WASHINGTON STATE DEPARTMENT OF ECOLOGY

Moses Lake Inflow-Outflow Balance – A Component of the Moses Lake Total Phosphorus Total Maximum Daily Load

Abstract

Between September 2000 and November 2001, Washington State Department of Ecology (Ecology) measured discharge and developed continuous stage records on Rocky Ford Creek and Rocky Coulee Wasteway, tributaries to Moses Lake in Washington State. In addition, Ecology performed a synoptic flow study on Rocky Ford Creek and took a series of discharge measurements at the South Outlet of Moses Lake (USBR Site 07). Measurements at the South Outlet included both Acoustic Doppler Current Profiler (ADCP) measurements and instream measurements within the control structure.

Monitoring supported a Total Phosphorus Total Maximum Daily Load (TMDL) Study developed by Ecology. The study assessed the assimilative capacity of Moses Lake with respect to the in-lake total phosphorus (TP) criterion of 50 ug/L (Carroll, 2001). Calculation of lake inflows and outflows allowed the determination of lake TP maximum loading.

Seven to eight instream flow measurements were taken at both continuous recorder stations. Rating equations were developed by relating discharge to stage. United States Geological Survey (USGS) records were used to determine discharge from Crab Creek. Standard hydraulic equations were used to calculate discharge from the gated control structures at both the North Culvert and the South Outlet (USBR Site 07) of Moses Lake. The maximum flow of Rocky Coulee Wasteway was just above 2300 cfs, and the minimum flow was 8.5 cfs.

The maximum flow at Rocky Ford Creek was 94 cfs, and the minimum was 33 cfs. A low-flow rating and a high-flow rating, based on eight instream measurements, were developed for the Rocky Coulee Wasteway site. Based on polynomial regression analysis, both ratings produced an r^2 of 0.99. The polynomial rating equation for Rocky Ford Creek, based on five instream measurements, also produced an r^2 of 0.99.

The average total inflow to Moses Lake via Rocky Ford Creek, Rocky Coulee Wasteway, and Crab Creek was 452 cfs during wateryear 2000-2001. The outflow through the North Culvert and the South Outlet averaged 536 cfs. The estimated outflow exceeded the measured inflow by 84 cfs. This difference can be attributed to unmeasured inflow from minor streams, ground-water inflow, and errors in the calculations.

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E-mail: ecypub@ecy.wa.gov
Phone: (360) 407-7472
Address: PO Box 47600, Olympia WA 98504-7600

Authors: Chris Evans and Art Larson
Washington State Department of Ecology
Environmental Assessment Program
Phone: (360) 407-6052
Address: PO Box 47600, Olympia WA 98504-7600

Introduction

Between September 2000 and November 2001, the Stream Hydrology Unit (SHU) of the Washington State Department of Ecology (Ecology) measured discharge and developed continuous stage records on Rocky Ford Creek and Rocky Coulee Wasteway, tributaries to Moses Lake in Washington State. In addition, SHU performed a synoptic flow study on Rocky Ford Creek. Streamflow of Rocky Ford Creek, Rocky Coulee Wasteway, and Crab Creek comprise the major inflow to Moses Lake. Outflow from the lake is via the North Culvert gates and the South Outlet gates. SHU also made a series of discharge measurements at the South Outlet of Moses Lake (USBR Site 07), and estimated outflow from the lake at both the North Culvert and South Outlet using USBR lake level data and the positions of the controlling gates.

Monitoring supported a Phosphorus Total Maximum Daily Load (TMDL) Study developed by the Watershed Ecology Section of Ecology. The study assessed the assimilative capacity of Moses Lake with respect to the in-lake total phosphorus (TP) criterion of 50 ug/L (Carroll, 2001). Calculation of lake-inflows and outflows allowed the determination of lake TP maximum loading.

Sites

SHU established continuous stage height recording stations at Rocky Coulee Wasteway and Rocky Ford Creek. The remaining discharge data were gathered from existing United States Geological Survey (USGS) and United States Bureau of Reclamation (USBR) monitoring stations.

