Memorandum

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SUBJECT: Effect of Wapato Dam Removal on Stream Profile

Introduction

Northwest Hydraulic Consultants (NHC) was retained by the Yakima County Surface Water Management Division to perform a preliminary evaluation of the impact of removing Wapato Dam on computed streambed and water surface profiles. To perform the evaluation, NHC utilized an existing SRH-1D sediment transport and hydraulic model of the Yakima River developed by the U.S. Bureau of Reclamation for Yakima County (Hilldale and Godaire, 2010).

Model Setup

Wapato Dam defines the downstream boundary of the existing SRH-1D model. The dam is located about one mile downstream of the City of Yakima and immediately downstream of natural constriction in the Yakima River corridor referred to as Union Gap. Wapato Dam is a diversion structure consisting two low head spillways, each with a crest elevation of approximately 940.5 ft (Hilldale and Godaire, 2010). The downstream-most cross-section at River Station (RS) 19.78 of the model includes the dam structure itself as well as an embankment spanning the entire 700-ft wide left overbank elevated approximately 8 to 10 ft above the surrounding floodplain. Downstream boundary conditions at the dam were defined by a rating curve assuming critical flow occurs over the crest of the structure.

Removal of the dam structure from the model was accomplished by replacing the original cross-section geometry at RS 19.78 (i.e. the dam and embankment geometry) with the geometry from a cross-section located upstream of the dam at RS 827.64. The geometry at RS 827.64 consists of a single-thread channel with an adjacent overbank floodplain at natural grade typical of that observed upstream of the dam. To approximate the formation of a "pilot channel" immediately following dam removal, the newly inserted cross-section geometry at RS 19.78 was lowered uniformly by 10 ft. The geometry of the next cross-section upstream (RS 298.77) was lowered uniformly by 5 ft. Figure 1 shows the original cross-section geometry at RS 19.78 (with dam) and the replacement geometry copied from RS 827.64 (dam removed).

To account for changes to the downstream boundary condition following dam removal a new rating curve was computed using a duplicate HEC-RAS hydraulic model. The new rating curve was computed assuming normal depth with an estimated slope of 0.0026, for discharges ranging from 300 to 70,000 cfs. The rating curve based on normal depth was then inserted into SRH-1D model for all dam removal runs. The same upstream boundary conditions for each run relied on the same hydrologic time series and sediment inflows as that in the Bureau's original model (Hilldale and Godaire, 2010). The specific hydrologic time series utilized for these SRH-1D runs included an average 25-year hydrograph based on observations from water years 1985-2009. The Bureau determined that this record would best represent probable future hydrology.

Two different dam removal scenarios were evaluated to test the sensitivity of varying the width of active channel erosion on the degradation profile. Scenario 1 uses the same erosion limits utilized in the Bureau's model, i.e. erosion is allowed to occur across the entire cross-section. Scenario 2 sets the erosion limits to the active bank stations at each cross-section between the dam (RS 19.78) upstream approximately three miles to RS 15646.45. This location corresponds to the downstream limit of the existing levee structure on the left overbank of the Yakima River.

