WR Stream Reach Summary

Study Reach: WR, Williams Fork from Williams Fork Reservoir downstream to Colorado River.

Reach Description: Approximate channel length: 2.25 miles, approximate channel slope 1.4%.

The Williams Fork River extends between Williams Fork Reservoir to the Colorado River, confluencing near Parshall, Colorado. Current flow conditions support a healthy and well-vegetated riparian corridor in this reach. Flows are highly regulated from the reservoir and tend to be cool. This is a popular reach with anglers as there is good public access and an abundant fish population.

Williams Fork upstream of PHABSIM site

Flow Recommendations:

Environmental Flow Methodology: Tetra Tech established a PHABSIM study site within this reach in summer 2007. See Appendix A for methodology and Appendix E for PHABSIM survey information. In addition, based upon trout habitat - flow relations, Chadwick Ecological Consultants (1997) developed "most beneficial" flow ranges for this reach and Denver Water developed minimum flows and ramping flows in conjunction with the Environmental Assessment for the Hydroelectric Power Project (DW 2004).

Water Users:

- Irrigators, municipalities and industry flow-related issues: none reported
- Recreational flows: Angling only, no floatboating reported.

Summary of Flows:

Environmental, recommended target flow ranges

- 40 to 140 cfs, April through September
- 40 to 100 cfs, October through March
- Flushing flow, at least 200 cfs for a 3-day duration with a frequency of 1 in 2 years during the early June to early July.

Other (Chadwick Ecological Consultants 1997)

- 50 to 150 cfs, April 1 to June 30
- 50 to 250 cfs, July 1 to September 30
- 75 to 150 cfs, October 1 to November 30
- 50 to 150 cfs, December 1 to March 31

Environmental Assessment for the Hydroelectric Power Project (DW 2004)

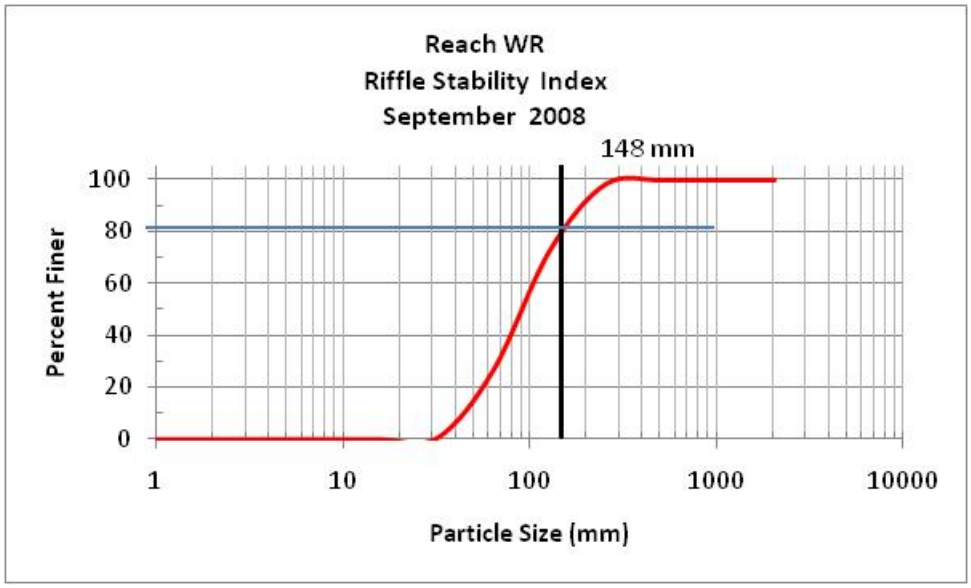
- 15 cfs or inflow, minimum releases
- Ramping: between 25 to 100 cfs per hour depending on reservoir outflow

Water Users

- Irrigators, municipalities and industry: The local diversions in this reach could potentially divert up to approximately 35 cfs. Most of the diversions are made in the summer for irrigation and likely have some return flows.
- Recreation:
    - Angling: 50 cfs

Stream Assessments: In August 2008 Tetra Tech conducted three stream assessments in WR. These included Stream Reach Inventory /Channel Stability Evaluation (SRI/CSE), EPA Habitat Quality Assessment (HQA) and a Riffle Stability Index (RSI) evaluation. The SRI/CSE evaluation scored in the 'fair' category, the EPA HQA evaluation scored in the high 'suboptimal' category and the RSI of 80 indicates riffle substrate is moderately unstable with up to 80% of particles mobilized by recent high water events. Relevant issues revealed in the stream assessments include accelerated bank erosion likely due to the high discharges released from the reservoir. Results of the assessments are summarized in the following table and plot. Details and methodology are presented in Appendix A.

