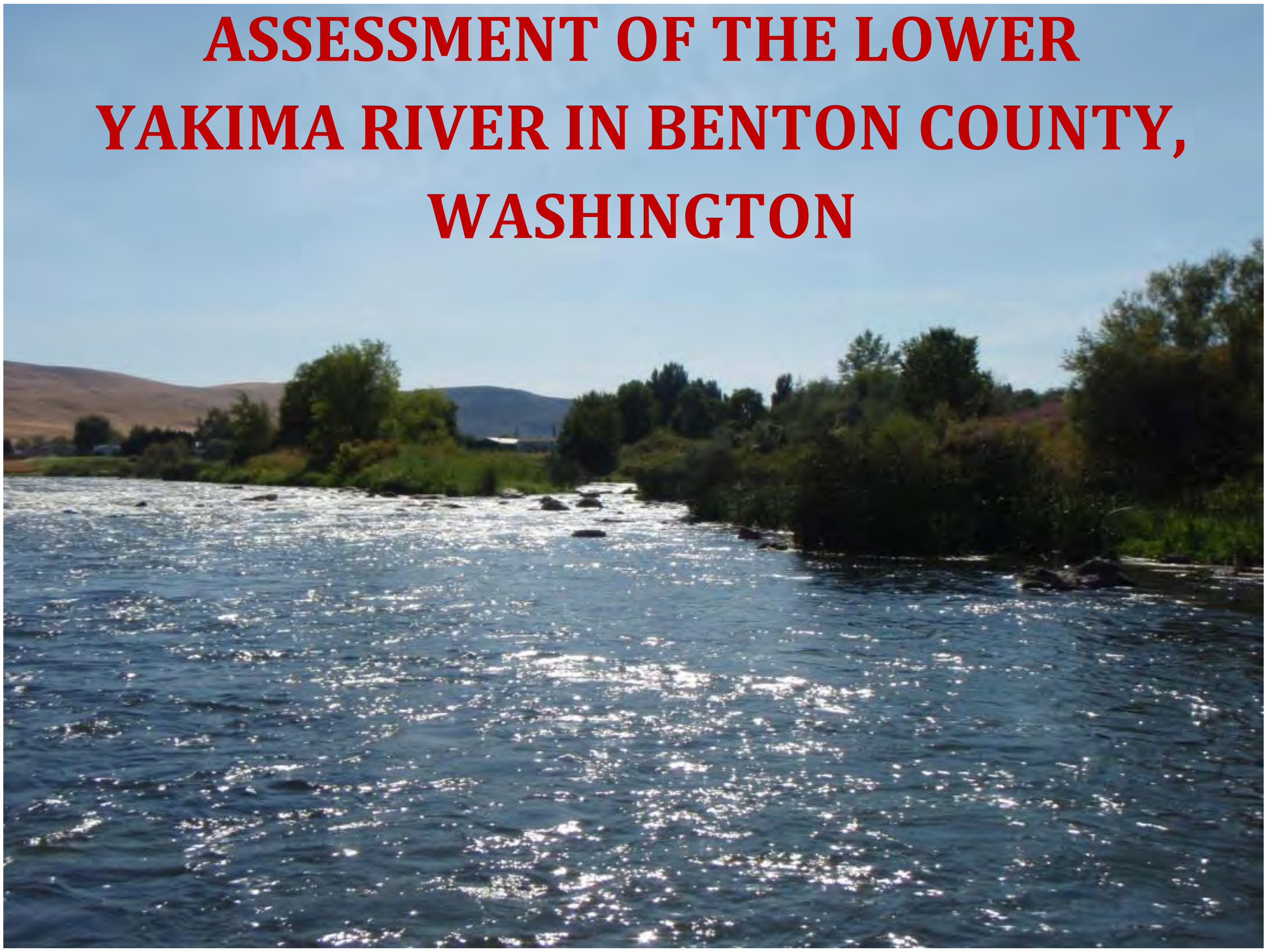
ASSESSMENT OF THE LOWER YAKIMA RIVER IN BENTON COUNTY, WASHINGTON



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In cooperation with:
The Yakima Basin Fish and Wildlife Recovery Board

Salmon Recovery Funding Board Grant #07-1566
February 15, 2011

EXECUTIVE SUMMARY

Benton Conservation District (BCD) investigated the lower Yakima River from Prosser, WA to Richland, WA with the purpose of identifying and assessing high priority actions for the benefit of local and basin-wide salmon recovery efforts. This assessment, funded by the Salmon Recovery Funding Board (SRFB), was conducted from 2008 to 2010 and included thermal profiling of the lower Yakima River, investigation of the thermal dynamics of the Yakima River delta, river depth measurements at baseflow conditions, identification of local fish screening needs, and inventory of riverbank, island, and floodplain conditions.

Based on this assessment, the following have been identified as high priority restoration actions and/or areas requiring further assessment. Listed items were chosen based on feasibility by local community and/or governmental agencies, ability for near-future completion, and have a high degree of certainty for improving lower Yakima River conditions.

1. **Yakima River Delta and Bateman Island Causeway**. Elevated temperatures at the Yakima Delta confluence with the Columbia River are likely causing adult salmonids to delay migration. Further investigation is needed to determine if removal of the Bateman Island Causeway will result in increased mixing with the Columbia River, decreased sedimentation, and decreased temperatures within the Yakima Delta, thereby improving delta function and minimizing water temperature issues.

2. **Fish Screening and Irrigation Water Conservation**. Over 60 privately owned irrigation intakes were identified during this assessment. River floats indicated that at least half of these intakes were not compliant with current fish screening standards and need to be updated. Outdated irrigation systems should be converted for irrigation efficiency and water savings as well as protecting salmon from uptake and impingement.

3. **Restoration of Riparian Buffers**. Shoreline residential development, grazing, and non-native riparian vegetation are common on the lower Yakima River. Working with private landowners to restore native riparian buffers and to manage streamside grazing is imperative.

4. **Side Channel Restoration and Protection (Prosser to Richland)**. Side channel degradation is apparent by many of the islands, especially between Benton City and Richland. Degradation appears to be due to extensive water stargrass, sedimentation, low flows, and non-native vegetation. Projects aimed at restoring side channels either through water stargrass removal or scouring with large woody debris (LWD) should be considered. Priority should be given to islands near identified thermal refugia pockets and/or historical spawning grounds. Projects will need to be implemented with community support, as the islands and neighboring lands are primarily privately owned.

5. **Off-channel Restoration and Re-connectivity (Benton City to Richland)**. Previous research found off-channel habitat has been lost as a function of lower flows (Stanford et al. 2001). Managing higher summertime flow is outside of the scope of this assessment, however, projects aimed at enhancing current flow scenarios (especially spring-time flows) to off-channel habits and promoting scour are recommended. Much of this land is privately owned and located between Benton City (e.g., Benton City oxbow, floodplain adjacent to Songbird Island) and West Richland/Richland (e.g., Fox Island channel, island habitat under I-182 bridge).

6. **Island and Floodplain Protection (Benton City and West Richland)**. Investigations to lease or purchase floodplain habitats in Benton City and West Richland and islands (e.g., Fox Island, Twin Bridges Island) from willing participants should be further explored. Partnerships with other entities such as Benton County and Tapteal Greenway may foster management of riparian areas for both conservation and recreation.

7. **Protection, Enhancement, and Further Analysis of Thermal Refugia Potential**. Although predominantly a losing reach, this study determined that thermal heterogeneity is present along the lower Yakima River and may provide critical temperature differentials for migratory species at the tail end of out-migration and the front-end of in-migration. Additional studies should be performed to determine dissolved oxygen levels and temperature differentials between the identified “cooler” areas and the average river temperature at the end of spring run-off and the beginning of fall migration to determine the suitability of existing cool pockets as migratory thermal refugia.

   Pockets of cooler water were mainly associated with interstitial groundwater flow along riverbanks and point-and non-point source irrigation returns. A few “holes” were identified that also coincided with localized decreased temperatures. Segments of the river within West Richland had thermal suppression; this may be in part due to West Richland‘s extensive floodplains and irrigation. The sources of water for these cool pockets (i.e., percentage of river recharge vs. irrigation recharge) should be investigated to help with future decisions of river management. Projects coupled with these identified “cooler” areas are likely to provide the greatest benefit.

8. **Water Stargrass Management**. Removal of water stargrass and development of removal techniques in critical salmonid spawning habitat areas should continue as water stargrass represents both a direct physical threat to habitat and a threat to water quality and temperature. It is recommended that removal efforts be targeted at historical fall Chinook spawning grounds and threatened side-channel habitats.

9. **Large Woody Debris (LWD).** Historical documentation indicates that the lower Yakima River and delta primarily obtained its large woody debris from upstream

sources with only minor contribution from growth along the lower riverbanks. Capture of wood at the Prosser Dam needs to be managed so as to promote the continuation of wood downstream within the lower Yakima River. Large woody debris is captured by island heads and floodplains within the lower Yakima River and along the banks during high flow events. Placement of LWD may help with island side channel scour, habitat complexity, and enhance areas of thermal refugia.

10. **Levees and Flooding**. Options should be investigated for converting the existing levees (e.g., Yakima Delta) to more fish friendly levees that provide both flood control protection and ecological benefit. In addition to improving the levees, other programs to reduce fecal coliform contamination should be developed to help reduce the impact of flooded areas contiguous to the river that contain pasture and old septic systems.

