Eastern Washington University
Department of Biology
Fisheries Research Center

From: Allan T. Scholz, Ph.D.
Eastern Washington University
Department of Biology
258 Science Hall
Cheney, Washington 99004
Telephone (509) 359-6397
Email: ascholz@ewu.edu

To: Washington Department of Ecology
Eastern Regional Office
4601 N Monroe
Spokane Washington 99205-1295

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This letter is about the Washington Department of Ecology’s establishment of a minimum instream flow June 16 – September 30 in the Spokane River of 850 CFS below Monroe Street Dam and 500 CFS at Greenacres. The minimum flow established by WDOE is unacceptable from the standpoint of sufficiently protecting the existing and future needs of aquatic life in the Spokane River for several reasons. Before I get into those reasons, I want to provide some background about myself.

I. Background & Qualifications

I am Allan T. Scholz, and a copy of my CV is attached as Exhibit 1 to this letter. I received BS, MS, and Ph.D. degrees in Zoology from the University of Wisconsin (Madison) in 1976, 1978 and 1980 respectively. While at Wisconsin, I worked at the Laboratory of Limnology under the direction of Arthur D. Hasler, an eminent Limnologist and Fish Biologist, who was my major advisor. I am currently Professor Emeritus in the Department of Biology at Eastern Washington University, where I taught courses in Ichthyology and Fisheries Management for 34 + years (fall 1980 to fall 2014). I am the senior author of six books about eastern Washington fishes and a coauthor of a book (Hasler was the senior author) about olfactory imprinting and homing in salmonid fishes.[1]

Pages 166 – 182 of Scholz (2012a), in a chapter titled "Geology" presents a discussion about the relationship between aquifers and surface water in eastern Washington. It includes a discussion about the Spokane Valley—Rathdrum Prairie Aquifer and its relationship to providing flows for the Spokane and Little Spokane Rivers. Pages 440 – 486 of Scholz (2012a), in a chapter titled "Columbia River Basin Hydrology and Fish Distribution in Eastern Washington", provides a summary of what is known about the distribution of fishes of the Spokane River Basin.

Additionally I have published (as a senior author or coauthor) numerous papers in peer reviewed scientific journals such as the Science, American Scientist, Transactions of the American Fisheries Society, North American Journal of Fisheries Management, Journal of the Fisheries Research Board of Canada, Journal of Fish Biology, Aquaculture, Journal of Freshwater Ecology, and Northwest Science.

In 1986 and 1987 I became familiar with the Instream Flow Incremental Methodology (IFIM) developed by the United States Fish and Wildlife Service (USFWS) when I directed two projects that employed this methodology to evaluate stream flows on fish habitat in two tributaries of the Spokane River, Chamokane Creek and Blue Creek, located on the Spokane Indian Reservation. I hired people to perform this work and sent one of them to attend IFIM workshops/courses (put on by the USFWS) that described how to perform field work for IFIM and use the Physical Habitat Simulation (PHABSIM) model. This person (Mike Barber) brought back the various IFIM manuals and described what he had learned in the class to me and Kate O'Laughlin, one of my graduate students. I read the numerous IFIM manuals published by USFWS (e.g., Bartholow and Waddle 1986; Bayha 1978; Bovee 1978, 1982, 1986; Bovee and Cochnauer 1977; Bovee and Milhous 1978; Milhous et al 1984; Raleigh et al. 1984; Schamberger et al. 1982; Stalnaker and Arnette 1976; Theurer et al. 1984; Trihey and Wegner 1981; Wassenberg et al 1979) and assisted in the collection of field data and in the analysis of those data. We investigated the minimum

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[1] The authors and titles of each of these books are presented below

Hasler, A.D. and A.T. Scholz. 1983 Olfactory Imprinting and Homing in Salmon: Investigations into the Mechanism of the Imprinting Process. Zoophysiology, Vol. 14. Springer-Verlag, Berlin, Heidelberg, New York, Tokyo. 134 pp.

Scholz, A.T. and H.J. McLellan. 2009. Field Guide to the Fishes of Eastern Washington. Eagle Printing, Cheney, Washington. 310 pp.

Scholz, A.T. and H.J. McLellan. 2010. Fishes of the Columbia and Snake River Basins in Eastern Washington. Eagle Printing, Cheney, Washington. 771 pp.

Scholz, A.T. 2012a. Fishes of Eastern Washington: A Natural History. Volume I. Eagle Printing, Cheney, Washington. pp. 1-545.

Scholz, A.T. 2012b. Fishes of Eastern Washington: A Natural History. Volume II. Eagle Printing, Cheney, Washington. pp. 546-909.

Scholz, A.T. 2014a. Fishes of Eastern Washington: A Natural History. Volume III. LithoArt Printing, Spokane, Washington. pp. 910-1432.

Scholz, A.T. 2014b. Fishes of Eastern Washington: A Natural History. Volume IV. LithoArt Printing, Spokane, Washington. pp. 1433-2089.

All of these books are available on the EWU John F. Kennedy Library Digital Commons website. Hard copies are available at EWU JFK Library and at the Washington Department of Fish and Wildlife Regional Office in Spokane, Washington.

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instream flows needed to maintain the Brown Trout, Rainbow Trout, and Sculpin habitat and invertebrate habitat in Chamokane Creek, and estimated the habitat available for Rainbow Trout in Blue Creek.[2]

Hard copies of these reports are available at the EWU John F. Kennedy Library. Additionally, Mr. Barber and Ms. O'Loughlin completed MS theses on the IFIM analysis that was accomplished for the fish and invertebrates respectively in Chamokane Creek. [3] I was the major professor who advised both of these students.

After this study was completed I continued to read new IFIM papers that became available from USFWS in order to update the section on IFIM that I presented in my Biology 463 (Fisheries Management) course. These papers included: Maughan and Barrett (1992); Stalnaker et al. (1995); and Bovee et al. (1998) and several other papers. The paper by Maughan and Barrett (1992) was a critical evaluation of how IFIM was applied. The paper by Stalnaker et al. (1995) was intended as a primer on the IFIM and compared the IFIM to other methods used for assessing fish habitat such as Montana's Wetted Perimeter Method and the Tennant Method. The paper by Bovee et al. (1998) described the IFIM in its entirety and was intended to serve as the textbook for USGS introductory training courses about IFIM. It also explained the Delphi technique for obtaining habitat curves for water temperature, substrate, depth, cover, and focal point velocity for each life stage of each target organism to plug into the Physical Habitat Simulation (PHABSIM) models that are used to define the weighted useable area (WUA) for each life history stage of the target species. The IFIM for the Spokane River Mountain Whitefish used the Delphi approach to develop habitat preference curves for that target species. These curves were prepared by Locke (2002) and Addley et al. (2003) who evaluated instream flows in the South Saskatchewan River Basin, Alberta.

I have also read the following reports about various aspects of the fishery and other aquatic life in the Spokane River (from the outlet of Coeur d'Alene Lake to it junction with the Columbia

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[2] These investigations culminated in the reports listed below.

Barber, M.R., A.T. Scholz, and K. O'Laughlin. 1988a. Predicting the effect of reduced stream flow on rainbow trout, brown trout and sculpin populations in Chamokane Creek using the Instream Flow Incremental Methodology (IFIM). Eastern Washington University, Department of Biology, Upper Columbia United Tribes Fisheries Center, Cheney, Washington. Technical Report. No. 12: 137 pp. + appendices.

Barber, M.R., A.T. Scholz and T. Kleist. 1988b. Determination of habitat availability for rainbow trout in Blue Creek using the Instream Flow Incremental Methodology (IFIM). Eastern Washington University, Department of Biology, Upper Columbia United Tribes Fisheries Center, Cheney, Washington. Technical Report. No. 8: 77 pp. + appendicies.

O'Laughlin, K., M.R. Barber, A. T. Scholz, F. Gibson and M. Weinand. 1988. Instream Flow Incremental Method (IFIM) analysis of benthic macroinvertebrates in Chamokane Creek, Spokane Indian Reservation. Eastern Washington University, Department of Biology, Upper Columbia United Tribes Fisheries Center, Cheney, Washington. Technical Report. No. 14: 317 pp. + appendices.

[3] Both of their theses can be obtained from the EWU JFK Library. Citations are listed below.

Barber, M.R. 1988. Predicting the effect of reduced streamflow on rainbow trout, brown trout, and sculpin populations in Chamokane Creek using the instream flow incremental methodology (IFIM). MS thesis. Eastern Washington University, Cheney, Washington. xxvi + 301 pp.

O'Laughlin, Kate. 1988. An instream flow (IFIM) analysis of benthic macroinvertebrates in Chamokane Creek, Spokane Indian Reservation. MS thesis. Eastern Washington University, Cheney, Washington. xv + 361 pp.

River) and all of its tributaries.[4] Additionally I have read many reports on water quality/quantity issues on the Spokane River and tributaries that are available on the WDOE website. I have not cited many of these reports because they are included in Chapter 26 of Volume IV of the *Fishes of Eastern Washington: A Natural History* (Scholz 2014b), which is a chapter that covers various limnological and water quality/quantity studies that have been conducted in eastern Washington.

I hope that I may be forgiven these digressions as I intend them to illustrate that I am familiar with: (1) The fishes in the Spokane River; (2) the relations between the Spokane Valley—Rathdrum Prairie Aquifer and the Spokane and Little Spokane rivers, and (3) the IFIM methodology that was used by WDOE as a basis for the Instream Flow Rule. For the following discussion, I will describe locations along the length of the Spokane River using the Spokane River Mile Index published by the Columbia Basin Inter-Agency Committee (1964). Some notable points by location [River Mile (RM)] include: confluence of Spokane and Columbia rivers (RM 0.0), Little Falls Dam powerhouse (RM 29.1), Long Lake Dam (RM 33.9), confluence of Little Spokane River (RM 56.3), Nine Mile Dam (RM 58.1), Monroe Street Dam (RM 74.2), Upriver Dam (RM 80.2), Trent Avenue gage / bridge (RM 84.8 / 85.3), Greenacres gage (RM 89.0), Barker Road (RM 90.4), Harvard Road (RM 92.7), Washington / Idaho state line (RM 96.5), Post Falls Dam (RM 102.0), and Spokane River at outlet of Coeur d’Alene Lake (RM 111.1).

My comments about the minimum instream flow promulgated by WDOE of 850 CFS below the Monroe Street Dam and 500 CFS at Greenacres center around three main points:

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[4] These reports are listed in alphabetical order by author and date: Addley and Peterson (2011); Anderson and Soltero (1984); Avista Corporation (2012a, 2012b); Bailey and Saltes 1982: Barber (1988); Barber et al. (1988a, 1988b); Bean (1895); Beckman et al. (1985); Bennett and Hatch (1991); Blake et al. (2015); Bryant and Parkhurst (1950); Butler and Crossley (2003, 2005, 2006), Chung (1975); Cichosz et al. (1997; 1999); Columbia Basin Inter-Agency Committee (1964); Dames & Moore and Cosmopolitan Engineering Group (1895); Davis and Horner (1997); Dellwo and Flett (1994); Divens et al. (2001, 2002a, 2002b); Doughtie et al. (1993); Duff (1979, 1980); Duff et al. (1978, 1981, 1995, 1996, 1997); Earnest (1946, 1947, 1950, 1951, 1952, 1953, 1954, 1955 1965, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1967, 1966, 1967, 1968, 1969 1970, 1971a, 1971b, 1971c, 1972); Earnest et al. (1966); Easy (1995); Falter and Mitchell (1982); Fields et al. (2004); Fletcher (198, 1984, 1987); Fulton (1968, 1970); Funk et al. (1973, 1975); Geist et al. (1988); Golder Associates (2003); Golder Associates, Inc. (2004, 2011, 2014); Golder Associates and HDR (2004); Greene and Miller (1978); Greene and Soltero (1975); Gregory and Covert (2006); Griffith and Scholz (1991); Griffith et al. (1995); Halfmoon (1976); Hall et al. (1985); Hallock (2004); Hartung and Maier (1980, 1995); HDR Engineering, Inc., (2005); Heaton (MS 1992); Heaton et al. (1993); Hisata (1992a, 1992b); Horner (1999); Jack and Roose (2012); A. Johnson (1994, 1997, 2000a, 2000b); E. Johnson (1993, 1994, 1995, 1997); Joy (1985); Kendall (1917, 1921); Kershner (1995); King and Lee (2012); King and McLellan [2007 (2013)]; Kiser (1964); Kittle (1977); Kleist (1987); Knudson et al. (2013, 2014); Knudson and Nichols (2015); Ko et al. (1974); Laumeyer (1976); Laumeyer and Maughan (1973); Lee (2008, 2012, 2013a, 2013b, 2014); Lee et al. (2006, 2010, 2013,); Lee and King (2013); Lee and McLellan (2011); Lines (1992); Maret and Dutton (1999); Marion (1952); Maughan and Laumeyer (1974); H. McLellan et al. (2003, 2004; 2008); H. McLellan and Scholz (2012); J. McLellan (1998, 2003a, 2003b, 2004, 2005a, 2005b); J. McLellan and King (2011); J. McLellan and Lee (2011); J. McLellan et al. (1999, 2002, 2005); Merrill (1986); Merrill and Soltero (1986); Mongillo and Hallock (1995, 2001);Moore and Ross (2010); Munn (2000); Munn et al. (1995); Munn and Short (1997); Neuman (2007); NHC & HD, Inc. (2004); Nichols and Scholz (1987, 1989); Nichols and Soltero (1984); Nielsen (1974, 1975, 1976, 1977, 1978, 1979); Nigro et al. (1981, 1983); NPPC (1986); O’Connor and McLellan (2008a, 2008b, 2009); O’Laughlin (1988); O’Laughlin et al. 1988a, 1988b); Osborne and Divens (2005); Osborne et al. (2003); Ostermann (1995); Parametrix (2003, 2004); Patmont et al. (1985, 1987); Pavlik-Kunkel et al. (2005, 2008); Peck (1980, 1982, 1992, 1993, 1994, 1995, 1998); Peck and Vail (1994); Peck et al. (2002); Pelletier (1994a, 1994b); Pelletier and Merrill (1998); R. Peone (1992); R. Peone et al. (1993); T. Peone et al. (1990); Phillips and Divens (2006); Plotnikoff (1998); Plotnikoff et al. (1988); Richards (1994); Ross (2011, 2013); Scholz [2012a, 2012b, 2014a, 2014b, MS (2015)]; Scholz and McLellan (2009, 2010); Scholz et al. (1985, 1986, 1988a, 1988b, 1988c, 2013a, 2013b); Schultz and DeLacy (1935/1936); Scofield et al. (2004, 2007); Serdar and Johnson (2006); Serdar et al. (2011); Shields et al. (2002); Singleton (1981); Small et al, (2005, 2007); Smith (1992); Smith and Johnson (1992); Snouwaert and Noll (2011); Soltero et al. (1974a, 1974b, 1975a, 1975b, 1976, 1978, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1990, 1992a, 1992b, 1992c, 1993a, 1993b); Soltero and Gasperino (1975); Soltero and Nichols (1979, 1980, 1981); Spence and Earnest (1961); Spotts et al. (2000); Stober et al. (1977a, 1977b); Stone (1883, 1884); Stroud et al. (2014a, 2013b); Thatcher et al. (1993, 1994); Thomas and Soltero (1977); Tilson (1993); Uehara et al. (1988); Underwood and Bennett (1992); Underwood and Shields (1996a, 1996b); Underwood et al. (1996); URS Company (1981); Vail et al. (2000, 2001); Wagstaff and Soltero (1982a, 1982b, 1984); Wallace and Zaroban (2013); Wargo (1992); WDOH, WDOE and SRHD (2002); WDW, IDFG and WWP (1990); Whalen (2000); Williams (1975); Williams and Soltero (1978); Wydoski and Whitney (1979, 2013); and Zook (1978).

