Upper Umatilla River Sediment Analysis

Robin Harris, Hydrologist, and Caty Clifton, Forest Hydrologist

Umatilla National Forest
November 13, 1998

Abstract

The Umatilla River provides multiple beneficial uses including native salmon habitat, water supply, and recreation. Because of existing water quality, the Umatilla River has been listed as water quality limited for temperature and sediment by the state of Oregon. The Umatilla National Forest maintains gaging stations at three sites on the upper Umatilla River watershed: the North Fork Umatilla River, the South Fork Umatilla River and Umatilla River at Corporation. Streamflow records are available for 1965 to present, and suspended sediment data are available for 1987 to present. Streamflow and sediment data are analyzed, with emphasis placed on: identifying tributary flow and sediment contributions; determining annual and seasonal suspended sediment loads; and, identifying relationships between suspended sediment and discharge, and between suspended sediment and turbidity. Contributions of individual peak flow events are also investigated.

Major findings of the assessment include: high annual variability in suspended sediment loads, for example, suspended loads on the Umatilla River at Corporation ranged from 14 to 196 tons/mi^2, an order of magnitude difference in annual suspended sediment production. Comparing tributary streams, the North Fork produced more sediment than the South Fork, even though the South Fork is a larger watershed and has higher peak flows. Watershed characteristics contribute to differences in sediment production. Rating equations for Total Suspended Solids (TSS) to discharge were not developed because of high variability. Predictive equations for turbidity and TSS were developed for the Umatilla River at Corporation and South Fork Umatilla River. Most of the total suspended load is transported during relatively short periods during spring snowmelt.

Recommendations include: evaluating the representativeness of automatic sampler fixed-point sampling by collecting concurrent depth-integrated samples; determining the frequency of sampling needed to characterize the sediment parameters; and, sampling bedload to determine transport rates and contributions to total sediment loads.

Background

The Umatilla Barometer Watershed, located in the Blue Mountains in Northeastern Oregon (Figure 1), was established in 1965 as part of the national USDA Forest Service Barometer Watershed Program. Seven monitoring stations were established on the National Forest; three mainstem stations located on the North Fork Umatilla River, the South Fork Umatilla River, and the Umatilla River at Corporation, and four stations in the High Ridge Evaluation Area. The High Ridge Evaluation Area is located in the headwaters of Buck Creek, which drains into the lower South Fork Umatilla River.

The original objective of the Umatilla Barometer watershed was to evaluate the effects of land management on hydrologic processes, emphasizing timber harvest - water yield relationships. The project focus was later expanded to address water quality issues, which included suspended sediment monitoring at all the stations and bedload sampling at the four stations in the High Ridge Evaluation Area.

Streamflow measurements began in 1965 at all seven stations. Automated pumping samplers were installed in 1984 to collect samples for sediment analysis at all seven stations. Because the focus was on the High Ridge Evaluation Area, sediment monitoring on the mainstem stations came on line later, in WY87 for the North Fork and South Fork Umatilla sites, and in WY88 at Umatilla River at Corporation.

The High Ridge summary analysis is complete (Helvey and Fowler, 1996), and those stations were discontinued. The three mainstem stations are currently operational. This report will focus on sediment data collected at the mainstem stations from 1987 to 1997.

Current Issues

The development of Total Maximum Daily Loads (TMDL's) for the Umatilla River is currently in progress. Water quality monitoring is an important component in the development and validation of TMDL's. The Umatilla River is listed as water quality limited for sediment on the basis of Oregon Department of Fish and Wildlife (ODFW) stream survey information. Ten years of suspended sediment data are available for the upper Umatilla River, at three USDA Forest Service-operated gaging stations, and at three stations on the Umatilla Indian Reservation, operated by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the USGS. These long term records can be used to identify annual and seasonal variability in sediment loads, and approximate baseline conditions for the upper watershed.

The Umatilla TMDL Technical Committee implemented an extensive winter sediment monitoring project throughout the Umatilla Basin in 1997-98 for purposes of characterizing mainstem and tributary contributions to sediment loads (Lambert and Harris, 1998). Winter weather conditions during the extensive monitoring effort were not generally representative of long term average winter weather. The ten years of sediment data (1987-97) described in this report illustrate longer term variability in the annual, seasonal, and storm sediment loads transported by the upper river.

Report Objectives

- Characterize the annual and seasonal suspended sediment loads on the upper Umatilla River, and compare the contributions of the two main forks;
- Evaluate the potential for developing suspended sediment rating curves;
- Identify the relationship between turbidity and total suspended solids;
- Determine the contribution of suspended sediment from major storm events; and,
- Present a tabular summary of all available streamflow and sediment data, 1987 to 1997.