Although not presented as part of this action list, predation, water quality, and altered flow regimes are recognized as important factors to consider for salmon recovery efforts in the lower Yakima River. Solutions to these problems require basin-wide support with the involvement of many stakeholders and multiple government agencies and, as such, are outside of the intent of the proposed action list above. It should be noted that predation and water quality and flow are discussed within the report document. Furthermore, results of the temperature profiling performed as part of this assessment raise interesting questions regarding temperature and the lower Yakima. Shifting the current view of the lower Yakima River as one continuous slug of warm water to a model that incorporates thermal heterogeneity could have implications for future flow management discussions (e.g., managing to enhance and maintain thermal refugia for migration versus managing flows to lower entire main-channel summer temperatures).

As a result of this assessment, the first three identified inventory actions along with water stargrass management (#8) have already procured additional grant funding. BCD was awarded three grants from the Community Salmon Fund (CSF) in 2009 and 2011 to help private landowners with riparian restoration/fencing activities and implementation of water stargrass removal from island-side channels. Additionally, BCD procured two SRFB grants to screen 23 privately owned irrigation intakes so that they are compliant with current screening criteria. To date, 15 screens have been replaced with fish friendly screens. Lastly, a collaborative study with Mid-Columbia Fisheries Habitat Enhancement Group, BCD, and the Yakama Nation has been funded by SRFB in order to assess the fish dynamics and hydrodynamic properties of the Yakima River delta in order to ascertain if removal of the Bateman Island Causeway will lead to improved passage within the Yakima Delta. The results of this study will be available by 2013.

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ACKNOWLEDGEMENTS

This assessment was funded by a grant from the Salmon Recovery Funding Board (SRFB) 07-1566N. We appreciate the support and guidance provided by the granting agency.

Special thanks to those who helped with river floats and data collection: Alex Conley and Angie Begosh (YBFWRB), Jennifer Scott and Eric Bartrand (WDFW), Pat Monk and Richard Visser (USFW), Laura Buelow (EPA), Matt Morgan and Elaine Brouillard (RSBOJC), John Marvin (Yakama Nation), Heather Simmons-Rigdon (RC&D), Marie Zuroske (SYCD), Pat and Kara Kaelber, Richland Rod and Gun Club, Frank and Wendy Shaw, Matt Perrot, Wes and Conni Lindseth, and Aaron Appel (PNNL).

We appreciate the Atom Duck Diving Club's help in retrieving temperature probes within the confluence and their underwater scouting of the delta and causeway.

Thank you Robert Mueller (PNNL) and David Child (DC Consulting) for setting up and performing the aerial redd surveys of the lower Yakima River and collecting these invaluable data for this assessment.

We would also like to thank our lower river aerial photographers and pilots: Bill Miller, Tom Seim and Wendy Shaw.

Thank you to all our Lower Yakima River TAG participants for guiding the project and providing valuable insight on the lower Yakima River.

CHAPTER 1 INTRODUCTION

Benton Conservation District (BCD) was awarded a $36,000 grant with a match of $45,000 through the Salmon Recovery Funding Board in 2007. The grant was awarded to perform an assessment of the Yakima River in Benton County. The end goal of the assessment was to identify high priority actions for the benefit of salmon and people. Fisheries advocates generally focus on anadromous fish habitats higher up in the Yakima Basin. The many tributaries draining the mountains and the complex floodplains of the middle and upper mainstems attract the majority of attention and funding. When the lower Yakima is noted, it is as a migration corridor that, despite many challenges, generally delivers adults and smolts to the upstream and downstream habitats on which they depend.

Discussions on the lower Yakima River typically involve two basic perceptions. One perception views the lower Yakima as a fundamentally altered and irrecoverable habitat, where there is little opportunity for significant fish returns from restoration efforts and as such the only goal should be moving fish through to better habitats as quickly as possible. A second perception assumes that the fundamental issue in the lower Yakima is a lack of water, and that a more natural flow regime is a requirement for significant improvement in fish survival and production in the lower Yakima. The goal of this assessment is to understand and identify the value of the lower Yakima River for anadromous fish, investigate the aforementioned perceptions of the lower Yakima River and identify concrete restoration projects linked to specific fish benefits.

As part of this assessment, BCD convened a technical advisory group (Lower Yakima River TAG) to provide input and feedback for the assessment. The lower Yakima River, as used in this study, includes the portion of the river that flows through Benton County and runs from Prosser, WA to its confluence with the Columbia River at Richland, WA (Figure 1). BCD and the Lower Yakima River TAG identified knowledge gaps and prioritized assessment efforts for the lower Yakima River. The primary areas of focus determined by BCD and the Lower Yakima River TAG were:

1. Data collection on the historical conditions of the lower Yakima River and delta
2. Determination of temperature heterogeneity of lower Yakima River and thermal refugia potential
3. Salmonid utilization of the lower Yakima River (historical and current spawning)
4. Riparian vegetation and riparian bank conditions (both historical and current)
5. Assessment of irrigation intakes and potential fish screening needs
6. Presence and importance of large woody debris in the Lower Yakima River
7. Assessment of river islands, channels and floodplains

The primary data gathering for this assessment was a two year thermal profiling effort in which data were collected to assess river temperature heterogeneity (e.g., cooler pockets of water resulting from groundwater or pools) and identify thermal refugia potential of the lower river. Thermal profiling was conducted during base flow conditions in July and August of 2008 and 2009 in the lower Yakima River. During the thermal profiling floats, data were also gathered pertaining to riparian vegetation and riverbank condition, riverside livestock grazing, island and side channel habitat condition, presence/absence of large woody debris, and irrigation intakes. Depth data on the lower Yakima River were also collected. The results of the assessment are discussed herein and a list of high priority actions and projects are presented.

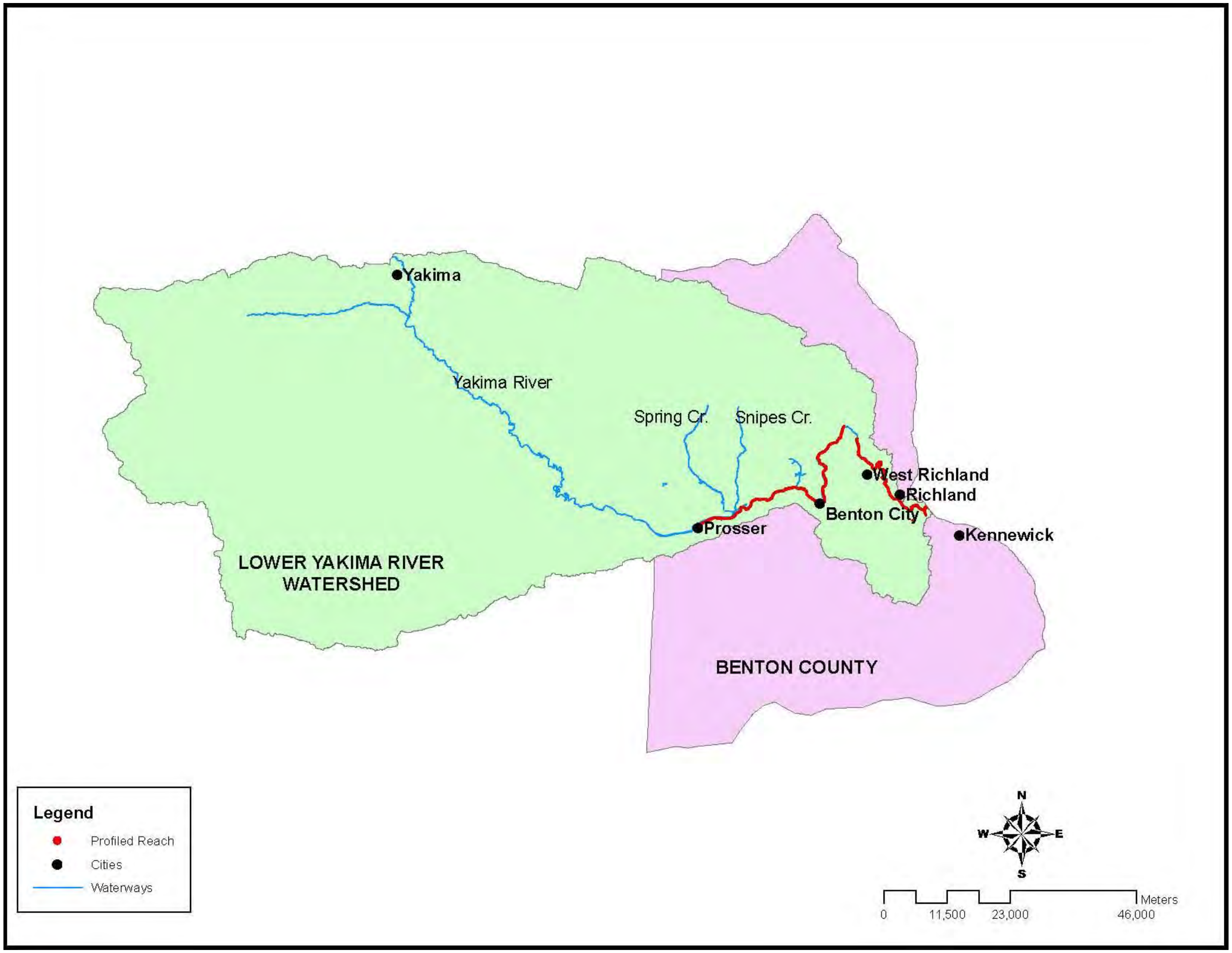

Figure 1. Lower Yakima River Study Reach (Prosser, WA to Richland, WA)

CHAPTER 2 HISTORICAL OVERVIEW

When talking about ecological restoration, we often fall prey to a simplified vision of history, in which an idealized past is compared to a degraded present. This quickly leads to cognitive dissonance, as the impression that everything needs fixing bashes against the sense that all is hopelessly lost. But if we step back and take a more nuanced view of history, we may find ourselves on a middle ground, looking at a modern river that faces fundamental constraints, but where there are also real opportunities to make significant changes that have tangible benefits.