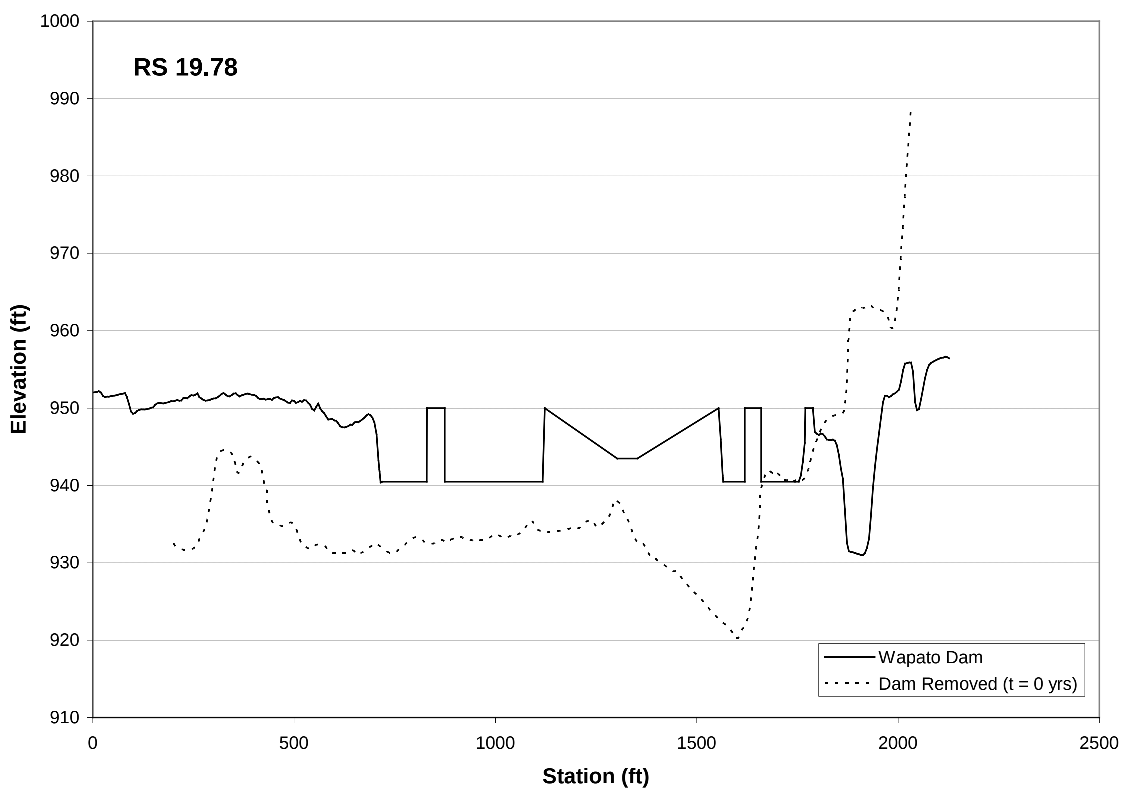

Figure 1. Comparison of downstream boundary cross-section with and without Wapato Dam.

Results

Figure 2 compares the existing (with dam) streambed profile with those computed by the SRH-1D model 25 years after removal of Wapato Dam. Results from both Scenarios 1 and 2 show a similar pattern of degradation of the streambed profile with 2 to 10 ft of vertical incision computed between the Wapato Dam to approximately 1.7 miles (9,000 ft) upstream. However, slightly less degradation is computed under Scenario 1 from 3,500 ft to 5,500 ft upstream of the dam. Both Scenarios 1 and 2 show little degradation upstream of the 1.7 mile station.

Figure 2 also shows the computed flood profiles for the estimated 100-year event. Flood profiles were computed using HEC-RAS and the channel geometry computed by SRH-1D after 25 year runs. The 100-year discharge, as reported in a preliminary draft of the Yakima County Flood Insurance Study (FIS), is 59,700 cfs (FEMA, 2009). Results indicate that removal of the dam would decrease 100-year flood levels by 2 to 11 ft up to 1.7 miles upstream of the dam, with the most pronounced decrease occurring in the first 1,000 ft immediately upstream of the dam. Upstream of the 1.7 mile river station, computed changes in flood levels from dam removal are negligible.

The computed flood level is not particularly sensitive to the different erosion limits set in Scenarios 1 and 2. It is interesting to note that while Scenario 2 results in generally lower streambed elevations the flood levels are slightly higher compared to Scenario 1. A likely explanation is that the Scenario 2 erosion limits (set to the active bank stations) do not allow deposits in overbank areas to be eroded. As such aggradation can occur unimpeded in the overbanks resulting in a net decrease in conveyance area and slightly higher computed water levels.