- The Rocky Coulee Wasteway site was located on the left edge of water on the downstream side of the K Road bridge at 4° 09’ 38”N longitude and 119° 27’ 09”W latitude, just upstream from the confluence with Crab Creek.
- The Rocky Ford Creek station was located below the check dam along the left edge of water between Hwy 17 and the mouth of the creek (47° 14’ 38”N longitude, 119° 27’ 025”W latitude).
- Data for Crab Creek was gathered from the USGS station (#12467000) located at the Road 7 bridge (47° 11 22”N, 119° 15’ 52”W), above the confluence with Rocky Coulee Wasteway.
- Discharge from Moses Lake was calculated using lake elevation and gate data from the USBR station in the South Outlet forebay (USBR Site 07 at 47° 04’ 48”N, 119° 19’ 57”W) and the elevation data for the Potholes reservoir.

Methods

The two streamflow stations were equipped with a pressure transducer and a datalogger that recorded stage height at 15 minute intervals from September 2000 to November 2001. The dataloggers used by SHU are Design Analysis H-510's with H-310 SDI-12 pressure transducers. These transducers are factory set for depths of 0 to 34 ft. Daily average discharge at each station was calculated from rating curves comprised of six to eight wading measurements.

Discharge measurements followed the USGS mid-section method (USBR, 1997). The measured cross-sections, perpendicular to the stream flow, were established by driving re-bar into opposing banks. This allowed field staff to return to the same cross-section at different stage heights and improved the reliability of the measured discharge. In the case of Rocky Coulee Wasteway, high-flows were measured from a bridge. In general, the cross-sections were divided into approximately 20 cells so that no more than 5% to 10% of the total discharge passed through any single cell. The width of the individual cells varied in keeping with the 5% to 10% discharge criteria. Velocity measurements were taken at 0.6 times the stream depth when the total stream depth was less than 1.5 ft. and at 0.2 and 0.8 times the stream depth when the depth was greater than 1.5 ft (Hopkins, 1999). The instream velocity measurements were made with a standard USGS top set wading rod fitted for Swoffer type optical sensors and propellers or standard bridge measurement equipment. Stream discharge was calculated from field notes using an in-house software program. Continuous stage records were converted to discharge in cubic feet per second (cfs) using rating equations developed from the instream measurements.

The outflow of Moses Lake into Potholes reservoir was estimated using four methods; one for each of the four outflow regimes common to the operation of the radial gates:

1. Under the most common conditions, the gates are lowered below the elevation of Moses Lake and control the lake outflow into Potholes reservoir. Usually, the elevation of Potholes reservoir is low enough that it does not restrict the outflow from the gates. Under this regime the gate-orifice equation recommended by the US Bureau of Reclamation was used. The equation is:

$Q=c*V*A$
where:
Q=discharge, cfs
V=velocity, fps
A=area, sq ft. (gate width times gate opening)
c=coefficient of discharge - value used was 0.65

Velocity was estimated as the square root of (2gH) where g is the acceleration of gravity (32.174 ft./sec sq) and H is the head. The head was estimated as the distance from the water surface (Moses Lake Elevation) to the center of the gate opening.

2. Another regime occurred when the gates were controlling outflow to Potholes reservoir but the elevation of the Potholes reservoir was above the sill elevation of the gates

(1041.30 ft.). At this point the outflow from Moses Lake was impeded and the head (H) was estimated as the difference in elevation between Moses Lake and the Potholes reservoir. The same equation was used as in the first regime with the substitution of a different H value.

3. A third regime occurred regularly when the gates were raised completely out of the water and flow was no longer controlled by an orifice. During these conditions, we used the standard Manning's equation with a roughness (n) of 0.014 to estimate velocity. The slope length was fixed at 33 ft., the length of the confining channel, and the elevation decrease was estimated as the difference between the Moses Lake elevation and the sill elevation of 1041.3 ft. The area was estimated as the gate width times the depth of water over the sill (Moses Lake elevation minus the sill elevation).

$$v = 1.486/n \, R^{0.67} \, S^{0.5}$$

where:
v = velocity
n = Manning's n
R = hydraulic radius
S = slope

Discharge or Q = v * Area

4. A fourth regime was a modification of the third regime and occurred when the elevation of the Potholes reservoir exceeded the sill elevation and began to impede the free outflow of water from Moses Lake. In this case, the same Manning's equation was used except the elevation decrease was estimated as the difference between the Moses Lake elevation and the Potholes reservoir elevation.