Looking at the history of the lower Yakima in some detail allows us to see how some problems have already solved themselves (e.g. the extremely low flows of the early 20th century in the lower Yakima), even as unexpected new issues arise (the now-clear regulated flows of the modern lower Yakima fostering the recent expansion of water star grass). Understanding specific issues and their drivers allows us to formulate specific actions to address them, or to think about how we can accommodate the changes that we cannot reverse. To foster this kind of thinking, the following section gives an overview of how the Yakima River has changed over the last 160 years.

2.1 Geological History

The lower Yakima River is located within the Columbia Plateau, which is consists of a series of basalt lava flows. A majority of the basalt flows is interspersed with sedimentary layers and are known as the Columbia River Basalt Group (Kinnison and Sceva 1963). The basalt plateau of the eastern basin was folded and faulted into a series of northwest-southeast trending anticlinal ridges and synclinal valleys known as the Yakima Fold Belt and extend from the Cascades to the Columbia River (Kinnison and Sceva 1963). Columbia River basalts dominate between Prosser and Benton City, and as such the river channel is generally confined throughout this reach with minimal area for braiding and meander. Alluvial deposits are present Between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology.

2.2 The Pre-European River

Though dwarfed by the Snake, the Yakima River is one of the largest tributaries to the Columbia River in both area and flow. It is estimated to have produced anywhere from 400,000 to 2 million adult salmon each year prior to the 19th century collapse of salmon populations. It sustained a large population of humans made up of many of the bands now brought together as the Yakama Nation, and fish returning to the Yakima also supported the salmon-based cultures along the Columbia River.

The lower Yakima carries the snowmelt of the Cascades to the Columbia, with pre-settlement flows typically climbing through the spring, to peak in June and then drop rapidly in July to reach annual low flows in August and September. The upper curve in

Figure 2 shows the estimated average unregulated hydrograph used by the Bureau of Reclamation (while this does not exactly match the presumed pre-settlement hydrograph, it gives a solid approximation of its general shape, magnitude and divergence from approximate modern flows as represented by the lower line) (Bureau of Reclamation 2008).

Figure 2. Hydrograph of the unregulated versus regulated flow for the lower Yakima River

The lower Yakima presumably offered resumed unimpeded physical passage for adult and juvenile fish, though rapids in the river at Horn Rapids/Wanawish and Prosser funneled fish past native fisheries where the level of fishing pressure unknown. While outmigration timing for smolts in this period is unknown, the June freshet would have delivered smolts to the July high flows in unregulated Columbia, and the greatest extension of the estuary‘s freshwater plume into the Pacific. [1]

Water quality is generally presumed to have been good, although there is still much debate regarding historical temperatures at baseflow in the lower Yakima River (see discussion in CHAPTER 9). Whether or not the river was historically warmer or cooler at baseflow conditions, there was likely to be a greater amount of thermal heterogeneity (temperature variation) in the lower Yakima than exists today. Historically, floodplain recharge may have greatly influenced and benefited thermal heterogeneity and thermal refugia along the riverbanks and off-channel habitat. A study by Stanford et al. (2001) indicates that under higher flows there is greater amount of floodplain connectivity, interstitial flow, deeper water, and more riffles below Prosser Dam. This may lead to

[1] Whether pre-1850 smolts left the basin at the height of the freshet or whether they had similar run timings to the present when yearling and older smolts typically leave the basin from March through May is unknown. Selective pressures since 1850 have clearly favored earlier outmigration over the May through early July outmigration that may have been present earlier.

greater thermal heterogeneity in the lower river, even if baseflow summer temperatures in July and August remain too warm for salmonids:

> *Although this is based on a conceptual framework (sensu Ring and Watson 1999), it is supported by underlying fundamental principles of hydrology; namely that the infusion of cooler water, earlier in the season (e.g., during historic spring runoff) over the active floodplain would provide relatively more thermal refugia below Prosser than exists under the current regulation scenario and with the significant alteration and disconnection of the floodplain.* (Snyder and Stanford 2001)

If river temperatures did rise to inhospitable levels from mid July through some point in August, upstream migration of adults and downstream migration of smolts through the lower Yakima is likely to have been unimpeded the remainder of the year. Whether or not temperature conditions allowed for rearing of juvenile salmonids in the lower Yakima through the summer is a topic of much debate.

The records of early surveyors (see section 2.3) tell of banks with extensive willows and scattered cottonwoods, with larger groves of riparian trees on limited areas of bottomland. However, even under pre-settlement conditions, shade was likely limited when compared to width and orientation of river. While riparian vegetation in the reach may have contributed some wood to the river, local inputs are likely to have been less significant than the import of large woody debris from higher in the watershed. As surveyors noted in 1863:

> *Yearly, the Yakama River disgorges from its mountain sources [an] abundance of driftwood, composed of the finest quality of timber, whole trees from 20 to 70 in diam. And from 100 to 250 feet in length of fir and cedar lumber are often seen winding their way down its current, into the broad waters of the Columbia.*

This significant influx of large wood from upstream can be hypothesized to have caused wood accumulations that scoured pools and encouraged island formation. Periodic large floods would have moved the river‘s cobble bedload on regular basis, likely creating excellent spawning habitats for fall Chinook.

There is no evidence that any of the tributaries to the lower Yakima flowed perennially; early surveys note springs higher in the foothills, but current perennial flows are generally acknowledged to be a function of modern irrigation in the surrounding uplands (Child and Courter 2010). The first significant unambiguously perennial tributary (Satus Creek) enters the Yakima River well above the study reach.

While this description of the pre-European river is inherently speculative, descriptions of the Yakima at the time of initial settlement give it some credence.

2.3 Historical Records Prior to 1865

The earliest written records of the Yakima River come from Lewis and Clark‘s expedition. Their journals note the abundant salmon and tribal fisheries on the Columbia at the mouth of the Yakima, and note, from their highest upriver point on Bateman Island, that ―…. there is no timber of any Sort except Small willow bushes in Sight in any direction.”[2] Ross briefly stopped at the mouth of the Yakima on August 16, 1811, again noting the Columbia River fisheries, but saying little about the Yakima.

The McClellan railway survey of 1853 noted, ―The lower part of the Yakima Valley is less fit for cultivation than higher up, but contains much good grass land. It is wide, open, and destitute of timber except in the bottom lands, and even there few trees are found for fourty [sic] miles up” (p. 141). And later, ―You pass up the Yakima seventy miles before you reach the building pine, though cottonwood is found along its banks sufficient for camping purposes.” (p. 257).[3]

The most detailed early records come from the General Land Office surveys that laid out the township/section grids. The surveyors‘ detailed notes provide an excellent sense of the country just prior to widespread settlement by Europeans.[4] According to the Prosser Historical Museum, the earliest recorded white settlers in Prosser were in the 1870's. Richland had its first settlers in 1864. Surveyors note a few settlers on Bateman Island, and the presence of half-wild cattle in some areas. Notes regarding the lower Yakima River from the general overview sections of the 1863-1864 surveys are provided in Appendix C.

2.4 Comparison of Mapped Channel Locations

Overlaying General Land Office survey maps allow us to look at whether and how channel and island locations have changed over the last 145 years. The following images show these overlays from Prosser to the Confluence. The general picture they give is of a river whose channel and islands have moved very little. The confluence of the Yakima and the Columbia Rivers highlight the increased amount of inundation on the delta floodplains as a result of backwater from McNary Dam.