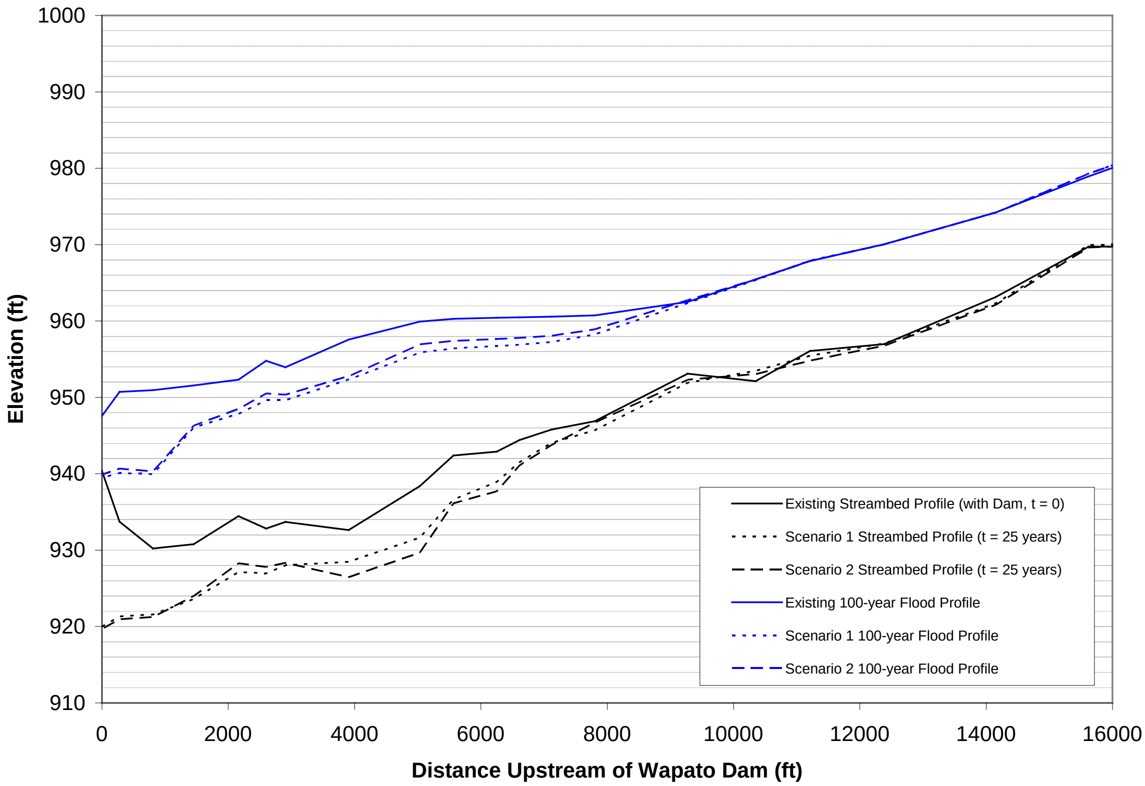

Figure 2. Comparison of streambed and 100-year flood profiles for existing conditions and those computed 25 years after dam removal.

Figure 3 illustrates the evolution of the Scenario 1 streambed profile over 25 years. In the first year a substantial amount of degradation is computed in the 2,500 ft reach immediately upstream of the dam. This type of rapid degradation would likely be caused by upstream migration of a knickpoint. After the first year, as the local stream gradient is reduced, degradation occurs more uniformly, but at varying rates, along the lower 1.7 miles of the study reach.

It is interesting to note that from year 10 to 15 the rate of vertical degradation appears to double compared to the previous 10 years. A cursory glance at the 25 year average hydrograph, shown in Figure 41 of the Bureau's 2010 report, may provide a partial explanation. This hydrograph indicates that during this 5 year period (1994-1999) relatively high flows with a corresponding increased transport capacity occurs annually. Following this period, in years 15 to 20, some aggradation is computed to occur along a portion of the lower 1.7 mile reach possibly as a result of the relatively 'dry' period between observed between 1999 and 2004 (Hilldale and Godaire, 2010, Fig 41). The last 5 years of the SRH-1D model run results in relatively little change to the streambed profile which indicates an approach toward equilibrium.