Discharge was estimated individually for each of the five gates and the results summed for total outflow. Two ADCP measurements were made below the fore bay of the South Outlet and several velocity measurements taken within the gated structures. These were used to verify the outflow estimates.

The outflow at the single Moses Lake Irrigation and Rehabilitation (MLIRD) outlet was estimated using the gate-orifice equation as in regime 1 and 2 above. Throughout the study period, the gate opening was fixed at one foot, and the area of flow was three square feet. When the elevation of Potholes reservoir did not impede the outflow, the head (H) was estimated as the difference between the Moses Lake elevation and the culvert base elevation (1040.76 ft.). When the elevation of Potholes reservoir was above the culvert base elevation, head (H) was estimated as the difference in elevation between Moses Lake and the Potholes reservoir.

Quality Assurance

The quality of this study relied primarily on the accuracy of the field measurements and the care and operation of the instruments.

Discharge Measurements

Because the largest potential source of error involved with a discharge measurement is in the velocity measurement itself, site selection and equipment calibration are of high importance. In this study, the measured cross-sections were rated between good and fair. Based on physical conditions encountered at each site, a good cross-section assumes an error of up to 5% and a fair cross-section assumes an error of up to 8%. Depending on the selected cross-section, a minimum of the assigned error is assumed and carried forward to the final discharge calculation. An additional source of error in velocity measurements is the calibration of the Swoffer instruments. The ideal calibration value of a Swoffer propeller is 186. The Swoffer propellers used during this project were pre and post calibrated with values ranging from 186 to 182. A calibration rating of 186 means that for every 186 revolutions of the propeller, 10 ft.of water have passed the measurement point. A calibration value of 182 underestimates the discharge measurement by 2%. Once a rating curve was established, discharge measurement accuracy was tracked by comparing the measured discharge values to the predicted discharge values at the same stage. The range of difference between the measured and predicted discharge fell within the assumed variation in the measured cross-sections. The combination of propeller variations, poor cross-sections, and low-flow conditions contributed to the measured and predicted discharge differences ranging from less than 1% to just over 15%.

Pressure Transducers/ Staff Gages

Based on manufacture specifications, the theoretical precision of the pressure transducers is less than or equal to 0.02% of the full-scale output. For the transducers used by SHU, this precision is considered linear from 0 to15 psi or 0 to 34.6 ft. During the study period, the accuracy of each probe was addressed by using staff gage versus transducer regressions. The r^2 values for the regressions of discharge against staff gage readings ranged from 0.96 to 0.99.

Results

Results are presented separately for each of the three major inflows to Moses Lake, and the two outflow locations.

Rocky Coulee Wasteway

The continuous record for Rocky Coulee Wasteway encompasses wateryear 2001, from September 7, 2000 to October 28, 2001. During this period there were three instances when the recorder failed. These data gaps were filled by interpolating data from USBR gage # 29

upstream from the Ecology gage. The maximum flow measured at Rocky Coulee Wasteway was 2084 cfs and the minimum measured flow was 13 cfs. A low-flow curve and a high-flow curve, based on 8 instream measurements, were developed for the Rocky Coulee Wasteway site. Based on polynomial regression analysis, both curves produced an r^2 of 0.99.

The average flow during the 2000-20001 wateryear was 365 cfs. The maximum daily flow was 2274 cfs and the minimum was 8cfs. Daily discharge values are included in Appendix A.

Rocky Ford Creek

The continuous record for Rocky Ford Creek runs from September 6, 2000 to October 30, 2001, encompassing all of wateryear 2001. During the study period there was one instance when the recorder failed to log. Because of the relative stability of the discharge record, this data gap was filled with a linear interpolation between the start and end points of the gap. The polynomial rating equation for Rocky Ford Creek, based on 5 instream measurements, produced an r^2 of 0.99. The maximum measured flow at Rocky Ford Creek was 90 cfs and the minimum measured flow was 34 cfs. The predicted maximum flow was 94 cfs and the predicted minimum flow was 33 cfs.

The average flow during the 2000-2001 wateryear was 61cfs . The maximum daily flow was 93 cfs and the minimum was 34 cfs. Daily discharge values are included in Appendix B.

