee position: Higher flow velocity, more sediment movement, less ability to form gravel bars, still meanders within its constraints.[6]

Methods

The complexity of the PR was measured in three different ways: sinuosity, width, and the River Channel Complexity Ratio (RCCR). The study area was divided into upper and lower channels (UC and LC, respectively). It's important to acknowledge that the images available were during a wide variety of flow periods, which may have an impact on the results.

- Sinuosity: For the UC and LC the ratio of the wetted channel length (L_C) and the valley length (L_V) were calculated.[6] For simplicity, only the main channel was measured.
- Width: The average width of the active channel was calculated from 10 sites of the UC and LC each.The active channel was defined as the wetted channel and where sediment with no vegetation indicated recent flow.
- RCCR: One site in the UC was considered to capture the largest range of change. All the segments were the same length as the initial segment, which was measured from a pool-riffle-pool sequence in 2021 to adequately capture the characteristics of the river. The length of the permanent bank, the inside of the point bar, and the perimeter of the gravel bars divided by the length of the permanent bank and outside of the point bar (Fig.2-3).[7]

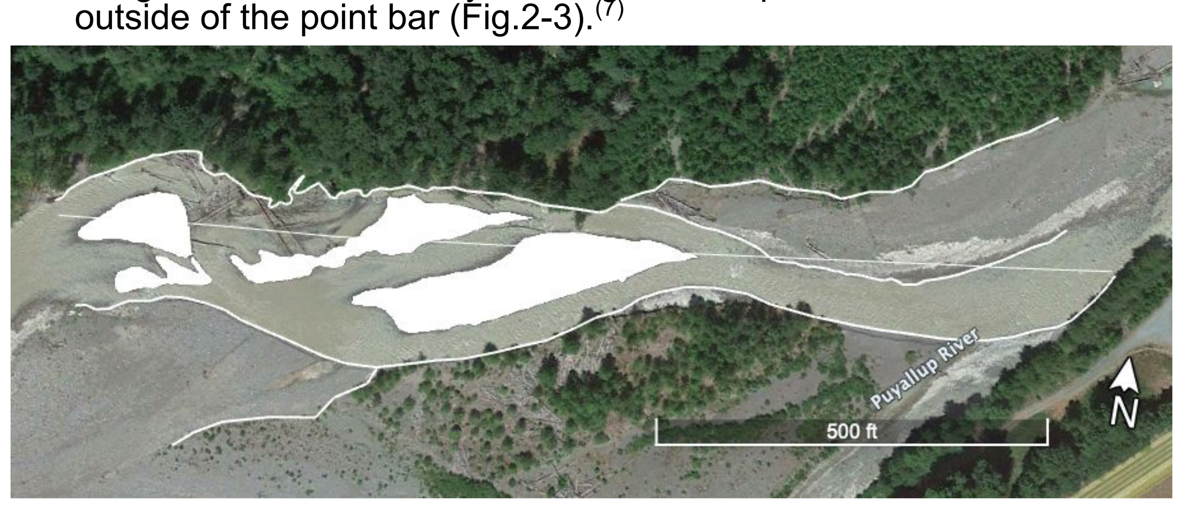
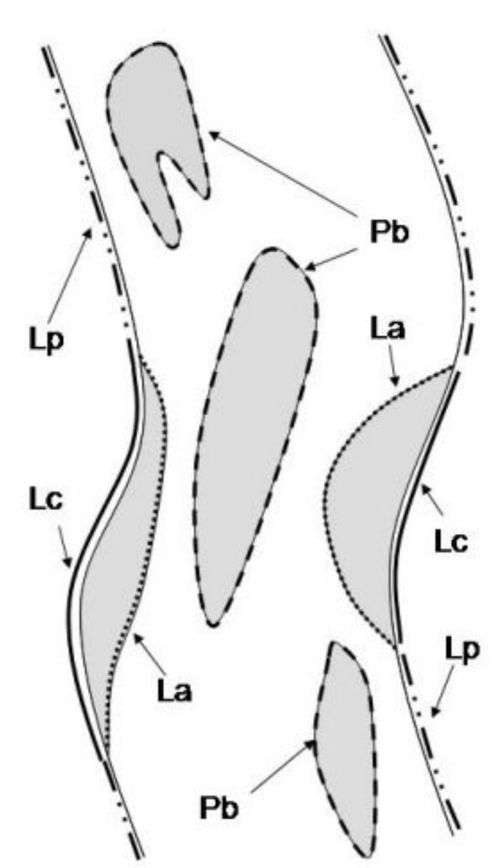