Reach WR Stream Assessments					
Stream Reach Inventory/Channel Stability Evaluation			**EPA Habitat Quality Assessment**		
Attribute			**Attribute**		**Score**
Upper Banks			**Channel**		
1	Landform Slope	2	1	Aquatic Habitat Barriers/ Diversion	13
2	Mass wasting hazard	3	2	Aquatic Structure as Cover	14
3	Debris Jam Potential	6	3	Velocity/ Depth Regimes	18
4	Vegetation Cover	6	4	Channel Flow Status	14
	Upper Bank Score:	**17**	5	Channel Alteration	18
Lower Banks			6	Frequency of Riffles	18
5	Channel Capacity	2	7	Channel Sinuosity	8
6	Bank Rock Content	6		**Channel Score**	**103**
7	Flow obstructors & Deflectors	3	**Banks**		
8	Cutting	10	8	Bank Stability	10
9	Deposition	10	9	Riparian Vegetation Cover and Disturbance	16
	Lower Bank Score:	**31**	10	Riparian Vegetation zone width	16
Channel Bottom				**Bank Score**	42
10	Rock Angularity	3		**Total Score**	**145**
11	Brightness	2	**Notes**		
12	Consolidation/Particle Packing	4			
13	Bottom size distribution	8			
14	Bed Scour and Deposition	12			
15	Clinging Aquatic Veg	2			
	Channel Bottom Score:	**31**			
	Total Score:	**79**			



Spawning Observations: A spawning survey was conducted in the vicinity of the PHABSIM site on 29 October 2008. Six likely brown trout redds were identified and measured. Deep, fast flow conditions likely reduced the number of redds we could locate and measure.

Hydrologic Records: USGS Gage Station 09038500 (WF below WF Reservoir) has been in operation from 1949 to 1954 and 1959 to present. The reservoir releases are currently controlled in a manner to draw down the reservoir during the fall and winter months to a capacity of approximately 60,000 ac-ft as carry-over for the following year. Prior to 1988 the reservoir was typically drawn down to an even greater extent with the objective of maximizing power generation. Thus flow records were investigated before and after 1988. The daily streamflow exceedence plots and the IHA analysis indicate flows within the environmental flow ranges have been commonly available within the reach over this period-of-record. Based upon the flood frequency analysis, the recommended flushing flow approximates the 1.05 year return period event. The flushing flow recommended is well supported by both the historic and the recent hydrologic record.

Water Temperature: WR is a Tier I stream reach as designated by CDPHE with a chronic temperature standard of 17^{o}C MWAT and an acute temperature standard of 21.2^{o}C DM. Temperature data reviewed in reach WR indicate stream temperatures for Williams Fork in this area are generally well below the MWAT and DM standards.

Water Quality: Available data for Williams Fork has shown low DO values from 1999 to present. Out of the 92 samples reviewed for DO, 16 samples equaled or fell short of 6.0 mg/L. These are unexpected readings given the surface water temperatures and natural aeration of this relatively steep reach. However, it may be possible the low DO readings are the result of flow releases from the bottom of the reservoir and warrants further investigation.

Water Supply Issues (UPCO): No water supply issues are reported for this reach.

Summary of Results and Additional Remarks:

1. The recommended flow ranges are commonly present, and often exceeded, within the WR reach.
2. Some bank erosion is occurring due to high flow releases from Williams Fork Reservoir.
3. Temperatures and water quality are supportive of a cold-water fishery.
4. Flows for recreation are generally adequate.
5. Previous water quality sampling indicates there may be low DO, possibly as a result of flow releases from the bottom on the reservoir.
6. Williams Fork Reservoir has been operating under ramping rules since 2004, which allows for a minimum flow of 15 cfs 15 cfs is lower than the recommended flows in this SMP as well as the minimum recommended flows developed by Chadwick (1997). Ramping rates likely exceed State guidelines (see Executive Summary).
7. CDOW electrofishing data from 2003 indicate both brown and rainbow trout occur within the reach, with browns comprising over 96 percent of the game fish catch.
8. The recommended environmental flows are based on habitat requirements for both species, as CDOW is attempting to restore rainbow trout populations through stocking in this section of the Colorado River system. Recommended flows are quite similar to those described as “most beneficial” by Chadwick Environmental Consultants (1997).

Restoration Opportunities:

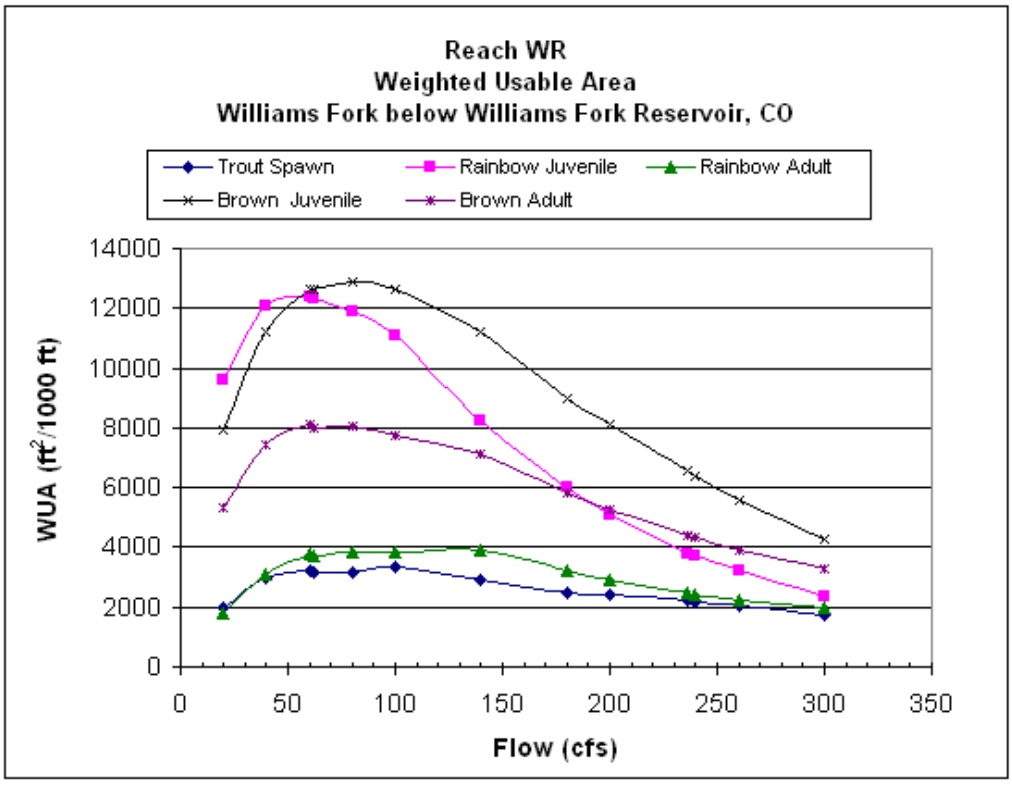
- ✓ Further analysis and monitoring should be conducted to evaluate the minimum flows and ramping rates for hydroelectric power operations.

Monitoring: Monitor flows and ramping rates. Follow up with additional spawning surveys. Continue to monitor DO levels. The results of this analysis could result in future recommendations.

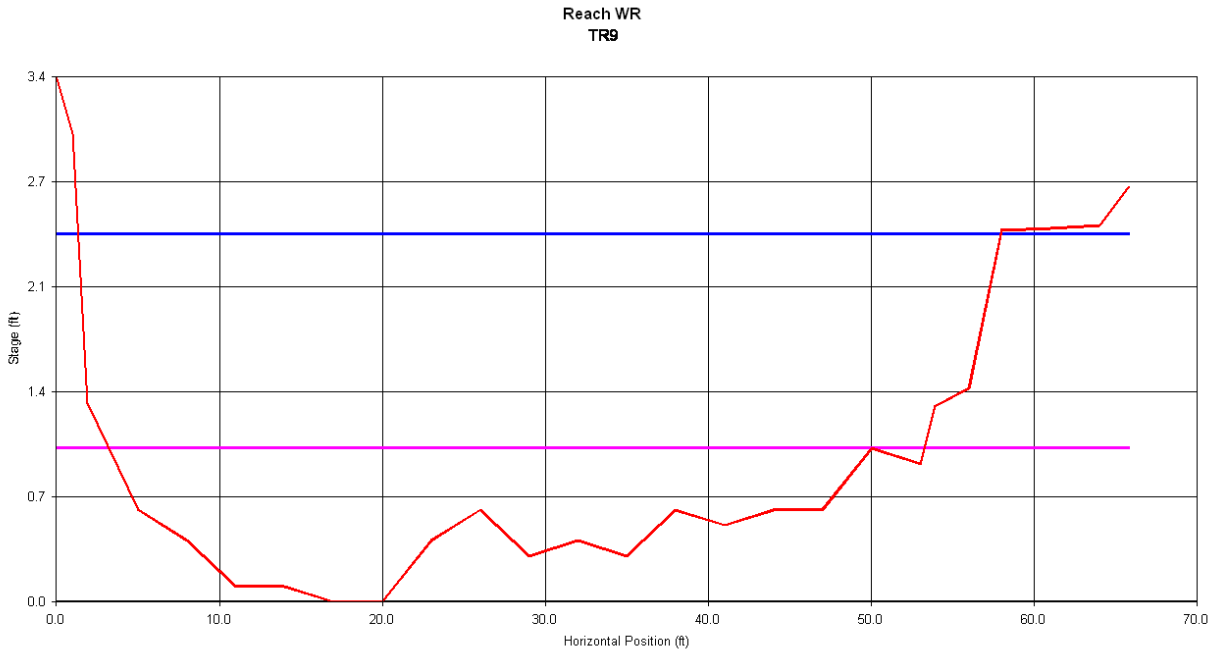
Support Data
Weighted Useable Area Plots and Tables

Habitat-flow relations for the target species and life stages for ReachWR , Tetra Tech site.