In addition to developing a rating curve near the mouth of Rocky Ford Creek, SHU measured flow at five upstream sites for a synoptic flow study. The gauging station located at the mouth of Rocky Ford Creek was used as a reference point during the study period. Site descriptions and results can be found in Appendix C.

Crab Creek

Discharge for Crab Creek was determined from USGS records. Daily discharge values are included in Appendix D. The maximum flow was 54 cfs and the minimum flow was 6.3 cfs. The average flow during wateryear 2000-2001 was 26 cfs.

South Outlet and North Culvert

A series of discharge measurements were taken in the South Outlet structure of Moses Lake (USBR site #7). In addition to these measurements three Acoustic Doppler measurements were made downstream from the structure. The average outflow from the South Outlet during the 2000-2001 wateryear was 508 cfs, with daily flow ranging from 12 to 2141 cfs. During wateryear 2000-2001, the average outflow through the North Culvert was 28 cfs, ranging from 8 to 37 cfs. The estimated daily outflow from the South Outlet and the North Culvert are presented in Appendices E and F, respectively.

Summary

The total inflow to Moses Lake via Rocky Ford Creek, Rocky Coulee Wasteway, and Crab Creek averaged 452 cfs during wateryear 2000-2001. The outflow through the North Culvert and the South Outlet averaged 536 cfs. The estimated outflow exceeded the measured inflow by 84 cfs. This difference can be attributed to unmeasured inflow from minor streams, ground-water inflow, and errors in the calculations. The majority is probably ground-water inflow to Moses Lake.

References

Carroll, Jim, 2001. *Moses Lake Total Phosphorus Total Maximum Daily Load, Quality Assurance Project Plan*. Washington State Department of Ecology, Olympia, Washington.

Hopkins, Brad, 1999. Determination of Instantaneous Flow Measurements on Rivers and Streams: Washington State Department of Ecology, Olympia, Washington. Draft Paper. 6p.

United States Bureau of Reclamation, 1997. *Water Measurement Manual*. U.S.G.P.O., Denver, Colorado.

Appendix A
Ecology 2000-2001 Rocky Coulee Wasteway Mean Daily Discharge (cfs)

Ecology 2000-2001 Rocky Coulee Wasteway Daily Discharge Averages (cfs)

Day	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1	-	49	91	23	17	14	13	2238	641	1091	82	66	1107	250	
2	-	50	88	24	17	14	13	2143	578	1100	81	66	1207	236	
3	-	50	86	21	17	14	12	2049	471	1100	86	67	1212	167	
4	-	47	73	22	17	14	12	2021	321	1009	83	68	1202	135	
5	-	49	49	24	17	14	12	1745	299	780	80	67	1210	219	
6	-	64	41	22	15	14	12	1528	238	552	84	63	1174	431	
7	59	49	33	22	15	13	12	1292	106	326	89	60	1016	661	
8	56	50	35	23	15	14	12	1169	23	84	83	72	1057	648	
9	53	51	33	20	15	13	12	1074	162	11	81	64	1063	694	
10	54	49	30	23	15	13	12	1097	315	11	81	66	1098	746	
11	54	49	29	22	15	13	12	1213	395	11	81	69	890	647	
12	55	50	29	21	15	13	12	1250	357	14	81	68	746	620	
13	51	47	31	20	15	13	12	1587	433	11	82	198	608	657	
14	52	46	28	19	15	13	12	1668	426	11	83	608	614	662	
15	51	50	29	20	15	13	12	1788	260	8	84	838	644	543	
16	49	45	31	20	15	13	12	1879	147	8	85	1052	640	457	
17	49	47	30	19	15	13	12	1594	35	8	85	1223	692	372	
18	49	47	27	18	15	13	12	1454	37	8	85	1261	880	307	
19	47	48	25	19	15	13	12	1332	35	11	86	1236	990	148	
20	47	48	27	18	15	13	12	1208	37	15	75	1235	983	123	
21	48	53	26	19	15	13	25	1171	49	61	71	1197	1018	109	
22	47	49	24	18	15	14	274	1130	245	467	73	1159	956	86	
23	48	53	26	18	15	14	565	936	617	933	67	1047	962	28	
24	51	944	25	18	15	14	1028	843	958	943	65	660	834	28	
25	47	1042	26	18	14	13	1174	533	1176	616	63	543	713	28	
26	47	1029	26	18	14	13	1281	345	1195	432	63	598	803	29	
27	47	984	23	18	14	13	1756	384	1177	214	64	566	849	28	
28	47	460	25	17	14	13	2145	493	1082	166	62	558	702	27	
29	51	178	23	18	14	-	2101	529	1085	157	64	680	464	28	
30	49	153	25	18	14	-	2224	549	1089	109	65	759	255	-	
31	-	118	-	18	14	-	2274	-	1081	-	67	883	-	-	
	50	**195**	**36**	**20**	**15**	**13**	**487**	**1275**	**486**	**342**	**77**	**551**	**886**	**314**	339