[2] http://columbiariverimages.com/Regions/Places/yakima_river.html

[3] http://quod.lib.umich.edu/cgi/t/text/text-idx?c=moa&idno=AFK4383.0012.001

[4] Survey notes viewable at http://www.blm.gov/or/landrecords/survey/ySrvy1.php

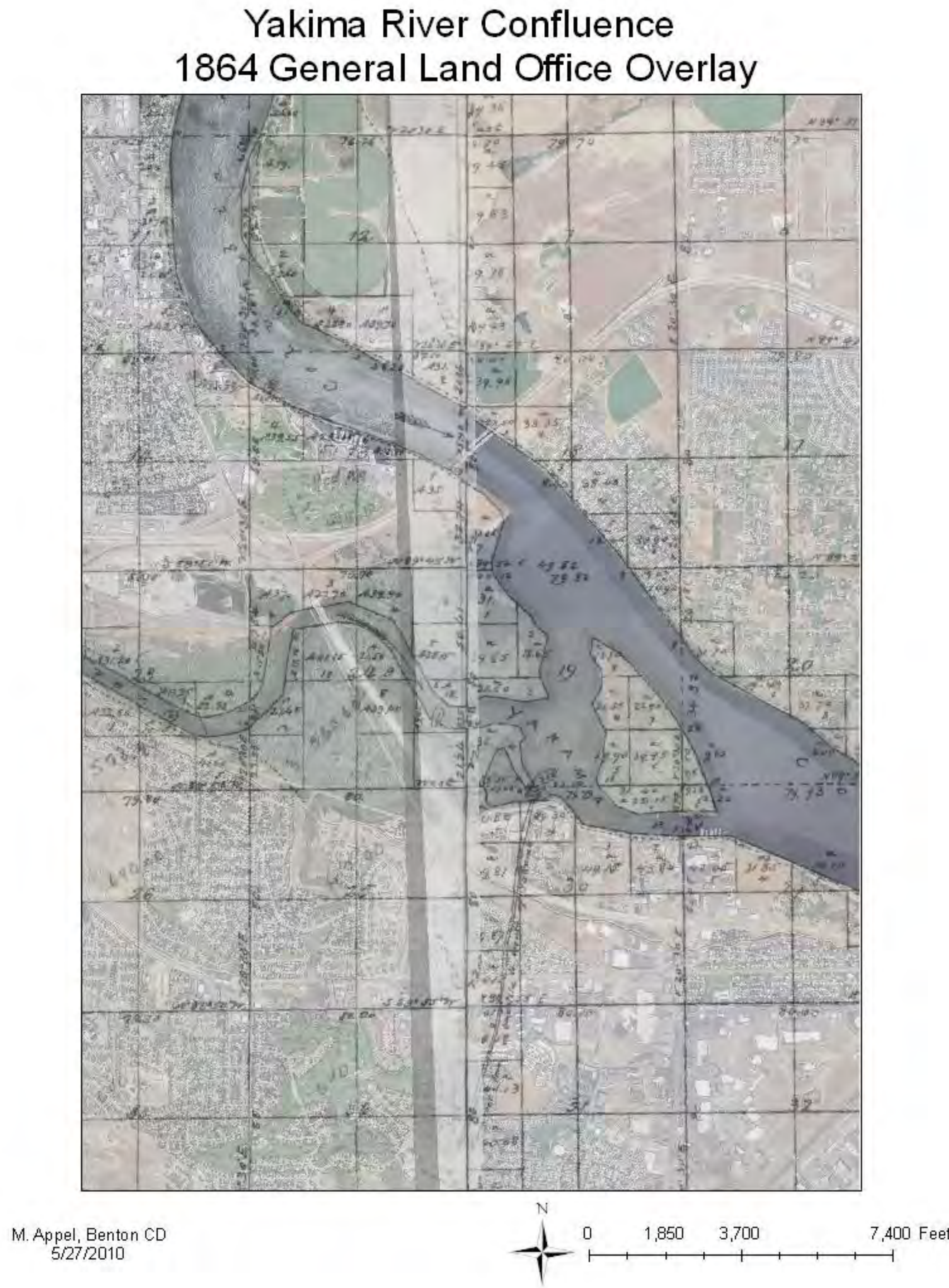

Figure 3. Overlay of 1864 GLO survey (Yakima River Confluence) over current 2009 aerial image

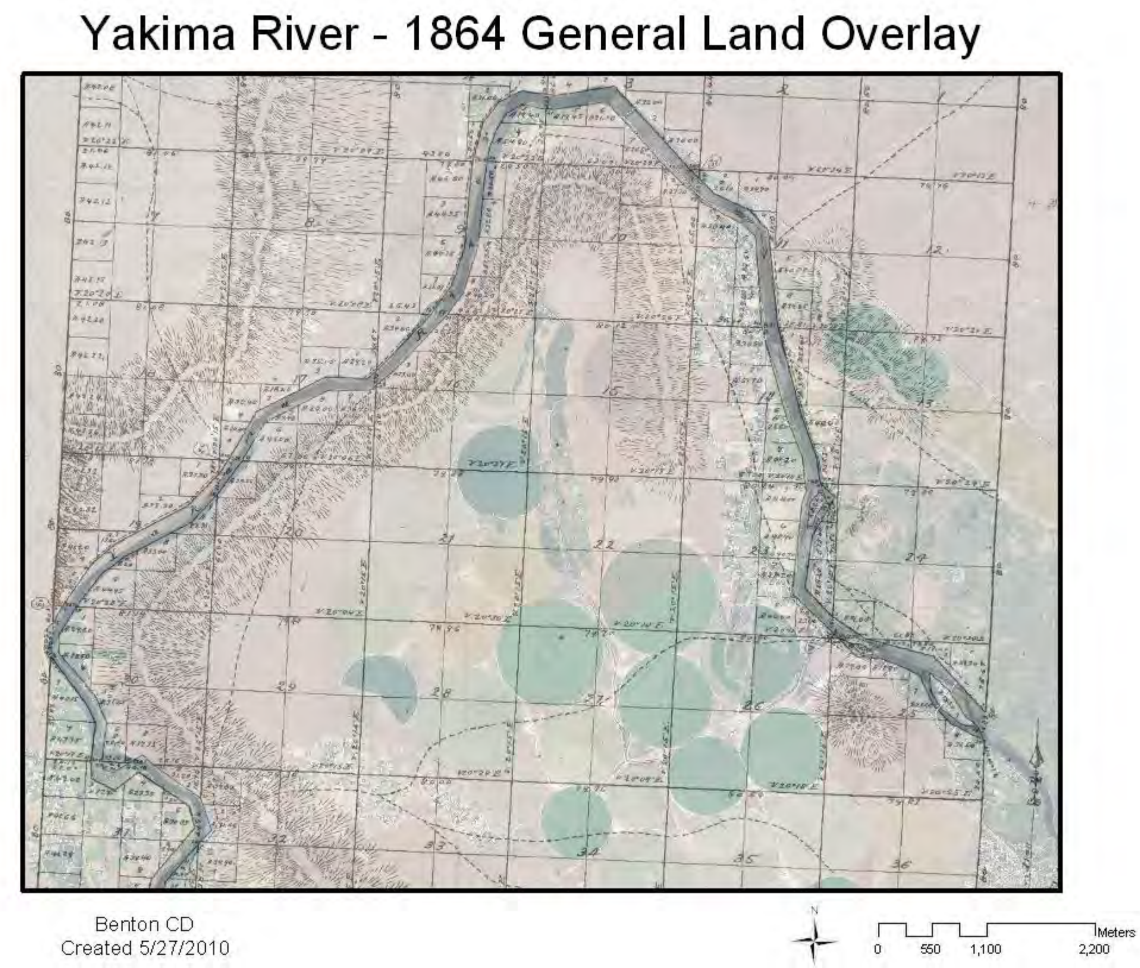

Figure 4. Overlay of 1864 GLO survey (T10N27E, Benton City, Horn Rapids and West Richland) on current 2009 aerial image

Figure 5. Overlay of 1864 GLO survey (29N26E, east of Chandler to east of Benton City) on current 2009 aerial image

Figure 6. Overlay of 1864 GLO survey (T9N25E, east of Prosser to east of Chandler) on current 2009 aerial image
Note: The drainage marked —dy in summer” is west of Spring Creek and Snipes Creek wasteways and is a separate drainage system. This drainage outlet is still present today and was located during thermal profiling (see Section 9).

2.5 1850 to 1890: The Early Years

Prior to 1850, European presence in the Yakima Basin was largely limited to the fur trapping expeditions of 1811-1830, which reduced beaver abundance but made few other changes to the landscape. The 1850s saw the establishment of the first missions, the Yakama Wars, and the first cattle drives into the Yakima Valley. As noted in the Bureau of Reclamation's history of the Yakima Project:

> *The first settlers came to the Yakima Valley in about 1860. They were cattlemen attracted by the abundance of bunch grass and wild game, and the fertile bottom lands. The first irrigation ditch of record was constructed in 1864. The ditch conveyed water from Ahtanum Creek for irrigation of a small garden above the Catholic mission. Hops were first raised in 1872, and alfalfa was successfully grown in 1881. Construction of the Northern Pacific Railway into the valley in 1886 gave greater impetus to irrigation development.*[5]

During this period, irrigation development significantly affected tributaries of the Yakima above the study area. Extensive grazing and wood gathering for firewood, fences, lumber and hop kilns presumably lead to heavy impacts on riparian vegetation and wood floated down from the mountains by the river. However successful irrigation development on the mainstem was quite limited until the 1890s, resulting in only minor changes to mainstem flows and flood frequencies.

Anadromous fish were heavily impacted by harvest—both local, and more heavily, in mainstem Columbia fisheries—and by the changing conditions in tributaries, but while riparian and floodplain cover was changing rapidly, the hydrology of the lower Yakima and the Columbia largely resembled that of pre-settlement times.

2.6 1890 to 1920: The Diverted River

From 1890 on, more extensive irrigation systems were developed in Kittitas and Yakima Counties, greatly increasing diversions above the study area. Within the lower Yakima, a number of gravity fed ditches were developed to water accessible bottomlands. The Columbia Irrigation District system began with the construction of Horn Rapids Dam in 1892, while the Benton Irrigation District was delivered water from the Sunnyside system in 1912, and the Kiona District organized in 1917. Smaller ditches watered portions of

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[5] http://www.usbr.gov/projects/Project.jsp?proj_Name=Yakima+Project

the limited bottomlands in the lower Yakima. The combined upstream diversions greatly reduced flows into the lower Yakima during the July to August base flow periods, and resulted in slight to moderate reduction in the spring freshet. However, only the last part of this period saw reduced spring flows and flood frequencies as the federal dams higher in the basin were completed (Bumping in 1910, Kachess in 1911, and Keechelus in 1917).