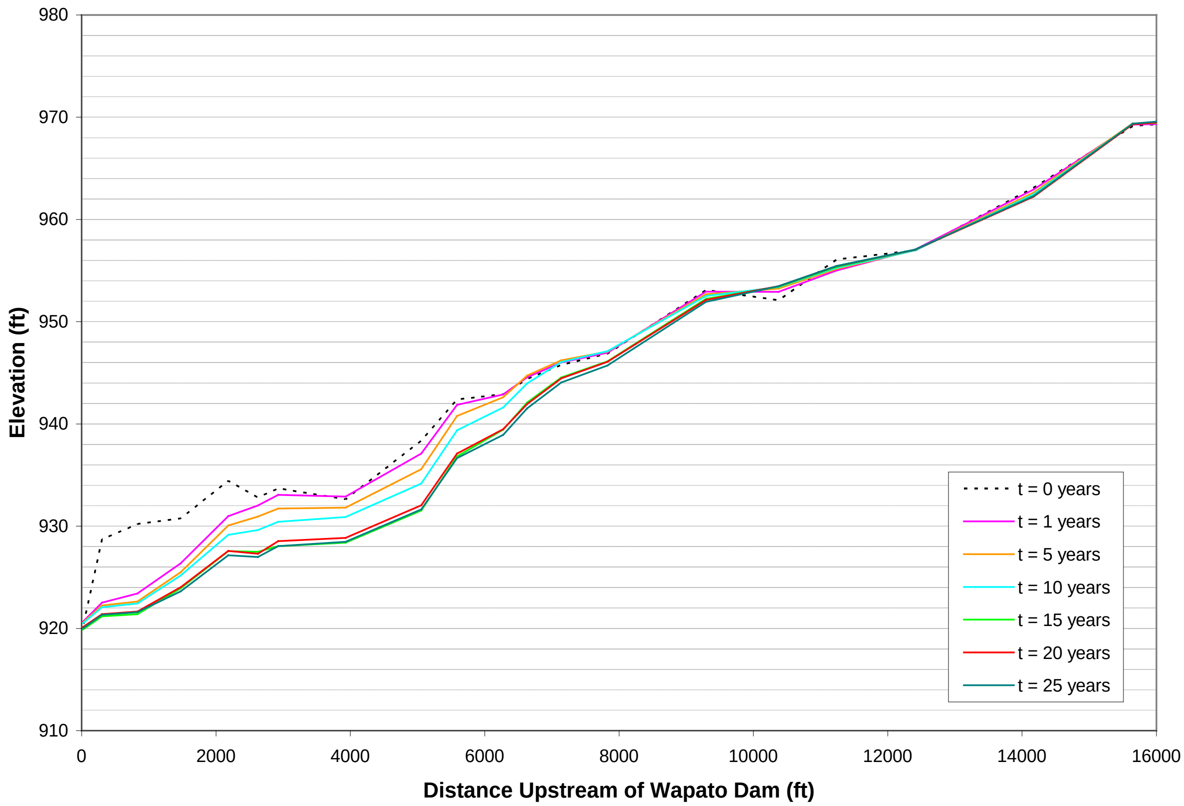

Figure 3. Evolution of the streambed profile.