Estimated from USBR gauge

Average discharge for wateryear 2000-2001 = 365 cfs

Appendix B
Rocky Ford Creek Daily Discharge Averages 2000-2001

Rocky Ford Creek Daily Discharge Averages 2000-2001

Day	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1	-	90	85	75	59	49	41	38	36.6j	52	62	71.8j	77	81	
2	-	90	85	75	59	49	41	39	36.7j	52	62	72.2j	79	81	
3	-	91	85	74	58	49	41	38	36.9j	51	63	72.6j	78	81	
4	-	89	85	73	58	49	41	38	37j	52	63	73j	78	81	
5	-	89	85	73	57	49	40	37	37.2j	52	63	73.3j	78	81	
6	-	88	84	72	57	49	40	37	37.4j	54	63	73.7j	78	80	
7	89	88	84	71	56	48.6j	40	37	37.5j	54	63	74.1j	78	81	
8	91	88	84	72	55	48.5j	41	37	37.7j	54	64	74	78	81	
9	91	88	85	71	54	48.4j	42	37	37.8j	55	64	74	78	81	
10	91	88	85	70	54	48.3j	41	36	38j	55	64	74	79	81	
11	91	88	83	69	53	48.2j	40	36	38.2j	57	64.1j	75	80	81	
12	92	88	82	67	53	48.1j	40	38	38.3j	57	64.4j	75	79	81	
13	93	88	82	65	53	48.0j	40	34	38.5j	58	64.8j	75	80	81	
14	92	88	82	65	53	47.9j	40	35	38.6j	58	65.2j	74	81	81	
15	91	87	81	64	53	47.8j	41	35	38.8j	58	65.6j	74	81	81	
16	91	87	81	64	52	47.6j	41	36	39	58	65.9j	72	80	81	
17	91	87	80	63	52	47.5j	41	36	46	58	66.3j	71	81	81	
18	91	88	80	63	52	47.5j	40	35	47	58	66.7j	75	81	81	
19	91	87	80	63	52	47	41	35	48	58	67j	75	81	81	
20	91	87	79	62	51	43	41	36	49	59	67.4j	74	81	81	
21	90	88	79	62	51	43	40	35	48	59	67.8j	74	81	81	
22	91	87	79	62	51	43	40	34	49	58	68.1j	75	81	81	
23	90	86	78	62	51	43	40	35	50	58	68.5j	75	81	81	
24	90	86	78	62	51	43	40	35	50	59	68.9j	76	81	81	
25	90	86	77	62	50	43	41	36	50	60	69.3j	75	81	81	
26	90	86	77	61	51	42	41	36	50	60	69.6j	75	81	81	
27	90	86	77	60	50	42	41	37	50	61	70j	75	82	81	
28	90	86	76	60	49	41	40	36	52	64	70.4j	76	82	81	
29	89	86	76	60	49	-	41	36.4j	51	62	70.7j	76	81	81	
30	89	86	75	59	49	-	40	36.5j	51	62	71.1j	78	81	81	
31	-	85	-	59	49	-	39	-	52	-	71.5j	77	-	-	
AVG	**91**	**87**	**81**	**66**	**53**	**45**	**41**	**36**	**49**	**57**	**63**	**75**	**80**	**81**	65