Records from the long defunct Richland gage were used to quantify the ―wastage” left to flow from the Yakima into the Columbia. As shown in Table 1, August flows in 1909 ranged from 64 cfs to 660 cfs; September flows from 38 cfs to 400 cfs; and October flows from 375 cfs to 660 cfs. Irrigation developments had indeed nearly eliminated ―wastage” in the summer and fall, essentially drying out the lower Yakima (Stevens, Rue and Henshaw 1911).

Table 1. Daily discharge for Yakima River 1909

Daily discharge, in second-feet, of Yakima River near Richland, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	......	64	375	11	387	38	465	21	133	167	562
2	......	64	387	12	368	64	400	22	96	215	562
3	614	64	400	13	337	64	465	23	96	268	530
4	614	51	400	14	337	59	660	24	96	257	595
5	725	64	498	15	279	80	595	25	80	279	562
6	465	64	562	16	279	64	595	26	64	325	562
7	387	59	465	17	225	59	595	27	80	337	595
8	387	51	465	18	225	80	582	28	133	337	595
9	375	51	465	19	133	103	582	29	133	350	595
10	356	38	498	20	133	96	582	30	133	400	595
								31	96	......	628

NOTE.—These discharges are based on a fairly well-defined rating curve.

Looking at flows at Kiona from 1906 to 1915 (Figure 7) the river consistently reached 10,000 to 20,000 cfs in late spring early summer and then rapidly dropped to lows of 100 to 300 cfs in average to poor years. The average flow at Kiona in august of 1906 was 171 cfs. These flows are much lower than typical modern low flows of 750-2000 cfs at Kiona, especially as the later development of the Kennewick Irrigation District means that diversions upstream of Kiona run 100-200 cfs higher in the modern period.

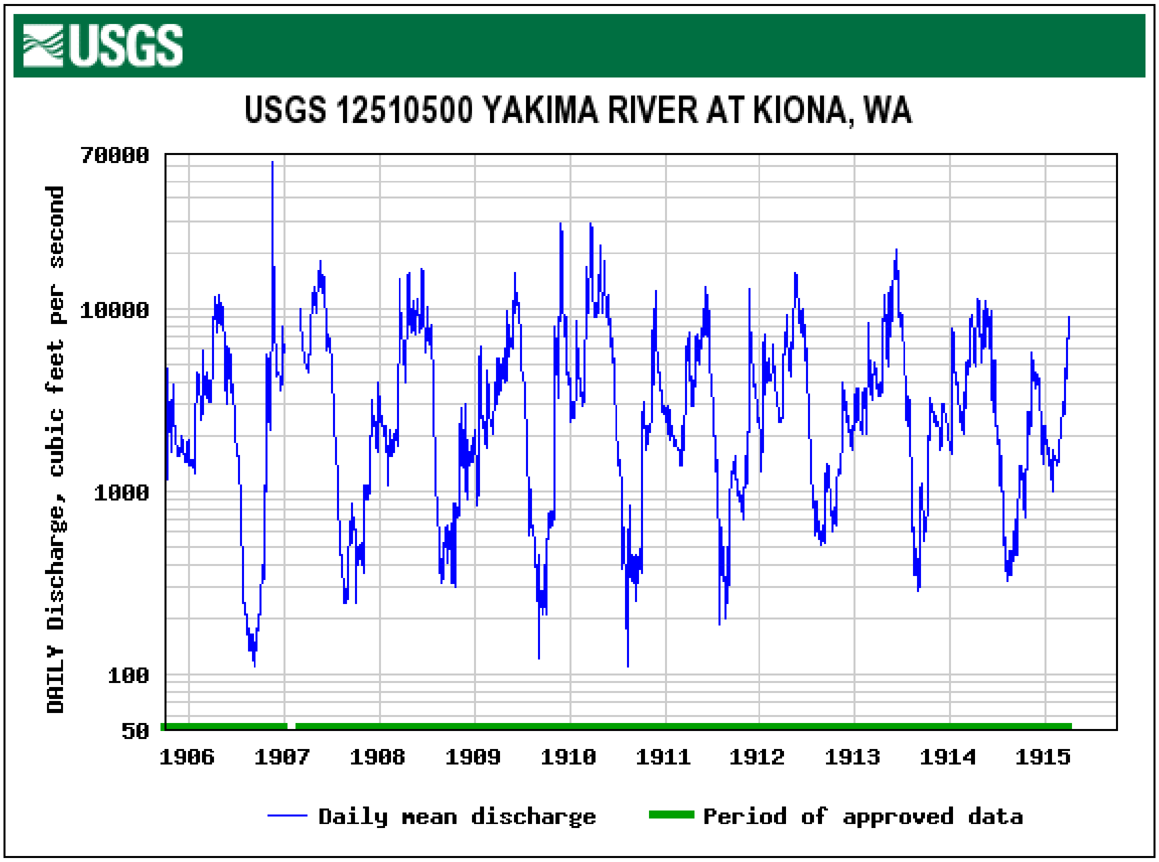


Figure 7. Historical daily discharge for lower Yakima River

Looking at monthly means for Kiona (Table 1 and Table 2) tells a similar story, with 1906-14 flows averaging 3,000 to 5,000 cfs higher than 1998-2008 flows in April through June, and then dropping rapidly in July to end up averaging ~1000 cfs less in August through October.

Table 2. Kiona gage, monthly average flow

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1906-1914	2,900	3,160	5,650	7,640	9,320	7,540	2,300	467	634	1,150	4,670	3,580
1998-2008	3,900	5,020	4,810	4,590	4,690	3,690	1,590	1,490	1,710	2,030	3,010	3,650
Early-recent	-1,000	-1,860	840	3,050	4,630	3,850	710	-1,023	-1,076	-880	1,660	-70

Two full spanning dams were constructed in the lower Yakima in this period; Horn Rapids in 1892, and the low head dam at Prosser that powered the Prosser Flour Mills starting in 1887 and served irrigation by the Prosser Falls Land Company and Irrigation Company (see photo; this initial low head dam was significantly modified by Reclamation in 1932-1933 and 1956).

http://www.yakimamemory.org/cdm4/item_viewer.php?CISOROOT=/memory&CISOPTR=7942&REC=7

The degree to which these two barriers constrained adult upstream migrations is unknown, but the combination of physical barriers and low flows and associated high river temperatures must have severely limited passage opportunities through the lower Yakima from late July through September. This is hypothesized to have placed significant constraints on summer migrant adults (lamprey, summer Chinook, sockeye and the earliest part of the steelhead run), by placing selective pressure to move migrations either earlier (when conditions in the Yakima were more hospitable, but when migration conditions in the Columbia were tougher (due to the height of flows in the Columbia at Celilo and other rapids) or into the fall. Indeed it is during this period that the summer Chinook was greatly reduced and sockeye were extirpated (both runs were also heavily impacted by conditions above the study reach, with the river sometime dry at Parker, and sockeye blocked from their natal lakes by new dams).

Fall through spring migrants (steelhead, spring Chinook and coho) presumably fared better in the Lower Yakima through this period, though severe impacts in their upstream habitats and in Columbia River fisheries drove populations downwards.

During this period, all of the major ditches were insufficiently screened. High smolt mortality in ditches was regularly documented upstream of this reach and is presumed to have occurred at diversions in the study reach (Tuck 1995). While the limited extent of diversions in this reach during this period and high April through June flows mean that early season entrainment likely had a minor impact on smolts in this reach, high rates of entrainment would be presumed for any smolts migrating out from July on. Combined with low flow and high temperatures, this would presumably have driven strong selection against late outmigrating smolts, even as the flow regime of the Columbia River had not yet changed.

2.7 1920 to 1980: The Regulated River

After 1920, the regulation of flows that became possible as federal storage facilities were built in 1911 through 1917 became more dramatic with the completion of Tieton Dam in 1925 and the significant expansions of Cle Elum‘s storage capacity in 1932 and 1936. Irrigated acreage continued to expand with the growth of existing districts and the creation of the Roza and Kennewick Irrigation Districts (provided water starting in 1941 and 1957, respectively). The lift pumps and hydropower diversion installed as part of the Kennewick Irrigation System in 1956 increased the amount of water diverted at Chandler Dam significantly, as in addition to the 150 to 250 cfs diverted for KID, diversions of up to 1500 cfs are made to drive the turbines and lift pumps. These diversions significantly reduce instream flows in the approximately 13-mile bypass reach between Prosser Dam and the Chandler Powerhouse. This period also saw a shift from ditches to small pump diversions to serve bottomlands along the lower Yakima and the expansion of groundwater pumping to irrigate lands around the lower Yakima.

By the 1940s, the modern regulated flow regime was largely in place (see the lower curve in Figure 8 for a generic representation). The historic spring freshet is greatly reduced and shifted earlier (as lower elevation snowmelt enters the Yakima below storage facilities, while the higher elevation snowmelt that fueled the latter part of the freshet is retained in the storage reservoirs), winter flows are significantly reduced higher in the basin, though year round return flows reduce that difference lower in the Yakima, and the low flow/high temperature baseflow period, which historically generally began in July now began anywhere from late April (in a drought year) to early July, with a drop to baseflow levels occurring around storage control. Fall cooling of the river still occurs anywhere from mid August to mid-September, when the cooling climate typically leads to a relatively rapid drop in river temperatures.