First, the minimum flow of 850 cfs adopted into the Spokane River instream flow rule for the reach below the Monroe Street dam is insufficient to protect fisheries and other aquatic life in the Spokane River.

Second, there are two major sources of water to the Spokane River, and each should be accounted for separately in the Spokane River instream flow rule: surface water from Lake Coeur d'Alene, and the Spokane-Rathdrum Aquifer.

Third, the Instream Flow Incremental Method (IFIM) reports that were utilized as a basis for adopting a flow for the Spokane River have a number of problems and should be revisited.

II. The Minimum Flow of 850 CFS is Insufficient to Protect Fisheries and Other Aquatic Life in the Spokane River.

The Washington State Water Resources Act of 1971 (RCW 90.54.020) states that, "*Perennial rivers and streams in the state shall be retained with base flows necessary to provide for preservation of wildlife, fish, scenic, aesthetic and other environmental values, and navigational values.*" Flows that exceed 850 CFS will not harm and, in fact, almost certainly will improve survival of native Columbia River Redband (Rainbow) Trout (*Oncorhynchus mykiss gairdneri*) and Mountain Whitefish (*Prosopium williamsoni*).

A. History of Spokane River Fisheries.

Spokane River flows during summer months have been dropping over the last 125 years (See Table 1).

Table 1. Spokane River 7-day low flows, June 1-October 31, Monroe Street Gauge (USGS #12422500).

Date	Average Flow (CFS)	Range (CFS)
1890-1925	1800	1300-2600
1980-1989	981	570-1320
1990-1999	938	560-1600
2008-2015	1141	679-1268

Before 1925, the salmonid populations in the Spokane River were more robust than at the present time. In prehistoric and historic times, the Spokane Indians and other tribes assembled annually at several sites along the Spokane River to harvest predominantly Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead [i.e., the anadromous life history variant of the Columbia River Redband (Rainbow) Trout (*Oncorhynchus mykiss* var. *gairdneri*, of which the resident variant is still (now) present in the river]. In the Spokane River, Spring / Summer

Chinook Salmon historically ascended to Spokane Falls, at RKM 120 (RM 75), which was a barrier falls (Bryant and Parkhurst 1950; Fulton 1968, 1970; Scholz et al. 1985). At least four, and, perhaps, five major Indian fisheries were established along the length of the Spokane River, one near present day McCoy's Marina [RKM 10.0 (RM 6.3)], a second at Little Falls [RKM 44.5 (RM 28.0)], the third at the confluence of the Spokane and Little Spokane rivers [RKM 90.6 (RM 56.6)], and the fourth from the confluence of Hangman Creek to below Spokane Falls [RKM 120.0 (RM 75.0)].

Additionally, Spokane and Coeur d'Alene Indians harvested Chinook Salmon, Columbia River Redband (Steelhead) Trout and Coho Salmon (*Oncorhynchus kisutch*) at least at 29 other sites on the Spokane River or tributaries (Scholz et al. 1985; Scholz MS). At each of the four major sites the daily catch of Chinook Salmon and/or Redband Steelhead Trout in the Indian fishery generally numbered about 400 to 1700 daily, totaling 1,600 to 6,800 fish daily, during the peak of the fishing season [Scholz et al. 1985; Scholz MS (2016)]. This harvest rate suggests that the Spokane River sites, taken in aggregate, may have produced as many, or maybe even more, salmon daily than were harvested by Indians at more celebrated fisheries such as Celilo and Kettle Falls! The Celilo Falls fishery harvested about 1,000 to 3,000 daily, and the Kettle Falls fishery harvested about 800 to 1500 fish daily during the peak of the run [Scholz et al. 1985; Scholz 2012a, 2014a, MS(2016)].

Lieutenant Robert Johnson, a member of the United States Exploring Expedition under the command of Charles Wilkes, explored the lower 45 km (28 miles) of the Spokane River on 14 and 15 June, 1841 and recorded: "*The river is pretty, its waters transparent . . .To judge from the number of sheds* [the Indians employed] *for drying salmon it must abound with that fish*," (Wilkes 1845). At about the same time, a Presbyterian missionary who established the Tshimikain Mission among the Spokane Indians near present day Ford, Washington, Rev. Cushing Eells, reported in a letter to the Missionary Herald (1840) that in June of 1839 approximately 1000 Indians were congregated at the Little Falls fishery, harvesting 400 to 800 salmon per day, weighing from 10 to 40 pounds each. On July 25, 1825, Hudson's Bay Company fur trapper, John Work, reported that Indians at Little Falls were "*catching 700 or 800 salmon daily*" (Elliot 1914). In 1869, cadastral surveyor L.P. Beach (1869) estimated that the Spokane Indians "*put up at least 250 tons* [500,000 pounds] *of dried salmon during the fishing season*" at their Little Falls fishery.

David Douglas, the noted British naturalist, visited the Indian fishery at the confluence of the Spokane and Little Spokane rivers on 3 and 4 August, 1826. He observed that the Spokane Indians took 1,700 salmon / steelhead in one day (by 2:00 PM) out of a trap they had constructed in the Little Spokane River (Douglas 1914). He did not report on the number of fish collected out of a similar trap the Spokane's had constructed across the Spokane River near the same spot. Livingston Stone, a fisheries biologist working for the United States Fish Commission, visited the Little Spokane River. He reported that in 1882, 40,000 to 50,000 salmon and/or steelhead were seen on drying racks at the Indian encampment there, but in 1883 the Indian catch was estimated at only about 2,000 fish from the Little Spokane (Stone 1883, 1884). He attributed this decline in catch to the commercial fishery for salmon downstream from Celilo Falls.

At Spokane Falls, the Indians speared or dip-netted salmon from rocks or platforms that overlooked the falls or caught them in J-shaped basket traps similar to those employed for the fishery at Kettle Falls. Spokane Falls was a migration barrier for most anadromous salmonids. Many fish turned back downstream. The Indians also built elaborate traps near the mouth of Hangman Creek to trap thousands of these diverted fish. Mr. J.N. Glover, the "father" of Spokane, Washington, wrote in his memoirs:

> *"The first fall I was here, in 1873, and for several years after that, Spokane was the great rendezvous for all the Indians in this part of the country . . . At that time the salmon used to come up in great numbers. I have seen them so thick in the river that the rocks on the bottom would not be visible. The Indians took the fish out of a shoal near the flat at the mouth of Hangman Creek. They had traps set there and besides, they would spear the fish. They would build high scaffolds of willow limbs for drying fish*." (Glover 1985).

Gilbert and Evermann (1895) noted that, by 1892 and 1893, although Chinook Salmon populations had declined in the Spokane River owing primarily to their overharvest in commercial fisheries in the lower Columbia River, "*the Steelhead is an abundant fish. …. especially about Spokane. Several fine examples of this fish were taken by Mr. B.A. Bean in September 1892, near Spokane*."

In addition to anadromous salmon and steelhead, the Spokane River also formerly produced prodigious numbers of resident trout. For example, in August 1877, General William T. Sherman toured the Pacific Northwest. While encamped on the north shore of Coeur d'Alene Lake, he sent Lieutenant William R. Abercrombie ahead to reconnoiter Spokane Falls in preparation for moving his troops to that site. Abercrombie proceeded to the falls and purchased fishing tackle from J.N. Glover's store and then he and a friend began to fish the runs and pools in the Spokane River above Havermale Island. Abercrombie (cited in Oliphant and Gaston 1927) recalled that in a single afternoon of fishing,

> "*We caught 400 or 500 fish – salmon trout Mr. Glover called them*[5]*– In fact as fast as we dropped in a hook baited with a grasshopper we would catch a big trout. . . The greatest part of the work was catching the grasshopper. We dropped* [the trout] *into gunny sacks and when the men came we distributed them around the camp*."

Given these types of numbers of fish harvested during a period that the base flow of the Spokane River was presumably closer to a 7-day low base flow of 1800 – 2800 CFS, it is difficult to believe that salmonid fishes could be negatively impacted at base flows above 850 CFS. Therefore, I suggest that WDOE should establish a minimum flow much closer to the historical

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[5] Note: I am uncertain what species this was as the name salmon trout as used by the early settlers most frequently referred to Bull Trout, but occasionally referred to the anadromous (steelhead) life history and, perhaps, the larger freshwater resident (fluvial or adfluvial) variant of the Columbia River Redband Rainbow Trout.

base flow that averaged between 1800 – 2800 CFS as I believe that this flow would do a better job of protecting salmonids, including the Redband Trout that are the predominant salmonid in the Spokane River at this time.

B. Basis for Historic Fisheries Success: Food Abundance.

What supported this abundance of fishes? The large production of salmonid fishes in the Spokane River was likely related to the number of food organisms it produced. This was first noticed by Gilbert and Evermann (1895) who reported that the Spokane River contained water that was "*clear, cold and pure. The only contamination is that from the City of Spokane, and that does not appear to be at all serious as yet. An abundance of fish food such as insects and their larvae, small mollusks, and crawfish was noticed in this river*."

Both the high salmonid production and abundance of fish food organisms in the Spokane River is probably related to the relationship between the Spokane River and the Spokane Valley – Rathdrum Prairie Aquifer. The river and aquifer are interconnected. This is critical for maintaining the flow of the Spokane River during the summer low flow period. At certain points along the river, notably between Flora Road and Greene Street, between Monroe Street Dam and the head of Nine Mile Reservoir, and along the lower 16 km (10 miles) of the Little Spokane River between Dartford and the mouth, the water table is higher than the river bed and aquifer water seeps into the River (MacInnis et al. 2004). This provides an influx of cold water into the river, which furnishes both discharge and cool temperatures necessary to maintain both salmonid fishes and the food utilized by them, during the summer low flow period.

At other points along the river, notably between Coeur d'Alene, Idaho and Greenacres, Washington, the water table is below the bed of the river and water percolates down through the gravel into the aquifer to recharge it (MacInnis et al. 2004). This stabilizes the flows during periods of high discharge by moderating them, so that devastating floods seldom, if ever, occur in the Spokane River, which protects the habitat that produces both salmonid fishes and their prey from disruption. Thus, it is unlikely that the Spokane River suffered from stochastic events that affected many other salmon producing streams in the Columbia Basin. The Spokane River was a noted fishing place on the Columbia Plateau and the Spokane Indians were known to other tribes by Indian sign language as "the salmon eaters" (Ruby and Brown 1970/2006; Ross 2011). This may explain, in part, why Indians from the Coeur d'Alene, Kalispel, Sinkiuse (Columbia), Yakama, Nez Perce and Palus Nations annually came to the Spokane River as part of their annual subsistence round to partake in, or trade for, salmon and steelhead caught in the Spokane River [Scholz et al. 1985; Scholz MS (2016)].

Stream dwelling salmonid fishes in eastern Washington eat primarily aquatic insects.[6] Typically, in rivers, aquatic insects are produced primarily in riffles and salmonids occupy pools and runs, feeding on insects that get dislodged from the riffles and drift downstream into an adjacent pool or run. One problem in going from a base 7-day low flow of 1800 – 2800 CFS to one of 850 CFS is that significant amounts of riffle habitat are likely to become dewatered and, thus, not produce as many insects. Moreover, the lower current flow may not be sufficiently strong to dislodge the insects and make them available for salmonid consumption. This leads to the obvious conclusion

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[6] See Scholz and McLellan (2010) and Scholz (2014a), who compiled fish food habits data for eastern Washington fishes, for details.

that a base flow of 850 CFS, when compared to 1800 – 2800 CFS, will likely significantly reduce the productivity of river for producing salmonid fishes. This also suggests that, perhaps, it would have been prudent for the IFIM that was accomplished on the Spokane River to have selected two or three aquatic invertebrates that contribute to Redband Trout and Mountain Whitefish diets, as target organisms rather than just using fish as target organisms.