Fig 2. Solid white areas are gravel bars. Lines are permanent bank and point bars. For simplicity, very small gravel bars and channels were not interpreted as being separate from the main channel or larger gravel bars, respectively.



RCCR = (Pb + La + Lp) / (Lp + Lc)

Fig 3. Pb = perimeter of bars, Lp = permanent bank, Lc = outside of point bar, La = inside of point bar.[7]

Results

From Fig. 4-5 it is visually obvious that PR becomes more sinuous through time. Fig. 6 shows that the upstream section becomes more sinuous than the downstream section through time. However, the trend to becoming more sinuous is not tidy: the upstream section peaks circa 2007 and the downstream peaks circa 2012.

The width varied widely shown not only by the mean but the confidence intervals (Fig. 7). The UC fluctuates much more and on a larger scale than the LC. The UC differs the most in 2010. The LC has a much more constant range of confidence interval. Both the UC and LC show peak mean width in 2010.

The change in the RCCR showed an increase in complexity (Table 1). Similar to sinuosity, when RCCR = 1 there is little to no complexity. In 1990 RCCR = 1.19 and in 2021 RCCR = 1.98, which is about 1.7 times as complex as in 1990.

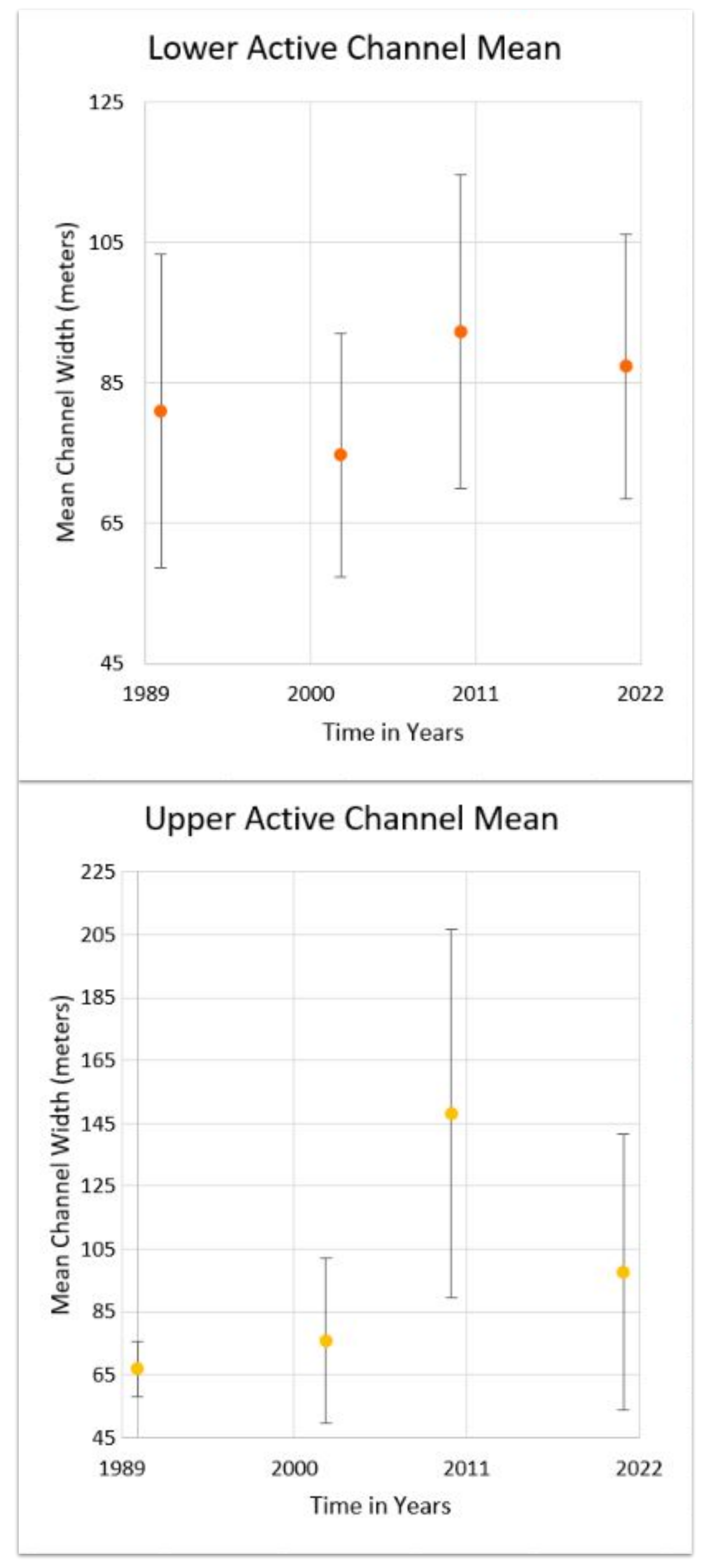


Fig. 7 Mean width of the UC and LC with a confidence interval of 95%. Note the different scale on each graph.

