DISCUSSION

By

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Decisions in the field of water development and management should aim toward the preservation of the integrity of the hydrologic continuum (Leopold 1990).

This research combines the best available science from the fields of riverine and cultural ecology into a holistic assessment of current conditions on seven alluvial floodplains in the Yakima River basin. Using a summary of conditions for each floodplain as a case study in the evolution of cultural landscapes, this discussion focuses on how cultures define resources and how the application of those definitions affects biophysical systems.

Since Euroamerican settlement of the Yakima River basin began, resource use has focused on extraction activities. These activities have altered the fluvial geomorphic processes that initiate and sustain the ecological structure and function of the basin's large alluvial floodplains. Flow regulation and reductions in lateral connectivity are two fundamental factors responsible for these alterations. Flow regulation alters the timing and size of peak flow events, while the loss of lateral connectivity extends the effects of flow regulation across its lateral scale and further along the longitudinal scale of the river than would otherwise occur.

Because cultural ecology acknowledges the essential and variable interactions of people to the landscapes they inhabit, it is an appropriate tool for understanding how and why the alluvial floodplain reaches of the Yakima basin have been altered.

CULTURAL ECOLOGY

Rivers underscore the foundation of nearly all cultures, but our perception of what rivers are and of our relationship to them varies widely. Consequently, as resource thresholds are approached or crossed, conflicting interests within and between cultures usually arise. This is the case in the Yakima River basin today.

Cultural appraisals of available resources help define and justify strategies for utilizing, maintaining, and enhancing those resources. How we assess our resources ultimately dictates the value we place upon them. These values have been translated into a system of various policies, laws, and regulations now governing land and water resources that define their distribution and use at the local, regional, and national scales (Fraser 1996). Intensifying land use across all of these scales has begun to alter how rivers are perceived, used, and managed. Some individuals and groups now place a higher value and meaning on rivers that function like rivers, rather than just for the resources they provide. The Independent Scientific Group highlights this new value, embodied in the concept of a normative river:

> We recognize that, because we are dealing with an ecosystem that has sustained extensive human development for over 150 years, numerous social and biophysical constraints exist for enhancing normative conditions. The challenge before the region is to reach consensus on the extent to which these constraints can be relaxed or removed to achieve Fish and Wildlife Program goals. Nevertheless, we believe strongly that approaching more normative ecosystem conditions is the only way in which Fish and Wildlife Program goals for recovery of salmonids and other fishes can be met (Independent Scientific Group 1999).

Given the Yakima River basin's critical role within the broader context of anadromous fish recovery throughout the Pacific Northwest, it is imperative that we as a culture adopt this concept.

THE CULTURAL ECOLOGY OF THE YAKIMA RIVER FLOODPLAINS

Cultural alterations to the large alluvial floodplains of the Yakima Basin result from how we have chosen to define them as a resource. Current and popular uses range from the obvious: transportation corridors for railroad and road systems, irrigation and its attendant structures, gravel mines, flood levees, farming, ranching, logging, agricultural processing facilities, sewage treatment facilities, hydroelectric plants, primary and secondary residences, scrap yards, landfills, and a host of recreational activities--to their less obvious affects: altered thermal regimes, reductions of sediment transport, reductions in surface water/groundwater interactions, altered groundwater flow paths, exotic species introductions, and truncated lateral connectivity. These activities reflect our culture's appraisal of the Yakima River's value and are part of a larger, complex cultural landscape focused on and supported by its large alluvial floodplains (Johnson 1994). The cultural ecology of today's river is the primary force directing the evolution, persistence and extinction of species, populations, communities, landforms, and ecosystems. It is within the context of cultural ecology that resource management opportunities must be considered.

RESOURCE MANAGEMENT

Since they are inseparable, it is necessary to understand the interconnectedness of cultural activities and resource management (Haydon 1997). Cultural ecology can impede or facilitate efforts toward preservation, enhancement, and management of fish and wildlife within the Yakima River basin. Therefore, the adaptation and survival of most riverine populations depends on how resource management systems handle the details of river ecology (Arango 2001).

In the Yakima basin, an increasingly complex mosaic of cultural uses has incrementally altered landscape-scale processes that created and maintained a functional ecological legacy. It is now clear that restoration of altered riverine ecosystems is not only desirable and possible, but also requisite to preserving future opportunities and our quality of life.