Reach WR						
Discharge	Total Area	Trout Spawn	Rainbow Juvenile	Rainbow Adult	Brown Juvenile	Brown Adult
(cfs)	(ft^2)	Weighted Usable Area (ft^2/1000 ft stream length)				
20.0	36398.9	1979.5	9596.4	1780.5	7902.8	5338.3
40.0	39908.4	2973.5	12083.8	3084.6	11228.3	7441.0
60.0	42636.5	3198.6	12410.1	3758.2	12639.4	8087.1
62.0	42918.3	3172.4	12342.4	3709.3	12637.4	8015.7
80.0	43926.8	3189.9	11874.4	3848.9	12861.1	8038.9
100.0	44505.2	3338.8	11058.8	3821.2	12635.8	7770.1
140.0	45208.6	2881.0	8253.0	3920.5	11218.4	7138.6
180.0	45937.9	2497.2	6005.0	3225.0	9012.2	5835.2
200.0	46139.9	2396.3	5091.3	2916.7	8100.3	5266.8
236.0	46460.5	2210.4	3798.3	2481.9	6537.0	4391.1
240.0	46495.8	2185.6	3692.4	2440.1	6363.1	4306.9
260.0	46771.5	2034.7	3197.8	2255.4	5549.5	3923.3
300.0	47422.4	1760.9	2362.4	1970.5	4259.4	3282.2



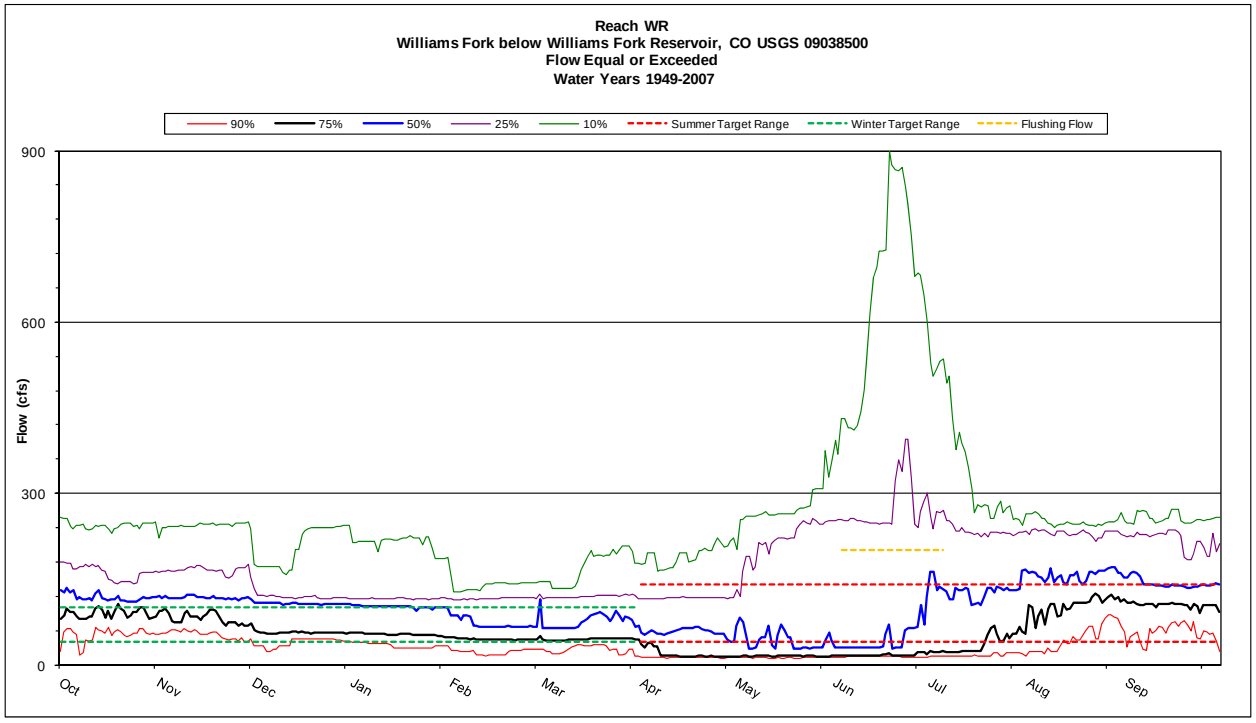
Transect and Bedload Threshold Plots and Tables