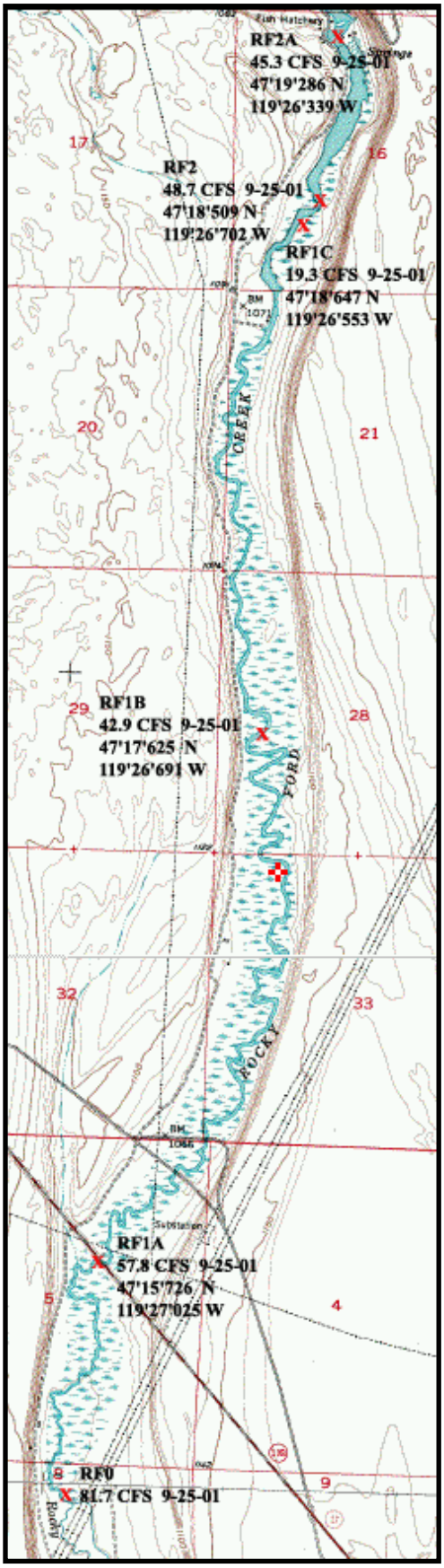
j= estimate during equipment failure

average for wateryear 2000-2001 = 61 cfs

Appendix C
Rocky Ford Creek Synoptic Flow Study

On September 25th, 2001, the Stream Hydrology Unit (SHU) measured flow at five sites on Rocky Ford Creek. The SHU gauging station located at the mouth of Rocky Ford Creek was used as a reference point during the study period. An established rating curve for this site was also used to determine the flow at this site.

Rocky Ford Creek is historically an algae and aquatic plant weed choked system. These are not ideal conditions for flow measurement. In an effort to get a better representation of the overall discharge at each site, 6/10th ft measurements were used. It was felt that by measuring at 6/10ths depth, the weed effect was minimized as best as could be. Regardless, the % error introduced by the presence of instream biota can add up to a 20% error to the assumed error of the cross-section.



RF2A 47’19’286N, 119’26’339W **45.3 cfs**

The uppermost site located 20ft downstream from the property line of the upper hatchery. Cross section was rated as fair, which assumes an error of up to 8%.

RF2 47’18’509 N, 119’26’702 W **48.7 cfs**

Located at the old USGS gauge, measurement was made along the downstream side of the aluminum footbridge. Cross section was rated as poor which assumes an error of over 8%.

RF1C 47’18’647 N, 119’26’553 W **19.3 cfs**

Located at the three by-pass weirs at the lower hatchery. This was the best of the cross sections. Rated as good, it assumes an error of up to 5%. From our measurements, it is estimated that the lower hatchery was diverting 29.7 cfs.

RF1B 47’17’625 N, 119’26’691 W **42.9 cfs**

Located just upstream from the private wood bridge on property owned by Rod Swanson. This cross section was rated as poor which assumes an error of over 8%. A soft substrate and a large plant/algae presence adds to the assumed error at this site.

RF1A 47’15’726 N, 119’27’025 W **57.8 cfs**

Located at the Highway 17 bridge, this cross section was rated fair. This assumes an error of up to 8%.