Driven by shifts in land use and the accompanying decrease in fish and wildlife habitat, a new direction in resource management emerged in the late 1970s. This trend, related to an increasing knowledge of ecological and biophysical interactions, encompassed international, national, regional, landscape, and place scales. In the Yakima Basin, resource management agencies shifted away from extraction to focusing on preservation, recovery, and maintenance of aquatic resources (Washington 1971; Washington 1989). Recently, management goals have expanded to encompass the acquisition of remnant habitats that contain vestiges of ecological integrity. This activity, initiated by various federal, tribal, state, county, and municipal entities, attempts to form partnerships with industry, conservancies, foundations, and citizens. Acquiring habitat, reconnecting parceled land, and re-establishing truncated ecosystem processes is essential for restoration of threatened and endangered species. In 1994, the 103rd Congress passed H.R. 1690, commonly known as the Yakima River Basin Water Enhancement Project (U.S. Congress, House 1994). Unprecedented in the history of the basin, culturally meaningful and legally mandated goals for preservation, restoration, and enhancement of the basin's ecological integrity drove passage of this bill.

It is within the complex cultural ecology of the Yakima River basin that this study outlines the direction of historic change and current conditions of the major alluvial floodplains relative to flow regulation and lateral connectivity. We offer these details with the recognition that increasing ecological integrity throughout the Yakima River basin can only occur though a comprehensive and diversified effort by agencies, groups, and individuals.

FLOODPLAIN SUMMARIES

This research project directly and indirectly documented the following consequences resulting from flow regulation and disruption of lateral connectivity (figure 7):

- ·Desiccation of aquatic habitat
- ·Reduction in the area available for lateral exchange of matter and energy between the river and the floodplain
- ·Acceleration of hydrarch succession
- ·Reduction in the formation of floodplain water bodies
- ·Reduction in the succession of alluvial forests

Ward and Stanford (1995) synthesize and elaborate these points, and Braatne and Jamieson (2001) address riparian forest senescence specifically in the Yakima River system. Although areal measurements were not specifically made for each of these consequences, the floodplain metrics generated clearly document their occurrence on each floodplain.

The processes of flow regulation and lateral confinement have decreased the spatial extent of the active floodplain zone and decreased the ability of flow pulses to dissipate energy laterally across all seven floodplains. In each floodplain, channel forms are tending toward those found in gorge functional sectors due to confinement of the river system by railroads, roads, and flood revetments. This confinement causes simplification of riverine ecosystems, increases the potential for channel entrenchment, and ultimately decreases biomass production (Amoros et al. 1987). Channel entrenchment reduces the ability of floodplains to store water during peak flow events and store nutrients for riparian forest use (Steiger, James and Gazelle 1998).

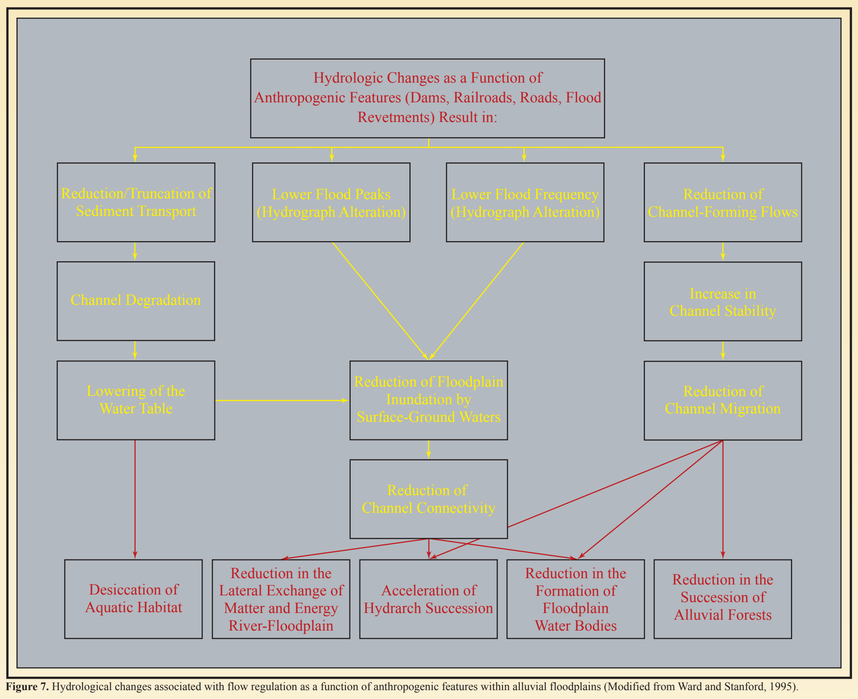

Figure 7. Hydrological changes associated with flow regulation as a function of anthropogenic features within alluvial floodplains (Modified from Ward and Stanford, 1995).