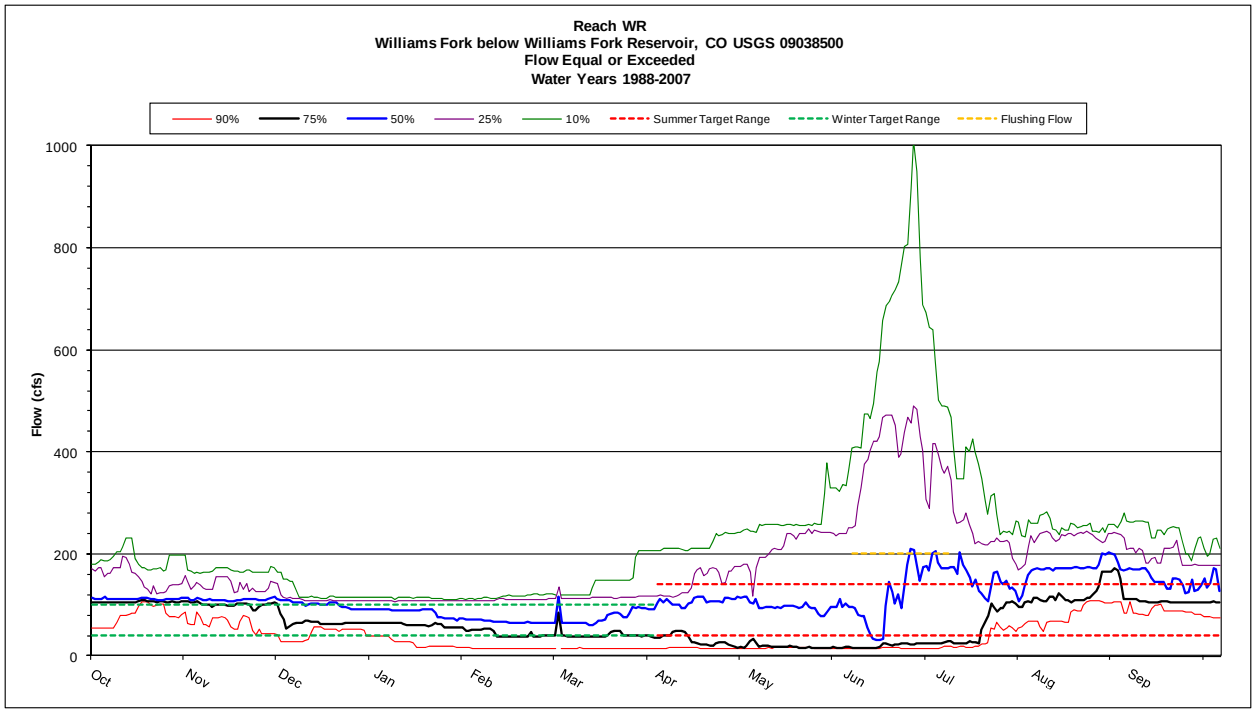


Reach WR
Tr9 TT2007 site
Resistance Method: Jarrett's Equation

STAGE (ft)	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.0	28.42	50.20	50.02	0.57	0.57	0.007	0.065	1.31	37.2	0.25
1.1	33.45	50.92	50.70	0.66	0.66	0.007	0.063	1.48	49.6	0.29
1.2	38.56	51.64	51.39	0.75	0.75	0.007	0.062	1.65	63.6	0.33
1.3	43.73	52.71	52.43	0.83	0.83	0.007	0.061	1.80	78.7	0.36
1.4	49.07	54.50	54.16	0.90	0.91	0.007	0.06	1.93	94.5	0.39
1.5	54.50	54.83	54.40	0.99	1.00	0.007	0.059	2.09	113.9	0.43
1.6	59.95	55.16	54.65	1.09	1.10	0.007	0.058	2.25	134.9	0.47
1.7	65.42	55.49	54.89	1.18	1.19	0.007	0.058	2.41	157.6	0.51
1.8	70.93	55.82	55.14	1.27	1.29	0.007	0.057	2.56	181.8	0.55
1.9	76.45	56.15	55.38	1.36	1.38	0.007	0.056	2.71	207.5	0.59
2.0	82.00	56.48	55.63	1.45	1.47	0.007	0.056	2.86	234.7	0.63
2.1	87.58	56.81	55.87	1.54	1.57	0.007	0.055	3.01	263.5	0.67
2.2	93.18	57.14	56.12	1.63	1.66	0.007	0.055	3.15	293.7	0.71
2.3	98.80	57.48	56.36	1.72	1.75	0.007	0.054	3.29	325.4	0.75
2.4	104.45	57.81	56.61	1.81	1.85	0.007	0.054	3.43	358.5	0.79

Hydrographs and Exceedence Plots and Tables





Return Period T (year)	**Probability P (percent)**	**Flood Discharge Q (ft^3/sec)**
1.05	95.2	195
1.11	90.1	217
1.25	80	256
2	50	393
5	20	723
10	10	1072
25	4	1738

Flood frequency analysis for USGS 09038500 Williams Fork below Williams Fork Reservoir CO, for 53 years of record (Water years 49-2006; regulated).