Further evidence of equilibrium is suggested by the change, relative to the initial condition (t = 0 years) of thalweg elevation and surface median particle diameter (D50) over time as shown in Figures 4 and 5, respectively. Each of these figures present results computed under Scenario 1 at six select cross-sections. Figure 4 shows that changes to thalweg elevation towards the end of the 25 year run begin to approach a constant, or near constant, value. Figure 5 indicates that D_{50} sediment size initially increases with coarsening of the surface material at the four lowest cross-sections in the reach, which is characteristic of degradation processes in gravel-bed rivers. However, towards the end of the 25 year run, the change of D_{50} size over time either becomes negligible or alternates within a coarser range (e.g. RS 2620.78 and 5052.80). This may be due, in part, to finer material being deposited during the previously mentioned "dry" period observed between years 15 to 20.

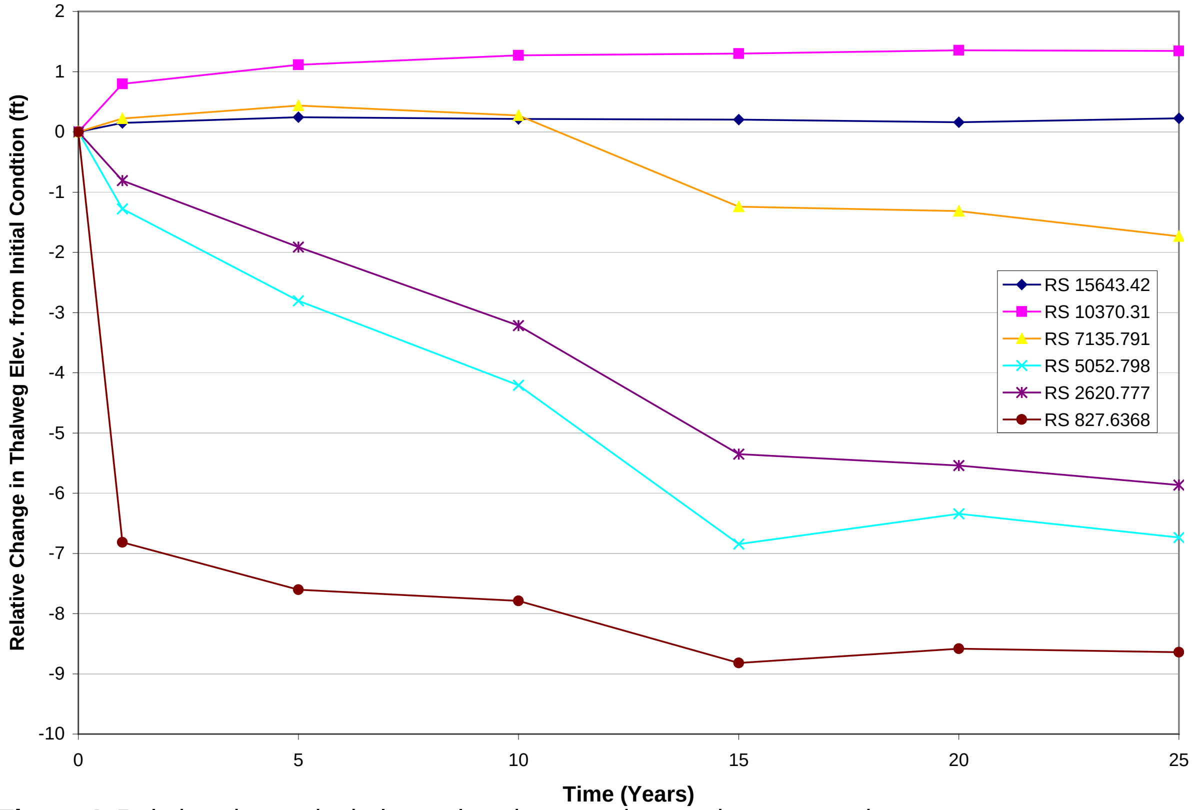

Figure 4. Relative change in thalweg elevation over time at six cross-sections.