At the same time that the spring freshet of the Yakima declined and shifted earlier due to increased in-basin storage capacity, the flow regime of the Columbia River was transformed. The construction of Columbia River dams with significant storage, starting with Grand Coulee‘s completion in 1941 and ending with Mica Dam‘s completion in 1973 dramatically changed the hydrograph of the Columbia River by spreading the water from its early summer peak flows across a broader season, while the construction of the Columbia dams below the Yakima affected adult and smolt survival and changed the nature of the mainstem Columbia. Under modern conditions, outmigrating smolts face increasingly harsh conditions from late May through July. Higher survival rates for earlier fish mean that later outmigration, which may have once been adaptive, has been heavily selected against since the 1940s.

Figure 8. Lower Yakima River hydrograph

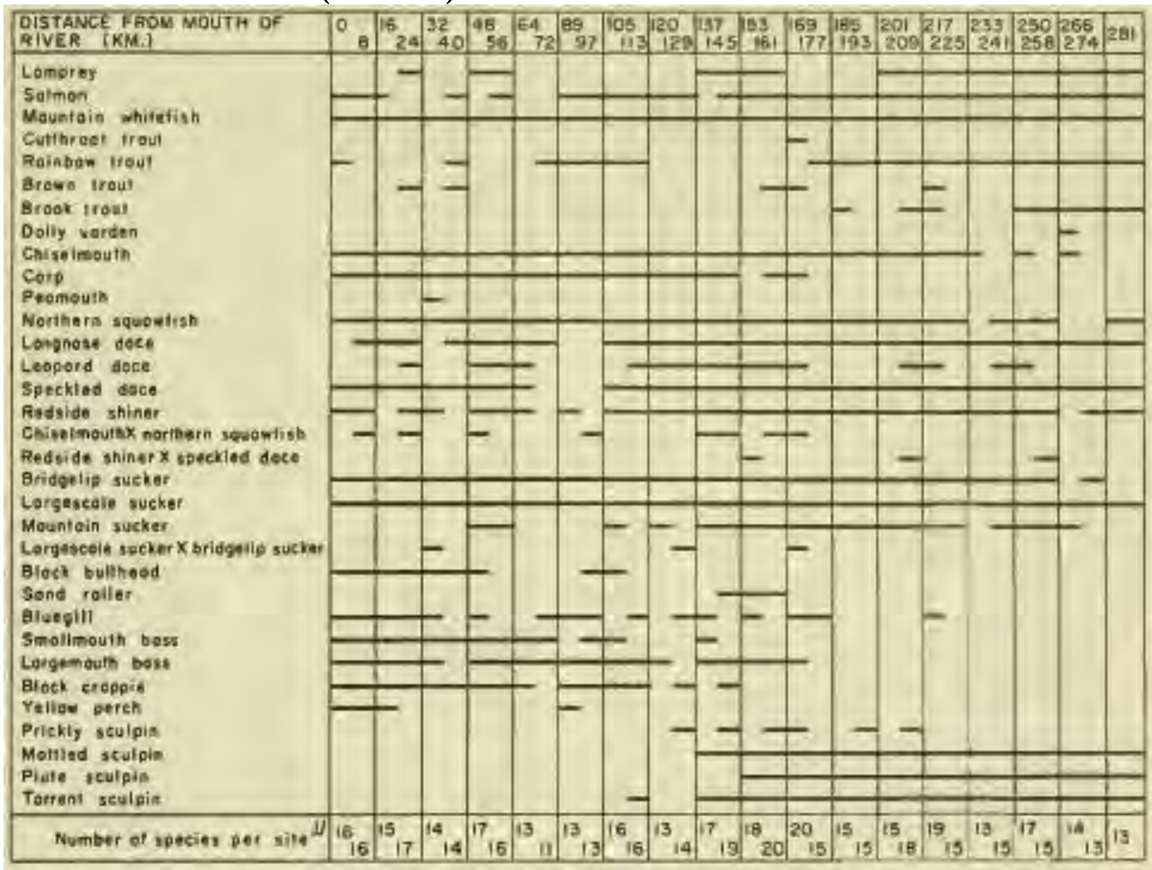
During this period, saturation of shallow aquifers lead to increased irrigation return flows to the lower Yakima, with many of the tributaries developing perennial flows that increase over the course of the irrigations season, and significant subsurface returns reaching the river. The combined effects of regulation and increased return flows mean that August and September flows in the lower Yakima ran as much as 10 fold higher than during the previous period.

The completion of McNary Dam in 1957 resulted in backwatering of the Yakima delta and 2 miles of the Yakima Mainstem River. This combined with the causeway to Bateman Island turned the south side of Yakima delta into a backwater area and prevented the Columbia River from flowing around the west side of Bateman Island. The impact of this change on anadromous fish are addressed in Section 9.5.6

High levels of fine sediment, nutrients and agricultural chemicals in runoff and agricultural return flows led to severely degraded water quality. Temperature conditions were presumably similar to modern conditions.

The changes in both the Yakima and the Columbia created favorable conditions for exotic fish species. The report of a USFWS survey of fish distribution in the Yakima Basin conducted from April of 1957 to May of 1958 makes clear that the makeup and distribution of fish species in the lower Yakima resembled that of today (Table 3) with non-native smallmouth bass, carp and catfish all widespread and perch, bluegill, largemouth bass and brown trout present in the lower river (US Fish and Wildlife Service 1970). The effects of these species are discussed in more detail in Section 3.7.

Table 3. Distribution of fish (1957-1958)



The period from 1920 to 1980 saw the ongoing decline of the remaining runs of anadromous fish, as conditions in the Columbia River, intense ocean and Columbia River fisheries and degraded habitat conditions in the Yakima Basin took their combined toll. Coho were extirpated and steelhead and spring Chinook dropped to their lowest levels (~500 fish each) by the early 1980s. By the 1970s, the demise of anadromous fish in the Yakima Basin was widely predicted.

2.8 1980 to 2010: The Multi-purpose River

The irrigation infrastructure and basic flow regime of the modern Yakima was in place by the 1950s, as noted above, but by 1980, an increased emphasis on the need to rebuilt dwindling runs of anadromous fish began forcing significant changes in how the Yakima Project was run. Adjudication of water rights for the Yakima Basin in 1977 began the long process of allocating water among agricultural users, and between agriculture as a whole and the Yakama Nation's treaty right to flows to protect and maintain fisheries. In 1980, legal action by the Yakama Nation led to changes in management of the Upper Yakima and Tieton Rivers to avoid dewatering of spring Chinook redds. In 1984, Phase I of the Yakima River Basin Water Enhancement Project authorized the construction of fish ladders and fish screens at major diversion dams and diversion canals. This funded major improvements to fish screening at Chandler Dam and other Bureau facilities upstream of the study reach.

Phase II of the Yakima River Basin Water Enhancement Project was authorized by Title XII in 1994 (108 Stat. 4550, Public Law 103-434). Phase II created the Yakima River Basin Water Conservation Program, which uses federal and state funds to acquire water for fish and wildlife and fund water delivery efficiency projects that allow conserved water to be used to improve in-stream flows for fish. Phase II also provided for installing and upgrading screens at many mid-sized irrigation districts, including several in the lower Yakima.

Phase II also specified in-stream target flows over Sunnyside and Prosser Diversion Dams during April through October of each year in relation to the total water supply available. This new operating regime was initiated in 1995, and has resulted in the maintenance of at least 500 cfs in-stream flow in the Prosser to Chandler bypass reach. Subsequent commitments by Reclamation call for subordination of power generation at Chandler during the spring migration season in order to maintain at least 1000 cfs in the bypass reach.

The original legislatively mandated purpose of the Yakima Project was irrigation. The Kennewick Division was authorized for irrigation, hydroelectric generation, and the preservation and propagation of fish and wildlife, and Title XII authorized fish, wildlife, and recreation as additional purposes of the Yakima Project as a whole. These purposes however, are mandated to not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts.

Thanks to the changes associated with YRBWEP and Title XII, significant investments in habitat improvements higher in the Yakima Basin, changes in management of the Columbia river, restrictions on fisheries, new hatchery programs for coho and Chinook in the Yakima, and improved ocean conditions, resulted in significantly improved anadromous fish runs from their lows in the late 1970s and early 1980s (Figure 9).