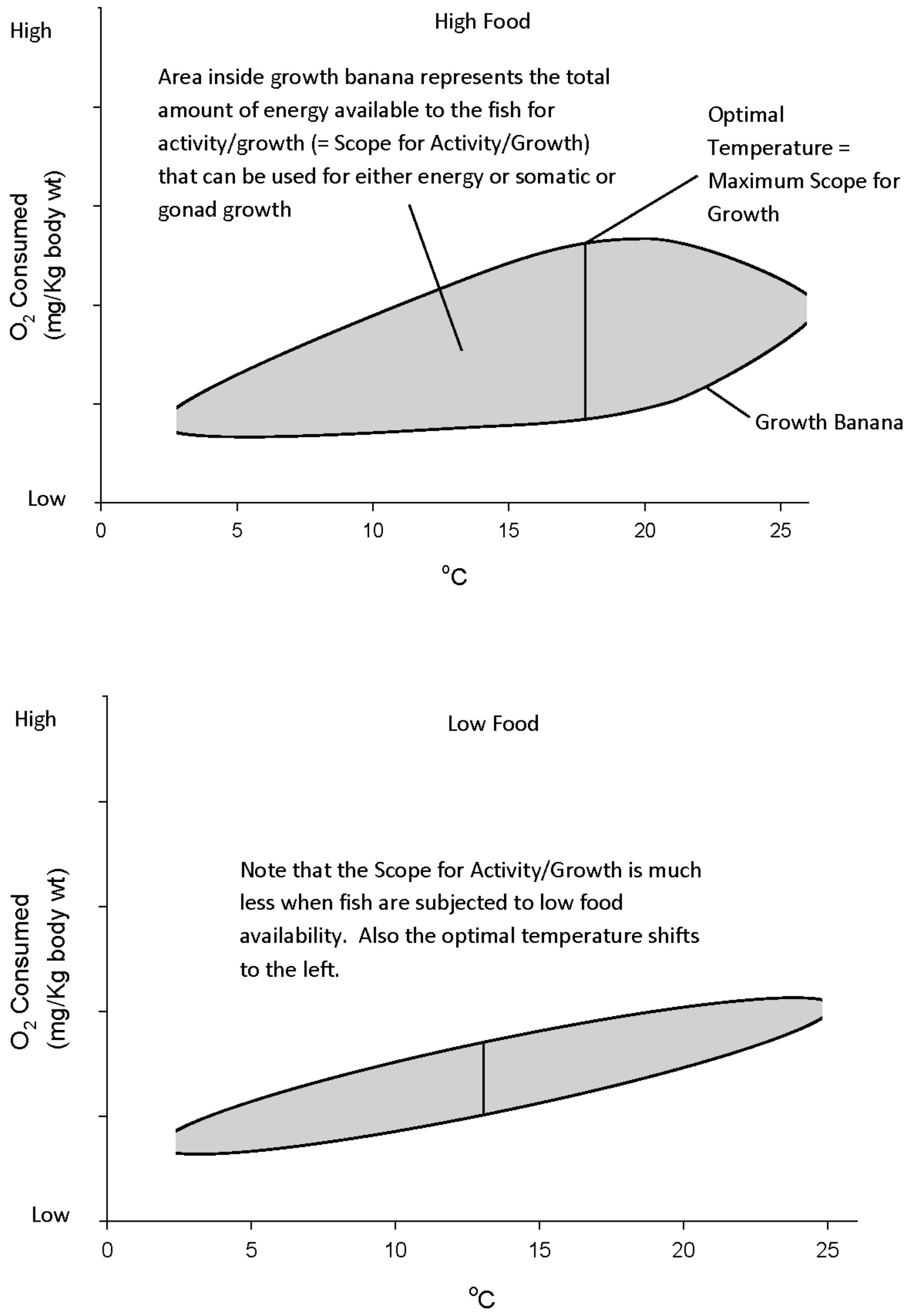
Irvine et al. (1987) noted that the IFIM predicts the potential amount of habitat in a stream rather than fish numbers or biomass. They introduced rainbow trout into stream channels in New Zealand and maintained a constant rate of flow in these channels. The biomass of rainbow trout in individual runs and pools of each stream was compared to the amount of weighted useable area (WUA) available using IFIM. They found no correlation between biomass and the amount of WUA. The authors cautioned:

> "*Users of the* [IFIM] *should realize that the method cannot be expected to predict fish biomass or numbers when fish are not limited by the amount of space available to them. When fish are food-limited, as apparently occurred in our streams, relationships between* [WUA], *fish food organisms, and fish biomass must be understood before one can predict flow change impacts*."

A similar situation may exist in the Spokane River, especially since trout are presently concentrated in more limited habitat during the summer low flow period when water temperatures become too warm for them to occupy much of the Spokane River.

C. Food Abundance and Fisheries Population Fitness.

The amount of food available to support salmon production is important when considering the bioenergetics of salmonid fishes. In studies where salmonids are placed in a swim tunnel (respirometer) and tested by measuring the amount of oxygen that they consume under various flows and temperatures, their performance at base flow and the maximum flow at which they can swim against the current are tested and the two lines are plotted on a graph (with temperature on the x-axis, and the amount of oxygen consumed by the fish at base flow and the highest flow they can swim against are plotted on the y-axis). After the current velocity in the swim tunnel has been raised to the point that the fish can no longer swim against it and, instead, gets swept back onto a grating in the swim tunnel, the fish has reached its maximum level of activity. The bottom line represents the fish's basal metabolism at that temperature. The top line represents the fish's maximum active metabolism (or maximum exertion) at that temperature. The distance between the two lines represents the amount of energy that is available to the fish for carrying on its routine metabolism, active swimming, somatic cell growth and gonad growth, i.e., if the fish is not actively swimming at its maximum speed against the current, the excess energy above that needed for its basal metabolism (or active metabolism if it is swimming in a current that is less than the maximum in which the fish can swim) can be stored as either somatic cell growth or gonad growth. Energy stored as somatic cell growth can provide energy at times when the fish is stressed and large size usually conveys other advantages to the fish, such as dominance in selecting better feeding territories, spawning sites or mates. Energy stored in gonads usually increases the number of gametes produced, and hence, the fish's reproductive fitness.



Area inside growth banana represents the total amount of energy available to the fish for activity/growth (= Scope for Activity/Growth) that can be used for either energy or somatic or gonad growth

Optimal Temperature = Maximum Scope for Growth

Note that the Scope for Activity/Growth is much less when fish are subjected to low food availability. Also the optimal temperature shifts to the left.

Figure 1. Hypothetical Scope for Growth/Activity at high and low food availability.

When plotted on a graph as described above, the two lines representing the basal metabolism and maximum metabolism form roughly a banana shape that is called "the growth banana" (Figure 1). The amount of energy represented by the growth banana is called the "Scope for Growth or Scope for Activity," which refers to the total amount of energy available to the fish that can be used for either activity (i.e., maintaining its position in a current, chasing down prey, subduing and digesting prey, avoiding predators, migrating to spawning sites, spawning activity, etc.) or storing as either somatic cell or gamete growth. The temperature at which the distance between the oxygen consumed at the basal metabolic rate and at the maximum sustained swimming rate is greatest represents the fishes optimal temperature, defined as the temperature at which the fish can store the most energy in either somatic or gonad growth.

Both the optimal temperature and the total amount energy available to the fish are affected by food availability. Before being tested in the respirometer the fish are either fed a large amount (high food availability) or fed just sufficiently to maintain them (low food availability). Under low food conditions the optimal temperature shifts to the left (i.e., is lower) and the total area between the two lines (i.e., amount of energy available for activity or growth) is less. Under high food availability, the optimal temperature shifts to the right (i.e., is higher) and the total area between the two lines (i.e., amount of energy available for activity of growth) is higher. [See Figure 1.]

This phenomenon relates to the WDOE minimum flow of 850 CFS because of the potential for reducing food production if a minimum flow of 850 CFS reduces the amount of riffle habitat available for producing aquatic insects. It is unclear if 850 CFS minimum flow will impact the amount of riffle habitat needed for benthic insect production in the Spokane River. If it is reduced, the amount of food available for trout will likely also be reduced and the temperature at which the fish grow optimally will be lower. (Refer to Figure 1).

D. Reasons for Fisheries Decline.

Barton Bean, United States Fish Commission, (1895) recorded observing "*large numbers*" of Mountain Whitefish from all of the city bridges in Spokane Washington in 1893. In 1992, Mountain whitefish accounted for 668 of 709 total fish (i.e., 92.4 % of the relative abundance of all fishes) captured in electrofishing surveys conducted by the Washington Water Power Company between Monroe Street and Upriver dams (Johnson 1993). In 2007, Mountain Whitefish accounted for only 18 of 404 total fish (i.e., 4.4 % of the relative abundance of all fishes) captured in a similar survey conducted by the Washington Department of Fish and Wildlife between Monroe Street and Upriver dams (O'Connor and McLellan 2008). It is uncertain why Mountain Whitefish declined in relative abundance but decreased 7 day low flows may have contributed. [i.e., The 7-day low flow at the Monroe Street gauge averaged (ranged) approximately 1,831 (1,300 – 2,580) CFS during the period 1890 – 1899, 938 (560 – 1,600) CFS during the period 1990 – 1999, and 750 (500 – 1090) CFS during the period 2000 – 2010.] If so, this would seem to provide at least circumstantial evidence that the 850 CFS minimum flow adopted by WDOE is too low and that a higher minimum flow would provide more protection for Mountain Whitefish.

Also, Bailey and Saltes (1982), based on conducting a mark-recapture study, estimated that in 1980 between 7,200 and 13,200 trout were present in the Spokane River between Post Falls and Upriver dams. The numbers actually collected included 613 Brook Trout and 1,241 Rainbow Trout for a total of 1,854 trout, so it may be inferred that rainbow trout accounted for about 67 % of this population estimate (i.e., 4,824 to 8,844 individuals). This range represented the equivalent of the 95 % confidence intervals for the estimate. WDFW estimated the Rainbow Trout population, using mark-recapture techniques, in a 21 km segment of the Spokane River downstream from the Washington / Idaho border in 2007 (O'Connor and McLellan 2008), 2008 (O'Connor and McLellan 2009) and 2009 (McLellan and King 2011). The populations (± 95 % CI) were estimated at 1,149 (± 859 – 1,600) in 2007, 1,314 (± 1,137 – 1,545) in 2008, and 1,464 (± 1,001 – 2,465) in 2009.

There are a number of possible reasons for this decline from a minimum of about 4,824 Rainbow Trout in 1980 to fewer than 1,500 by 2007 – 2009, including: 1) dewatering of redds between peak spawning and fry emergence (Underwood and Bennett 1992; O'Connor and McLellan 2008), 2) establishment of Smallmouth Bass in this segment of the Spokane River in about 2000 (O'Connor and McLellan 2008), 3) non-compliance with fishing regulations (Parametrix 2004), 4) and the general declines in the 7-day low flow (or base flow) noted on page 10.

E. Smallmouth Bass Predation.

Although studies conducted by WDFW and EWU have shown that Smallmouth Bass numbers increased between 2007 and 2015, there was no indication that Smallmouth Bass were consuming Redband Trout in a food habits study performed by EWU in 2015 (McCroskey 2015). Population (± 95 % CI) of Smallmouth Bass was estimated in 2007 between river mile (RM) 147.1 and RM 155.1, using mark-recapture techniques, at 908 (524 – 1691) individuals > 200 mm TL (O'Connor and McLellan 2008). Population (± 95 % CI) of Smallmouth Bass was estimated in 2015 between RM 92.1 and RM 96.3, using mark-recapture techniques, at 1,307 (945 – 1807) individuals >200 mm TL and 1,645 (1,171 – 2,310) individuals > 150 mm TL (McCroskey 2015). Thus, smallmouth bass density increased from about 114 fish to 222 fish > 200 mm TL per river mile between 2007 and 2015 (McCroskey 2015).

Increase in Smallmouth Bass population is of concern because of the propensity of these species to eat juvenile salmonids. For example, Fritts and Pearsons (2004) determined that Smallmouth Bass populations in the Yakima River increased from an average of 3,347 individuals in March to an average of 19,438 individuals by June in each of four years (1998 – 2001) coinciding with the salmonid smolt migration out of the Yakima River. These Smallmouth Bass were estimated to have consumed an average (range) of 200,405 (120,922 – 335,626) salmonids annually during this period. Stroud et al. [2010 (2012) determined that a population of 25,022 Smallmouth Bass > 150 mm TL in the Sanpoil River Arm of Lake Roosevelt consumed 2,774 1-year old Redband Trout and 110 2-3-year old Redband Trout emigrating out of the Sanpoil River in the spring of 2010. This predation was estimated to have consumed 19.0 percent of 14,578 1-year old and < 0.5 percent of 23,738 2-3-year old that were migrating out of the Sanpoil River into Lake Roosevelt in the spring of 2010.

McCroskey (2015) analyzed the stomachs of 251 Smallmouth Bass > 150 mm TL collected from the Spokane River between RM 149.2 and RM 155.1, from June 7 to September 21, 2015. This area is the most important spawning area for Redband Trout in the upper Spokane River as it is one of the few areas that contained suitable spawning gravels. The thought was that Smallmouth Bass might potentially prey on Redband Trout as they were emerging from, or shortly after emergence from, their redds. At these times they would be particularly vulnerable to predation. However, McCroskey (2015) found no indication Smallmouth Bass were selectively preying on Redband Trout, and, in fact, found no evidence of Redband Trout in their diet whatsoever. None of the diagnostic bones in the diet of these fish were identified as Redband Trout when compared to keys of diagnostic bones (e.g., Stroud and Scholz 2014).

It is possible that in the past Smallmouth consumed more Redband Trout at a time when Redband Trout were more abundant than at present but all we can say at the present time is that there is no evidence that Smallmouth Bass predation was the principle factor for the decline in Redband Trout in the upper Spokane River. The reason for the high rate of predation on salmonid fishes in the Fritts and Pearson (2004) and Stroud et al. (2010) studies in comparison to McCroskey's (2015) study may relate to the fact that salmonid fishes eaten by Smallmouth Bass were much larger (generally > 90 mm TL) in the former studies as compared to the latter study (generally < 50 mm TL) (See paper by Fritts and Pearsons 2006.). McCroskey (2015) did find that Smallmouth Bass ate many of the same types of prey typically found in Redband Trout diets and could potentially become competitors of Redband Trout if food resources become limited. The occurrence of piscivory in their diet was 33 percent by weight (McCroskey 2015). In view of this piscivory it should be recognized that few Redband Trout (n =5 young-of-the-year) were observed in the river in 2015, in a year with extremely low flow (McCroskey 2015). It is probable that in a year with normal spring flows, with higher numbers of Redband Trout emerging from redds, the occurrence of piscivory on Redband Trout by Smallmouth Bass would be expected.

F. Noncompliance with Fishing Regulations.

Current regulations do not permit the harvest of Redband Trout in the upper Spokane River. Fish may be caught and released using only artificial lures or flies with single barbless hooks. No live bait fishing is permitted. Parametrix (2004) suggested that Redband Trout might be harvested illegally from the upper Spokane River, but provided little definitive evidence in support of this accusation, i.e., nothing that could be used to quantify how much illegal harvest was occurring and whether illegal harvest could account for the decline in abundance of Redband Trout. WDFW has not conducted any creel surveys since the Parametrix (2004) study (Charles Lee, WDFW fisheries biologist, Region 1 Office, Spokane, Washington, pers. comm.). WDFW enforcement agents have occasionally reported anglers fishing with live bait and harvesting redband trout in the upper Spokane River but not at levels that would support claims that illegal harvest was the primary factor responsible for the decline in redband trout abundance. For example, the WDFW enforcement agent who monitored the upper Spokane River in 2014 and 2015 told me that she had observed only one person fishing with bait who had caught and killed a Redband Trout (Jo Lynn Beauchene, WDFW enforcement agent, Region 1 Office, Spokane, Washington, pers. comm.). Ms. Beauchene cited the individual and confiscated the fish. She informed me that WDFW enforcement agents were "spread thin," so she was unable to make daily checks of the Spokane River. She also told me that the upper Spokane River during the past two years has been posted with signs informing anglers about the special fishing regulations, so she would not be surprised if more anglers were obeying the regulations at the present time as compared to a decade ago.