IHA Results

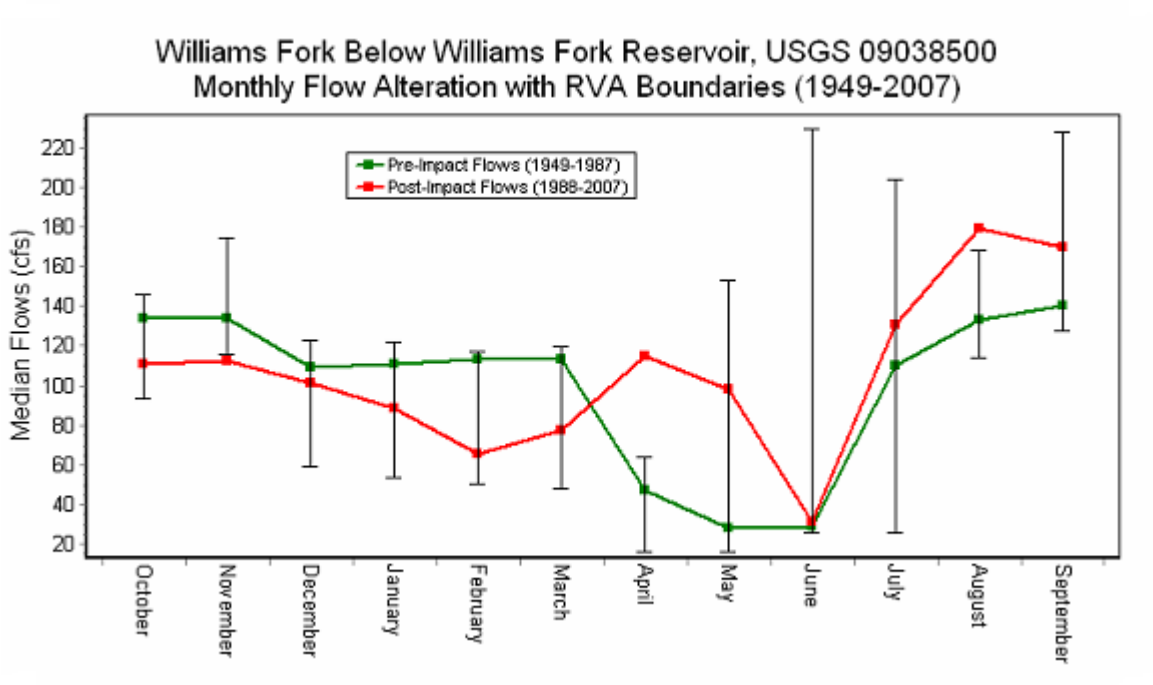
Reach WR
Non-Parametric IHA Scorecard
Williams Fork Below Williams Fork Reservoir, USGS 09038500

	Pre-impact period: 1949-1987 (35 years)	Post-impact period: 1988-2007 (20 years)
Mean annual flow	129.7	126
Mean flow/area	129.7	126
Annual C. V.	1.03	0.85
Flow predictability	0.42	0.43
Constancy/predictability	0.65	0.71
% of floods in 60d period	0.29	0.27
Flood-free season	1	85

	MEDIANS		COEFF. of DISP.		DEVIATION FACTOR		SIGNIFICANCE COUNT	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
Parameter Group #1								
October (cfs)	134	111	0.597	0.2275	0.1716	0.619	0.2442	0.2102
November (cfs)	134	112	0.9851	0.2589	0.1642	0.7371	0.0961	0.1381
December (cfs)	109	101	0.9083	0.4332	0.07339	0.5231	0.3624	0.1491
January (cfs)	111	88.5	0.6937	0.5056	0.2027	0.2711	0.4555	0.4444
February (cfs)	113	65	0.6858	1.102	0.4248	0.6067	0.5556	0.2983
March (cfs)	113	77.5	0.6814	0.9806	0.3142	0.4391	0.6176	0.3874
April (cfs)	47	114.5	1.362	1.302	1.436	0.04355	0.006006	0.8929
May (cfs)	28	98	7.857	2.173	2.5	0.7234	0.1962	0.5405
June (cfs)	29	31	7.931	11.7	0.06897	0.4749	0.7317	0.6116
July (cfs)	110	131	1.918	0.8779	0.1909	0.5423	0.3624	0.06306
August (cfs)	133	179	0.9323	0.648	0.3459	0.3049	0.03504	0.1962
September (cfs)	140	169.5	0.9786	0.4159	0.2107	0.575	0.2563	0.0991
Parameter Group #2								
1-day minimum (cfs)	13	15	0.7231	1.383	0.1538	0.9131	0.008008	0.2883
3-day minimum (cfs)	13.67	15	0.3512	1.383	0.09756	2.939	0.02002	0.1001
7-day minimum (cfs)	14	15.14	0.3816	1.375	0.08163	2.603	0.1061	0.06607
30-day minimum (cfs)	16.07	17.12	0.7448	2.025	0.06535	1.719	0.6817	0.05906
90-day minimum (cfs)	41.24	56.34	1.281	1.114	0.366	0.1301	0.1712	0.6867
1-day maximum (cfs)	289	335.5	0.7751	1.317	0.1609	0.6988	0.3043	0.4535
3-day maximum (cfs)	288	325.8	0.7245	1.367	0.1314	0.8871	0.3834	0.2733
7-day maximum (cfs)	279.6	304.9	0.6648	1.27	0.09044	0.9097	0.2422	0.2773
30-day maximum (cfs)	260.5	250.3	0.5029	0.7968	0.03916	0.5846	0.3814	0.4494
90-day maximum (cfs)	225.5	198.9	0.5187	0.5467	0.1179	0.054	0.5285	0.8428
Number of zero days (count)	0	0	0	0				
Base flow index (7day minimun in cfs/median in cfs)	0.1346	0.1446	0.8012	0.9921	0.07422	0.2383	0.2673	0.5155
Parameter Group #3								
Date of minimum (Julian day)	126	136	0.3279	0.2432	0.05464	0.2583	0.3103	0.7648
Date of maximum (Julian day)	186	181.5	0.347	0.1148	0.02459	0.6693	0.7377	0.1401
Parameter Group #4								
Low pulse count (#)	4	1	0.5	1.75	0.75	2.5	0.02503	0.003003
Low pulse duration (days)	9.25	26.25	2.541	1.548	1.838	0.3908	0.009009	0.4044
High pulse count (#)	3	3.5	1	1.071	0.1667	0.07143	0.3954	0.8979
High pulse duration (days)	23.5	9.5	2.25	2.474	0.5957	0.09942	0.3383	0.8288
The low pulse threshold is (cfs)	44							
The high pulse threshold is (cfs)	182							
Parameter Group #5								
Rise rate (cfs difference between consecutive days)	2	2	1	1.563	0	0.5625	0.1341	0.2853
Fall rate (cfs difference between consecutive days)	-2	-3	-1	-1.583	0.5	0.5833	0.01301	0.3063
Number of reversals	73	68.5	0.3973	0.3978	0.06164	0.001384	0.6426	0.995

