Suitability of the West Fork Amon Wasteway for Salmonids

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Executive Summary

Amon Wasteway is a major irrigation delivery canal, operational spill, and return flow facility for the Kennewick Division of the Yakima Reclamation Project, which serves thousands of water users within 20,201 acres (USGS, 1978). Fish (including salmon and trout) have been found in the wasteway, and questions continue to be raised about the waterway's suitability for salmonids.

The purpose of our study was to provide resource managers with an objective and quantitative accounting of the West Fork (WF) Amon Wasteway's suitability for salmonids, with special focus on whether available habitat and fish presence during summer flow conditions could support production of significant numbers of salmonids.

To do this we reviewed available information and conducted our own independent study of habitat conditions and fish presence in the wasteway. We found relatively few biological studies documenting habitat conditions or aquatic species sampling in the WF Amon Wasteway, so it was necessary to supplement our review with unpublished data and information gathered.

Our review revealed that the WF Amon Wasteway does support a limited number of salmonids (*Oncorhynchus mykiss*), but the WF Amon Wasteway is not capable of producing salmonids in significant abundance. Data collected in 2014 revealed that the most abundant fish species residing in the WF Amon Wasteway was the mosquito fish (*Gambusia affinis*), a species introduced by the Benton County Mosquito Control District in ponded sections of the system.

After conducting habitat surveys, water quality sampling (including continuous monitoring of water temperatures at eight sites), fish sampling in the wasteway, and salmonid carrying capacity modeling; we discovered several important factors that limit salmonid production potential in the WF. The most significant factors were warm summer water temperatures, excessive levels of fine sediments, absence of cobble substrate, and lack of fast-water habitats. These habitat characteristics are principally controlled by local climatic and geologic conditions. Low salmonid carrying capacity predictions were consistent with low abundances observed during electrofishing surveys.

The primary limiting factors for salmonid carrying capacity in the WF Amon Wasteway are not within management control. Therefore, alterations to the wasteway would be expected to yield relatively small gains or losses in salmonid production.

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Introduction

From the late 1800's through the 1950's, a network of canals, pumping plants, and laterals were developed to distribute irrigation water to agricultural lands within the Yakima River Basin and Kennewick Irrigation District (KID). The Kennewick Division is part of the Yakima Reclamation Project, a federal (Bureau of Reclamation) irrigation project located in the Yakima River Basin of central Washington State. The Kennewick Division provides irrigation water to 20,201 acres of agricultural and urban land in the Project. Along with the water distribution system, a network of drains and wasteways were designed and constructed to convey irrigation return flows and irrigated agricultural drainage back to the Yakima River.

Water that is diverted, but not used consumptively by plants or lost to evaporation, is considered irrigation return flow. Generally, irrigation practices have led to return flows accounting for as much as 50% of the water that is diverted (Lentz, 1974), although water conservation measures seek to improve the proportion of return flow relative to diverted flow. Thus, the drainage network of the Yakima Reclamation Project is nearly as extensive as the delivery network, and some of the drains carry significant amounts of flow, particularly during the irrigation season.

Amon Wasteway (USGS, 1978) [1] is a major irrigation facility for the Kennewick Division of the Yakima Reclamation Project which is used as a canal for delivery of water to the Gage Pumps, collects return flows, and releases operational and emergency spills for the Yakima Reclamation Project. The KID operates and maintains project facilities, including canals, drains, pumping stations, and Amon Wasteway. The wasteway carries spills of excess water from the main canal and delivers water to about 1,500 water users in the district, all via the Gage Pumps located in the lower wasteway. The wasteway also carries storm water runoff from the cities of Richland and Kennewick. Nearly all of the flow in the Amon Wasteway is Yakima Reclamation Project waters either in the form of return flows, operational spills, or deliveries to the Gage Pumps (Smith, et al 2005). Smith et al. found that the primary source for water in the east branch is from intentional releases from the Kennewick Irrigation District's main canal (2005). Nearly all of the flow from the west branch of the Amon Wasteway (WF Amon Wasteway in this report) consists of returns from groundwater inputs influenced by applied irrigation and canal seepage in the Badger Canyon area (USGS, 1986). Refer to appendix 4 for a detailed map of the KID.

Currently, the Yakima Basin Joint Board, and members of the Yakima River Basin Coalition are assisting the Bureau of Reclamation in an Endangered Species Act (ESA) consultation for the operation and maintenance of the Yakima Project, including all Reclamation facilities operated by the irrigation divisions, including the Kennewick

[1] The term Amon Wasteway (legal use) or WF Amon Wasteway is used rather than Amon Creek, based on the 1978 USGS Badger MTN topographic map and further clarified in the Yakima Basin Steelhead Recovery Plan, page 26 (Conley et al. 2009) and as labeled on the Kennewick Division Construction Documents in 1955 (Revell, 2010). Functionally, however, the Amon Wasteway was designed as a delivery system to the Gage Pumps and is more accurately called a "canal" at least above those pumps.

Division. The resulting Biological Assessment (BA) may provide a detailed description of operations and maintenance of irrigation drains and wasteways, and a description of fish resources and habitat conditions. This research can provide information for the BA.

There are ongoing efforts by the KID under their Water Conservation Plan to improve water distribution systems through the installation of lining and automated gates on the canals, and the construction of re-regulation reservoirs that will substantially reduce and may ultimately result in little or no water releases into Amon Wasteway. These actions may also decrease groundwater inputs to the WF Amon Wasteway. Future climate change predictions have also stimulated discussions about water conservation measures. Generally the KID may spill water to the Amon Wasteway or convey water to the Gage Pumps during the periods of early April to late October, annually. Given probable changes in water operations, it appears likely that Amon Wasteway and WF Amon Wasteway discharge will decrease in the future as irrigation water use becomes more efficient.

In recent years there has been some speculation by some that the Amon Wasteway is a natural stream and not a man-made irrigation drain. However historical evidence indicates that the wasteway is man-made and was established in 1957 (Early, 2002) as a designed and constructed part of the Kennewick Division. Mistaking the wasteway for a natural watercourse is understandable since portions of the wasteway flow down a natural topographic canyon to the Yakima River. Since 1957, irrigation water supplied to the area by KID has resulted in development of trees and wetland vegetation creating a vegetated corridor and habitats for aquatic invertebrate and vertebrate species. None of this vegetation was present in historic pre-irrigation conditions, as demonstrated by Farm Service Agency aerial photos (see Figure 1).

In 2005, Smith et al. studied the hydrology and geology of Amon Wasteway through a project funded by the Yakima Basin Joint Board. With a drainage area of 62 square miles, the study found that the natural runoff of the wasteway drainage would range from 250-500 acre-feet per year, or less than 0.51 cubic feet per second if the discharge was on a continual flow basis (Smith et al. 2005). The flows would have likely occurred as infrequent, unpredictable snow melt over frozen ground, rain-on-snow, or local storm events. The area that is now Amon Wasteway would have been dry except for such events. The results of Smith's hydrology models have been supported by research done by KID and aerial photographs of the area prior to irrigation development. This information leads us to conclude that the Amon drainage did not have sufficient flow to provide fish habitat under natural, pre-irrigation conditions, including those portions now utilized as the WF Amon Wasteway.

Currently, there is access for aquatic species to travel from the Yakima River and to lower reaches of Amon Wasteway. Fish, including salmonids, have been documented in the wasteway, but until now it was not known which, if any, species were able to maintain self-sustaining populations. Reports of a limited number of rainbow trout *Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*) and fall Chinook salmon (*Oncorhynchus tshawytscha*) sighted or collected in the wasteway (Meadow Springs

Country Club, 2003, Child & Courter, 2010) have elevated public interest in understanding the wasteway's capacity to produce salmonids, despite the fact that most of the flow in the wasteway is artificial. In particular, there was interest in providing fish passage from the lower main stem to the wetland areas upstream of the golf course ponds in the WF Amon Wasteway. However, the value of that management action remained unclear because the quality of salmonid habitat conditions in the WF had not been documented nor formally evaluated.

The potential for fish use of Amon Wasteway may have important implications for the Bureau of Reclamation, Yakima Project ESA consultation, KID operations, as well as local fisheries and water resource management. Building on our previous study conducted in the lower reaches of the Wasteway (Child and Courter 2010); the purpose of this study is to provide managers with an objective and quantitative analysis of the WF Amon Wasteway's ability to produce salmonids, with an emphasis on available habitat and fish presence during summer flow conditions. Further, the studies' purpose is to present the best science on the issue of habitat quality within the WF Amon Wasteway.

Review of Available Information

This section summarizes available biotic and abiotic information about Amon Wasteway. Findings are presented by topic. It was necessary to draw on literature and data from outside the Yakima Basin when appropriate in order to thoroughly explore issues that were important to our understanding of how salmonids might respond to habitat conditions in Amon Wasteway.

Historical Context

Historical photos of Amon Wasteway document its pre-irrigation condition influences (Figure 1). Prior to establishment of the wasteway, the area lacked riparian vegetation and wetland habitat, and appears to be completely dry at the time of the photograph taken in 1950. Some postulate that the local geology indicates the Yakima River's course once followed Badger Canyon and the Amon Wasteway drainage, but the Missoula Floods blocked access to the canyon with alluvial sediments, which set the Yakima River in its current channel (Shaw, 2008).