RF0 **81.7 cfs**

This cross section is considered fair which assumes an error of up to 8%. The discharge from this site is estimated from the SHU rating curve. A gage height was recorded both before and after the study period. The SHU gage recorded a change of .001 psi over a seven-hour period.

Appendix D
Crab Creek (USGS station 12467000) - October 2000 through October 2001
Mean Daily Flow (cfs)

Crab Creek (USGS station 12467000) - October 2000 through October 2001
Mean Daily Flow (cfs)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1	44	29	20	15	11	9	7.6	45	25	32	35	40	39	
2	42	29	19	15	11	9.5	7.2	41	29	31	34	38	41	
3	44	29	19	15	10	9	7	41	32	32	35	39	40	
4	46	28	19	14	10	8.9	6.9	40	32	32	35	37	38	
5	47	27	19	15	12	9.4	6.8	40	32	31	37	36	40	
6	49	27	19	14	11	9.7	6.7	39	31	32	37	37	38	
7	51	26	18	13	10	9.7	6.5	40	25	35	38	36	38	
8	49	33	18	13	9.8	11	6.3	43	22	34	41	34	39	
9	49	34	18	13	9.6	11	6.4	43	21	33	42	38	36	
10	51	28	15	13	9.8	9.7	6	42	25	32	43	39	37	
11	49	25	13	12	10	9.1	8.5	41	29	32	40	39	38	
12	50	24	14	12	10	9.4	7.9	43	31	32	37	38	38	
13	47	24	14	13	9.8	9.4	6.8	46	29	32	39	37	39	
14	48	24	14	14	9.7	8.8	11	50	24	32	41	36	38	
15	45	22	14	13	9.9	8.8	28	54	24	34	41	36	38	
16	44	21	14	12	9.7	9.6	37	49	24	33	38	37	39	
17	45	21	14	12	9.3	8.9	35	48	26	34	34	37	37	
18	44	21	14	12	9.7	9	32	47	29	33	34	36	36	
19	44	20	14	12	10	9.3	34	46	28	34	34	37	36	
20	46	20	13	12	10	8.3	38	46	28	36	32	38	36	
21	46	19	13	12	10	8	38	49	28	34	31	37	36	
22	44	19	14	12	12	7.6	38	49	24	35	35	36	37	
23	44	19	14	15	12	7.4	36	45	23	35	39	34	38	
24	48	19	15	12	11	7.3	37	27	26	34	39	35	36	
25	42	19	15	12	10	9.3	38	29	28	33	39	36	38	
26	35	19	15	12	9.5	9.6	39	24	28	34	37	37	38	
27	33	18	15	11	9.1	8.3	43	22	33	33	36	37	37	
28	33	19	15	11	9	10	44	21	35	33	38	37	37	
29	35	20	15	11		8.6	41	21	34	35	40	38	36	
30	31	20	15	10		7.8	43	26	32	35	42	39	44	
31	30		17	10		7.5		27		36	40		44	**Average**
Avg	**44**	**23**	**16**	**13**	**10**	**9**	**23**	**39**	**28**	**33**	**38**	**37**	**38**	**27**

Average for wateryear 2000-2001 = 26 cfs

Appendix E
South Outlet - October 2000 through October 2001
Estimated Daily Outflow (cfs)