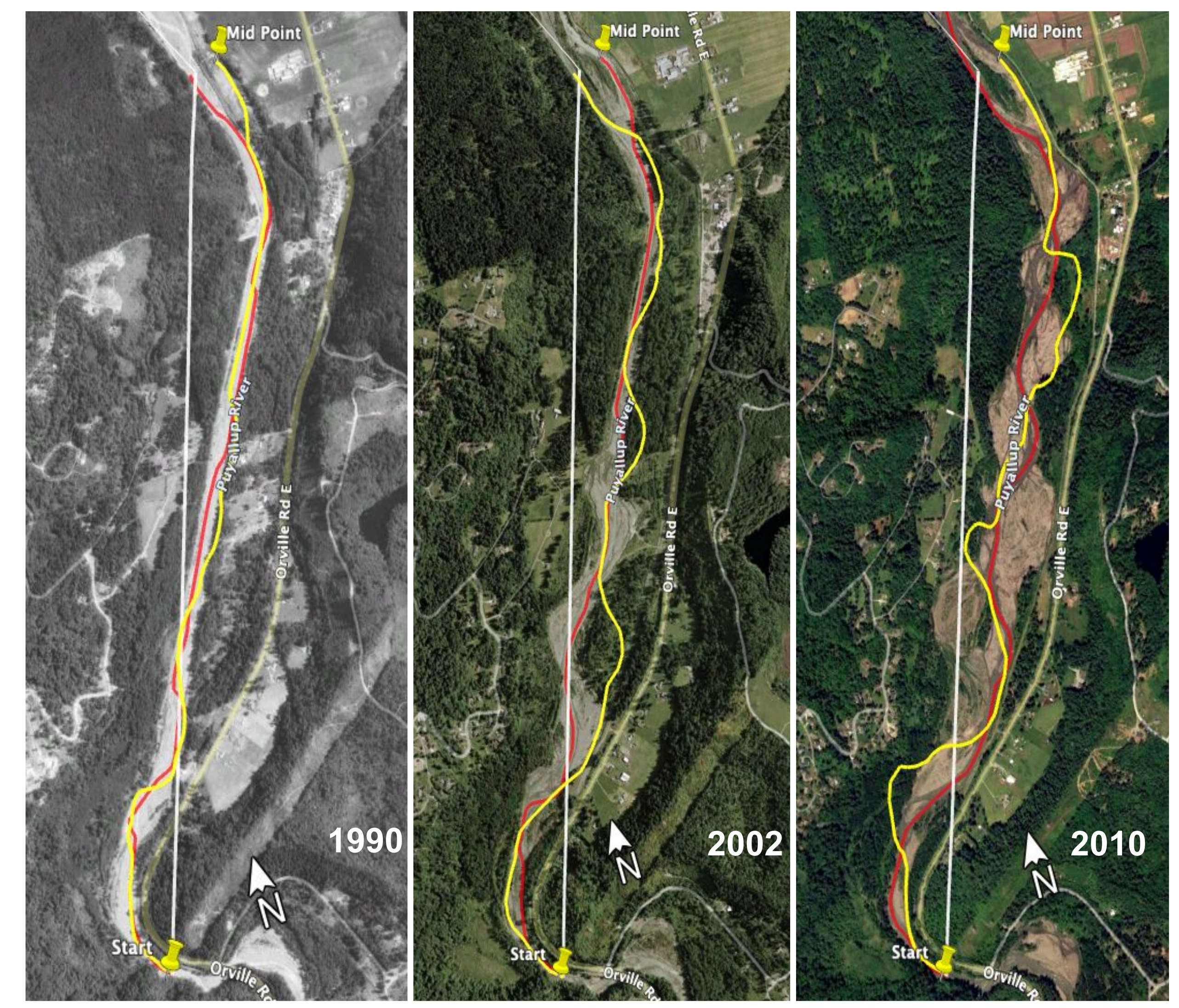


Fig 4. Three images from 1990, 2002, and 2010 of Upstream segment. Main channel of each image in red; future main channels in yellow. They show the sequential change from 1990-2002, 2002-2010, and 2010-2020 from left to right. The white line is the valley length.