Figure 1. Aerial photos from 1950 versus 2008 of Amon Wasteway.

In the 1970s irrigation return flows caused flooding in the Yakima Delta area administered by the Corps of Engineers. To prevent excessive mosquito production, an overflow channel was constructed to carry excess waters to the Yakima River. The overflow channel eroded significantly forming a gully that has since become the main channel from the Amon Wasteway to the Yakima River (McKern 2014).

Flow

Smith et al. provides evidence that nearly all of the flow in the WF is from KID Division seepage or return flows (2005). This hypothesis is further supported by the USGS in 1986, a study comparing groundwater levels pre and post development. Furthermore, CH2MHILL (1983) completed a groundwater study in Badger Canyon, which supports that the source of the water in the WF is likely from the Yakima River via KID Division operations. The WF is denoted as the East Badger Drain on some KID right of way maps (Revell, 2010). Witty and Monk (2005) found that water flows in the wasteway fluctuate daily, weekly and seasonally, especially during the irrigation season. As mentioned in the introduction Smith et al. (2005) presented natural stream flow estimates for several drainages within the lower Yakima River and concluded that with an area of 62 square miles natural runoff of the Amon drainage would range from 250-500 acre-feet per year, or 0.51 cubic feet per second per day of discharge (Table 1). Thus, it appears that the vast majority of current discharge from Amon Wasteway is derived from irrigation return flows.

Table 1. Calculated Natural Flow Contributed From Runoff in Amon Wasteway

Drainage	Watershed (square miles)	Precipitation (inches)	Discharge Estimates (cfs/day)
East Fork	26.66	7.58	0.23
West Fork	31.80	7.58	0.28
Totals	58.46	7.58	0.51

***Data from the Western Regional Climate Center (www.wrcc.dri.edu) and from Smith et al., 2005. Discharge estimates were calculated based on mean annual runoff.**

Temperature

Salmonids are cold water fish, with few species capable of tolerating temperatures greater than 24°C for an extended period of time. Child and Courter (2010) deduced from the scientific literature that density declines as the maximum weekly average temperature (MWAT) exceeds approximately 16°C. There is some variation in temperature tolerances across species and between populations. However, the upper limit is consistently between 21°C and 23°C with most species and life histories preferring temperatures between 10°C and 16°C. Analysis of both juvenile coho and rainbow trout rearing densities were highest at MWATs between 14°C and 16°C (Child and Courter (2010). The highest MWAT at which coho were observed was 23.4°C, although most fish were found in pools with MWAT less than 21°C. Rainbow trout also showed similar temperature preferences, with the highest densities observed in sites with MWAT below 15°C. Relative densities of rainbow trout at MWATs greater than 20.5°C were less than 3% of the maximum densities observed.

Water Quality

A limited amount of water quality monitoring has been conducted in the wasteway. Early (2002) studied water quality and macroinvertebrate communities and concluded that some attributes of the wasteway's water quality are better than other drainages in the lower Yakima Basin, namely the Spring Creek Wasteway and Satus Creek below the Dry Creek confluence. Amon Wasteway rated higher in both macroinvertebrates community indices and in water quality than the nearby Yakima River. However, others have documented high levels of turbidity in the wasteway (Witty and Monk, 2005). Littleton (2010) continued to study water quality in Amon Wasteway, and compared the results of her study with the results obtained by Early in 2002. Littleton found that Amon Wasteway had lost macroinvertebrate diversity in the nine years between the two studies, and while still productive, was declining in ecological health (2010). This is important, since macroinvertebrates are a source of food for salmonids in the wasteway. Another water quality study exists, conducted by a volunteer, Alexandra Amonette from the Tapteal Greenway Association, with funding from the Washington Department of Fish and Wildlife Aquatic Lands Enhancement Account (Littleton, 2009 and Amonette, 2009). Amonette (2009) concluded that water quality in the main stem of Amon Wasteway was suitable for salmonids between November and April.

Spawning Habitat Conditions

Blair (2005) provides a comparison of coho salmon habitat suitability indexes within the irrigation and non-irrigation season in Amon Wasteway. He concluded that instream and riparian habitats in some portions of the wasteway, considering substrates, water velocities and depths, were suitable for spawning adult coho salmon. More specifically, the Delta (much of the area below Columbia Park Trail), West Fork and East Fork reaches were deemed inadequate for spawning, but the section of the wasteway that roughly parallels Leslie Road appeared to be more likely to be able to support spawning coho. This section was also where most of the spawning coho salmon were found in surveys (Hoffarth, 2009 and 2014 personal communication). Blair (2005) also suggested that the reach running through the Meadow Springs Golf Course may provide suitable habitat for spawning coho. Coho spawning surveys have been completed in Amon Wasteway by the WDFW and by Yakima Basin Joint Board biologists, Pat Monk and David Child (Table 2).

Salmonid Monitoring Surveys

Fish sampling has been conducted on a number of occasions, but none of this data is available in written reports, in part because the surveys are typically small in scope and are not organized as part of a systematic effort to study fish abundance or assemblage in the wasteway. To our knowledge there have been two types of salmonid surveys in the wasteway: spawner/redd surveys and electrofishing. WDFW has also conducted two electrofishing surveys, with one survey occurring in 2001 (see results of these in Child & Courter 2010). A limited number of salmonids were collected along with a variety of other species including smallmouth bass, bluegill and mosquitofish. Evidence of low salmonid densities was corroborated by Monk and Witty (2005) who noted a lack of salmonids during habitat surveys in the wasteway.

Table 2. Summary of redd surveys for Amon Wasteway (adapted from Hoffarth, 2008, 2009 with 2007 - 2014 data provided by Pat Monk and David Child *unpublished data/surveys*) *not surveyed in 2002, 2003, and 2004. Salmon redds (assumed coho) have been observed, primarily between the mouth and Canyon St., with the majority of them found in the ½ mile upstream of the Columbia Irrigation District flume.

Year	Redds	Coho Observed
2014	4	0
2013	2	0
2012	11	3
2011	0	3
2010	0	0
2009	16	0
2008	4	2
2007	1	0
2006	47	3
2005	0	0
2001*	0	7

Study Methods: 2014 Data Collection and Analysis

Amon Wasteway is located in the cities of Kennewick and Richland, Washington near the mouth of the Yakima River (Figure 2). The uppermost reaches of the east fork are located in the dryland wheat fields of the Horse Heaven Hills; the point of operational spill into the east fork of the wasteway occurs in an area of open space, which is rapidly converting to residential developments moving down towards the urbanized parts of Kennewick and Richland. The uppermost reaches of the west fork, like the east fork, are in dryland wheat fields of the Horse Heaven Hills. The west fork runs through Badger Canyon, where land use is predominately hay and corn fields, fruit orchards, small farms and ranches, and low density rural residential development (DeFoe 2015). The East and West Forks converge at the Meadow Springs Country Club. Downstream of the confluence, wasteway water then flows through the remainder of the golf course into a topographic canyon, surrounded by a series of residential developments until ultimately reaching the Yakima River delta. The analyses reported herein focus on three reaches in the West Fork.

To determine salmonid production capacity in the WF, we collected field data and modeled fish carrying capacity. The primary field data components included stream habitat surveys, fish sampling, and water quality monitoring. Habitat and fish sampling data were then compared to values from scientific literature to assess salmonid suitability. Modeled estimates of fish rearing density were also used to evaluate rainbow trout/steelhead production potential.