G. Streamflow Reductions and Fisheries Decline.

Thus, the idea that reductions in stream discharge between 1980 and 2015, appears to be the most plausible explanation for the decline in redband trout abundance in the Spokane River. At the present time, insufficient data are available to determine if declines in flow during May and early June that caused dewatering of redds or declines in the 7-day low flow (i.e., base flow) later in the summer that could potentially cause extensive temperature related mortality of, or reduced food supply for, all age classes of Redband Trout in the population is the primary factor causing the decline in the Redband of the upper Spokane River. Dewatering of redds was addressed by the IFIM but the threats posed by low flows at the end of the summer appeared to be largely ignored by the IFIM. Therefore, WDOE should consider a much higher minimum flow.

Genetic analysis conducted on wild Rainbow Trout from the upper Spokane River between Upriver and Post Falls dams, as well as those from the middle Spokane River below the Monroe Street Dam, confirmed that both groups were interior Columbia River Redband Trout, with limited hybridization of Spokane Hatchery Rainbow Trout (Small et al. 2005, 2007).

It appears that the decline in the 7-day low flow from 1890 to the present time is most likely related to a loss of aquifer flow into the river because the amount of water being pumped out of the aquifer has increased over time. Figure 2 shows a plot of the 7-day low flow discharge into the Spokane River at the Monroe Street gage from 1890 to 2007. This figure illustrates that the 7-day low flow has declined from an average of about 1800 to 2000 CFS between 1890 and 1920 to about 578 to 1000 CFS between 2000 and 2007. (From 2008 to 2015 the 7-day low flow averaged (ranged) 1141 (679 – 1268) CFS. Aquifer contribution to Spokane River discharge was calculated by subtracting the average September discharge recorded at the Post Falls gage (USGS # 12419000) from the average September discharge recorded at the Monroe Street gage (USGS # 12422500) from 1913 to 2007 a plotting this difference (Figure 3). This graph shows a gradual decline in aquifer contribution over time, from about 350 to 900 CFS from 1913 to the mid-1960's to about 100 to 300 CFS from 2000 to 2007.

[Note: However, it needs to be emphasized that this plot does not represent the true aquifer contribution because the Spokane River loses flow between Post Falls and Greenacres. In late August 2011, when the flow below Post Falls Dam was 800 CFS, the flow at Green Acres was 400 CFS [Golder Associates, Inc. 2011; for a more complete discussion of this see (2) p. 17 below]. In 2011, the 7-day low flow at Post Fall averaged (ranged) 754 (738 – 784) CFS from August 30 to September 5 and the 7-day low flow at Monroe Street averaged (ranged) 1269 (1240 – 1320) CFS from August 31 to September 6. The difference (Spokane gage – Post Falls gage = 1269 CFS – 754 CFS = 515 CFS) does not represent the true aquifer contribution because about 400 CFS of the Post Falls Flow was lost between the Post Falls Dam and Greenacres, so the Post Falls average flow should be reduced by about 400 CFS to calculate the true aquifer contribution (i.e., 754 CFS – 400 CFS = 354 CFS). Thus, the aquifer contribution in 2011 becomes 1269 CFS – 354 CFS = 915 CFS rather than 515 CFS.]

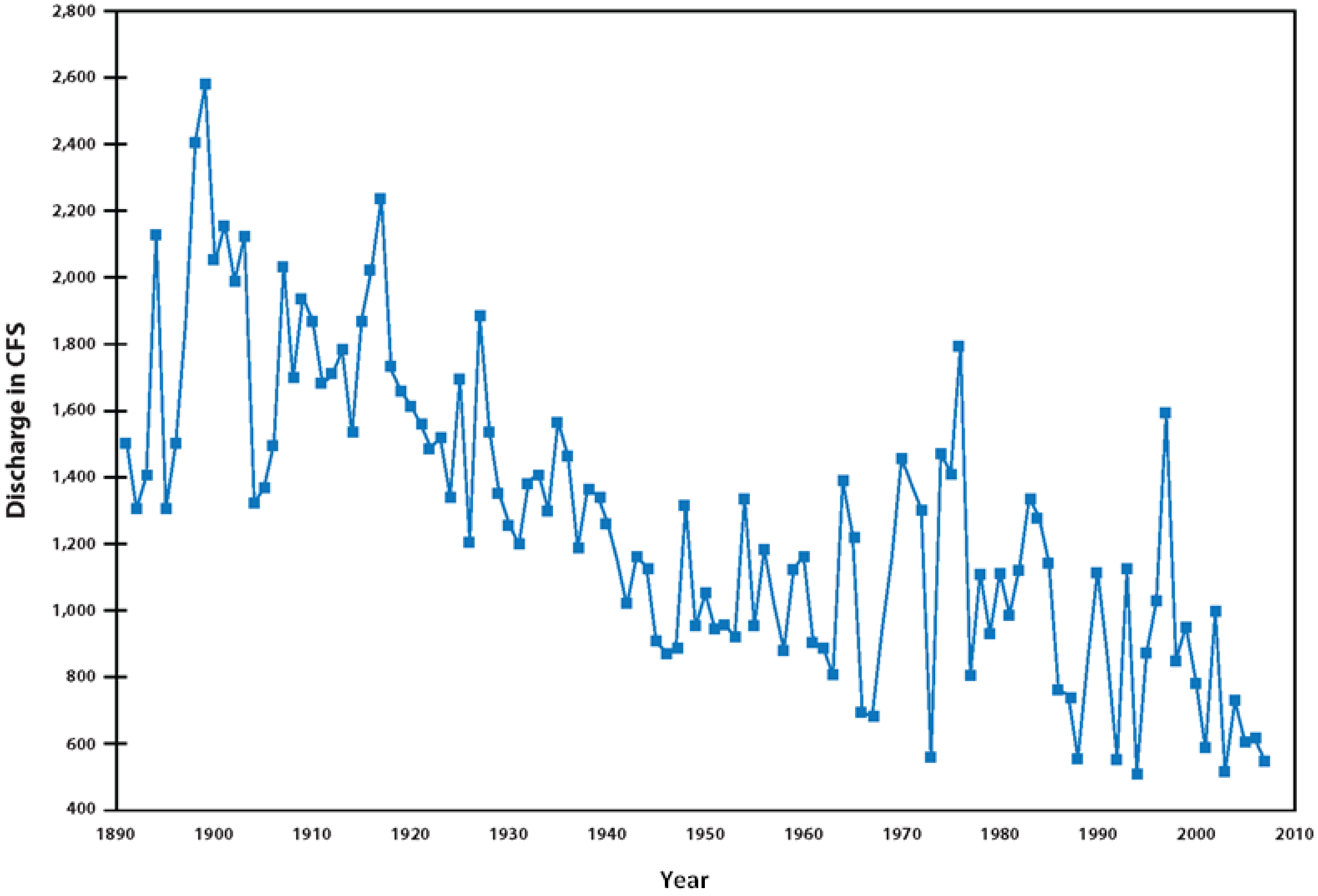


Figure 2. Discharge (7-day low flow) between 1 June and 31 October of the Spokane River at Monroe Street (1890 – 2007) USGS gage # 12422500 has decreased from 1890 to present from an average of about 1,800 (1,300 --- 2,600) CFS before 1920 to about 800 (600 – 1000) CFS from 1998 – 2007.

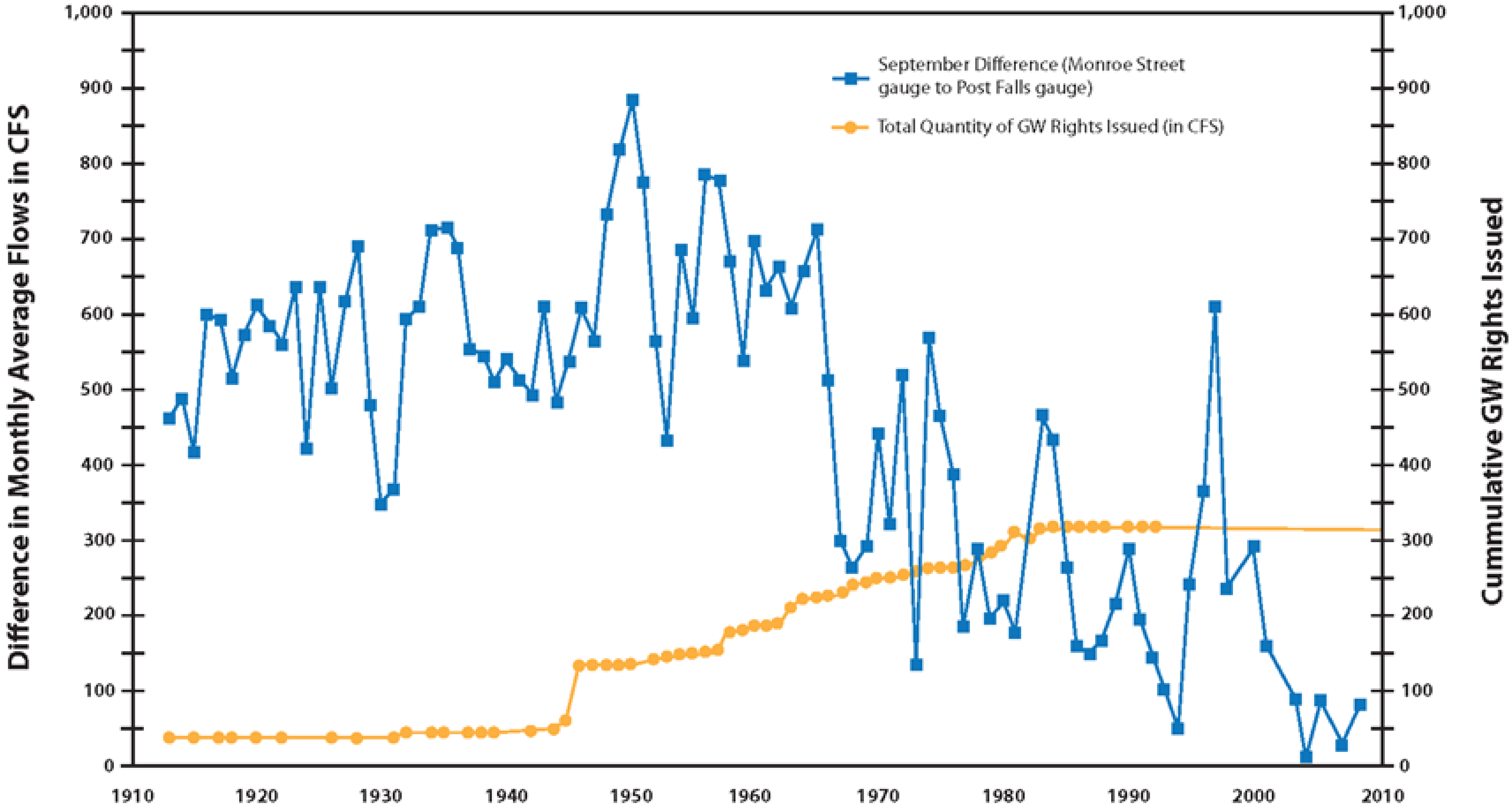


Figure 3.Aquifer contribution to Spokane River discharge was calculated by subtracting the September average discharge recorded at the USGS gage at Post Falls Dam (# 12419000) from that at the USGS gage at Monroe Street (# 12422500) from 1913 – 2007. Since no tributaries enter the Spokane River between Post Falls and Monroe Street Dams, the increased discharge at Monroe Street was assumed to be due to aquifer inflow into the Spokane River between the two dams. Also shown is the total quantity of ground water rights issued (in CFS) from 1913 to 1992 . No new permits issued since 1992. Discharge in the contribution of aquifer inflow into the Spokane River declined by approximately the same amount (from about 500 – 700 CFS on average between 1913 and 1945 to about 100 – 300 CFS on average between 1992 and 2007 = about a 300 – 400 CFS decline) as the cumulative water rights (on paper) increased from about 50 to 310 CFS during the interval. John Covert, WDOE, provided data on cumulative water rights issued and data that indicated that, in recent years , purveyors of those rights only used about 50 % of the water to which they were entitled to pump out of the aquifer.

Also plotted on Figure 3 is the cumulative water rights issued to purveyors who are pumping water from the Spokane Valley – Rathdrum Prairie Aquifer. Note that the decline in flow more or less mirrors the increase in water rights issued, which suggests that the decline in the flows of the Spokane River appears to be mainly related to increased pumping of water from the Spokane Valley-Rathdrum Prairie Aquifer. However, a word of caution here is warranted because the water rights depicted in Figure 3 represent water rights issued on paper, not the amount actually pumped out of the aquifer by the purveyors that have been granted those rights. As noted below, the purveyors of those rights actually pumped only about 50 % of the water out of the aquifer to which they were entitled. WDOE should also keep in mind that purveyors in Idaho also tap the Spokane Valley – Rathdrum Prairie Aquifer. See report by Rachael Osborn (2015), tallying the totals for Idaho and Washington.

Plotted in Figure 4 is the mean annual precipitation for Spokane, Washington from 1890 to 2007. Superimposed on these data is a linear regression line that was used to determine if precipitation was increasing or decreasing over time. The linear regression line indicated that precipitation has remained relatively constant over the entire period of record and averaged approximately 15 to 16 inches per year. WDOE hydrologist, John Covert, has performed similar analyses of several other precipitation gage sites in the Spokane River Basin and obtained similar results. These data suggests that the reduced flow observed in the Spokane River in recent times cannot be explained by reduced precipitation, which points again to aquifer withdrawals as the principle factor contributing to the reduced discharge. Increased evaporation caused by ponding water behind the many dams now located on the Spokane River may have also contributed in a small way to the reduced flow.

III. Sources of Water Contributing to Spokane River Flows.

There are two important contributions to the flow of the Spokane River. One is the outflow of Couer d’Alene Lake into the Spokane River. Second is the contribution of the Spokane-Rathdrum Prairie Aquifer as described in point 1 above. Both of these contribute to the base flow (minimum flow).