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Plate XXV. Discussion.

The consequences of lateral confinement are nowhere more obvious than in the Selah floodplain. The log drives of 1902-1913 initiated confinement followed by reductions in flood frequencies and flood peaks attributable to upstream irrigation storage. Cumulatively, this led to fewer channel forming-flows, increased channel stability, and reduced channel migration (Ligon, Dietrich, and Trush 1995). Floodplain mining necessitated extensive flood revetment systems, and expanded confinement-initiated channel degradation, which further reduced floodplain inundation and channel connectivity. Elaboration of railroads, roads, and flood revetments exacerbated the consequences of lateral confinement and flow regulation.
Today the river expresses channel forms similar to a gorge functional sector. Structural and functional restoration of the shifting habitat mosaic typical of the historic floodplain is problematic.

The Selah floodplain was a premier indigenous fishery a short 150 years ago. In 1856, Colonel Wright of the United States Army underscored the importance of the Naches, Selah and Union Gap floodplains to indigenous people:

> I am now in the very heart of the Yakama Country; this river abounds with fish, and is a real resort for the Indians early in the season. This river [the Naches] flows into the Yakama about five miles below this point; hence I am within an hours ride of all the great fisheries of the Yakamas (Wright to Jones, May 18, 1856).

Where Selah represents a worst-case scenario in terms of floodplain degradation, the Wapato floodplain comprises 39% of the total remaining Holocene floodplain and 49% of the total remaining hydrologically active floodplain habitat across the seven floodplains examined. Almost half of the hydrologically active floodplain area in the Yakima Basin is found in the Wapato reach alone, underscoring the scale of loss to the Yakima Basin through flow alteration and lateral confinement processes on this floodplain. The Wapato reach is a gateway to enter or leave the basin from the other floodplains. As such, its geographic position amplifies the significance of inadequate flow and excessive thermal conditions to migrating fish and ecological connectivity (Lilga 1998; Conservation Advisory Group 1997; Pearsons et al. 1996).

Flow alterations through the Wapato floodplain seriously diminish its ecological structure and function by desiccating floodplain water bodies and reducing channel connectivity. Irrigation withdrawal throughout the summer exacerbates these problems by reducing flow stage. Preservation and restoration of critical floodplain habitat would result from increased summer flows (Stanford et al. 1996) and would augment longitudinal connectivity within the larger Yakima River watershed.

Current habitat acquisitions by the Yakama Nation, combined with lands managed by Washington Department of Fish and Wildlife and others, are important steps toward preserving and expanding critical floodplain habitat; however, these efforts must be accompanied by changes in flow regulation strategies that create and maintain a shifting habitat mosaic.

The Union Gap floodplain, directly upstream from the Wapato, is associated with the most intensive land use in the Yakima River basin. The urban-industrial matrix has radically transformed its planimetric configuration, most obviously in the upper three-quarters of the floodplain. The lower end of the Union Gap floodplain has significant potential for preservation and enhancement of ecological connectivity, especially in the legacy of channel complexity east of the river (Snyder and Stanford 2001). Restoring fluvial geomorphic processes would necessitate bridge redesign, flood revetment setback, and a normalized flow regime, activities requiring substantial land acquisition for their full effect to be realized.