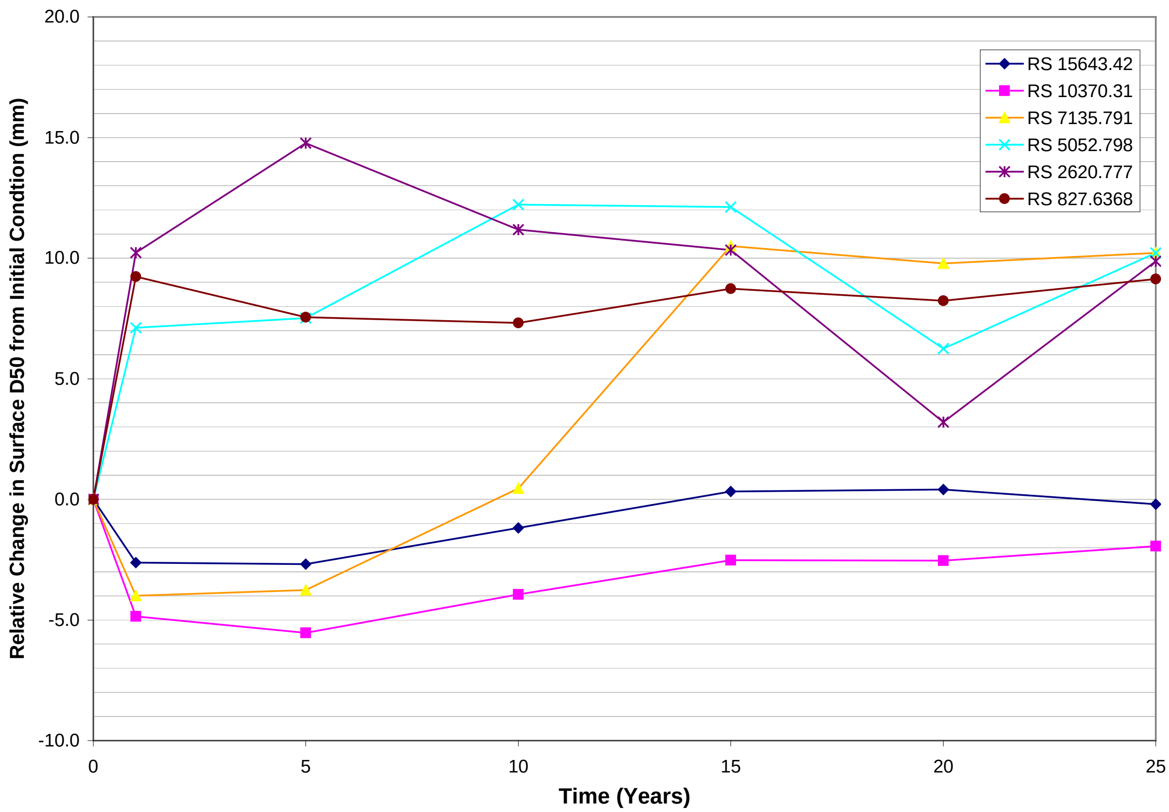

Figure 5. Relative change in surface D50 over time at six cross-sections.

Figure 6 illustrates the evolution of the channel cross-section over the 25 years for Scenario 1. The selected cross-section is located at RS 827.64, approximately 800 ft upstream of Wapato Dam. A pattern of rapid vertical incision followed by upstream knickpoint migration and channel widening is observed. Similar patterns have been observed following the recent removal of Marmot Dam on the Sandy River in Oregon (EOS, 2008), and Condit Dam on the White Salmon River in Washington (http://www.ecy.wa.gov/programs/wr/cwp/condit.html).