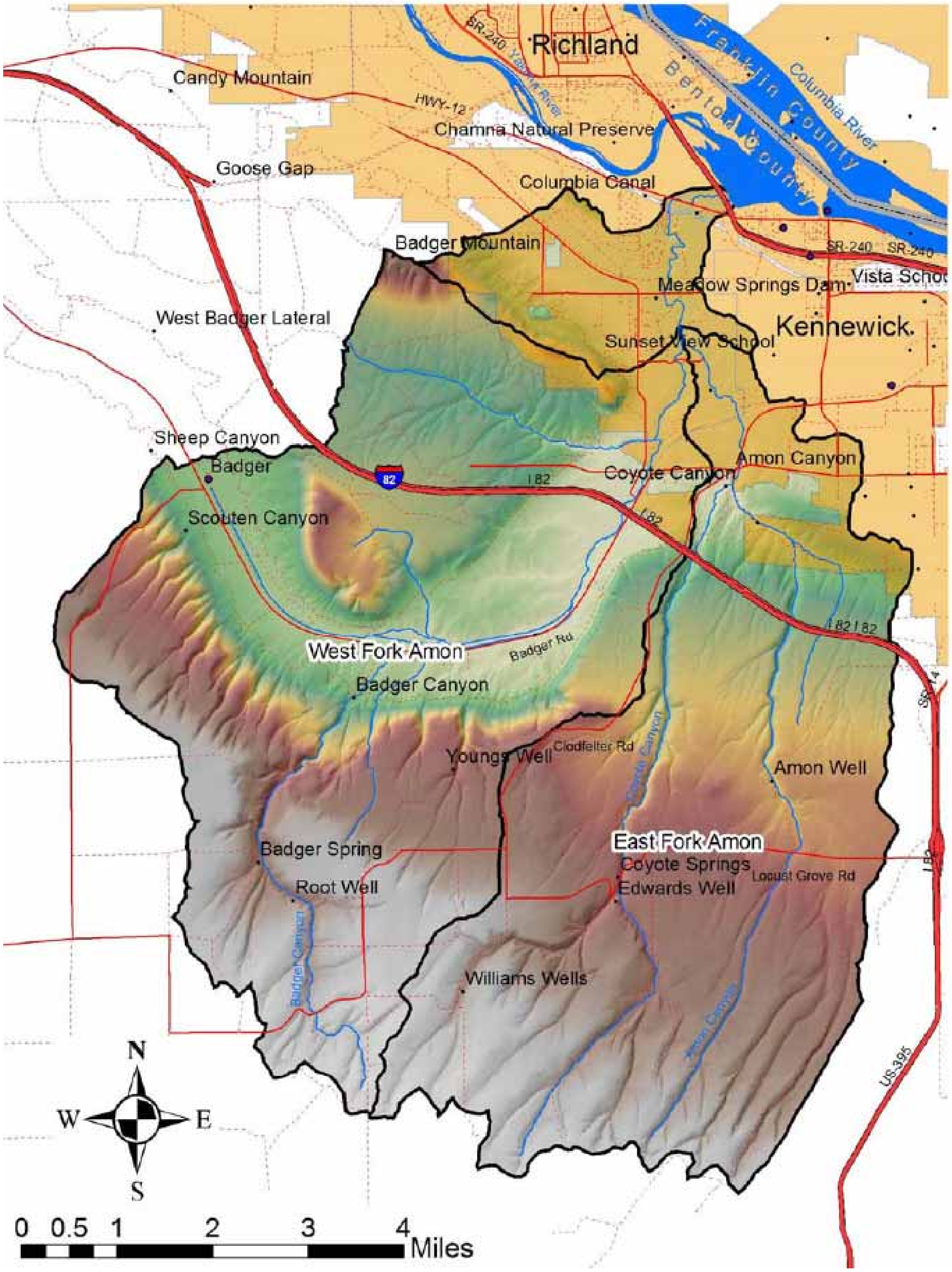

Figure 2. Amon Wasteway drainage area (Smith et al. 2005).

Habitat Survey Data Collection

Field surveys were conducted in three sampling reaches approximately 200 to 700 meters in length (Figure 3). Sample reaches were chosen to represent major shifts in gradient, geomorphology, and habitat conditions. Data collection followed the methods of Cramer and Ackerman (2009a), similar to the Oregon Department of Fish and Wildlife Stream Habitat Survey Protocol (Moore et al. 2002). Surveys were conducted in February of 2014.

Mesohabitat units such as pools, riffles, and glides were surveyed. Habitat features were described by the following variables:

- Total length of each channel unit
- Average width of each channel unit
- Maximum depth in pools
- Average depth in riffles and glides
- Classification of substrate, by proportion, into each of the following substrate classes: fine sediment (fines), gravel, cobble, boulder, bedrock
- Wood complexity index and count

Other useful information was noted such as flow, bankfull width, riparian vegetation, and the presence of fish passage barriers. In each reach, 2-3 temperature loggers were deployed for the term of the project from February – November. Water quality samples were also taken during the late winter, spring and summer of 2014, including flow volume (cubic feet per second), dissolved oxygen (mg/l and % saturation), pH (units) and turbidity measurements. Water quality monitoring locations are delineated with an "F" in Figure 3.

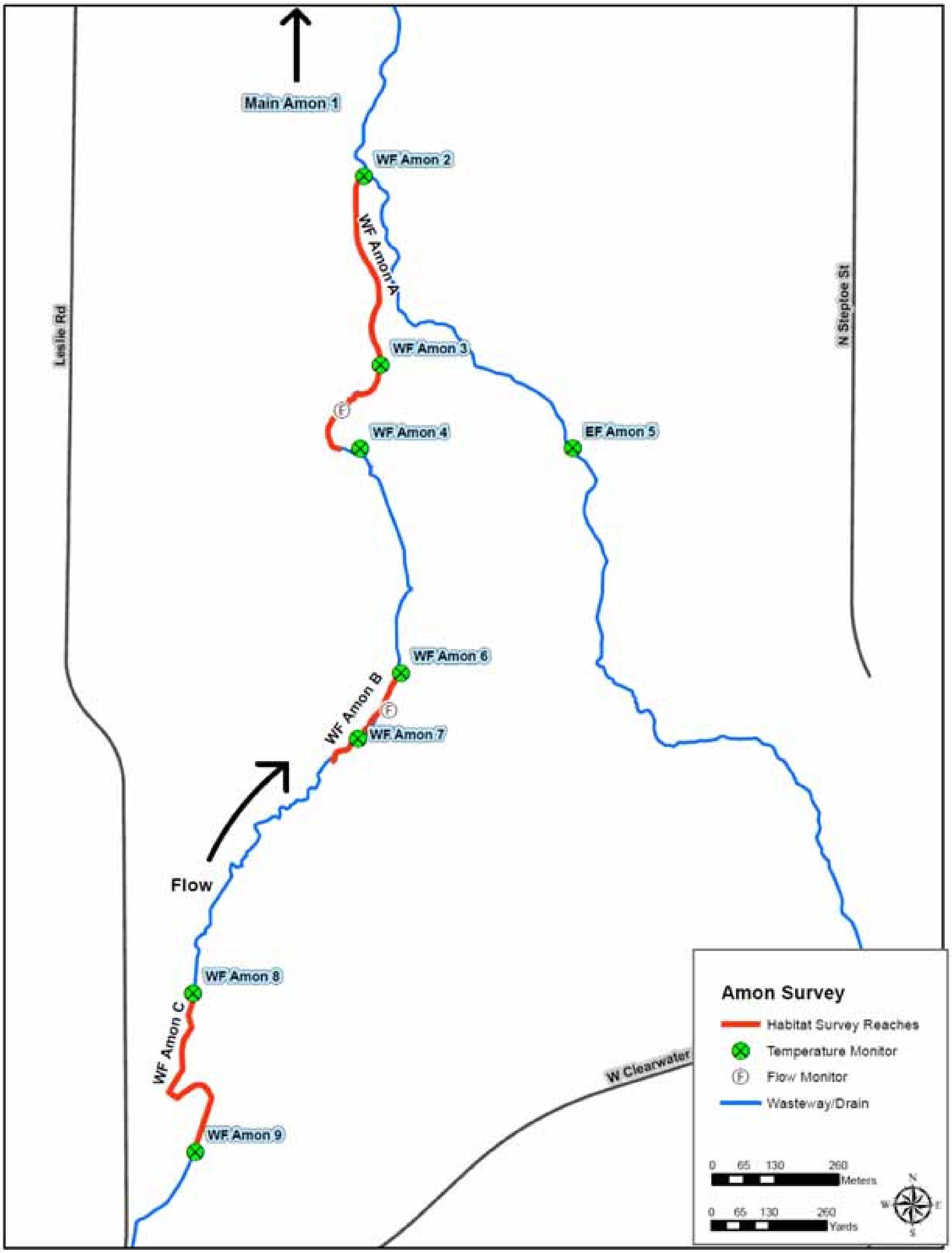

Figure 3. WF Amon Wasteway habitat survey reaches (WF Amon A, B, & C) and temperature monitoring sites (1-9).

Electrofishing Methods

In cooperation with Paul Hoffarth with the WDFW, we used a backpack electrofisher and dip nets to thoroughly sweep accessible areas of each of the two lower sample reaches, expending approximately one hour of sampling effort in each reach. Fish were individually identified by species and measured before being released back into the wasteway. Single-pass backpack electrofishing in small streams is known to provide a reliable index of fish abundance (Carter et al. 1998 and Douglas et al. 2005). Thus, this methodology was expected to provide a reasonable estimate of relative abundance of fish in WF Amon Wasteway.

Temperature Monitoring

In total, 9 temperature loggers (HOBOs) were deployed throughout the WF Amon Wasteway (Figure 3). Temperature data was collected on an hourly time step between February 25 and November 25, 2014. Three loggers were deployed in each representative habitat sampling reach, as well as one in the East Fork and one in the mainstem Amon Wasteway near the Columbia Irrigation District flume, upstream of the confluence with the Yakima River. All temperature loggers were recovered, except WF Amon 2 near the last pond on the golf course.

Salmonid Capacity Estimation

Stream habitat survey data was used to populate a rainbow trout/steelhead carrying capacity model according to the methods of Cramer and Ackerman (2009b). Habitat conditions in WF Amon Wasteway are different from typical interior Columbia Basin salmonid streams because the flow and habitat in the wasteway are not naturally occurring. Most of the WF is comprised of man-made ponds and irrigation induced bulrush-covered wetlands. Therefore, wetland areas and ponds were treated as “pool” habitat types in the model. Although we expected this assumption to overestimate carrying capacity, it allowed us to examine whether WF Amon wetlands have the potential to provide suitable salmonid rearing habitat.