Truncation of peak flows from the Tieton Reservoir and lateral confinement has altered ecological processes on the Naches floodplain. However, the Naches floodplain maintains a structural mosaic that resembles what one would expect in an unaltered cut-and-fill alluvial floodplain when compared to the Union Gap, Selah, Kittitas, Cle Elum, and Easton floodplains. In part, this results from the normal timing of spring peak flows despite the scaling down of their magnitude by 25% from estimated unregulated peak flow. In contrast, the distinctly aberrant late summer spike in flow (plate VIII) is unprecedented in the natural hydrographs of western rivers. Although the magnitude of flip-flop discharge in the Naches system does not equal the spring melt, this abnormal flow peak likely has a profound impact at multiple ecosystem levels. Additionally, flow withdrawal at Wapatox Power Canal initiates low flow conditions and reduces longitudinal channel connectivity for several kilometers downstream from the diversion point in July, August, and November (Croci 2002). However, the Wapatox Power Canal exacerbates low flow conditions that exist because of BOR's flow storage for the annual flip-flop operation. Preservation and expansion of the potentially active floodplain area is critical in the Naches and expansion is essential in areas where lateral confinement creates gorge-like conditions and alters sediment transport processes.

Culturally defined by I-90, confinement in the middle of the Kittitas floodplain narrows the active foodplain width to an anthropogenic gorge, simplifying channel forms and complexity. In combination with upriver railroad bridges and flood revetments, I-90 effectively divides the Kittitas into two floodplain areas where cut and fill alluvial processes could potentially function. Lateral confinement and flow regulation in the Kittitas floodplain translates to extreme limitations in the river's ability to create and maintain a shifting habitat mosaic. Furthermore, irrigation diversions and dewatering of creeks has caused the disconnection of major tributary watersheds from the Kittitas floodplain and Yakima River, a significant loss of watershed connectivity within the Yakima Basin. Reconnecting tributary streams and expanding the Holocene floodplain area available to fluvial processes are essential strategies for increasing biodiversity and biocomplexity. Even more pressing is preservation of areas where connectivity is still high, for example the areas east of Thorp and at the downstream end of the Kittitas floodplain.

The Cle Elum floodplain is characterized by altered flow dynamics and effective lateral confinement from the top of the floodplain to the I-90 Bridge. Upstream from South Cle Elum, the river appears disconnected from the potential floodplain area by entrenchment and confinement against the NPRR bed. The lower end of the floodplain below the I-90 Bridge appears to be less altered than areas upstream. The highly constrained upstream river channel and the marked braiding and anastomosing zone at the lower end of this floodplain suggest anthropogenic activities have led to hydraulic tilting (*sensu* Creuze des Chatelliers, Poinsart, and Bravard 1994). This phenomenon causes the shallow floodplain aquifer to dewater while shifting the zone of groundwater infiltration from upstream to downstream. It is likely that this scenario is occurring on other floodplains in the basin where their upstream end is laterally confined. The downstream zone below the I-90 Bridge is under increasing developmental pressure. Floodplain area preservation strategies are critical and immediately needed if a legacy of increased lateral confinement is to be avoided. Floodplain expansion and increased connectivity at the upstream end of the floodplain may be achieved and probably will require relaxing of lateral constraints in the middle portions of the floodplain.

The Easton floodplain has experienced extreme development pressure, and land ownership maps demonstrate the potential for future development. These factors are problematic to establishing a more normative hydrograph and expanding the lateral extent of the floodplain; processes essential to maintaining cut and fill alluviation required for the habitat template. The highest restoration potential probably exists at the upper end of the floodplain where current development is less intense. Re-establishing flood flows between Pine Glen and Pine Valley, where subdivisions dominate floodplain land use, will be difficult. However, failure to initiate such flows will further alter cut and fill alluvial processes that provide essential ecological structure and function. Connectivity between the Cle Elum River and the Yakima River at the lower end of the floodplain must be preserved. Reconnection with tributary streams in the middle and upper end of the floodplain will extend connectivity to a larger watershed area.

CONCLUSIONS

These floodplains are clearly distinct, set apart by geographic position in a varied landscape, both physical and cultural. Nevertheless, they are clearly connected by biophysical and cultural processes at multiple spatial and temporal scales. This complexity requires careful attention. Preservation and restoration strategies need to be developed for all of these floodplains, and the challenges faced will vary within and between each. Clearly, preservation and restoration plans must be ecologically based. Planning for the future of these floodplains must be detailed and carefully coordinated among multiple entities. Plans that work successfully toward re-establishing floodplain biophysical connectivity must begin by recognizing, establishing, and enhancing normative processes.