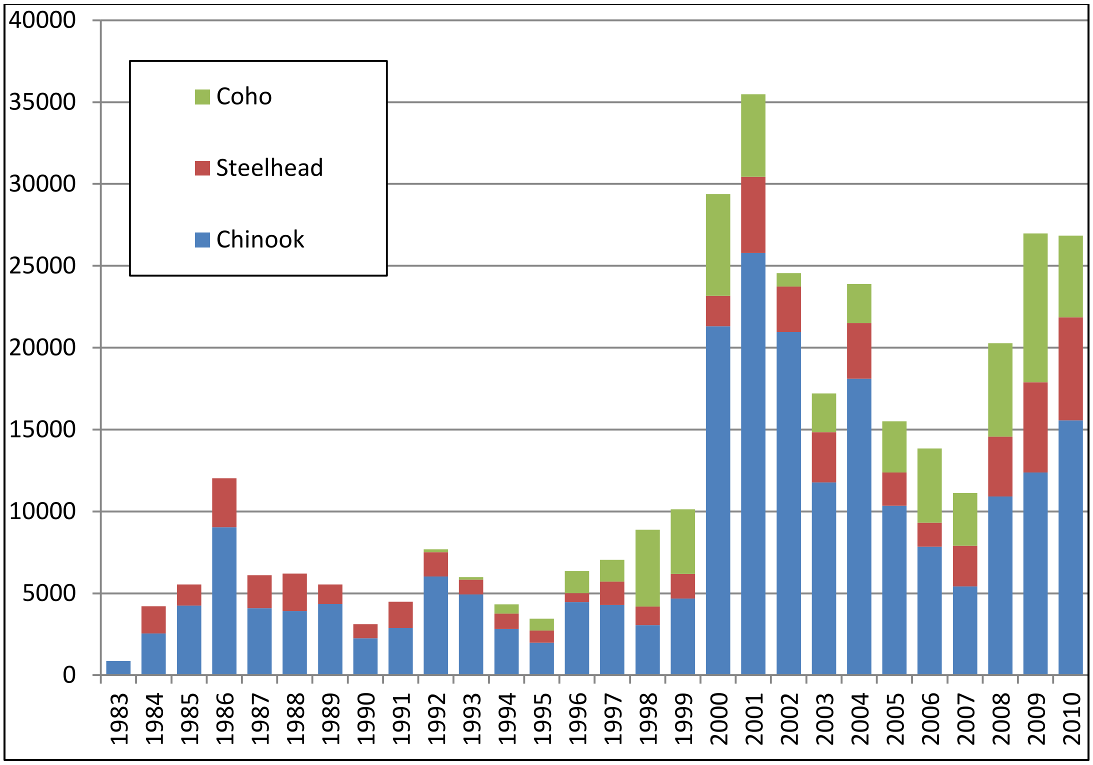


Figure 9. Graph of anadromous fish abundance in Yakima River

By 2009, conditions in the Yakima had improved enough for the Yakama Nation and partners to begin reintroducing sockeye and summer Chinook to the Yakima Basin. The success of these reintroduction efforts will be highly dependent on the ability of adult salmon to pass through the lower Yakima from June through September.

Where steelhead, coho and spring Chinook runs improved significantly, fall Chinook- the run most dependent on conditions in the lower Yakima- have not done as well. Together, these trends have increased the level of attention being paid to habitat conditions in the lower Yakima.

2.9 Water Quality

Water quality on the lower Yakima River had been severely degraded by sediment and legacy pesticide loading (DDT) from local agricultural practices. The lower Yakima River also suffers from many of the problems associated with urban streams, including leaking septic systems and storm sewer pollution (WDFW 1998). Summer in-stream temperatures make the lower Yakima River inhospitable to salmon and low dissolved oxygen levels threaten all aquatic life.

In 1997, the Department of Ecology (Ecology) implemented a Total Maximum Daily Load (TMDL) study and as a result targets were set for sediments and pesticides (DDT) allowed in the Yakima River (Johnson et al.1997). In response to the TMDLs, the Roza-Sunnyside Board of Joint Control, landowners and state and federal partners worked together to achieve dramatic reductions in the delivery of fine sediment and associated pesticides to the Yakima River.

As a result of these concentrated efforts, sediment loading and consequently pesticide loading decreased dramatically to the lower river improving river clarity and fish health. The Yakima Toxics Project was established by Ecology to investigate improvements in Yakima River Water Quality and update the fish consumption advisory for the river (Johnson et. al. 2007). It has been determined that soil sediment, DDT and associated chemicals were much improved in the mainstem river but still exceeded state criteria (Johnson et. al. 2007 and Johnson et. al. 2010). In 2009, state health officials determined that advisories on certain Yakima River fish species could be dropped as a result of improved agricultural practices, but that recent data (Johnson et. al. 2010) indicate eating common carp from the Yakima is still not advised due to poly-chlorinated biphenyl (PCB) levels.

Despite recent improvements in the water quality of the lower Yakima River, there still remains much work to be done. Legacy pesticides and chemicals in the water column and river sediments still pose a risk to human and fish health. Continued improvements in agriculture, irrigation, stormwater returns, and wastewater and processor plant discharges within the entire Yakima Basin will need to be made in order to improve lower Yakima River water quality.

Although not part of the TMDL, the lower Yakima River also suffers during the summer months from high in stream temperatures (over 21°C during the summer months), low dissolved oxygen levels, and at times high pH levels. These conditions have led to a very inhospitable river for more sensitive aquatic species. High in-stream temperatures in the lower Yakima River are primarily a result of the large expanse of slow-moving, shallow water exposed to full sunlight (see: Snyder and Stanford 2001; Haring 2001; and Lilga 1998). Solutions to the thermal problem in the lower Yakima River are under much debate. Increasing summer flow is likely to provide only ―slight" improvements in temperature (Harring 2001). Prolonging increased spring streamflow into the early summer may provide a few extra weeks of lower in-stream temperatures thus aiding spring migration.

Improved water clarity has led to a dramatic increase in water stargrass expansion, changing the nature of much of the lower Yakima (see CHAPTER 7). Coinciding with its expansion was the change in geographic distribution of fall Chinook spawning; spawning has shifted from the majority of spawning occurring below Prosser dam to the majority of spawning occurring upstream of the study reach in the vicinity of the town of Granger. Dense mats of water stargrass are influencing dissolved oxygen levels and pH in the lower Yakima River. As a response to water stargrass proliferation, a recent study was conducted by the United States Geological Service (USGS) and South Yakima Conservation District (SYCD). Wise et al. (2009) investigated several parameters within the Kiona reach including nutrient loading, gross primary productivity, pH, dissolved oxygen, and temperature. They found that large amounts of plant growth caused large daily fluctuations in dissolved oxygen concentrations and pH levels that exceeded the

Washington State water quality standards for July-September. The daily swings in dissolved oxygen and pH were greater during low-flow periods. During much of the irrigation season (March-October), the dissolved oxygen concentrations were below 8 mg/L with the onset of low dissolved oxygen occurring earlier in spring low-flow years. It was determined that daily dissolved oxygen concentrations were negatively correlated with the preceding day's maximum water temperature (Wise et al. 2009). This is something that may help future predictive models of dissolved oxygen in the lower Yakima River. Wise et al. (2009) found that pH levels were above the Washington State standard of 8.5 during almost all of the irrigation season in low flow years, and following spring runoff in high flow years.

2.10 The River of the Future

Discussing the upcoming river of the future is as important as looking at the past. There are several trends worth noting that are likely to result in changes in fish habitats in the lower Yakima River in future years. These include:

1. Climate change increasing water temperatures in the lower Yakima during summer and changing how flows in the Yakima River are regulated;
2. Continuing change in agricultural cropping patterns;
3. Increased suburbanization throughout the area and continued growth of the Tri-Cities urban area;
4. Increasing efficiencies in irrigation water delivery (e.g., canal lining) thereby decreasing return flows to the lower Yakima; and
5. Possible changes to the flow regime of the lower Yakima River, through:
    a. The use of conservation water being acquired through the Yakima River Basin Water Enhancement Project (YRBWEP) (currently 20 kaf, but projected to increase to 70-100 kaf of water over the next 5 to 10 years).
    b. Major changes to the water supply infrastructure of the Yakima River, such as the construction or expansion of in-basin reservoirs or the transfer of Columbia River water to serve irrigation needs in the Yakima Basin (all of which are under consideration as part of the Yakima Basin Integrated Water Resource Management Plan under development by the Bureau of Reclamation and Washington Department of Ecology) [6]
    c. The proposed reconfiguration of the Kennewick Irrigation District to move a portion of its diversions from the Yakima River at Prosser to the Columbia River below the confluence of the Yakima and/or electrify the pump system at Chandler.

2.10.1 Climate Change and the Yakima River Basin

The Climate Impacts Group (CIG), which is part of the Center for Science in the Earth System at the University of Washington, is currently investigating the impacts of climate

[6] See http://www.usbr.gov/pn/programs/yrbwep/2011integratedplan/index.html for more details

change on the future of the Yakima River Basin and salmon habitat. Climate change is already impacting the Yakima River Basin by altering the amount and timing of snowpack. A recent publication by Vano et al. (2010) on climate change and the Yakima River Basin states:

> *Climate change is expected to cause continued decline in snowpack and earlier snowmelt resulting in reduced water supplies. Analysis of past observations suggests that this process is already underway (Mote et al. 2005). Previous studies have shown that the Washington Cascade Mountains, from which the Yakima River drains, are likely to lose about 20% of their April 1st snowpack with 1◦C (1.8◦F) of warming (Casola et al. 2009), and an accompanying study (Elsner et al. 2010) suggests that for the Yakima basin, a similar temperature-snowpack sensitivity can be expected. Using +1◦C and +2◦C warming scenarios, Mastin (2008) showed a 12% and 27% decrease, respectively, in snowmelt within the basin over a base period of 1981–2005. Because the reservoir system is relatively small (total reservoir storage is about 30% of the mean annual flow of the river), and because the snowpack is highly sensitive to even modest warming, water deliveries from the reservoir system have been sensitive to even small departures from average historical conditions.*

Alterations in the amount of snowpack and snowmelt timing and their consequences on salmon habitat are predicted to become increasingly more problematic within the 21st century for the Yakima (Mantua et al. 2010). Impacts of climate change are predicted to result in reduced summer/fall flows and increased water temperatures for the Yakima Basin. Historically warm reaches are predicted to have greater increased summer water temperatures thereby resulting in increased thermal stress for migratory salmonids (Mantua et al. 2010). Mantua et al. (2010) suggests that it is possible to develop management options for mitigating the projected impacts of climate change on northwest salmon habitat, however, these options will require trade-offs with other land and water uses in the watershed. Hydrologic processes that influence streamflow timing, volume, and stream temperature are highly sensitive to projected changes in future climate scenarios. These are the same hydrologic processes that are highly sensitive to changes in land and water use impacts. Vano et al. (2010) concludes that the current approach to managing water supply in the Yakima Basin by using a regression-based forecast of total water supply available (TWSA) above Parker for the period of April through September is no longer tenable as this approach implicitly assumes that the historical conditions on which the forecasts and management strategies are based will persist into the future.