A. Discharge-Temperature Dynamics.

A study by Golder Associates, Inc. (2011) examined the relationship between discharge from Post Falls Dam and water temperatures below the dam as they relate to fish and fish habitat during the low summer discharge period from July to September 2011. Discharge was measured at several USGS gages at Post Falls [River Mile (RM) 100.7], Greenacres (RM 90.5), Trent (RM 85,4), and Spokane (RM 72.9). Thermographs were deployed between July 1 and July 18 at several locations downstream from Post Falls Dam [below Post Falls Dam, at Greenacres, at Sullivan Road (RM 87.0), and at Trent] and water temperature was monitored at each location until the end of September. From July 1 to September 6, 2011, AVISTA maintained a minimum discharge of at least 600 CFS at Post Falls Dam. Minimum discharge was approximately 2200 CFS in late July and 800 CFS in late August. Commencing on September 6, 2011, AVISTA began its annual drawdown of Coeur d’Alene Lake and the amount of water discharged from Post Falls dam increased from 738 to 1,140 CFS in less than two hours.

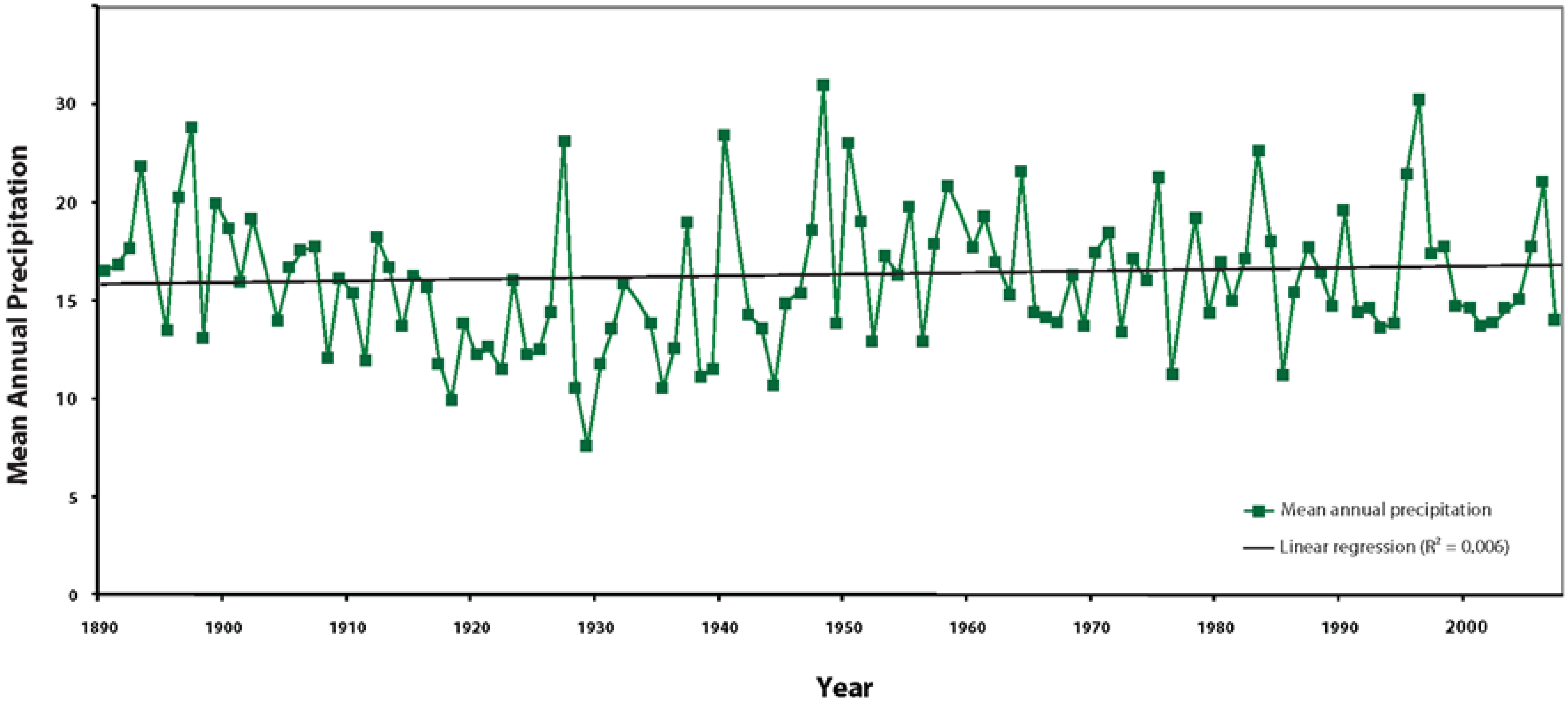


Figure 4. Mean annual precipitation (inches) for Spokane, Washington 1890 – 2007 (green line). Linear regression plot (black line) of precipitation data indicates that precipitation has remained relatively constant for this entire period, so reduced precipitation does not appear to be a factor that accounts for the decrease in the 7-day low flow in the Spokane River during this period. This points to declines in input into the Spokane River from the Spokane Valley – Rathdrum Prairie Aquifer as a primary factor for the decline in river discharge.

Discharge decreased (from about 800 CFS to about 400 CFS in late August) between Post Falls and Greenacres, indicating that water was lost to the aquifer in this reach. Increased discharge between Greenacres and Trent (from about 400 CFS to about 1050 CFS in late August) indicated the discharge was being augmented by about 650 CFS of inflow from the aquifer in this reach.

Likewise the flow at the Spokane gage ranged from about 1200 CFS to 1400 CFS in late August, indicating that an additional inflow of about 150 CFS to 300 CFS from the aquifer was augmenting the flow of the Spokane River. All told, in late August and early September 2011, the minimum flow in the Spokane River was about 1250 CFS, with outflow from Coeur d'Alene Lake contributing about 400 CFS (about 32 %) of the inflow and the aquifer contributing about 850 CFS (about 68 %) of the inflow.

Water temperatures were similar at the gages at Sullivan and Trent roads from mid-July until August 10, 2011 when the water at Trent became:

> "***a few degrees cooler*** *than all the other stations until the end of September. This indicated that there could be a significant amount of groundwater accretion (i.e., a net addition to stream flow from groundwater) between the Greenacres and Trent monitoring stations. The greatest difference in water temperature at Trent and Greenacres coincided with the lowest Post Falls discharges which occurred in late August and early September,*" (Golder and Associates 2011; emphasis added).

The following table shows maximum water temperature measured on July 25, 2011 in the Spokane River at five locations at and below the Lake Coeur d'Alene outlet.

Table 2. Water temperature data (rounded to nearest 0.1 ^{o}C) for the Spokane River on July 25, 2011.

Location	7-25-11	8-10-11	8-28-11	9-5-11	9-20-11
Lake Coeur d'Alene outlet	19.8	22.4	23.0	21.4	18.9
Post Falls	20.1	23.0	23.7	21.7	18.8
Greenacres	21.5	24.2	24.7	22.9	19.8
Sullivan Road	18.9	20.7	19.9	18.2	17.5
Trent Road	18.0	17.5	17.5	13.9	14.8

These data indicate:

(i) Water gradually warmed as it flowed down the Spokane River from the outlet of Coeur d'Alene Lake to the vicinity of Greenacres. This coincided with the loss of flow that infiltrated the aquifer.

(ii) The river gradually cooled down between Greenacres and Trent Road probably (most likely) owing from percolation of groundwater from the aquifer into the Spokane River.

(iii) The reduction in temperature, when the outflow from Coeur d'Alene Lake (after the loss to the aquifer was accounted for was about 400 CFS and cold aquifer inflow contributed about 650 CFS between Greenacres and Trent, amounted to about 7.2 ^{o}C [i.e., 24.7 ^{o}C(at Greenacres) – 17.5 ^{o}C (at Trent) on August 28]. I think that this is more than "***a few degrees cooler***" (Golder and Associates 2011), especially when considering the cold temperature requirements of salmonid fishes.

(iv) As the outflow from Coeur d'Alene Lake became reduced, the relatively greater amount of cold water from the aquifer cooled the river to temperatures that are more readily tolerated by salmonid fishes.

B. Redband Trout Temperature Requirements.

Rainbow/Redband Trout (*Oncorhynchus mykiss*) have a preferred temperature of 14.8 – 14.9 ^{o}C and their optimal temperature for growth is 12.2 – 18.8 ^{o}C (Bell 1986). Mountain whitefish optimum temperature for growth is 12.2 – 16.6 ^{o}C (Bell 1986). When food availability is low, the optimal temperature for the growth of both species is about 12 – 15 ^{o}C and when food availability is high the optimal temperature for growth is about 16 ^{o}C for Mountain Whitefish and about 17 – 18 ^{o}C for Rainbow/Redband Trout. Beitinger et al. (2000) found that the upper lethal temperature for Rainbow Trout was dependent upon the temperature to which they were acclimated. Fish acclimated to 8.0 ^{o}C died within a short period of time when placed in water that was 26.9 ^{o}C, whereas those acclimated at 20.0 ^{o}C died when placed in water that was 29.8 ^{o}C , so the upper lethal temperature was about 29.8 ^{o}C.

Columbia River Redband Trout (*Oncorhynchus mykiss* var. *gardneri*) live in either montane or desert environments. Those occupying the upper reaches of Spokane River are considered to be the montane Columbia River Redband Trout. Probability of occurrence of montane populations of Columbia River Redband Trout in Idaho was near 100 % in waters where the mean summer water temperature was between 11.0 and 17.0 ^{o}C, 60 % in waters of 10.0 ^{o}C, 30 % in waters of about 8.0 or 9.0 ^{o}C, and they were not (or rarely) found in streams where the mean summer water temperature was below 7.0 or above 18.0 ^{o}C, although some populations that were adapted to desert conditions were found at temperatures that exceeded 24.0 to 27.0 ^{o}C for brief periods (Meyer et al. 2010). Oxygen consumption of Redband Rainbow Trout increases from about 100 mg O_2 consumed / kg body weight / hour at a temperature of 14.0 ^{o}C to about 175 mg O_2 consumed / kg body weight / hour at a temperature of 20.0 ^{o}C in both small (40 – 140 g) and large (400 – 1,400 g) individuals (Rodnick et al. 2004). At temperatures above 20.0 ^{o}C, the larger-sized individuals begin to consume much more oxygen [e.g., about 400 mg (in large fish) versus 240 mg (in small fish) O_2 consumed / kg body weight / hour at a temperature of 26.0 ^{o}C (Rodnick et al. 2004)], indicating that larger individuals experienced more stress than small individuals at high temperature. Fieldhaus et al. (2010) found that Columbia River Redband Trout experienced a stress response at temperatures elevated above 19.0 ^{o}C by producing heat shock proteins in liver and muscle tissue and that whole body lipid levels began to decrease at temperatures above 20.4 ^{o}C. Body lipid content stores energy for the fish, so reducing lipid content means that the fish will have less energy for activity (i.e., chasing down prey, avoiding predators, migrating to spawning sites) and for somatic growth or gamete production.

Therefore a major objective of the establishment of a minimum instream flow for the Spokane River that is designed to protect fish should be to lower the water temperature to some prescribed level. Based on the information presented above, I suggest that maintaining the water temperature at ≤ 14.0 – 17.0 ^{o}C would be an appropriate level to aim for. Within this temperature range, I suggest that ≤ 14.0 ^{o}C is the most appropriate temperature for maintaining Redband Trout and Mountain Whitefish because both species grow best at temperatures around 14 ^{o}C when food availability is low. [Note: I assume that as riffle habitat becomes dewatered as base flow decreases, insect production in the Spokane River will decrease. This point is discussed further on p. 22.] Two additional reasons why I would select maintaining temperature ≤14 ^{o}C include:

(i) As indicated above, montane Redband Rainbow Trout prefer temperatures below 17.0 ^{o}C and begin to experience stress and consume more oxygen when temperatures exceed 17.0 or 18.0 ^{o}C; and

(ii) Warmer water holds less oxygen at saturation than colder water. The maximum amount of oxygen that can be dissolved in water is 12.8, 11.3, 10.2, 9.2 and 8.6 mg/L respectively at water temperatures of 5.0, 10.0, 15.0, 20.0 and 25.0 ^{o}C.

Having less oxygen in warmer water lowers the oxygen concentration gradient between the water surrounding the gills and the blood in the gill lamellae, making the uptake (by diffusion) of oxygen from the water by the fish less efficient.

Avista Corporation's current Federal Energy Regulatory Commission (FERC) license agreement (issued in July 2009) calls for Avista, in the summer months, to hold Coeur d'Alene Lake levels at or near 2,128 feet above mean sea level (AMSL) and maintain a minimum flow out of Post Falls Dam of 600 CFS (dropping to 500 CFS if lake levels drop 3 inches below 2,128 AMSL due to low inflows). For example, on July 10, 2015 Avista issued an announcement:

> "*In compliance with the FERC license, Avista expects that the Post Falls Hydroelectric Development (HED) will begin discharging the minimum of 500 CFS this weekend or early next week. This will help maintain Coeur d'Alene Lake levels as well as keep water in the Spokane River throughout the rest of the summer.*"

One problem with using water from Coeur d'Alene Lake to maintain the minimum flow in the Spokane River is that it is much too warm in the summer (as noted above) and could potentially reduce the effect of cold aquifer flow, and the benefit to coldwater salmonids.

A study by Parametrix (2004) illustrates some of these points in fish from the upper Spokane River. Parametrix (2004) tracked 45 wild Rainbow (Columbia River Redband) Trout in 2003 and 2004 in the segment of the Spokane River between Upriver and Post Falls Dams. Most of the fish tagged in both Idaho and Washington spawned in Washington. The fish in Washington tended to swim upstream to spawning sites and those in Idaho tended to swim downstream to spawning sites. Both groups of fish spawned in a 10 km segment below the Washington / Idaho State line. Six of the 31 fish released in 2003 eventually swam downstream to a thermal refuge when the temperature below Post Falls Dam reached 17 – 25 ^{o}C from late June to August. The fish swam downstream from the area below the state line (RM 96.5) to below the Sullivan Road bridge (RM 84.3) where aquifer flow into the Spokane River reduces the temperature to 14 – 17 ^{o}C from late June to August. These six fish survived. Most of the others died during the study owing to illegal harvest by anglers, predation and other unknown reasons. Possibly warm temperatures contributed to some of these deaths.