Note on Terminology

Total Suspended Solids (TSS), is a concentration in mg/l, used to approximate the suspended sediment transported by the river, and used interchangeably with suspended sediment throughout this report. Suspended sediment load refers to that part of the sediment load carried in suspension by turbulent motion. Sediment discharge and transport rate refer to the mass of sediment passing a stream cross section in a unit of time (Williams et al, 1988). Unit suspended sediment load is an average area distribution, arrived at by dividing the annual sediment load by watershed area.

Study Area

An extensive physical description of the study area can be found in the Umatilla Barometer Watershed Analysis (Ross and Moore, 1965), the Umatilla Barometer Watershed, survey-analysis-plan (Spandenberg, 1971), and the Watershed Hydrology for the Umatilla-Meacham Ecosystem Analysis (Clifton, 1996). Portions are summarized in this report.

The study area is characterized by steep, narrow valleys, with narrow or absent flood plains. The maximum elevation in the watershed is 5,507 feet at the east boundary and 2,301 feet at the Corporation gage station. Slope ranges from 0 to 80 percent. The soils in the watershed are fine silt loams to gravely silt loams, ranging from two inches to ten feet deep on the slopes and one to five feet deep in the floodplains. The North Fork Umatilla River above the gage station drains 30.1 square miles, the South Fork above the gage drains 47.5 square miles, and the Umatilla River above Corporation gage station drains 90.2 square miles (Figure 1).

Average rainfall is 50 inches in the North Fork watershed and 42 inches in the South Fork watershed. Winter precipitation dominates, as demonstrated by the High Ridge and Corporation records (Figure 2). Snow accounts for an estimated average of 50 to 60 percent of total precipitation.

The North Fork and South Fork watersheds are geologically distinct. The North Fork is characterized by widely spaced fractures and restrictive tuffs composed partially of clay between layers of Columbia River basalt, resulting in slow percolation rates. There are also a high number of large blocks tilted in an easterly direction, opposite of stream flow. These characteristics lead to extended periods of release to stream flow as compared to South Fork. The South Fork is characterized by long, narrow ridges and steep canyon slopes. The underlying geology consists of a more porous volcanic layer and few altered tuffs compared to the North Fork. An indicator of recent downcutting is the nearly vertical cliffs adjacent to the floodplain. These characteristics promote rapid release of water to stream flow.

The Umatilla Barometer Watershed is characterized by complex runoff processes which contribute to variability in the annual streamflow hydrograph and to variable sediment discharge. These include: (1) Rain event generating streamflow in which the magnitude of the resulting streamflow peak depends on the intensity of the storm and the percent soil saturation; (2) Rain on snow events in the Fall and Winter which have the potential to cause high peaks in streamflow, depending on soil saturation, depth of the snowpack, and storm intensity; (3) Rain on snow over frozen ground which causes the highest

peak streamflows because rainfall and snowmelt go directly into runoff; and (4) the Spring snowmelt peak which is often accompanied by rainfall.

Methods

Stream stage is recorded at the three gaging stations by float-sensors in stilling wells using Fisher-Porter analog-to-digital recorders. Stage is recorded on punch tapes in 15 minute intervals, and converted by a translator. Stage data are converted to discharge using the program HYDRA. Discharge measurements are used to develop rating equations. Operations and maintenance of gaging stations were performed mainly by one technician over the period of record, and data analyzed following U. S. Geological Survey standard methods (Rantz and others, 1982).

Water samples are collected using battery-operated pumping samplers located in each gage house. The intakes are positioned in the deepest part of the channel, off the streambed. Samplers are programmed to collect a daily composited sample consisting of four samples drawn at 6 hour intervals. To ensure the samplers only collect water flowing past the sample point, the sampler purges the line of water, draws the sample, and purges the line a second time to flush out any water or sediment remaining in the line. The samples are analyzed at the Umatilla National Forest Water Laboratory in Pendleton, Oregon.

The water samples are analyzed for specific conductance using a Hach meter, and for turbidity using a Hach 2100N turbidimeter. Total suspended sediment (TSS) is measured using a mass balance method; a 47 mm glass fiber filter is dried at 103-105 ^{o}C for one hour, weighed to 0.0001 g, a sample of known volume is filtered, and the filter is dried again and weighed. The difference in weight divided by the volume of water gives TSS (milligrams per liter). All tests are conducted following standard laboratory methods (American Public Health Association, 1992). Sediment data are entered into STORET on an annual basis. Daily mass sediment loads are determined from TSS concentrations multiplied by mean daily streamflow values. Streamflow and sediment data were tabulated using Microsoft Excel for Windows 95. Statistical analyses such as regressions were performed using Excel.