Modeling was used to estimate fish rearing density per square meter of wetted channel width. Resulting baseline rearing density estimates were then scaled to account for various habitat features, as previously described (Cramer and Ackerman (2009b)). The most limiting habitat variables in WF Amon Wasteway were water temperature (Figure 4), substrate conditions (Figure 5 and Figure 6), and the availability of fast water habitat types (Figure 7). Water temperatures were excessively high in WF Amon reaches A and B. In addition, the WF generally lacks riffle habitat, and fine sediments dominate the stream substrate composition.

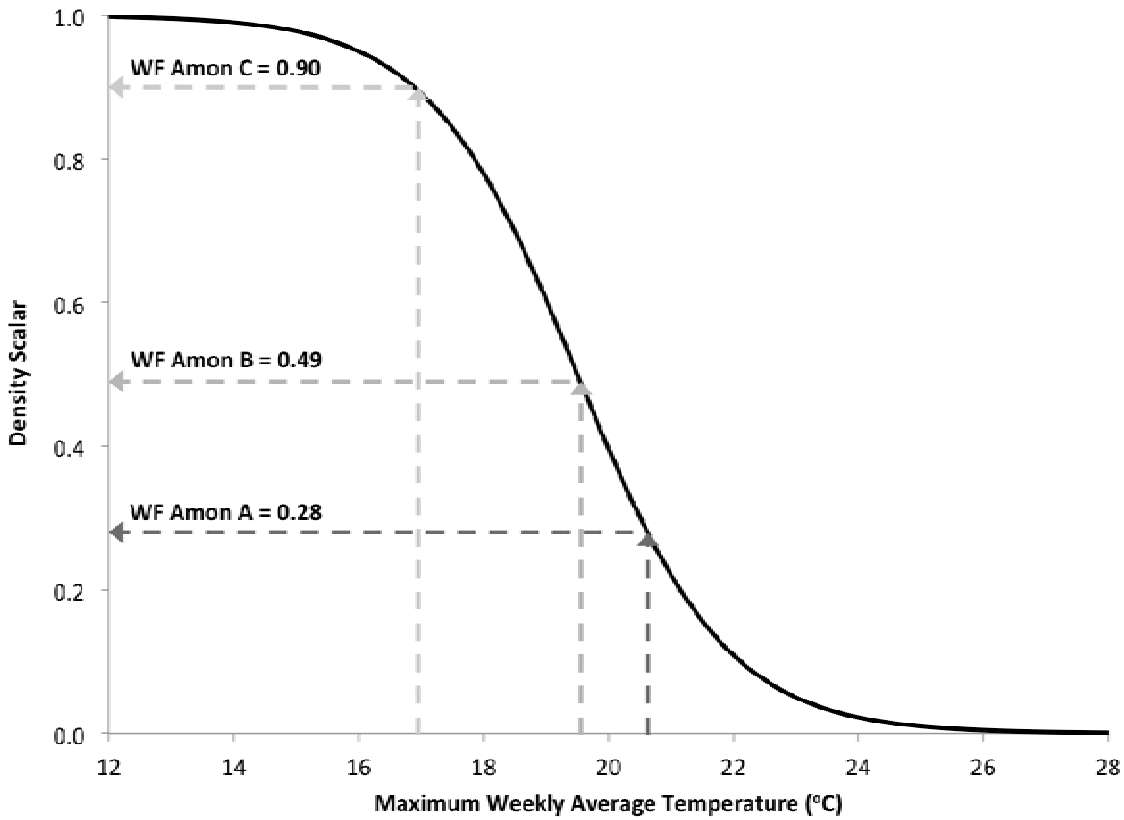

Figure 4. Logistic function used to predict temperature effects on rainbow trout/steelhead rearing densities in WF Amon Wasteway Reaches A, B, and C (from Child and Courter 2010). The function passes through values of 0.95 at 16 °C and 0.05 at 23 °C. Scalar values used during capacity modeling are displayed directly on the plot.

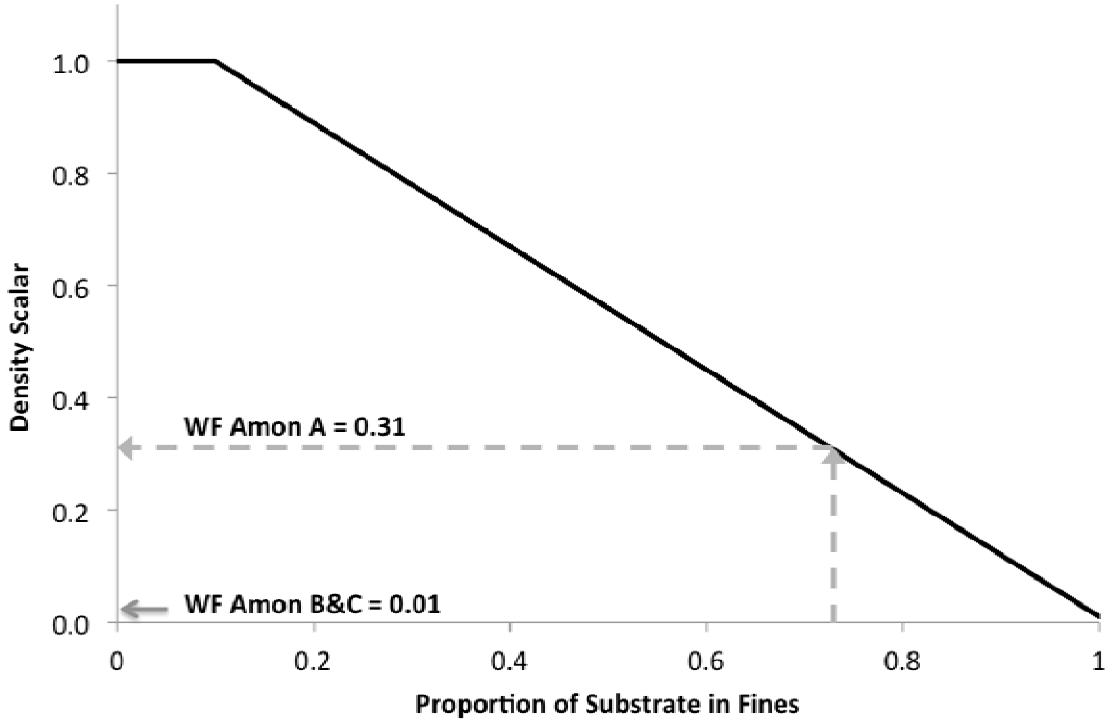

Figure 5. Linear function used to predict the impact of fine sediments on salmonid stream productivity (Cramer and Ackerman 2009b). Scalar values used during capacity modeling are displayed directly on the plot.

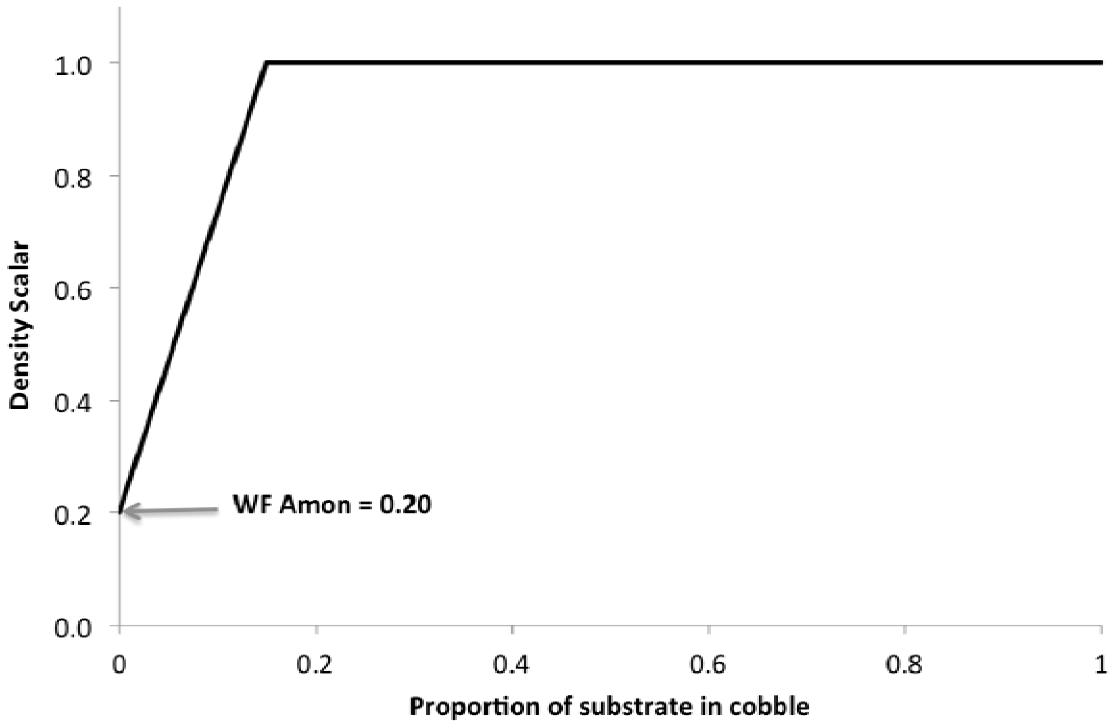

Figure 6. Linear function used to predict the impact of cobble substrates on salmonid stream productivity (Cramer and Ackerman 2009b). Scalar value used during capacity modeling for all three WF Amon wasteway reaches is displayed directly on the plot.