C. Biological Objectives for the Spokane River Instream Flow.

To sum up this section, I think that WDOE's establishment of an 850 CFS minimum flow for the Spokane River at Monroe Street trivializes the minimum flows needed in the Spokane River. The base flow during the late summer low flow period is established by both: (i) Warm water outflow from Coeur d'Alene Lake (that progressively becomes warmer as it passes over Post Falls Dam and flows to Greenacres and becomes too warm to be of any value to salmonid fishes (as indicated by behavioral avoidance of this region of the river by radio-tracked Redband Trout during the base flow period); and (ii) Cold water inflow from the Spokane Valley – Rathdrum Prairie Aquifer between Sullivan Road to Trent Avenue (which region attracted radio-tracked Redband Trout during the base flow period). It is therefore essential that the WDOE minimum flow recognize this dichotomy and establish separate minimum flows to be supplied by the outflow of the Spokane River from Coeur d'Alene Lake and the inflow provided by the aquifer. Since the river flow is too warm to be of any real value to salmonid fishes during the summer low flow period, and cold water from the aquifer is essential to maintain them in the Spokane River, I recommend that WDOE specifically identify the contribution of each source to the maintenance of the minimum flow. In establishing the minimum flow from Coeur d'Alene Lake /Post Falls Dam, WDOE needs to account for the fact that approximately half of this surface flow (during the summer low flow period) is lost between Post Falls Dam and Greenacres and infiltrates the aquifer in this region.

The approach that I would take to developing the base flow is first to identify the biological objectives of maintaining the base flow. I think that some reasonable objectives would include:

(i) Maintain the temperature of the Spokane River at ≤ 14.0 ^{o}C throughout the base flow period;
(ii) Maintain sufficient riffle habitat to insure that fish food organisms remain abundant in the river for salmonid fishes to eat and exhibit good growth (Note: I would further define what I meant by good growth by establishing criteria for mean length, weight, and coefficient of condition of each age class for a given population size of each age class);
(iii) Maintain sufficient salmonid habitat to protect whichever life stage is limiting; and
(iv) Maintain sufficient flow to meet the sanitary needs of the Spokane River (to dilute phosphorous, nitrogen, heavy metals, and other hazardous substances such PCB's and Dioxin contamination of the river).

[Note: As noted above, if food is unlimited, the optimal temperature for Redband Trout growth is about 17.0 – 18.0 ^{o}C, whereas, if food is limited, the optimal temperature for Redband Trout growth is closer to 13.0 – 14.0 ^{o}C. Since food is probably more limited at present as compared to historical times, because lower discharge is associated with the loss of insect producing riffle habitat, I recommend maintaining a temperature of ≤ 14.0 ^{o}C as more protective of Redband Trout and Mountain Whitefish.]

Next I would identify the flows that are needed to protect these objectives at various control points along the length of the river because a single flow for a river the size of the Spokane is too simplistic (Note: WDOE established minimum flows for the Spokane River throughout the year at only one point, although it did establish a summer minimum flow at a second point). For control points I would suggest one below Post Falls Dam (or perhaps near the state line), one at

Greenacres, one at Trent, one below Monroe Street (at the Spokane USGS gage), one below Nine Mile Dam (since additional flow is added to the river from the aquifer between Monroe Street and Post Falls Dam), and one below either Long Lake or Little Falls dams (or perhaps one below each of these dams).

D. Temperature Objective.

The first objective noted above would benefit from some predictive modeling work. I would use a combination of data previously collected (and collect some additional data needed if data gaps are identified in data previously collected) to construct a predictive model of the relationship between the amount of Spokane River flow and the amount of Spokane Valley – Rathdrum Prairie Aquifer flow into the Spokane River and its effect on maintaining water temperature ≤ 14.0 ^{o}C in the Spokane River below Trent. Such modeling **could** (easily) and **should** be accomplished before WDOE establishes a final minimum flow for the Spokane River.

E. Riffle Habitat Objective.

The second objective, maintaining sufficient riffle habitat, could be accomplished using the IFIM and selecting two or three species of aquatic insects that are commonly found in salmonid diets and sufficiently abundant in the Spokane River.

F. Salmonid Habitat Objective.

The third objective, maintaining adequate salmonid habitat, could be met by improving the IFIM modeling on Redband Trout and Mountain Whitefish as noted below.

G. Pollution Flow Objective.

The fourth objective could be approximated by totaling the amount of point source and non-point source phosphorus inputs along the length of the river and determining what minimum flow is needed to dilute them to the point that phytoplankton growth in Lake Spokane, and periphyton growth in the free-flowing segments of the Spokane River, will not be excessive. This needs to take into account the fact that the human population in the region all along the Spokane River and its tributaries upstream from Long Lake Dam is currently increasing at rates that are approaching that of a third world country, so it is likely that both point source and non-point source phosphorus loads into the Spokane River will continue to increase in the future unless the WDOE becomes even more restrictive in enforcing its total maximum daily load (TMDL) limits than at present.

H. Cold-Water Augmentation.

The second approach I would take in maintaining the base flow is pumping cold water into the river from the aquifer. To me, this appears to be the more reasonable thing to do as it appears to me that loss of aquifer recharge (as a result of increased pumping) is the main thing that has reduced the flows to this point in time [i.e., the loss from the baseline minimum flow 1800 – 2800 CFS) appears to me to be related mainly to withdrawals from the aquifer.] I think that there is plenty of water in the aquifer to be able to pump some into the Spokane River for purposes of augmenting the instream flows and I think that the hydraulic characteristics of the aquifer are such that it would easily refill in most years if some water is pumped into the Spokane River.

An alternative approach to pumping cold water from the aquifer would be to promote conservation by purveyors with existing water rights. However, as the purveyors are currently pumping only about 50% of the water they are entitled to pump and as the population of Spokane County continues to increase it appears to me that purveyors may increase their water usage above current levels. One approach to promote conservation may be to offer incentives to purveyors to pump less water than they are entitled to pump. However, these incentives may not be enough to encourage purveyors to reduce use from current levels since the population is expected to increase, resulting in more water use. At the current rate at which water is being withdrawn from the aquifer, the discharge of aquifer water into the Spokane River is approximately half of historical discharge. Therefore it appears to me that the more reasonable alternative is to pump water from the aquifer into the Spokane River.

I. Seven-Day Low Flow Changes Over Time.

The USGS gage had been set up at Monroe Street by 1891, so I looked up the 7-day low flow (base flow) for 1892 and 1893 at that gage as an indicator of 7-day low (minimum) flows that might be required to restore resident salmonids in Spokane River. The 7-day low flow in 1892 occurred from September 20 to September 26 and was 1,300 CFS on each day. The 7-day low flow in 1893 occurred from September 21 to September 27 and was 1,400 CFS on each day. However, it should be realized that the minimum flows occurred later in the year in the 1890's than at the present time. Table 3 shows 7-day low flow values for years between 1891 and 1900. Thus, the average (range) 7-day low flow for the 10-year interval was 1802 (1300 – 2580) CFS, commencing on an average (range) on start dates of October 6 (September 6 to October 26).

Table 3. Average 7-day low flows at the Spokane gage, 1891-1900.

Year	Date Range	Minimum Flow (CFS)
1891	10-17 to 11-01	1500
1892	9-20 to 9-26	1300
1893	9-21 to 9-27	1400
1894	10-19 to 10-25	2130
1895	9-15 to 11-05	1300
1896	10-9 to 10-24	1500
1897	10-26 to 11-8	1860
1898	9-6 to 10-17	2410
1899	10-9 to 10-17	2580
1900	9-14 to 9-20	2044
10-year average (range)	10-6 (9-6 to 10-26)	1802 (1300-2580)

As set forth in the Table 4, in more recent times 7-day low flows have been considerably diminished and occurred earlier in the year. Thus in the three most recent years for which data were obtained the 7-day minimum flow was only about 56% of average minimum flow from 1891 to 1900 and occurred approximately 40 days earlier in the year. Thus the flows on comparable dates in 2013, 2014 and 2015 ranged from 37% to 54% of those reported in 1892 and 1893.

Table 4. Average 7-day low flow at the Spokane gage, 2013-2015, compared with 1892-93 flows on same dates. All flows reported in CFS.

Year	Date Range	Average Flow	Range of Flow
1892	8-25 to 9-1	2737	1800-2900
1893	8-28 to 9-3	1890	1860-1990
2013	8-26 to 9-1	1016	1000-1030
2014	8-28 to 9-3	1014	1000-1040
2015	8-21 to 8-27	697	692-702

So, as indicated in the above paragraph, lower flows occurred about 40 days earlier in the year and, roughly, averaged about half the discharge at the present time as compared to a century ago. This is relevant to protecting fish in the Spokane River because these shifts mean that the period of low discharge formerly occurred at a time when the air temperatures were decreasing (and especially the nighttime temperatures were often very cold); whereas, at the present time, the low discharge occurs at a time when air temperatures are high. Thus, formerly the river remained relatively cool throughout the year because of the relatively higher flow in late August and early September; whereas, at the present time, it heats up in late August and early September because this period coincides with the lowest flow (and because the amount of cold aquifer water has been reduced). In the past water temperatures remained sufficiently cool to support salmonid fishes throughout the year. At the present time water temperatures in late August and early September are considerably warmer and may be too warm for salmonids to tolerate in some segments of the river (and may be warmer in the regions provided with aquifer flow than it previously was because the aquifer flow has been reduced due to human consumption).

Therefore, I recommend that WDOE establish a minimum discharge during the 7-day low flow period in August/September of 1,800 – 2,800 CFS at the USGS gage at Monroe Street as this range of flows should provide sufficient discharge for restoring lost resident salmonid production in the Spokane River (the average flow during the 7-day low flow period in 1892 and 1893 ranged from 1890 to 2737 CFS).

In 2015, the flow dropped below the minimum flow of 850 CFS on July 18 and remained continuously below this level for 83 consecutive days from July 21 until October 11. During the 84 days that discharge at the Monroe Street gage was below 850 CFS in 2015, discharge averaged (ranged) 744 (692 – 849) CFS. The 7-day low flow at Monroe Street in 2015 occurred between August 21 and August 27 and averaged (ranged) 697 (692 – 702) CFS, far below the minimum flow established by WDOE of 850 CFS. I think that this flow was comprised at the most of 250 CFS of discharge contributed by the Spokane River with the balance contributed by the aquifer. My reasons for this assumption are that the minimum flow maintained below Post Falls Dam was 500 CFS and I assumed that the discharge at Greenacres was about half this value (250 CFS), with the remainder of the discharge at Monroe Street contributed by the aquifer.

J. 2015 Water Temperature Data.

In 2015, I obtained 2015 water temperature data from the Spokane River Keeper, Jerry White, who maintained Hobo tidbit temperature loggers at four locations in the Spokane River between 16 July and 20 August 2015, which continuously recorded temperature at 30 minute intervals throughout each 24 hour period. The locations of the four gages were: Harvard Road (RM 92.7), Barker Road (RM 90.4), near where the Centennial Trail bridge crosses the Spokane River downstream from Donkey Island (~RM 84.2), and above T.J. Meenach Bridge (RM 69.9). The Harvard Road and Barker Road gages were upstream of the reach influenced by aquifer discharge while the Centennial Trail Bridge (just upstream of the head of Upriver Reservoir) and T.J. Meenach (in a free-flowing segment of the Spokane River between the tailrace of Monroe Street Dam and the head of Post Falls Reservoir) sites were both downstream of where the aquifer begins to contribute discharge to the Spokane River. With the help of Shawna Warehime, an EWU fisheries student, we converted these temperatures to an average temperature for each day and then averaged these daily averages to obtain the average temperature at each station for the 35 day period of record. The average temperature at each station for the 35 day period of record (range of daily average temperatures for the period of record) for each gage was: Harvard Road = 23.6 (22.3 – 25.2) ^{o}C; Barker Road = 23.6 (21.7 – 25.5) ^{o}C; Donkey Island = 13.6 (11.9 – 16.0) ^{o}C; and T.J. Meenach bridge = 15.1 (14.2 – 17.1) ^{o}C. The lowest temperatures at Centennial Trail and T.J. Meenach bridges both occurred on August 20 and were probably related to a combination of: i) declining outflow of the Spokane River while aquifer input into the Spokane River remained stable, and ii) low nighttime air temperatures during the last 5 days of the period of record. Temperatures at Donkey Island were in a range that was desirable for trout but it is likely that they were crowding into pools (and presumably competing for food) due to reduced river discharge at this time.

What was WDOE doing about monitoring of the river environment (e.g., temperature) during this time when river discharge was below the minimum flow (850 CFS) established by WDOE? Has WDOE increased their monitoring efforts on the river this year to better determine impacts to water quality and biota when it had plenty of warning that the river discharge would be at or near record lows? Instead of monitoring flows, temperatures and other indicators of water quality below Post Falls Dam, at Greenacres, Sullivan Road, Trent, Monroe Street Dam, Nine Mile Dam, Long Lake Dam and below Little Falls Dam, many of these stations have been shut down and are no longer measuring even flows or temperature. Clearly, what is needed is a monitoring system at all the stations noted above that should be monitored for discharge, water temperature, dissolved oxygen, and perhaps other water quality parameters.

K. Municipal Water Rights and Future Pumping.

In the case of the City of Spokane, Washington, the City, which was granted water rights between 1907 and 1961 amounting to 147,570 acre feet of water, only used about 74,064 acre-feet in 2005 and 77,196 acre-feet in 2014. This means the City of Spokane has used only a little over 50 % of the water to which it is entitled. If it actually uses most (or all) of its remaining rights, it has potential to reduce the discharge of the Spokane River by an additional 150 to 250 CFS (thus ensuring excursions below the 850 CFS minimum flow promulgated by WDOE).

In 2005, John Covert, WDOE, performed an analysis of the current water rights that have been granted to the City of Spokane and other water purveyors to withdraw water from the Spokane Valley-Rathdrum Prairie Aquifer and how much of these water rights were actually used in 2005. The amount of paper water rights granted to the City of Spokane amounted to 147,570 acre feet of water and the amount granted to other purveyors in Washington amounted to 135,416 acre feet, for a total of 282,986 acre feet. The amount of water actually pumped in 2005 was 74,064 acre feet by the City of Spokane and 63,642 acre feet by other purveyors in Washington, for a total of 137,706 acre feet. This means that the City and other purveyors in Washington were entitled to pump 145,280 acre-feet more out of the aquifer i.e., they pumped approximately 49% of the water to which they were entitled. The City pumped approximately 50 % of its water right and other purveyors pumped approximately 47 % of their water rights in 2005. In 2014, the City of Spokane pumped about 77,196 acre feet or approximately 52% of its total water rights. In 2005 and 2014, the 7-day minimum flow averaged (ranged) 601 (591 – 614) CFS from August 27 to September 2, 2005 and 1014 (1000 – 1040) CFS from August 28 to September 3, 2014, respectively.