Vano et al.(2010) modeled the influence of climate change on the irrigated agriculture within the Yakima River Basin. Their study found that historically the Yakima Basin had substantial water shortages 14% of the time. For the Intergovernmental Panel on Climate Change (IPCC) A1B emission scenarios, water shortages increased to 27% by the 2020s and 23% in the 2040s (Vano et al. 2010). Modeled future scenarios of climate change impacts on Yakima Basin water availability found that even senior water right holders will suffer curtailments with increasing frequency and that economic losses include expected annual production declines of 5%-16%, with greater possible operating losses for junior water rights holders (Vano et al. 2010).

Competition and water demand between ecosystem protection and water utilization will continue to rise as climate change continues, as such, sound management of water utilization should be developed now to help alleviate future costly conflicts (Mantua et al. 2010). Mantua et al. (2010) states that ―Restoring, protecting, and enhancing instream flows in summer are key management options for mitigating effects of projected trends toward warmer, lower streamflows as a consequence of climate change." Identifying and protecting thermal refugia provided by groundwater and tributary inflows may also help mitigate future warming impacts within the Yakima Basin (Mantua et al. 2010).

CHAPTER 3 LOWER YAKIMA FOCAL SPECIES

Several fish species populate the lower Yakima River. Historically, the Yakima River was a significant producer of important salmonid species, including Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and steelhead (*O. mykiss*). Each of these fishes utilizes the lower Yakima habitat to some degree. Although bull trout (*Salvelinus confluentus*) were historically found in the Yakima River, they are no longer considered a focal species in this reach. Other fishes of interest include lamprey, piscine predators on salmonids and other resident fishes, both native and non-native.

3.1 Steelhead (*Oncorhynchus mykiss*)

Steelhead represent one of two life history manifestations exhibited by the *Oncorhynchus mykiss* species. The anadromous *O. mykiss* spends one to three years in the ocean before returning to freshwater to spawn and is referred to as steelhead. Steelhead are iteroparous, so post-spawning adults called kelts, although weakened and often in poor condition, do not necessarily die. The resident form of *O. mykiss* is considered a rainbow trout. Progeny from both steelhead and rainbow trout may exhibit either the anadromous or resident life history, making restoration planning more difficult.

In 1999, NOAA listed as threatened the naturally spawning steelhead in the Yakima River as part of the larger Middle Columbia Evolutionarily Significant Unit. Steelhead are primarily tributary spawners, and most spawning activity takes place in the upper Yakima system. The Steelhead Recovery Plan emphasizes that improving migration conditions in the lower mainstem Yakima River is a critical recovery strategy for all threatened upstream populations of steelhead. Anadromous steelhead must migrate through the lower Yakima River during two vulnerable stages: as juveniles and kelts.

The returning adults begin passing Prosser Dam in September, later than other major Columbia River tributaries, probably because of elevated water temperatures and low flow in the lower river. Tagging data has shown that some Yakima steelhead over-shoot the Yakima and are captured at Priest Rapids Dam (Keefer et al. 2008). Perhaps they are avoiding seasonal warm water in the lower Yakima, as the McNary Pool of the Columbia is cooler in summer. Historically, a portion of the steelhead run would likely have traveled rapidly from the ocean into the Yakima system during the summer, but modern high temperatures in the lower Yakima River now limit that run timing. The extent to which adult migrants hold in the Columbia to avoid warm Yakima water is not known.

Steelhead over-winter in the cold water of December and January then move upstream again February through April. Most spawning occurs in April. Steelhead fry emerge from redds between early May and early August. Juveniles spend from one to three years in fresh water before migrating to the ocean during April through June. On average, a female steelhead in the Yakima subbasin produces 5,100 eggs. The Yakama Nation maintains an active steelhead kelt reconditioning program at their Prosser facility. Naturally spawning kelts are captured, medicated and fed for several months, improving survival rates and condition factors. Upon release the following year, many adults ascend upstream directly to spawning areas, able to forgo the treacherous migration to the Pacific.

A possible cause for the drift from anadromy to residency may be the lower survival rate for anadromous juveniles and adults, due to changed river conditions such as low flow, elevated water temperatures, passage issues and predation by non-native fishes. Causes of steelhead decline relevant to the lower Yakima include fragmentation and loss of rearing habitat; migration delays; degradation of water quality; decline of habitat complexity; alteration of stream flows, banks and channel morphology; alteration of ambient water temperatures; sedimentation; and loss of pool habitat and large woody debris. The Yakima River and its tributaries have been detached from their historical floodplains, impairing floodplain function, reducing access to off-channel habitats, reducing flow and elevating temperatures.

Predation in the lower Yakima River also has contributed to the decline of steelhead. Non-native smallmouth bass, and to a lesser extent channel catfish, take a heavy toll on juvenile steelhead. Gulls and white pelicans prey aggressively on juvenile steelhead, especially at in-stream structures like Wanawish Dam (Fritts and Pearsons 2006). Increases in water temperature in the lower river are thought to lengthen the outmigration for juvenile steelhead, causing them to spend more time in lower river areas where non-native predators are most effective. Non-native predators may be more efficient in warm water conditions. Poor water quality conditions in the lower Yakima River can lead to increased mortality rates in steelhead and other native anadromous smolts from water-borne pathogens.

3.2 Coho (*Oncorhynchus kisutch*)

Native coho salmon were extirpated from the Yakima River by the early 1980‘s as a result of overexploitation of fishery, water and habitat resources. Recently, the Yakima Nation and the Yakima Klickitat Fisheries Project have reestablished coho populations in the Yakima Basin. The lower Yakima River mainstem is utilized as a migration corridor for this species. Impaired lower Yakima River mainstem conditions limit productivity. Predation, mortality/injury from diversions (e.g., Chandler), altered flow regimes, floodplain/side-channel disconnection, and water quality are important migration barriers for juveniles. Projects to enhance and maintain the lower Yakima River migration conditions from September through June may help improve juvenile coho production. Adult coho are not significantly constrained by lower Yakima River temperature conditions based on their migration timing.

3.3 Chinook Salmon (*Oncorhynchus tshawytscha*)

Chinook salmon display a continuum of run timing, labeled as spring, summer and fall varieties. Beckman et al. (2000) described 0-year juvenile Chinook distribution in spring and summer as largely above Roza Dam. Fritts and Pearson (2006) describe two life histories manifested in Yakima River Chinook salmon: spring Chinook, which return in the spring and spawn in upstream portions of the basin; and fall Chinook, which return in the fall and spawn in the lower elevation portions of the basin. Spring Chinook rear for a full year before migrating downstream to the Pacific as yearling smolts. Fall Chinook migrate to the ocean as subyearlings by late June. Fall Chinook salmon populations in modern times have supported tribal and sport fisheries.

Spring Chinook

Spring Chinook are primarily considered limited by the available juvenile rearing habitat in the Yakima River (Harring 2001). As spring Chinook spawn above Prosser Dam, restoring spring Chinook juvenile rearing habitat is outside of the lower Yakima River assessment. In general, adult spring Chinook are not significantly constrained by warm summer temperatures as their run timing is predominantly before temperatures become inhospitable in the lower mainstem river. Spring Chinook, however, are constrained by other migration factors in the lower river and maintaining the lower corridor for juveniles from September through June is critical. Reducing diversion related mortality and injury at Chandler, reducing predation, improving flow conditions, and improving Yakima delta conditions are all primary goals related to improving juvenile spring Chinook production in the lower river (Haring 2001).

Fall Chinook

According to the Washington State Department of Fish and Wildlife (WDFW), before 2001 about 70% of the Yakima River fall Chinook salmon spawned downstream of Prosser. In contrast, during 2004 to 2008 about 80% of the estimated escapement was upstream of Prosser (Mueller 2010). Limiting habitat factors for fall Chinook include the amount of spawning habitat and the amount of juvenile rearing habitat (Haring 2001). Water quality and warm temperatures are also a concern. Projects to reconnect floodplain habitats and disconnected side-channels may improve fall Chinook production. Predation is also a primary concern.

The recent proliferation of water stargrass and sedimentation of spawning gravels has been attributed to decreased spawning habitat in the lower Yakima River. In 2002, the WDFW counted more than 1,000 redds in the lower Yakima but by 2008, the count had dropped to 42 (Hoffarth 2009). This upstream shift in spawning is most attributed to increased water stargrass abundance in the lower Yakima River (Hoffarth 2009). Water stargrass forms a thick mat over spawning gravel, preventing redd building. Spawning further upstream lengthens migration time and distance for both adults and juveniles, and potentially reducing survival rates. Water stargrass in the lower Yakima River is further discussed in CHAPTER 7.

As part of this assessment, fall Chinook spawning grounds in the lower river were examined. Recent historical spawning grounds were identified by WDFW (personal comm. with Paul Hoffarth) for the lower Yakima River and are shown in Figure 10 and Figure 11. These figures show locations that fall Chinook have been known to spawn prior to recent degradation of fall Chinook habitat.