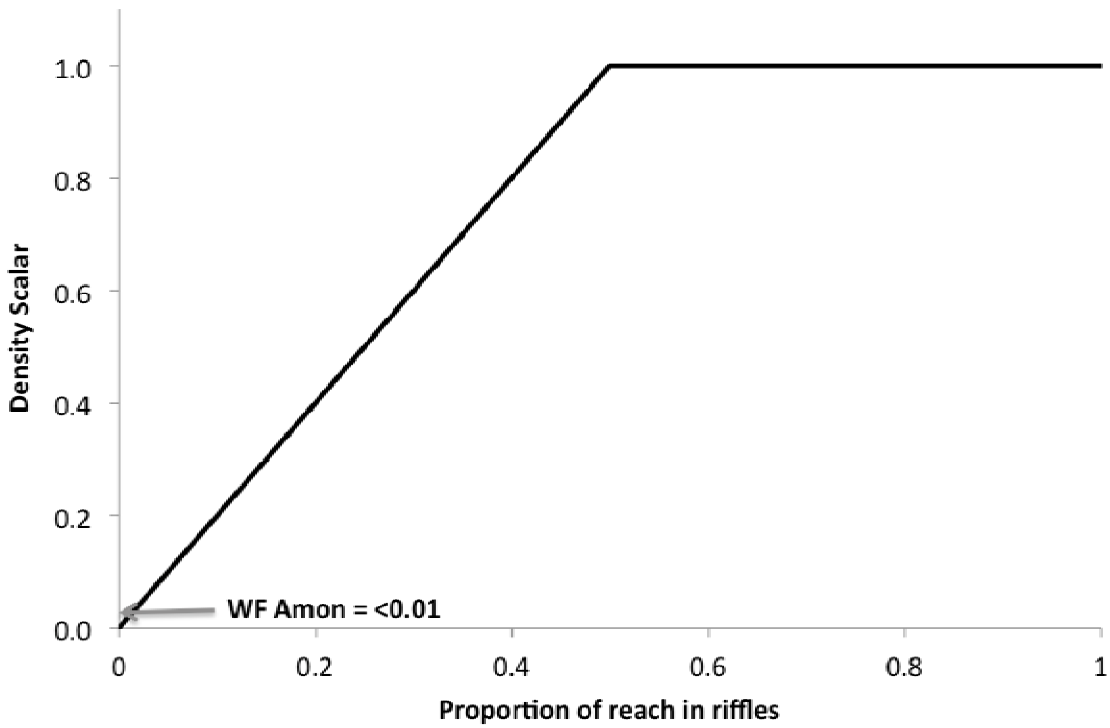

Figure 7. Linear function used to predict the impact of riffle habitat types on salmonid stream productivity (Cramer and Ackerman 2009b). Scalar value used during capacity modeling for all three WF Amon wasteway reaches is displayed directly on the plot.

Results

Habitat Surveys

The three sample reaches were comprised of shallow ponds and wetlands (pools), riffles and/or glides (Figure 8 and see Appendix 3 for representative habitat pictures). Cascades, rapids and other mesohabitat types were not observed. Pools composed nearly 100% of WF Reach A and 100% of Reach C. Glides comprised 100% of the habitat for WF Reach B. Substrate composition was 100% fines in reaches B and C and 74% in reach A. The remainder of Reach A was comprised of 23% boulder and 3% cobble substrates (Figure 9).

The amount of woody debris observed in the study areas was low. When scored on a scale of 1-5 (low-high), only one mesohabitat unit scored a 3 and the remainder of the habitats scored a 1. The pool in WF Reach A that scored a 3, had thick overhead cover; however, the substrate in this pool was comprised almost entirely of fine sediments, offsetting the habitat benefit of the wood cover.

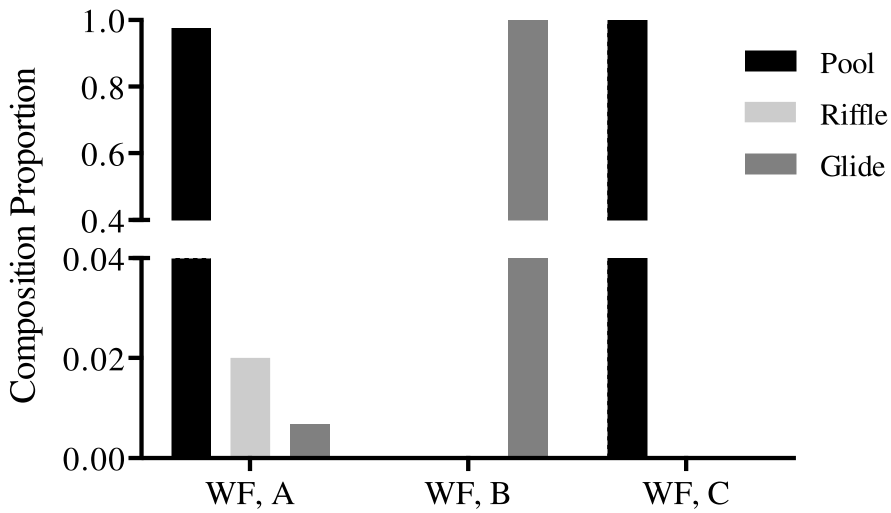

Figure 8. Proportion of pond and wetland (pool), riffle, and glide mesohabitat types in WF sample Reaches A, B and C, 2014.

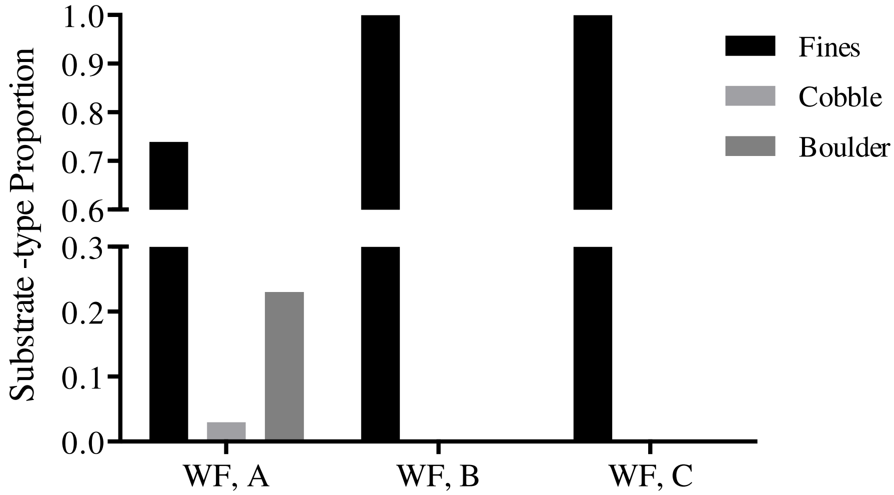

Figure 9. Proportion of fines cobble, and boulder substrate in WF sample Reaches A, B, and C, 2014.

Water Quality

Spot measurements of temperature, dissolved oxygen (DO), pH, and turbidity data were collected from the WF reaches A, B and C during spring, summer and early fall, 2014 (Table 3). DO readings were imprecise due to difficulties with equipment calibrations, but they did provide a useful measure for relative comparison between reaches and sampling events. With the exception of measurements taken in February, DO readings from WF Amon Wasteway were higher during winter months and lower during the warmer, summer months. The lowest DO measurements were taken in WF Reach A and C, which are also the two reaches with the highest pond and wetland habitat surface area. In general, WF Reach B water quality provided the most suitable conditions for salmonids of the three reaches studied. The pH and turbidity measurements observed throughout the WF were compatible with natural stream conditions elsewhere in the Yakima Basin.

Table 3. WF Amon Wasteway Water Quality Data, 2014.