IHA Percentile Data
Williams Fork Below Williams Fork Reservoir, USGS 09038500

	Pre-impact period: 1949-1987 (35 years)						Post-impact period: 1988-2007 (20 years)					
			Pre-Impact						Post-Impact			
	10%	25%	50%	75%	90%	(75-25)/50	10%	25%	50%	75%	90%	(75-25)/50
Parameter Group #1												
October (cfs)	60.6	81	134	161	252.2	0.597	102.4	106.8	111	132	173.5	0.2275
November (cfs)	57.4	74	134	206	248.3	0.9851	81.55	101.3	112	130.3	163	0.2589
December (cfs)	45	54	109	153	245.8	0.9083	56.5	65.25	101	109	114.6	0.4332
January (cfs)	38.4	52	111	129	256.8	0.6937	16.8	64.25	88.5	109	114.6	0.5056
February (cfs)	35.6	45	113	122.5	242.4	0.6858	15	38.5	65	110.1	118.5	1.102
March (cfs)	38.6	46	113	123	261.2	0.6814	15.1	38.5	77.5	114.5	148.6	0.9806
April (cfs)	12.8	15	47	79	158.9	1.362	15	22.13	114.5	171.3	209.6	1.302
May (cfs)	11.64	15	28	235	272.8	7.857	16	16.25	98	229.3	255.9	2.173
June (cfs)	12.2	16	29	246	612.2	7.931	16	17.63	31	380.3	633.8	11.7
July (cfs)	14.6	24	110	235	291.6	1.918	24.2	110	131	225	294.3	0.8779
August (cfs)	47.2	104	133	228	244.4	0.9323	106	116	179	232	246.6	0.648
September (cfs)	66.4	105	140	242	271.6	0.9786	87.7	107.3	169.5	177.8	207.3	0.4159
Parameter Group #2												
1-day minimum (cfs)	1.16	5.6	13	15	22.8	0.7231	8.23	14	15	34.75	50	1.383
3-day minimum (cfs)	1.98	10.53	13.67	15.33	31.6	0.3512	9.557	14	15	34.75	56.2	1.383
7-day minimum (cfs)	3.717	10.8	14	16.14	31.86	0.3816	10.68	14.04	15.14	34.86	62.86	1.375
30-day minimum (cfs)	7.44	13.77	16.07	25.73	47.31	0.7448	13.68	15	17.12	49.66	94.61	2.025
90-day minimum (cfs)	12.7	21.59	41.24	74.42	97.14	1.281	16.5	24.74	56.34	87.51	104.5	1.114
1-day maximum (cfs)	168.4	245	289	469	1288	0.7751	253.4	278.3	335.5	720	1096	1.317
3-day maximum (cfs)	158.2	244.7	288	453.3	1211	0.7245	244.5	257.7	325.8	703.2	1036	1.367
7-day maximum (cfs)	145.5	244.1	279.6	430	1064	0.6648	237.8	253.3	304.9	640.3	962.3	1.27
30-day maximum (cfs)	135.9	227.9	260.5	358.9	745.9	0.5029	199.9	228.8	250.3	428.3	649	0.7968
90-day maximum (cfs)	104.9	153.7	225.5	270.6	483.9	0.5187	138.5	163.6	198.9	272.3	389	0.5467
Number of zero days (count)	0	0	0	0	0	0	0	0	0	0	0	0
Base flow index (7day minimun in cfs/median in cfs)	0.02944	0.06627	0.1346	0.1741	0.2406	0.8012	0.0929	0.1338	0.1446	0.2773	0.3899	0.9921
Parameter Group #3												
Date of minimum (Julian day)	95.2	115	126	235	281.2	0.3279	45.7	86	136	175	276.4	0.2432
Date of maximum (Julian day)	34.4	148	186	275	298.4	0.347	152.3	171	181.5	213	259.8	0.1148
Parameter Group #4												
Low pulse count (#)	1	3	4	5	10.6	0.5	0	1	1	2.75	4	1.75
Low pulse duration (days)	2	2	9.25	25.5	69.75	2.541	8.8	17.13	26.25	57.75	81.7	1.548
High pulse count (#)	0	1	3	4	5.4	1	1.1	2	3.5	5.75	6.9	1.071
High pulse duration (days)	3	5.75	23.5	58.63	89.2	2.25	5.05	6.5	9.5	30	42.65	2.474
Parameter Group #5												
Rise rate (cfs difference between consecutive days)	1	1	2	3	7.2	1	1	1.25	2	4.375	11.8	1.563
Fall rate (cfs difference between consecutive days)	-10	-3	-2	-1	-1	-1	-10.7	-6.75	-3	-2	-1	-1.583
Number of reversals	49.4	58	73	87	103	0.3973	48.9	59.5	68.5	86.75	98.7	0.3978
EFC Monthly Low Flows												
October Low Flow (cfs)	27.2	57	70.5	108	124	0.7234	102	106	110	115	167	0.08182