South Outlet - October 2000 through October 2001 Estimated Daily Outflow (cfs)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	222	301	365	281	373	46	1658	522	1292	246	18	1150	382
2	221	301	354	280	696	53	1832	529	1299	176	18	1541	382
3	196	301	345	279	667	50	1578	538	1311	176	18	1543	382
4	115	300	334	281	568	47	1116	461	1146	176	18	1545	300
5	41	299	331	279	326	228	2141	317	893	176	18	1422	261
6	118	2526	331	280	312	379	1636	218	663	168	18	1395	452
7	230	2461	323	280	296	372	1340	49	390	98	19	1134	735
8	230	1693	314	215	286	374	1114	12	207	93	68	1314	828
9	231	1560	306	104	276	378	982	13	163	73	74	1314	998
10	231	1422	300	102	267	387	982	13	95	88	74	1315	995
11	230	1275	285		260	392	951	14	18	104	85	1315	895
12	230	1159	251	102	252	406	970	108	18	116	207	1201	693
13	235	1074	245	102	245	409	1223	363	18	134	403	753	629
14	238	941	196	105	237	399	1462	421	18	142	802	680	631
15	241	830	108	105	234	385	1622	402	35	142	1072	807	632
16	238	765	142	104	235	369	1702	219	39	141	1281	807	632
17	238	710	145	105	232	355	1736	91	52	141	1460	806	631
18	239	661	130	106	230	344	1360	56	57	141	1650	837	628
19	238	619	112	107	230	339	1047	15	57	142	1703	1329	542
20	239	580	113	108	162	333	908	27	58	142	1700	1327	248
21	238	545	112	108	45	326	839	42	58	141	1623	1326	131
22	239	517	212	109	44	323	835	398	303	142	1483	1325	132
23	239	493	281	109	50	346	844	681	682	142	1481	1208	132
24	871	472	281	110	48	400	624	725	814	142	1038	737	132
25	1342	450	281	108	45	486	486	1147	719	142	383	621	132
26	1342	434	282	108	44	376	352	1232	506	142	502	672	132
27	1341	416	282	107	45	307	289	1244	415	142	637	885	132
28	804	405	281	105	45	352	285	974	272	141	682	1012	149
29	301	394	280	104		644	443	1027	230	140	1098	892	268
30	302	378	281	103		900	530	1287	279	60	1210	455	1082
31	301		281	102		1324		1289		18	948		1225
Avg	**372**	**809**	**254**	**150**	**241**	**382**	**1096**	**466**	**404**	**134**	**703**	**1089**	**501**

Average 508

Average for wateryear 2000 - 2001 = 508 cfs

Appendix F
North Culvert - October 2000 through October 2001
Estimated Daily Outflow (cfs)

North Culvert October 2000 - October 2001 Estimated Daily Outflow (cfs)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1	36	37	23	22	22	10	27	24	35	37	37	36	37	
2	36	37	23	21	21	11	27	24	35	37	37	36	37	
3	36	37	23	21	20	11	28	24	36	37	37	36	37	
4	36	37	22	21	19	10	28	24	36	37	37	37	37	
5	36	37	22	21	18	10	28	24	36	37	37	38	36	
6	36	36	22	21	17	8	28	25	36	37	37	41	37	
7	35	35	22	21	17	8	27	26	36	37	37	38	37	
8	35	34	22	21	17	8	26	26	37	37	37	37	37	
9	35	33	22	21	16	8	26	27	37	37	37	37	37	
10	35	32	22	21	15	8	26	28	37	37	37	37	37	
11	35	32	22	21	15	8	25	29	38	37	37	37	37	
12	35	31	21	21	15	8	25	30	37	37	37	37	36	
13	36	30	21	22	13	8	25	31	37	37	37	36	37	
14	37	29	21	23	12	11	25	31	37	37	37	37	37	
15	37	28	21	23	12	12	24	31	37	37	37	37	37	
16	37	28	21	24	11	11	24	30	37	37	37	36	37	
17	37	27	21	24	11	11	23	31	37	37	37	36	37	
18	37	27	21	24	10	10	23	31	37	37	37	36	37	
19	37	26	21	24	9	9	23	31	37	37	37	36	36	
20	37	26	21	23	9	11	22	32	37	37	37	36	36	
21	37	25	21	23	9	11	22	32	37	37	37	36	36	
22	37	25	21	23	9	11	22	32	37	37	37	36	37	
23	37	25	21	23	10	11	22	32	37	37	37	36	37	
24	37	24	21	23	10	13	22	33	37	37	37	36	37	
25	37	24	21	23	9	15	23	33	37	37	37	37	37	
26	37	24	22	23	9	16	23	33	37	37	37	37	37	
27	37	24	22	23	10	19	24	34	37	37	37	37	37	
28	37	23	21	22	9	21	23	33	37	37	37	37	37	
29	37	23	21	22		24	24	35	37	37	37	37	37	
30	37	23	21	22		25	24	35	37	37	36	37	37	
31	37		21	22		26		35		37	36		37	**Average**
Avg	**36**	**29**	**21**	**22**	**13**	**12**	**25**	**30**	**37**	**37**	**37**	**37**	**37**	**29**

Average for wateryear 2000-2001 = 28 cfs