The total amount of water pumped by the City and other purveyors in 2005 was 74,064 and 63,642 acre-feet per day respectively, divided by 365 days per year yielded an average of 211.5 and 174.4 acre-feet per day respectively. To convert this to CFS, I employed the value of 0.504 CFS = 1 acre-feet per day, and calculated that 211.5 acre-feet per day was equivalent to 106.6 CFS and 174.4 acre-feet per day was equivalent to 87.9 CFS, and that the total pumped (385.9 acre-feet per day) was equivalent to 194.6 CFS . Assuming that the amount pumped during the summer is twice or three times the average amount and that this was compensated for by pumping less water during the fall, winter and spring months, the amount of water pumped per day during the summer probably amounted to somewhere between 771.8 and 1157.7 acre-feet per day, which is equivalent to 389.1 to 583.7 CFS. [Note that the value of 2 – 3 that I used to estimate the amount pumped during the summer is a conservative estimate because the City of Spokane Water System Plan reported a peaking factor of about 3.5 during the summer irrigation season.

Given the aquifer – river dynamics, pumping water from the aquifer during summer months contributed significantly to flow reductions in the Spokane River. Worse, this amount represents only approximately half the amount to which the City of Spokane and other purveyors in Washington are entitled to pump out of the Spokane Valley-Rathdrum Prairie Aquifer. If the City and other purveyors were ever to pump the full amount to which they are entitled, the discharge of the Spokane River would almost certainly drop below the minimum flows of 500 CFS at Greenacres and 850 CFS at Monroe Street, and could potentially reduce these flow to less than 300 CFS (or maybe even stop the flow entirely).

I think that the best way to think about the relationship of the aquifer to the river is to imagine the aquifer as a very deep bathtub that covers 322 square miles (in Idaho and Washington) and is from 150 to 600 feet deep. The volume of water this bathtub holds is about 10 trillion gallons.

The faucet of this bathtub is the rain and snowmelt from the surrounding mountains, which supplies the bathtub with a prodigious amount of water (about 650 million gallons or 2395.6 acre feet per day) that completely fills it to the top of the tub every spring. The main differences between this imaginary bathtub and a real one is that: (1) It is filled with rocks and gravels that are very porous [the water flows through them at rates as high as 50 feet per day in comparison to a typical aquifer which flows at rates of 0.25 inches to 5 feet per day]; (2) It is tilted slightly so that the water flows from the northeast to the southwest; (3) Its drain is near the top of the tub instead of at the bottom. The "drain" of the Spokane Aquifer bathtub is the Spokane and Little Spokane Rivers, which are at approximately the same level in the tub as the faucet. On average about 146 million gallons per day (538.1 acre-feet per day) are pumped out of the aquifer by all purveyors in Idaho and Washington and the peak daily summer withdrawal is about 450 million gallons (1685.5 acre-feet per day). [Note: this is why I multiplied the average number of acre-feet pumped in the summer by 2 – 3 in the preceding paragraph.] All this information was obtained from MacInnis et al. (2004), Kahle et al. (2005) and Boese et al (2015).

The problem with this bathtub is that the Spokane River drain is near the top of the aquifer instead of at the bottom. Note, from the preceding paragraph, that the average inflow (650 million gallons or 2395.6 acre-feet per day) greatly exceeds the average outflow (146 million gallons or 538.1 acre-feet per day). This has led to the concept that the aquifer contains a nearly inexhaustible supply of water. However, during the summer months, the average inflow drops below this average amount, especially after snowmelt runoff declines.

At the same time the daily withdrawal of water from the aquifer ramps up. Aquifer withdrawals during the summer apparently withdraw a sufficient amount of water off the surface of the tub to come close to intersecting the drain and, when this happens, aquifer recharge into the Spokane River declines. If a sufficient amount is withdrawn so that the water level in the tub falls below the level of the drain, flow from the aquifer into the Spokane River will cease. [Note that in regions where the aquifer supplies water to the river this intersection or drain is very close to ground level and what normally keeps water flowing from the aquifer into the river is the difference between the average inflow versus the average outflow.]

Thus, at current levels of summer withdrawal (i.e., water purveyors continue to withdraw 50 % of their entitlement), in years with high or average runoff, aquifer water will continue to discharge into the Spokane River at levels that exceed 850 CFS at Monroe Street; but, in years with low runoff, the discharge will be lower than 850 CFS at Monroe Street. This is what occurred in 2015.

If the City of Spokane and other water purveyors draw 100 % of their entitled water, however, the flows at Monroe Street will be less, or much less, than 850 CFS in years with low or average runoff, and will be close to 850 CFS only in years with high runoff.

L. Climate Change Impacts.

I am also concerned about global climate change in the event that the Inland Northwest shifts to a warmer climate with lower snowpack. If this occurs I think that it will be difficult to maintain the minimum flow above 850 CFS in most years as indicated by the present year (2015) where the average daily minimum flow averaged (ranged) 723 (692 – 846) for 38 consecutive days between July 21 and August 27 at the USGS gage at Monroe Street (#12422500).

M. Cold Water Augmentation, cont.

All this is a problem, of course, because the Spokane River drain intersects the aquifer at such a shallow depth. There appears to be no problem of hydraulic mining of water, such that water levels in the aquifer are constantly declining as is the case with the basalt aquifers in the Columbia Basin. Indeed, the water supply in the aquifer is almost nearly always topped off. Given that the characteristics of the aquifer are such that it easily refills every year suggests a way out of this morass: Namely, to sink wells into the aquifer and use the cold aquifer water to promote the flows in the Spokane River. I would place a well or series of wells near Starr Road to add about 200 – 250 CFS of flow to that segment of the river. This is the upper end of the main Redband Trout spawning area in the Spokane River. Although much of this flow would sink back into the aquifer before reaching Greenacres, it might keep sufficient flow in the river so that Redband Trout redds do not become dewatered before fry emerge from them. The colder water in this region might also make it less desirable for Smallmouth Bass, which presently occupy it in large numbers. At the very least, it should reduce any Smallmouth predation that occurs on trout fry since they consume less food at colder temperatures. I would sink additional wells into the reach between Trent and Sullivan Road to produce about 200 – 250 CFS of additional flow in this region because it is a known thermal refuge for upper Spokane River Redband Trout. The added flows would also likely benefit the Mountain Whitefish population that occurs between Upriver and Monroe Street dams. Additionally I would sink wells to produce about 200 – 250 CFS of flow to the region of the middle Spokane River that is occupied by Redband Trout. Also, I would sink a fourth well (or set of wells) that would supply about 200 – 250 CFS of flow to the Little Spokane River to improve conditions for resident fish that utilize the lower reach of the Little Spokane River and to provide attraction flows for resident fish that utilize Long Lake Reservoir (Lake Spokane) and migrate into the Little Spokane River on spawning migrations.

[Note: WDOE established minimum base flows at four control points along the Little Spokane River, at Elk (RM 34.4), Chattaroy (RM 20.0), Dartford (RM 10.6), and lower Little Spokane River (RM 3.7), for the 1st and 15th for each month of the October 1 to September 30 water year (WAC 173-555-030). At Dartford, for example, minimum flows were established for October 1 (130 CFS); October 15 (140 CFS); November 1 and 15, December 1 and 15, and January 1 and 15, and February 1 (all at 150 CFS); February 15 (170 CFS); March 1 (190 CFS); April 1 (250 CFS); April 15 (218 CFS); May 1 (192 CFS); May 15 (170 CFS); June 1 (148 CFS); June 15 (130 CFS); and July 1 and 15, August 1 and 15, and September 1 and 15 (all 115 CFS) (WAC 173-555-030). Aquifer water enters the Little Spokane River between Dartford and the lower Little Spokane River site where the minimum flow from July 1 to September 30 was established at 375 CFS (WAC 173-555-030). The Dartford gage (USGS # 12431000) has been operated continuously from 1 January 1947 to the present time. I obtained the daily discharge and determined the number of days per decade for the water years (inclusive), from October 1, 1948 – September 30, 1958 through October1, 1998 – September 30, 2008, that the discharge at the Dartford gage violated the minimum flows established in WAC 173-555-030. I chose decade intervals for this analysis because the amount of precipitation varies annually, creating high

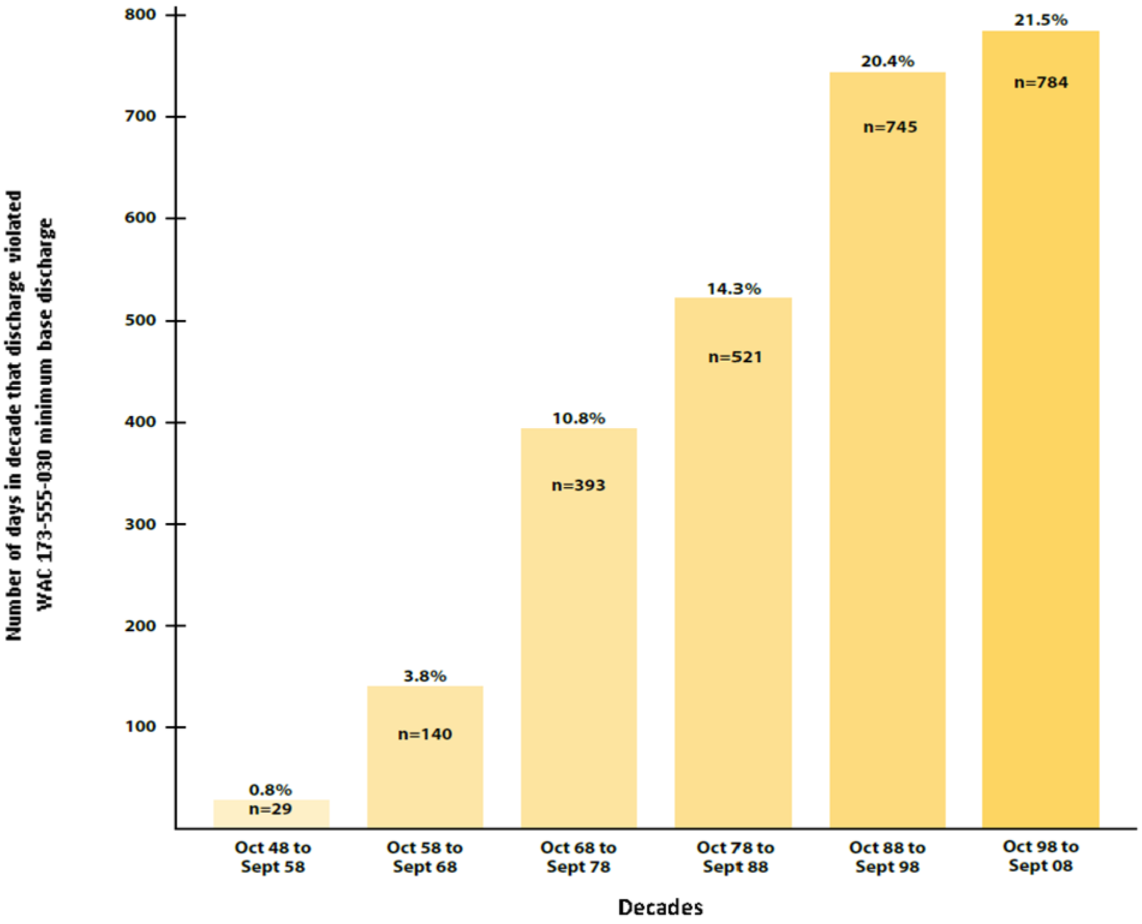


Figure 5. Number of days in each decade October 1948 to September 1958 through October 1998 to September 2008 discharge of the Little Spokane River measured at the Dartford gauge violated minimum flows established by WAC 173-555-030.

discharge and low discharge years. By analyzing at decade intervals, I hoped to account for some of this variation. The data are recorded in Figure 5. The number of days of violation (in the decade) was: 29 (October 1, 1948 – September 30, 1958), 140 (October 1, 1958 – September 30, 1968), 393 (October 1, 1968 – September 30, 1978), 521 (October 1, 1978 – September 30, 1988), 745 (October 1, 1988 – September 30, 1998) and 784 (October 1, 1998 – September 30, 2008). The percentage of days the minimum discharge established in WAC 173-555-030 was violated increased steadily (from 0.8 %, 3.8 %, 10.8 %, 14.3 %, 20.4 %, to 21.5 %) during the six decades. The majority of violations were associated with the summer low flow period (July 1 to September 30). To provide some numbers for comparison, the Dartford gage was operated during the draught years of the Great Depression. The discharge during the summer low flow period (July 1 – September 30) over four years (1929 – 1932) was less than 115 CFS minimum base flow on 320 of 368 dates (i.e., on 86.9 % of the dates). Discharge from July 1 to September 30 averaged (ranged) 106 (87 – 164) CFS in 1929, 83 (63 – 130) CFS in 1930, 77 (65 – 97) CFS in 1931 and 113 (104 – 146) CFS in 1932. In comparison, discharge, measured during a relatively wet period that included the 1948 flood event, during the summer low flow period over four years (1947 – 1950) was less than the minimum flow on only 51 (i.e., 13.9%) of 368 dates. Discharge from July 1 to September 30 in those years averaged (ranged) 116 (104 – 152) CFS in 1947, 230 (156 – 470) CFS in 1948, 145 (128 – 188) CFS in 1949 and 174 (149 – 248) CFS in 1950. In 2015, discharge at the Dartford gage from July 1 to August 29 has violated WAC 173-555-030 on all 60 (100 %) of the dates and the discharge has averaged (ranged) 83 (76 – 98) CFS.]

Each of the four well sites noted above would have to be operated for only about 2-3 months over the course of the warmest, lowest flow period of the year to provide benefit to the fish. The aquifer should be able to easily refill by the following spring.

Who should pay for these wells? A case could be made that the City of Spokane and other purveyors of the Spokane River-Rathdrum Prairie Aquifer should pay for them, especially if the City wants to maintain its "Near nature, near perfect" image. A case could be made that the State Legislature should pay for them as they are now needed because a state agency (WDOE or its predecessor agencies) over-appropriated the water in the Spokane Valley-Rathdrum Prairie Aquifer before its relationship to providing cold water to the Spokane River and its benefits to the fishery in the Spokane River were understood. In fact, state agencies over-appropriated water (defined as exceeding the base flow) of most rivers in eastern Washington (See discussion and several examples in Scholz 2012a, 2014a, 2014b). A case could also be made that Avista Utilities should contribute since the increased flows would allow them to produce more hydroelectric power at the many dams they have along the Spokane River.