November Low Flow (cfs)	49.75	62.5	91	117	169	0.5989	76.5	100	109	116	132	0.1468
December Low Flow (cfs)	15.9	49.5	65.5	109	119.2	0.9084	56.5	65.25	101	109	114.6	0.4332
January Low Flow (cfs)	33.8	51	59	115	123.4	1.085	26.8	64.25	88.5	109	114.6	0.5056
February Low Flow (cfs)	33.3	42.25	51	115	122.9	1.426	15.1	47.5	65	110.1	118.5	0.9635
March Low Flow (cfs)	38.2	46	56	117	125.4	1.268	16.9	39.75	77.5	112.5	117.8	0.9387
April Low Flow (cfs)	15	16	51.5	66	117.6	0.9709	15	24	85	114	118	1.059
May Low Flow (cfs)	15	16	22	45	97.4	1.318	16	16	49.5	106	113.1	1.818
June Low Flow (cfs)	15	16	25	28	67.5	0.48	15.5	16	28	52.75	153	1.313
July Low Flow (cfs)	15.2	23	36	107	162	2.333	20	26	99	109	166	0.8384
August Low Flow (cfs)	22.6	45.5	75.5	109.5	153.7	0.8477	46.4	85	108.5	167	175.4	0.7558
September Low Flow (cfs)	22.6	63.75	74.75	115.5	140	0.6923	86.8	106.1	117	173.8	177.5	0.578
EFC Parameters												
Extreme low peak (cfs)	2.6	3.9	13	14	14	0.7769	4.7	11.26	14	14	14	0.1955
Extreme low duration (days)	1.5	2	4.5	13.75	31	2.611	2	3.125	7.25	12.13	32	1.241
Extreme low timing (Julian date)	65	108.5	127.5	169.5	296.5	0.1667	27	59.75	117	144.4	177	0.2312
Extreme low freq. (#/year)	0	0	1	5	9	5	0	0	0	1.75	2.9	0
High flow peak (cfs)	138.9	150.8	183.3	202.9	257.1	0.2844	162.9	180.3	201	238.3	247	0.2886
High flow duration (days)	3.65	5	7.75	43.38	91.9	4.952	4.1	6.25	9	11.75	23.6	0.6111
High flow timing (Julian date)	143.6	187	234	295.8	325.8	0.2971	125.9	197.3	225.5	267	273.9	0.1906
High flow frequency (#/year)	0.6	1	3	7	14.4	2	2	3	4	5	7	0.5
High flow rise rate (cfs differnenc between consecutive days)	5.628	17.05	29.11	50.99	101.2	1.166	4.271	9.955	20.74	32.88	48.29	1.105
High flow fall rate (cfs difference between consecutive days)	-56.4	-36.88	-23.57	-16.98	-3.131	-0.8441	-34.8	-24.79	-18.13	-11.21	-9.323	-0.7491
Small Flood peak (cfs)	283.1	294.9	366	580.8	888.9	0.7811	285	302	405.5	735	1124	1.068
Small Flood duration (days)	13.15	29.13	64	103.4	182.3	1.16	9	22	28.5	80	119	2.035
Small Flood timing (Julian date)	70.3	150.4	197	242.5	263.3	0.2517	162.8	175	181	197.5	236.4	0.06148
Small Flood freq. (#/year)	0	0	0	1	2	0	0	0.25	1	1	2	0.75
Small Flood riserate (cfs difference between consecutive days)	5.371	11.9	22.46	32.47	68.88	0.916	3.875	13.62	26.5	88.71	127.4	2.834
Small Flood fallrate (cfs difference between consecutive days)	-88.55	-48.84	-11.78	-5.055	-3.614	-3.718	-74.63	-31.06	-24.29	-11.28	-7.603	-0.814
Large flood peak (cfs)	1330	1330	1520	1860	1860	0.3487						
Large flood duration (days)	36	36	65	154	154	1.815						
Large flood timing (Julian date)	163	163	166	180	180	0.04645						
Large flood freq. (#/year)	0	0	0	0	0.4	0	0	0	0	0	0	0
Large flood riserate (cfs difference between consecutive days)	31.86	31.86	42.91	77.96	77.96	1.074						
Large flood fallrate (cfs difference between consecutive days)	-60.3	-60.3	-42.13	-18.42	-18.42	-0.9941						


Williams Fork Below Williams Fork Reservoir, USGS 09038500
Monthly Flow Alteration with RVA Boundaries (1949-2007)
Pre-Impact Flows (1949-1987)
Post-Impact Flows (1988-2007)
Median Flows (cfs)
220
200
180
160
140
120
100
80
60
40
20
October
November
December
January
February
March
April
May
June
July
August
September

Surface Water Temperature Plots