Location	Sample Date	Time	Temp °C	DO (mg/l)	DO Sat%	pH	Turbidity
WF Amon A	2/26	956	6.6	8.67	72.5	7.91	clear
	3/24	1130	12.3	12.13	113.4	8.08	clear
	4/29	1130	14.2	15.1	145.8	8.45	clear
	5/27	1025	18.2	9.61	102.6	7.82	slightly turbid
	6/26	1140	20.5	6.46	73.1	7.75	clear
	7/30	939	22.1	7.41	85.4	7.72	very clear
	8/20	1100	20.0	5.44	59.0	7.25	slightly turbid
	9/24	1045	18.1	6.43	68.7	7.19	slightly turbid
WF Amon B	2/26	1200	10.3	10.06	77.0	7.9	clear
	3/24	1238	13.3	9.71	92.9	7.89	clear
	4/29	1300	16.4	10.59	105.9	8.32	very clear
	5/27	1115	16.6	6.9	70.6	7.79	very clear
	6/26	1234	19.3	5.94	63.4	7.64	very clear
	7/30	1025	18.3	5.92	62.5	7.36	very, very clear
	8/20	1015	18.7	7.92	74.3	7.37	very clear
	9/24	1010	15.9	8.27	80.4	7.47	clear
WF Amon C	2/12	1230	11.0	8.4	77.0	7.69	clear
	3/24	1315	14.9	8.64	85.2	7.65	clear
	4/29	1430	18.1	10.38	103.6	7.79	slightly turbid
	5/27	1141	18.7	9.38	100.7	8.27	slightly turbid
	6/26	1254	19.6	4.87	52.8	7.56	turbid
	7/30	1058	20.0	4.75	54.4	7.37	very clear
	8/20	940	20.2	6.9	78.9	7.23	slightly turbid
	9/24	930	17.2	4.82	50.6	7.25	slightly turbid

Water Temperature

Water temperature conditions were similar between all reaches in months March through May and September through October (Figure 10). From June through August, similar temperatures were found between the lower main stem and EF, and between reaches A and B within the WF, only varying by 1 ºC. The greatest difference in average daily temperatures during the months of June through August was found to be approximately 4 ºC (between the EF and WF Reach C). Further, on average, WF Reach C was approximately 2 ºC cooler than either reaches A or B during these summer months. Cooler observations in Reach C can be attributed to flow input from springs upstream. Further, warmer observations in the remaining downstream reaches are likely due to low flow conditions – causing a rapid increase in water temperature due to warmer ambient air temperatures. Differences in temperatures between all reaches can further be attributed to localized stream attributes, such as width, depth, and vegetation cover.

Maximum seven-day average temperatures exceeded 20 ºC from June 24 through September 2 for the Lower Main Stem and EF, peaking on August 4 at 24 ºC and 25 ºC, respectively (Figure 11). For WF, Reaches A and B, the maximum seven-day average at approximately 19 ºC or more, occurred during the month of July. For Reach C, the highest temperatures recorded occurred during late June through early September, with temperatures around 16 ºC.

During the summer irrigation season, flow discharge from the EF is larger in volume compared with the volume the WF. Therefore, EF temperatures heavily influence values recorded in the Lower main stem (Temperature Logger 1). Solar heating of the Country Club ponds may also increase temperatures in WF Reach A. In one recording, we found temperatures upstream of the Country Club 5 ºC cooler in the summer compared to what was observed in the Lower main stem. Whether by a combination of factors, or solely as a result of accretions from the EF, temperatures in Amon Wasteway are at or near equilibrium with air temperatures below the confluence of the EF and WF, and continue to be at equilibrium until reaching the Yakima delta.

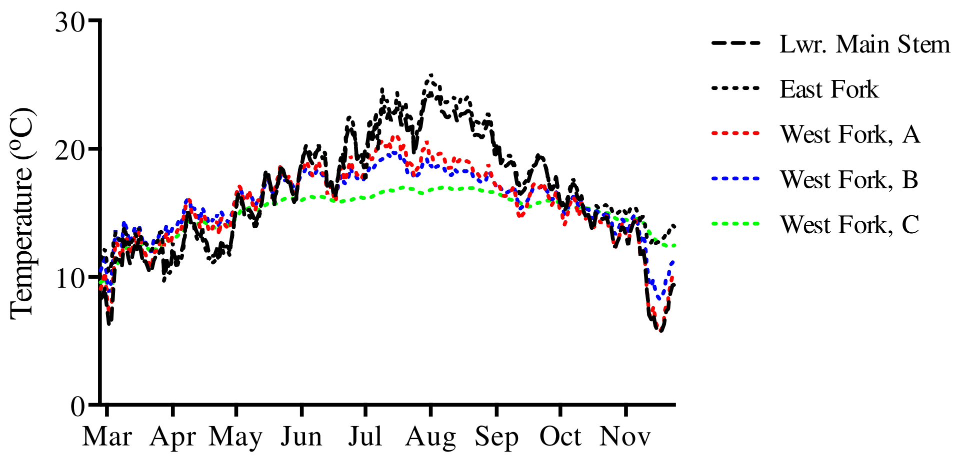

Figure 10. Average daily water temperature conditions in all reaches sampled in Amon Wasteway, 2014.

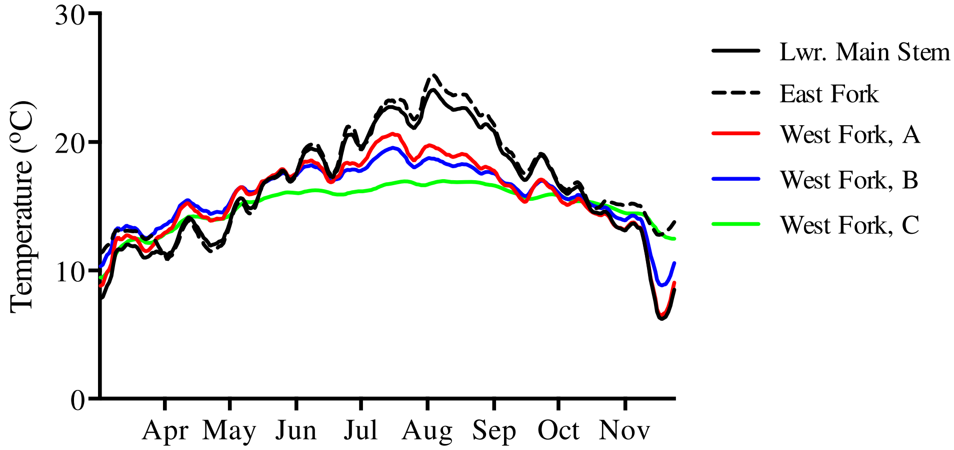

Figure 11. Seven-day average water temperature conditions in all reaches sampled in Amon Wasteway, 2014.

Electrofishing Surveys

In total, three salmonids were captured in the WF and one at the confluence of the WF and EF during our July 2014 electrofishing surveys in Amon Wasteway (Table 4). All four salmonids were rainbow trout. Species with higher temperature tolerance such as smallmouth bass, sunfish, speckled dace and peamouth were the most abundant species found in a previous mainstem Amon Wasteway survey (Child & Courter 2010). Findings in the WF were similar, although overall species diversity and fish abundance was lower. The number of salmonids captured per 100-meters of stream surveyed were <1, 0, and 0 for reaches A, B, and C respectively.

Table 4. Species and size of fish captured in the WF Amon Wasteway during July 2014 electrofishing surveys

Reach	Common Name	Fork Length (mm)	Location
WF Amon A	rainbow trout	450	In mainstem at WF confluence
	three-spined stickleback	41	In mainstem at WF confluence
	mosquito fish	38	In mainstem at WF confluence
	speckled dace	43	In mainstem at WF confluence
	mosquito fish	34	In mainstem at WF confluence
	mosquito fish	38	In mainstem at WF confluence
	speckled dace	44	In mainstem at WF confluence
	mosquito fish	32	In mainstem at WF confluence
	rainbow trout	82	Upstream of ponds in channel
	rainbow trout	93	Upstream of ponds in channel
	rainbow trout	97	Upstream of ponds in channel
WF Amon B	crayfish	N/A	In bulrush lined channel
	numerous mosquitofish		In bulrush lined channel margins
WF Amon C	numerous mosquitofish		Schools of fish observed in ponds

Salmonid Capacity Estimates

Modeled estimates of *O. mykiss* density in our sample reaches were extremely low (Table 5). In total, we estimated a rainbow trout/steelhead rearing capacity of <8 fish across 47,317 square meters of stream, pond, and wetland habitat surveyed. The habitat conditions that appear to be primarily responsible for low salmonid densities in the wasteway include warm summer water temperatures, excessive levels of fine sediments, absence of cobble substrate, and lack of fast-water habitats throughout the WF. Low salmonid density predictions were consistent with low abundances observed during electrofishing surveys.

Table 5. Estimated *O. mykiss* parr carrying capacity in sampling Reaches A, B, and C of the WF Amon Wasteway. Estimates were derived according to the methods of Cramer and Ackerman (2009b). Estimates were also adjusted to account for temperature effects following methods described in Child and Courter (2010).

Reach	Density (fish/m^2)	Habitat Area (m2)	Carrying Capacity
A	$2.06 x 10^{-4}$	27,261	6
B	$2.97 x 10^{-6}$	426	<1
C	$1.56 x 10^{-5}$	19,630	<1

Discussion and Conclusions

After conducting a literature review and an independent evaluation of habitat conditions and fish presence in the WF of Amon Wasteway, we conclude that the WF does not appear to be well-suited for salmonid production. Observed salmonid abundance and modeled densities were extremely low relative to salmonid-producing streams elsewhere in the Yakima Basin[2]. This result was similar to our previous findings in Amon Wasteway downstream of the EF and WF confluence (Child and Courter 2010).