IV. Problems Related to the IFIM that was Performed for the Spokane River.

A. Background for Understanding IFIM Studies.

The Instream Flow Incremental Methodology (IFIM) was developed by the United States Fish and Wildlife Service in the mid to late 1970s to determine gains or losses of fish habitat as stream discharge incrementally increases or decreases. The IFIM uses a collection of computer models called the Physical HABitat SIMulation (PHABSIM) model. The PHABSIM model has three components: (i) the hydraulic model; (ii) the "curves" programs; and (iii) the HABITAT programs. Hydraulic model data is collected about stream morphology and hydrology (macro and microhabitat available) at high and low flows and inputted into a data base, is one component of the model.

Another component is probability-of-use curves for selected habitat parameters (depth, velocity, substrate, and cover) utilized by each life stage of each selected target organism. The quantification of fish microhabitat is generally accomplished by: (i) determining the depth, velocity, substrate, cover and temperature preferences for each life stage of each target species being evaluated, and (ii) determining the amount of useable habitat at incremental stream flows based on these preferences. Habitat preference for each target species is determined by dividing the utilization of each habitat parameter measured in the field by the availability of that parameter (Bovee 1986). The information is then used to develop habitat suitability curves for each life stage of each target organism. These, in turn, are used by the HABITAT programs in PHABSIM to calculate total usable habitat, called Weighted Usable Area (WUA), for each life history stage of that target species at incremental stream discharge (Milhaus et al 1984). Temperature is evaluated in a separate model called SNTEMP (Theurer et al. 1984).

With respect to the data used for the "curves" programs, three procedures (or categories) are employed to obtain data (Bovee et al. 1998). Category I criteria are derived from personal experience and professional opinion or from negotiated definitions developed either in a roundtable discussion or Delphi technique (Zuboy 1981). The Delphi technique lacks the rapid feedback and short response time of a roundtable discussion, but instead uses a series of questionnaires sent out individually to a team of investigators and requires a series of feedback loops. The main advantage to using the Delphi technique over the roundtable method is that it is anonymous and therefore counters suggestions made by loud, dominant individuals. The advantage to using Category I criteria is that it is less costly than to collect Category II data (discussed below), especially in larger 1st and 2nd order rivers like the Spokane River. The main disadvantage to employing Category I criteria is that the curves constructed for different life stages of each target species are based upon opinion rather than actual data.

Category II criteria

> "*are based on frequency distributions of microhabitat attributes at locations used by the target species. These criteria are known as utilization or habitat use functions because they represent the conditions that were being occupied by the target species when the observations were made . . . . Depth, velocity, cover type, substrate, and* [temperature] *data were measured at each occupied location. After measurements had been taken at 100 – 200 locations, the investigator . . . fit the data to a univariate curve.*" (Bovee et al. 1998).

The primary advantage of using Category II criteria is that they are based on data rather than opinion. The major disadvantage of using Category II criteria is that they may be biased by microhabitat availability i.e., a habitat attribute that is highly favored by a particular life stage of a target species will not be used much if it is hard to find. Conversely, less favored habitat attributes will be used more by a particular life stage of a target species if they are the only ones available.

Category III data "*are designed to reduce bias associated with environmental availability. These criteria are also referred to as electivity or preference functions*." (Bovee et al. 1998). The primary advantage of using Category III criteria is that they compare the habitat attribute utilized by different life stages of a target species in the field to the availability of that habitat attribute in the field, so they are a true measure of preference. There are no disadvantages of using preference curves for conducting an IFIM that are apparent to me.

PHABSIM is comprised of a hydraulic model (e.g., IGF4) and a habitat model (e.g., HABITAT). The hydraulic model predicts depth and velocity distribution in relation to substrate and cover at different stream discharges. The habitat model integrates habitat quality of combinations of depth, velocity, substrate and / or cover into an index of habitat quantity [i.e., weighted useable area (WUA)]. Habitat quality of different values of depth, velocity, substrate and/or cover are entered into the habitat model as habitat suitability criteria (i.e., the curves based on Category I, II, or III criteria noted in the above paragraphs).

As it was first envisioned, the IFIM was designed to be applied to smaller 3rd and 4th order streams. It was assumed that the curves representing habitat occupied by different life stages of each target species were unique to each stream and would have to be collected for each stream. However, it soon became obvious that different life stages of a particular target species occupying variety of streams had similar preferences. USFWS then developed a set of standard curves, called habitat suitability index models, for a number of target species. Eventually, when IFIMs were used to evaluate minimum discharges in 2nd order rivers, like the Spokane River, investigators began to use a combination of these curves to develop a series of default curves for each state. This was because in large rivers it is difficult to collect data about habitat occupation/preferences of each life history of each target species without encountering considerable expense.

B. The Spokane River IFIM Study.

The Spokane River IFIM used default curves (used statewide by the State of Washington) that were the Instream Flow Study Guidelines at the time, for two species only, Redband Trout and Mountain Whitefish.

The curves for Redband Trout (*O.mykiss* var. *gairdneri*), which were utilized in the Spokane River IFIM, were developed by collecting data for a combination of presumably Redband Trout (*O. mykiss* var. *gairdneri*) from the Blue Mountains and eastern slopes of the Cascades, and presumably Coastal Rainbow (including Steelhead parr) Trout (*O. mykiss* var. *irideus*) in the Olympic Mountains. The curves were a composite from each of these areas weighted by sample size (Hal Beecher, WDFW, pers. comm., 24 August 2015). These curves were based on Category III data for the trout (Beecher 1995; Beecher et al. 1993, 1995); but, for the most part, they were derived from shallow, easy to wade streams (e.g., the Tucannon River in the Blue Mountains; Nason Creek, tributary of the Wenatchee River, and Mad River, tributary of the Entiat River) with the exception of some Okanogan River data that was contributed by the USFWS (Hal Beecher, WDFW, pers. comm., 24 August 2015). Thus, weighting the data by sample size possibly overemphasized habitat utilized by trout in shallow (easy to wade) streams and underemphasized habitat utilized by trout in large, deep rivers. In particular, the depths that are occupied/preferred by trout in large, deep rivers are probably different from that occupied/preferred in shallower streams. The curves for Mountain Whitefish were based on Category I data obtained from Alberta. These curves were developed from personal experience and professional opinions of investigators, who participated in a Delphi process, rather than collecting actual data.

The risk of using IFIM / PHABSIM in a big river, as deep as the Spokane River, is that it models the depth as if it is a 1-dimensional, as compared to a 3-dimensional, environment. The 1-dimensional and 2-dimensional hydraulic models used in instream flow modeling treat the entire water column as a cell (with velocity at 60 % of depth representing the entire vertical cell). Hal Beecher (WDFW, pers. comm., 24 August 2015) informed me that he thought this was not much of a problem when depths are < 1.5 meters but

> "*when much deeper I have seen fish layered in the water column. So the modeled velocity (at 60 % depth) is not what the near-benthic fish are experiencing. An interesting example came up in the Chehalis River where we modeled whitefish and largescale sucker. We used the Alberta whitefish curves that were Delphi curves for use with IFIM (recognizing that velocity was modeled at ~ 60 % depth) and sucker curves based on Wydoski and Whitney (2003), which cited a study for velocity use. We typically see these species in mixed schools, yet the WUA results were opposite. I believe the sucker curves were based on nose* [or focal point] *velocity and showed current avoidance, while the whitefish peaked at higher flows (like at Spokane).*"

Hal Beecher (WDFW, pers. comm., 23 October 2014), who has published several papers in peer reviewed scientific journals about habitat suitability criteria and is a respected member of the Instream Flow Council, informed me that he thought that the habitat suitability criteria for Mountain Whitefish, although based on Delphi method for obtaining data, were, in his opinion, adequate for use in the Spokane River. However, I am bothered by the fact that field data specific to the Spokane River were not used to develop the habitat suitability criteria for each life history stage of each target species (i.e., Redband Trout and Mountain Whitefish) for the Spokane River IFIM.

My primary concern with using habitat suitability criteria that were not developed specifically for the Spokane River is that the Spokane River is unusual with respect to the habitat it contains. For example, it contains unusually large amounts of basalt bedrock and the amount of spawning gravels that are suitable for Redband Trout spawning are unusually limited, yet Redband Trout still persist in this habitat. Substrate preferences might therefore be very different in the Spokane as compared to a river with a more balanced mixture of substrates. Standardized habitat curves, which, by nature, assume a somewhat normal distribution of habitat are thus inappropriate for use in the Spokane River. The biological basis for the 850 CFS minimum flow at Monroe Street and 500 CFS at Greenacres thus appears to be unsound. IFIM is an improper/inadequate tool to study fish habitat in a river the size of the Spokane, and with the unusual composition of habitat as the Spokane, unless adapted with appropriate field data specific to the Spokane River that can be used to construct habitat suitability criteria for each life history stage of each target species. That field data collection did not occur here. Were such field collections to occur, it would likely result in selection of a higher minimum flows to protect redband trout habitat during summer months.

Hal Beecher (WDFW, pers. comm., 23 October 2014) noted that although I was mainly concerned about the late summer / early fall minimum flows, the spring spawning flows (6,500 CFS at the Spokane gage between April 1 and June 15) were well studied. The purpose of these flows was to ensure that redds remained under water from the time the adult fish spawned until the time the juveniles emerged from them. Mr Beecher stated:

> "*The ground-breaking work on Spokane River flows concerned spawning and incubation by the trout. The studies by Hardin-Davis, Parametrix and Addley and Peterson, and subsequent analysis of hydrological records since the Spokane gage was first established were informed by Chris Donley's knowledge of Spokane River trout, their spawning and emergence timing, their age at first reproduction, fecundity and probable longevity, as well as the work conducted by the consultants. I am unaware of any instream flow study in the United States or Canada that has gone into such detailed assessment of the role of flow in spawning and incubation (and as a very active member of the Instream Flow Council, I would likely have heard of such studies had they occurred). As a result of the Spokane River analysis, I think the spring instream flows do a good job of ensuring continued spawning and incubation success that matches what has occurred since the end of the 19th century*."

I am in complete agreement with the above statement, but it is largely irrelevant to the problem of inadequate summer season flows. As noted earlier in this letter, the summer season (June 16 – September 30) 500 CFS minimum flow at Greenacres and 850 CFS minimum flow at Monroe Street do not come close to matching the historic flows. What concerns me is that the protection of spawning and incubation flows in the spring can be undone if the fish are unable to survive the low summer flow period because the minimum flows are too low. There is also the issue that lower instream flows means that there is less water volume in the Spokane River. Less water volume would increase the rate at which predators, such as Smallmouth Bass or great blue heron, encounter juvenile Redband Trout, which could lead to increased predation on juvenile trout. Also, reduced water volume could lead to increased bird predation (e,g, bald eagle, osprey) on subadult and adult Redband Trout because they would be more visible to these predators owing to the reduced depth of water that covers them. Therefore, I remain skeptical that the minimum flows promulgated by WDOE afford sufficient protection to the species of fish described in this report.

C. Temperature and Target Species Improvements to the Spokane River IFIM Studies.

The IFIM temperature model (Theurer et al. 1984) should have been incorporated into the Spokane River IFIM analysis. The temperature model predicts useable macrohabit, which is one component of total useable habitat. Since the radiotracking study performed by Parametrix (2004) demonstrated that large segments of the upper Spokane River appeared to be avoided by

Rainbow Trout because water temperatures were too warm, I am surprised that the IFIM temperature model was not incorporated into the analysis. If the fish total useable habitat is, in fact, limited by temperature, it puts a premium on the remaining habitat and its utilization by fish. It may also influence the WUA utilized by the fish if the fish are concentrated in limited areas of the stream.

I believe that the IFIM for the Spokane River would also benefit by the selection of more target species, especially two or three aquatic insects that are important in salmonid diets, such as mayflies, caddisflies, stoneflies, or chironomids. As explained above. Aquatic insect production might become severely limited by a minimum flow of 850 CFS owing to dewatering of riffle habitat where most aquatic insects are produced. If this occurs the Spokane River could become food limited rather than habitat limited.

In summary:

(1) In poor water years (e.g., 2015) there is insufficient discharge into the Spokane River to maintain a base flow of 850 CFS at the Monroe Street stream gage, and this problem may exacerbate as climate change alters the hydrology of the Spokane watershed;

(2) The average minimum flow at Monroe Street should be closer to the historical average of about 1800 – 2800 CFS, and minimum flows in this range will do a better job of protecting all biota than minimum flows of 500 or 850 CFS;

(3) Establishment of minimum flows of 500 CFS at Greenacres and 850 CFS at Monroe Street is a superficial response by WDOE to the problems related to discharge of the Spokane River. WDOE should, instead, establish minimum instream flows at several control points along the entire length of the Spokane River (e.g, at Post Falls, the Idaho/Washington State line, Greenacres, Sullivan Road, Trent, below Upriver Dam, Monroe Street, below Nine Mile Dam, below Long Lake Dam and below Little Falls Dam.) Moreover at each of these control points WDOE needs to develop a monitoring network to measure daily discharge, water temperature and oxygen. Also, WDOE needs to separate its minimum instream flow requirements into a component that is supplied by Spokane River outflow from Coeur d'Alene Lake (while taking into account that proportion of the flow that is lost to infiltration of the aquifer between Post Falls Dam and Greenacres) and into a component that is supplied by the Spokane Valley – Rathdrum Prairie Aquifer;

(4) WDOE should begin restoring aquifer discharge into the Spokane River by using a series of wells to augment cold water discharge into the river at four locations, with 200 – 250 CFS provided at each location;

(5) There are certain problems with the IFIM on the Spokane River, including: (a) Habitat suitability criteria need to be developed specifically for the Spokane River; (b) the IFIM temperature model should be incorporated: and (c) the IFIM model would benefit by incorporating more target organisms, including two or three aquatic insects common in fish diets.

The take home message here is twofold. First, WDOE should amend the instream flow rule to increase the minimum summer and autumn instream flows to an average of 1800 to 2800 CFS.

Second, WDOE should not, under any circumstances, issue any more water rights from the Spokane Valley – Rathdrum Prairie Aquifer until minimum flows in the Spokane River are restored to an average of about 1800 – 2800 CFS.

Sincerely,

Allan T. Scholz

Allan T. Scholz, Ph.D.
Professor Emeritus (Biology)

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