It is absolutely clear that the hydrographs of all these floodplains exhibit radical departures from historic conditions. It is also obvious that floodplain land use has developed in relationship to these cultural hydrographs, pointing to and implicating an unplanned association between flow regulation and lateral confinement. The combination of aberrant flow dynamics with lateral confinement locks fluvial geomorphic processes in place and precludes the occurrence of normal processes that provide ecological structure and function on the floodplains.

This study has demonstrated that land use activities have truncated lateral connectivity across the major alluvial floodplains of the Yakima Basin. Furthermore, flow regulation has altered the processes that generate and maintain a complex habitat template. Connectivity within an ecosystem is fundamental to its structure, function, and ultimately, the persistence of its given plant and animal communities. If the processes of flow regulation and disconnection are not reversed in Yakima Basin floodplains, they will continue to reduce the capacity of the ecosystem to support a complex and shifting habitat mosaic.

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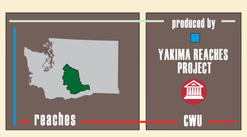

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Plate XXVI. Discussion.

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Appendix I

Raw Numerical Data for Seven Major Floodplains of the Yakima River Basin

	Easton				Cle Elum				Kittitas				Selah				Union Gap				Wapato				Naches			
	Total	T3	T2	T0	Total	T3	T2	T0	Total	T3	T2	T0	Total	T3	T2	T0	Total	T3	T2	T0	Total	T3	T2	T0	Total	T3	T2	T0
Size of the Holocene Floodplain (hectares)																												
	2687.93	1692.46	1536.89	1053.85	1749.32	1055.26	928.15	717.25	5420.15	3334.34	2735.14	1709.33	1182.17	1024.56	950.49	371.24	2324.86	1839.85	1592.03	921.47	26868.52	8285.75	7227.41	3968.99	3341.87	2548.14	1530.08	1421.71
Size of the Hydrologic Floodplain (hectares)																												
	X	X	749.26	468.23	X	X	497.70	333.91	X	X	1024.05	685.27	X	X	356.09	126.33	X	X	807.53	583.86	X	X	2951.33	2732.69	X	X	803.34	688.98
Channel Types on Holocene Floodplain (meters)																												
eupo1	X	X	29376.98	31979.14	X	X	25352.49	21512.63	X	X	45564.46	42651.31	X	X	18130.09	11304.73	X	X	32739.46	18523.04	X	X	76307.43	75822.80	X	X	40989.23	40643.57
eupo2	X	X	13443.67	6226.91	X	X	11871.75	7195.89	X	X	24741.60	16316.06	X	X	12836.84	3612.62	X	X	19418.17	23060.11	X	X	81600.94	71488.15	X	X	42263.89	23147.65
outflow	X	X	0.00	791.20	X	X	0.00	0.00	X	X	632.56	2653.07	X	X	0.00	7270.79	X	X	490.74	4743.17	X	X	74328.73	83031.93	X	X	0.00	3766.16
paleo	X	X	0.00	380.40	X	X	0.00	0.00	X	X	0.00	0.00	X	X	0.00	0.00	X	X	550.14	2037.88	X	X	90719.55	25105.89	X	X	0.00	0.00
para	X	X	1182.38	797.43	X	X	1847.82	2082.12	X	X	6744.19	6718.43	X	X	4122.83	787.17	X	X	8218.68	6580.74	X	X	10062.84	9533.43	X	X	8345.70	11021.57
plesio	X	X	1144.20	49.03	X	X	2470.04	1159.63	X	X	4464.95	3295.65	X	X	5086.46	934.36	X	X	190.24	136.90	X	X	1940.25	1138.47	X	X	0.00	1932.69