Although the WF ponds and wetlands had considerable wetted habitat surface area, the substrate was comprised of nearly 100% fines, which is not compatible with salmonid producing streams. Fine sediments fill in the interstitial spaces between the larger coarse substrate materials, reducing aquatic macroinvertebrate production, the primary food source for stream salmonids, and eliminating critical refugia for rearing salmonids. There was also a lack of fast-water habitats, such as riffles, rapids and cascades. These habitat types, often associated with higher gradient streams, help to remove fine sediments from fish and invertebrate rearing areas, and they provide insect drift, which is how salmonids typically feed on benthic macroinvertebrates. The only area within the WF where we documented salmonid presence was where the WF enters the Meadow Springs Country Club golf course. This particular area had a small patch of cobble which was part of the engineered stream channel that meanders through the golf course. There was also a small riffle directly upstream of the cobble patch. Though absent elsewhere in the WF, these are the types of conditions that would be more likely to support salmonids, and our field data confirmed this assertion. This area is above a fish passage barrier culvert at the last golf course pond (see WF Amon A reference picture in Appendix 3).

As explained by Child and Courter (2010), there are two broad-scale factors principally responsible for Amon Wasteway's low salmonid production capacity: 1) geomorphology and 2) climatic conditions. The wasteway exists within a geologic area characterized by plentiful fine silts, clays, and sands that do not provide suitable stream substrate for salmonids. Sedimentary deposits of glaciofluvial (glacial or riverine), lacustrine (lake), and eolian (wind blown) origin, and basalts of volcanic origin are the two principal formations found in the lower Yakima Basin (Molenaar 1985). Similarly, Smith et al (2005) found that the surface geology in the WF Amon was mostly composed of highly permeable outburst flood deposits (50%), with lesser amounts of loess (33%), mass wasting deposits (2%), alluvium (1%), and basalt (15%) of low permeability. The distribution of these sediments is an important driver of geomorphic conditions in Amon Wasteway. The land irrigated by the KID, the source of nearly all of Amon Wasteway's flow volume, lies to the west of the Yakima River at higher elevations than the river floodplain (Smith et al. 2005). Thus, the origin of sedimentary deposits in the KID is primarily lacustrine and eolian. These areas contain wind-deposited loess and fine silts and sands, left behind by the Missoula Floods (Molenaar 1985). In contrast, most soils in

[2] Trout densities in several different sites throughout Taneum Creek, a high priority watershed for salmonid restoration activities located in the upper Yakima Basin, averaged between 0.13 and 0.56 fish/m^2 over the years 1998-2008 (Gabriel Temple, pers. comm.).

the river floodplain lying to the west of the Yakima River in the vicinity of Toppenish and Wapato are cobbles, gravels, and sands of glaciofluvial origin. These areas support much higher salmonid densities compared with what we observed in the WF Amon Wasteway[2].

Romey and Cramer (2001) report that habitat conditions in Sulphur, Granger, and Moxee drains in the Yakima Basin were generally unsuitable for salmonids due to high levels of substrate embeddedness and low gradients. Salmonids are unsuccessful in Amon Wasteway for similar reasons. In addition to these limiting factors, Child and Courter (2010) documented extreme summer water temperatures throughout lower Amon Wasteway. The WF of Amon Wasteway provided cooler summer temperatures relative to the lower main stem, but only the upper portion of the WF (Reach C) had an MWAT below 19 ^{o}C. Although relatively cool groundwater feeds the WF, a short distance downstream the wasteway broadens in the vicinity of Amon Preserve where the hot, arid climate of Badger Canyon quickly warms numerous large, shallow wetland ponds. From that point downstream, water temperatures are at stable equilibrium with summer air temperatures. A thorough explanation of climatically-controlled habitat limitations for streams in general, and particularly for salmonids in the Amon region is provided in Child and Courter (2010).

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References

Amonette, A. 2009. Personal communication with A. Amonette, volunteer, Tapteal Greenway Association.

Amonette, A. 2009. Amon Basin 2008- 09 Water Quality Sampling Report. Prepared for the Tapteal Greenway Association. Funded by the Washington Department of Fish and Wildlife Aquatic Lands Enhancement Account.

Blair, P. S., 2005. An evaluation of fish habitat in Amon Creek: Benton County, Washington. unpublished master's thesis. Washington State University. Pullman, WA.

Carter G. Kruse, Wayne A. Hubert, Frank J. Rahel. 1998. Single-Pass Electrofishing Predicts Trout Abundance in Mountain Streams with Sparse Habitat. Series: North American Journal of Fisheries Management, Vol. 18, Page(s): 940-946.

Child D. B., Courter I. 2010. Suitability of Amon Wasteway for Salmonid Production. Report Prepared for Yakima River Basin Coalition. In Press.

CH2MHILL. 1983. Badger Canyon Groundwater Investigation. Prepared for the Kennewick Irrigation Distict. In Press.

Conley, A., Freudenthal, J., Lind, D., Mees, P., Visser, R. *Yakima Steelhead Recovery Plan*. Yakima Basin Fish and Wildlife Recovery Board [YBFWRB]. 2009. Yakima, WA.

Cramer, S. P., Ackerman, N. K. 2009a. Linking Stream Carrying Capacity for Salmonids to Habitat Features. American Fisheries Society, Series: Symposium, Vol. 71, Page(s): 225-254.

Cramer, S.P., Ackerman, N.K. 2009b. Prediction of Stream Carrying Capacity for Steelhead (Oncorhynchus mykiss): the Unit Characteristic Method. American Fisheries Society, Series: Symposium, Vol. 71, Page(s): 255-288

Defoe. S. (2015). Personal communication with S. Defoe, District Planner for the Kennewick Irrigation District.

Douglas S. Bateman, Robert E. Gresswell, Christian E. Torgersen. 2005. Evaluating Single-Pass Catch as a Tool for Identifying Spatial Pattern in Fish Distribution. Series: Journal of Freshwater Ecology, Vol.(20)2, Page(s): 335-345

Early, S. K., Newell, R.L., and Medina, V.F., 2002. Use of macroinvertebrate and chemical indices to assess water quality of an irrigation wasteway: Journal of Freshwater Ecology, v. 17, No. 2, p. 189-191.

Hoffarth, P. 2009 & 2014. Personal communication with P. Hoffarth, regional biologist for Washington Department of Fish and Wildlife.

Hoffarth, P (2008). 2007 Lower Yakima River Annual Report. Unpublished data. Washington Department of Fish and Wildlife, Pasco, WA.

Lentz, C.R. 1974. CR Lentz review, Yakima Project water rights and related data. Prepared for U.S. Bureau of Reclamation, Yakima Project, WA 235 pp.

Littleton, M. 2009. Personal communication with M. Littleton, Washington State University Masters Student.

Littleton, M. 2010. Water Quality Assessment of Amon Wasteway Using Aquatic Macrointvertebrate and Chemical Indices. unpublished master's thesis summary.Washington State University. Pullman, WA.

Meadow Springs Country Club. 2003. Amon Creek fish passage: biological assessment for ESA listed species. Prepared for Meadow Springs Country Club, Richland, WA. 36 pp.

McKern, J. 2014. Personal communication with J. McKern, Retired fisheries biologists with the ACOE and owner of Fish Passage Solutions.

Monk, P. 2001. Fish surveys in the Roza-Sunnyside Board of Joint Control irrigation drain network: Summary of Major Findings for 2001. Roza-Sunnyside Board of Joint Control, Sunnyside, WA.

Revell, S. 2010. Personal communication with S. Revell, then District Planner for the Kennewick Irrigation District.

Romey, B., and S.P. Cramer. 2001. Aquatic habitat survey of irrigation drainage networks, lower Yakima River Basin. Prepared for RSBOJC and USBR, prepared by S.P. Cramer and Assoc., Sandy, Or., 97055. 76 pp.

Shaw, C. 2008. Geologic illustrations prepared for the Amon Creek Natural Preserve kiosk. used with permission from the Tapteal Greenway Association.

Smith, D.L., B.A. Gardner, and T. Williams. 2005. Natural streamflow estimates for watersheds in the lower Yakima River basin. Prepared by S.P. Cramer and Associates for the Yakima Basin Joint Board. 29 pp. + Appendix.

United States Geological Survey [USGS]. (1978). Badger MTN, WA 7.5 minute quadrangle. 1:24,000 topographic map. Washington DC: Author.

United States Geological Survey [USGS]. (1986). Changes in Ground –Water Levels and Groundwater Budgets, from Predevelopment to 1986, in parts of the Pasco Basin, Washington. Water-Resources Investigations Report 96-4086. Prepared in cooperation with the Washington State Department of Ecology. Washington DC: Author.

United States Bureau of Reclamation. 2000. Draft Biological assessment of Yakima Project operations and maintenance. Prepared for USBR, Yakima Field Office, Yakima, WA. 98901.

Appendix 1. Habitat Survey Measurement Protocol

Delineation into Geomorphic Unit Types

Channel geomorphic units are relatively homogeneous lengths of the stream that are classified by channel bed form, flow characteristics, and water surface slope. With some exceptions, channel geomorphic units are defined to be at least as long as the active channel is wide. Individual units are formed by the interaction of discharge and sediment load with the channel resistance (roughness characteristics such as bedrock, boulders, and large woody debris). Channel units are defined (in priority order) based on characteristics of (1) bedform, (2) gradient, and (3) substrate.