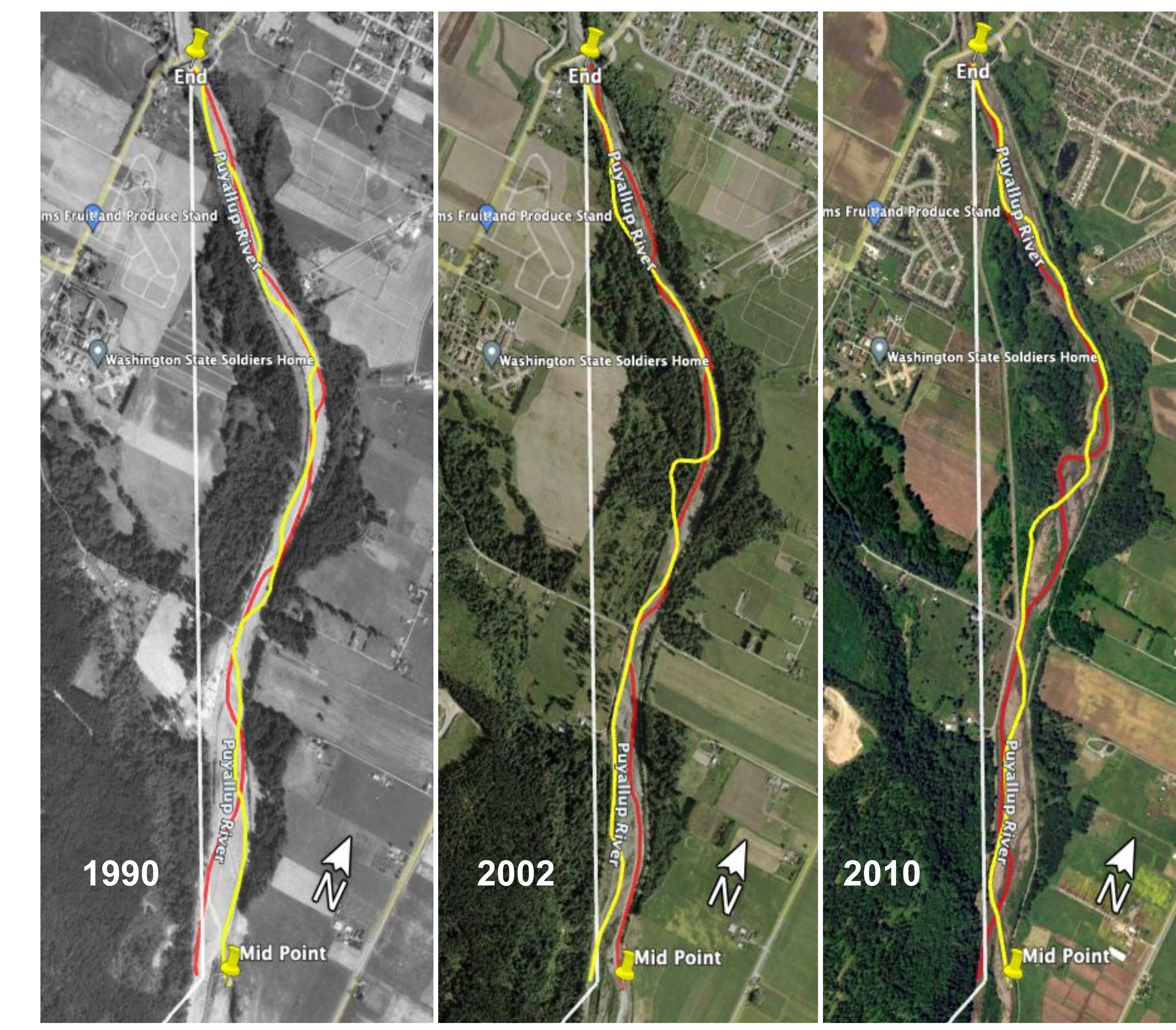


Fig 5. Three images from 1990, 2002, and 2010 of Downstream segment. Main channel of each image in red; future main channels in yellow. They show the sequential change from 1990-2002, 2002-2010, and 2010-2020 from left to right. The white line is the valley length.