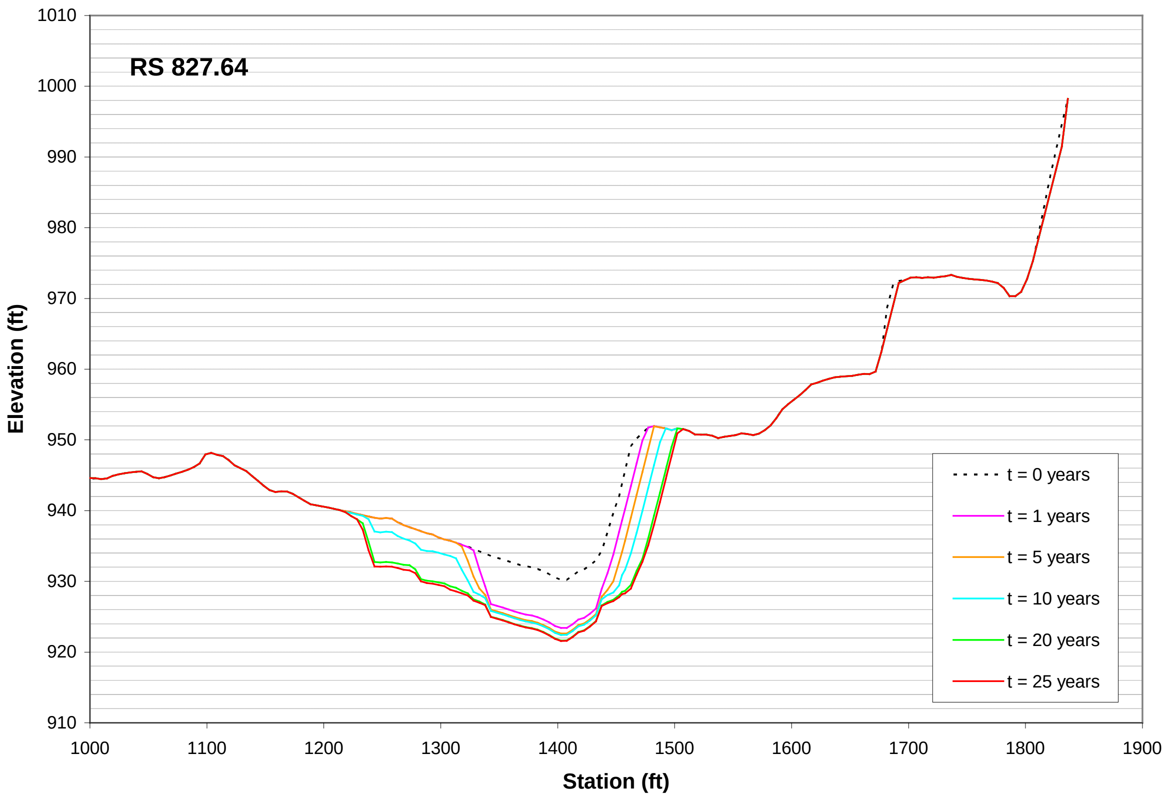

Figure 6. Evolution of cross-sectional profile at RS 827.64.

Conclusion

Removal of Wapato Dam will have impacts on both streambed and water surface profiles; although, the impacts are expected to remain within the approximately 1.7 mile (9,000 ft) reach immediately upstream of the dam. Computed results from the SRH-1D sediment transport and hydraulic model show significant streambed degradation occurs rapidly after dam removal with continued degradation propagating further upstream over the longer 25 year period. Patterns of degradation also suggest that equilibrium is attained within 25 years, meaning impacts related to dam removal are not likely to propagate further upstream over a longer period. In general these computed results appear reasonable when compared to observations made following recent dam removals. Regardless, results from a sediment transport model should be interpreted cautiously and as only indicators of general trends and time scales. The results presented in this preliminary assessment are indicative and more detailed analysis would need to be carried out to quantify potential hydraulic benefits and impacts if it were decided to proceed with this option further.

References

EOS. 2008. "Initial Fluvial Response to the Removal of Oregon's Marmot Dam". Transactions, American Geophysical Union. Vol. 89. No. 27. July 1.

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Hilldale, R.C., and Godaire, J.E. 2010. "Yakima River Geomorphology and Sediment Transport Study: Gap to Gap River, Yakima, WA". United State Bureau of Reclamation (USBR) Tech Report No. SRH-2010-08. November