It should be noted that the unit types listed below do not necessarily describe all units that may be encountered in a stream, but describe all of the unit types likely to produce juvenile salmonids. Other unit types such as isolated pools, dry channel units, culverts, or steps are unlikely to produce salmonids and typically make up only a very small portion of a stream. When a stream diverges into multiple channels, each of the channels should be surveyed.

<u>Pools</u>

A section of stream channel where water is impounded within a closed topographical depression. Pools are typically created when fluvial processes such as scour associated with a channel obstruction form depressions in the channel bed. The scour forms a depression which acts as a basin that would continue to hold water if there was no flow. Some pools are created by impoundments such as a debris flow, a log jam, or a beaver dam.

<u>Glides</u>

An area with generally uniform depth and flow with no surface turbulence. Low gradient; 0-1 % slope. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. Generally deeper than riffles with few major flow obstructions and low habitat complexity. There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993).

<u>Riffles</u>

Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Generally broad, uniform cross section. Low gradient; usually 0.5-2.0% slope, rarely up to 6%. Some riffles may contain numerous sub-unit sized pools or pocket water created by scour associated with small boulders, wood, or stream bed dunes and ridges. In these instances, sub-unit sized pools comprise 20% or more of the total unit area.

<u>Rapid</u>

Swift, turbulent flow including chutes and some hydraulic jumps swirling around boulders. Exposed substrate composed of individual boulders, boulder clusters, and partial bars. Moderate gradient; usually 2.0-4.0% slope, occasionally 7.0-8.0%. Rapids over bedrock may appear as swift, turbulent, "sheeting" flow over smooth bedrock. Sometimes called chutes. Little or no exposed substrate. Moderate to steep gradient; 2.0-30.0% slope.

Cascade

Much of the exposed substrate composed of boulders organized into clusters, partial bars, or step-pool sequences. Fast, turbulent, flow; many hydraulic jumps, strong chutes, and eddies; 30-80% white water. High gradient; usually 3.5-10.0% slope, sometimes greater. Cascades over bedrock are similar except that structure is derived from sequence of bedrock steps. Slope 3.5% or greater.

Backwater

Pool found along channel margins; created by eddies around obstructions such as boulders, root wads, or woody debris. Part of active channel at most flows; scoured at high flow. Substrate typically sand, gravel, and cobble.

Beaver Pond

Pool formed by a beaver dam.

Geomorphic Unit Length

Total length of each unit in meters.

Geomorphic Unit Width

Average width of wetted channel in meters. Average width should be estimated by observing the wetted width in at least three locations along the longitudinal axis of the unit, and then averaging. We prefer width measurements approximately every 10-12 meters for each unit to ensure an accurate average width measurement.

Maximum Depth in Pools

Maximum depth should be recorded in pools in meters. It is also advisable that maximum depth be recorded in backwater units and beaver ponds, though these measurements are currently not needed for the UCM.

Average Depth in Riffles

Average depth in meters should be recorded in riffles. It is also advisable that average depth be recorded in glides, rapids and cascades, but the model can be run without depth data for these select units. Depth measurements should be taken in conjunction with each width measurement.

Substrate Classification

Percent distribution by streambed area of substrate material in six size classes: fines (<2mm), gravel (pea to baseball; 2-64mm), cobble (baseball to bowling ball; 64-256mm), boulders, and bedrock. Estimate distribution relative to the total area of the habitat unit (wetted area). Round off each class to nearest 5 percent.

Wood Complexity

Each pool and glide should have a wood complexity rating assigned. Wood complexity is rated on a 1-5 scale as defined below. Other measures (counts) of LWD availability are also advisable, though currently there are no means to incorporate these data into the UCM. Future use of these data in the UCM are possible.

Table 6. Wood complexity rating definitions.

Wood Complexity Rating	Definition
1	Wood debris absent or very low
2	Wood present, but contributes little to habitat complexity. Small pieces creating little cover.
3	Wood present as combination of single pieces and small accumulations. Providing cover and some complex habitat at low to moderate discharge.
4	Wood present with medium and large pieces comprising accumulations and debris jams that incorporate smaller root wads and branches. Good cover for fish over most flow levels.
5	Wood present as large single pieces, accumulations, and jams that trap large amounts of additional material and create a variety of cover and refuge habitats. Woody debris providing excellent persistent and complex habitat. Complex flow patterns will exist at all discharge levels.

Alkalinity and Turbidity

Measures of alkalinity (mg/L $CaCO_3$) and turbidity (NTU) at low flow are needed to parameterize the UCM. Ideally, these values would be available for each reach surveyed. However, this is typically not the case in which instance it is desired to have several measurements available from various locations within the watershed so as to provide a representative estimate of the value for the entire basin. Previously, S.P. Cramer & Associates has undertaken analysis to estimate low flow values for these parameters if measurements were only available from other times of the year. Also, when no data are available within the watershed of interest, data from nearby representative watersheds may be used.

Other Useful Stream Survey Information

Other data may be collected that are not directly needed to parameterize the UCM, but may be useful in post modeling analysis, or to estimate capacity where no habitat survey data are available. These include active channel width, flow, gradient, and potential barriers.

Appendix 2. WF Amon Wasteway Flow Measurements From Surveys

Table 7. WF Amon Wasteway Flow Measurements From Surveys

WF Amon Wasteway flow measurements from surveys

Date	WF Amon A (cfs*)	WF Amon B (cfs*)
2/26/2014	3.33	2.99
3/24/2014	2.8*	4.99
4/29/2014	4.21	3.45
5/27/2014	5.31	4.32
6/26/2014	4.26	4.07
7/30/2014	3.76	5.47
8/20/2014	5.37	5.98
9/24/2014	9.6	4.69

**flows are calculated in cubic feet per second (cfs)*
**on 3/24/2014 the ponds on the golf course were drained, so perhaps much of the water was lost subsurface with that water surface elevation change, as this is the day when Amon A was much less than Amon B in flow volume, note similar, but less difference on on 7/30 and 8/20; though the reasoning is unclear, at this time.*

WF Amon A Location: Downstream of Broadmore Rd., but on the golf course before 1st pond

GPS Northing	46.2175
GPS Easting	119.25800

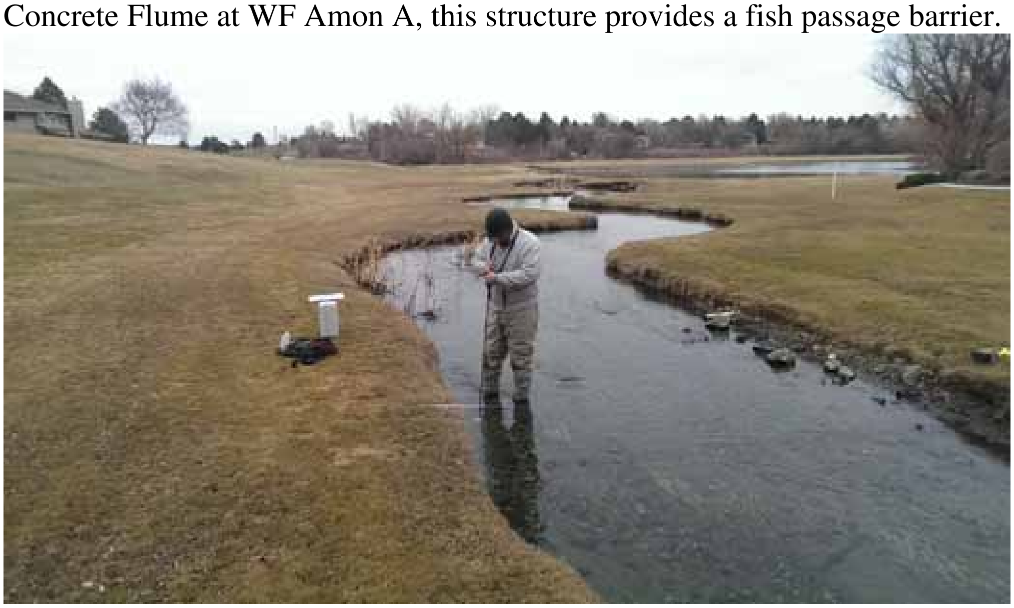
WF Amon B Location: Just downstream of the culvert below the KID pond

GPS Northing	46.21162
GPS Easting	119.25749

Appendix 3. WF Amon Wasteway Representative Habitat Pictures

It was suggested during a review period with local biologists of the draft Suitability of the West Fork Amon Wasteway for Salmonid Production report, that representative habitat pictures be provided. Here are representative pictures of WF Amon A, B & C.

Concrete Flume at WF Amon A, this structure provides a fish passage barrier.



The author at the upstream end of WF Amon A, note the fine sediment substrate.

Representative habitat in the Amon B survey reach.

The co-author at the WF Amon C habitat survey reach.

Appendix 4. Detailed map of the Kennewick Irrigation District service area, Amon Wasteway meets the Yakima Delta near I-182.