Table 1. River Channel Complexity Ratio

Year	1990	2002	2010	2021
RCCR	1.19	1.57	1.38	1.98
# Gravel Bars	1	3	2	4

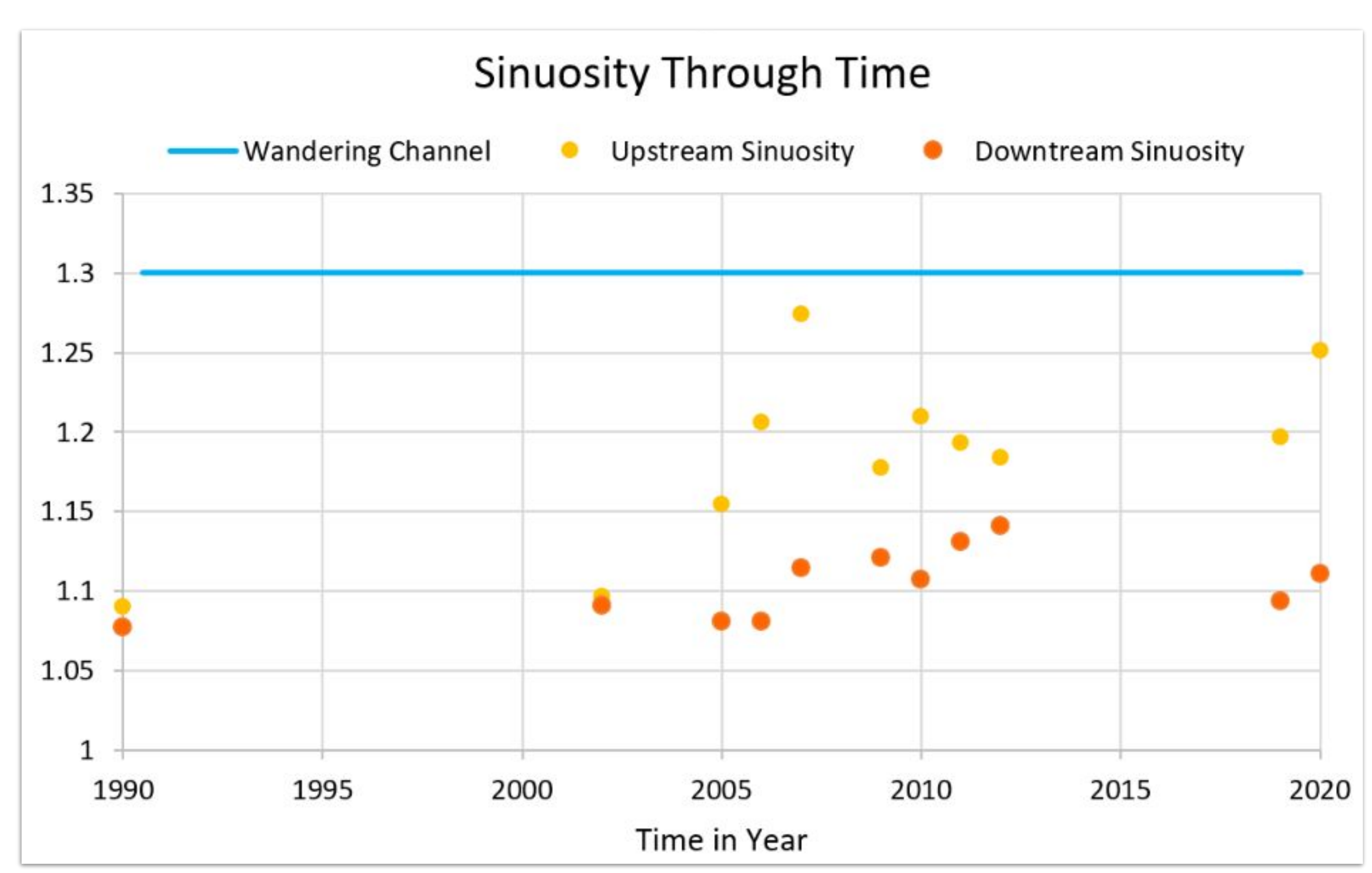


Fig 6. Sinuosity, L_c/L_v of the upstream and downstream segments. The blue line marks the transition from a straight (<1.3) to wandering channel.[6]

Discussion

From Fig. 6 the sinuosity increases faster upstream than downstream, suggesting that the changes propagate downstream. Fig. 6 also shows a hiccough where the sinuosity quickly increases from 2002-2007 and then drops off. This dramatic result may be due to a substantial difference in discharge through the years, which would either mask the complexity of the river at high discharge or accentuate it at low discharge. The highest sinuosity was measured in Nov., 2007 which had an uncharacteristically low discharge that month (USGS).

The increase of width in the UC compared to LC also suggests changes spread downstream. From 1990-2002, the UC and LC were similar magnitudes, but then the width of the UC increased remarkable. This seems to be tracking the progression of increased amplitude of the cut bank. Both width and sinuosity show a slight decrease in 2021. Also, from visual inspection, 2021 has more vegetation encroaching on the channel. This could be a result of the river becoming more stable allowing more vegetation, and since there's more vegetation the river is more stable.

The larger RCCR values seems to correspond to segments with more gravel bars. For this reason it is sensitive to the amount of water in the channel (masked vs accentuated). For this reason it is suggested that multiple measurements during different flow velocities are taken (thorp o'neill).

Conclusion

From 1990-2021 the Puyallup River changed significantly. It became more sinuous, almost reaching the status of a wandering river. Its width fluctuated quite a bit, ultimately becoming wider. And it became almost 1.7x as complex from the RCCR. Summatively, the PR became more complex. Due to the sinuosity and width from 2021 being less than the maximum sinuosity and width, the Puyallup River could be becoming more stable. This is supported by the increase in vegetation around the channel in 2021.

The effectiveness of the methods could be increased by having more images during different levels of discharge every year. Especially for measuring sinuosity and RCCR, the amount of river bed visible changes the outcome substantially.

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References

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