springbrk	X	X	17840.63	13708.56	X	X	10347.16	7855.89	X	X	29671.42	38755.91	X	X	14736.92	4084.05	X	X	42340.74	34284.19	X	X	221890.38	125571.90	X	X	21863.27	22270.47
trib	X	X	8110.21	8846.53	X	X	1970.35	2017.49	X	X	31027.80	29296.30	X	X	49.86	49.86	X	X	2665.89	2964.14	X	X	84715.95	79353.75	X	X	576.03	217.07
Channel Types on Potentially Active Holocene Floodplain (meters)																												
eupo1	X	X	29376.98	31893.38	X	X	21362.97	21512.63	X	X	45454.43	42651.45	X	X	17684.58	11304.73	X	X	29611.96	18523.04	X	X	76105.70	75822.72	X	X	40161.23	40643.57
eupo2	X	X	13443.67	5362.05	X	X	10889.58	7118.06	X	X	23367.80	15865.84	X	X	12207.85	3619.23	X	X	19011.56	23060.11	X	X	44898.71	29982.78	X	X	38968.69	23147.88
outflow	X	X	0.00	510.79	X	X	0.00		X	X	206.31	425.70	X	X	0.00	3179.01	X	X	490.74	489.52	X	X	8576.95	5424.04	X	X	0.00	2691.00
paleo	X	X	0.00	380.40	X	X	0.00		X	X	0.00	0.00	X	X	0.00	0.00	X	X	0.00	699.02	X	X	22830.89	8865.82	X	X	0.00	0.00
para	X	X	1182.38	798.31	X	X	1755.63	2082.12	X	X	6744.19	4761.82	X	X	4122.83	787.17	X	X	6597.04	6580.74	X	X	10038.98	9533.43	X	X	7622.23	11019.80
plesio	X	X	1101.20	0.00	X	X	1814.64	668.15	X	X	3710.55	1612.84	X	X	2609.91	0.00	X	X	190.24	136.90	X	X	1937.55	889.28	X	X	0.00	1108.68
springbrk	X	X	16769.02	11814.66	X	X	9337.31	5260.44	X	X	27238.08	26190.56	X	X	13143.03	1454.46	X	X	25152.60	16621.41	X	X	102045.14	64828.73	X	X	9945.78	15554.47
trib	X	X	3792.14	3270.07	X	X	836.78	1099.13	X	X	3562.57	1108.13	X	X	49.86	49.86	X	X	1948.79	713.25	X	X	5238.76	5814.58	X	X	576.03	217.07
Channel Types on Hydrologic Floodplain (meters)																												
eupo1	X	X	29376.98	31918.67	X	X	25352.49	21512.63	X	X	45564.65	42651.45	X	X	17683.97	11304.73	X	X	32739.46	18523.04	X	X	76105.70	75781.50	X	X	40177.86	40643.57
eupo2	X	X	13443.67	5829.36	X	X	11498.47	7118.23	X	X	22427.47	15865.84	X	X	10513.60	3633.64	X	X	18226.77	23060.11	X	X	32158.83	27735.20	X	X	36671.19	22465.45
outflow	X	X		134.05	X	X	0.00	0.00	X	X	238.80	222.37	X	X	0.00	584.03	X	X	34.00	489.52	X	X	1441.40	2167.29	X	X	0.00	719.33
paleo	X	X			X	X	0.00	0.00	X	X	0.00	0.00	X	X	0.00	0.00	X	X		470.63	X	X	3582.82	5349.85	X	X	0.00	0.00
para	X	X	914.78	797.43	X	X	1847.82	2082.12	X	X	6625.09	4145.50	X	X	4123.18	798.53	X	X	7209.08	6580.74	X	X	10038.98	9533.43	X	X	7865.98	11019.80
plesio	X	X	843.25	49.03	X	X	1814.64	250.73	X	X	946.24	0.00	X	X	0.00	0.00	X	X	190.24	136.90	X	X	1937.55	1138.47	X	X	0.00	195.25
springbrk	X	X	12879.41	8603.02	X	X	7383.01	5008.49	X	X	14228.09	15886.95	X	X	4425.98	1375.17	X	X	13039.00	8202.04	X	X	55895.34	55902.10	X	X	7259.68	9694.93
trib	X	X	1378.62	1309.56	X	X	158.92	333.03	X	X	417.93	380.96	X	X	49.86	49.86	X	X	1242.33	1283.33	X	X	30.31	454.97	X	X	576.03	217.07

Notes: The potentially active floodplain is the area of the Holocene floodplain that is still connected. **Plate V Defines the Channel Types.**
The hydrologic floodplain is the area that is frequently flooded. **Plate X Defines Floodplain Terms.**
With respect to channel lengths Easton, Cle Elum, and Kittitas are directly comparable in the temporal scale. Wapato is comparable with caution. Naches, Selah, and Union Gap should not be compared.

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Plate XXVII. Appendix I and Acknowledgments.