Average daily suspended sediment loads are determined by summing the daily loads from the year and dividing by the number of days sampled. A total annual load is determined by multiplying the average daily load by the number of days in the year. This method of accounting for data gaps was preferred when the sampled points represented conditions for the year. This approach was not used if the data gaps spanned an entire season. Annual unit loads are calculated by dividing the annual load by the watershed area.

Results

Discharge

The North Fork and South Fork Umatilla exhibit different flow regimes, illustrated by the hydrographs in Appendix A. Watershed characteristics contribute to differences in peak flows, water yield, and low flows. The North Fork watershed is characterized by higher elevations, deeper soils, greater snow accumulations, and bedrock units oriented away from streamflow, compared to the South Fork. The North Fork tends to have lower peak flows but greater discharge over most of the year. Low flows average 30 cfs. The east-west orientation of the valley also provides topographic shading, producing cooler water temperatures. The North Fork is largely a wilderness watershed, with no streamside roads in the main valley, and intact riparian vegetation cover providing shade to the stream, further lowering water temperatures. In contrast, the South Fork watershed is characterized by relatively shallow soils, lower average elevations, and a south to north channel orientation, factors that result in lower, warmer baseflows of about 7 to 10 cfs. The road system along the South Fork Umatilla and Thomas Creek open the canopy, allowing for more solar radiation, which contributes to warmer temperatures.

Overall, annual maximum discharge is lower on the North Fork compared to the South Fork, for the same storm event. Annual water yields were higher on the North Fork in nine out of nineteen years measured, or about half of the time (Figure 3).

Discharge at Umatilla at Corporation consistently reflects the sum of the South Fork and North Fork, with a small component that is attributed to Buck Creek (Figure 3). Low flow at Umatilla River at Corporation, at 40-50 cfs, reflects the importance of the North Fork contribution to streamflow during the late summer.

Suspended Sediment

Unit sediment loads (in mass per unit area) represent sediment production distributed over a watershed, and are useful in comparing temporal and spatial variability. Annual unit suspended sediment loads were calculated for each station (Table 1, Figure 4). Annual loads for the Umatilla River at Corporation ranged from 14 tons/mi^2/yr in WY97, to 197 tons/mi^2/yr in WY93, an order of magnitude difference in annual load. For WY88 and WY89, limited data which was not representative of the entire year was available to determine annual loads; these years were excluded from the analysis.

Table 1. Annual suspended unit loads (tons/mi^2) - Umatilla Barometer Watershed.

	WY 88	WY 89	WY 90	WY 91	WY 92	WY 93	WY 94	WY 95	WY 96	WY 97
Umatilla @Corp.	N/A	N/A	60	93	24	197	33	143	45	14*
North Fk. Umatilla	109	354	71	40	42	251	52	149	21	42*
South Fk. Umatilla	2.4	4.1	36	70	18	39	13	28	37*	12*

N/A Not applicable, measurements not representative of entire year
* Limited data available

Unit loads on the North Fork Umatilla River ranged from 21 tons/mi^2/yr in WY96 to 354 tons/mi^2/yr in WY89. Unit loads on the South Fork Umatilla River ranged from 2.4 tons/mi^2/yr in WY88 to 70 tons/mi^2/yr in WY91. In general, year to year variability in suspended sediment loads is the result of variability in weather conditions, storm events, sediment sources, and storage on hillslopes, floodplains, and channels.

In eight out of ten years, the North Fork Umatilla River produced more suspended sediment per square mile than the South Fork Umatilla River. In WY88, North Fork Umatilla River produced 45 times the suspended sediment of the South Fork Umatilla River, and in WY89 the North Fork Umatilla produced 86 times the suspended sediment of South Fork Umatilla River. Watershed characteristics contributing to higher unit suspended sediment loads in the North Fork watershed include higher precipitation, deeper soils, and higher sustained stream velocities. Total sediment loads are unknown for both streams without sampling the bedload component of the total sediment load. The South Fork, with its "flashier" discharge regime, may move a higher proportion of bedload than the North Fork.

The total annual suspended load at the Umatilla River was expected to be slightly higher than the sum of the North Fork and South Fork because of the ungaged contribution of Buck Creek. In seven out of eight years, total suspended load at the Umatilla River was higher than North Fork and South Fork combined, ranging from 2.2 times higher in WY95, to 1.02 times higher in WY92 (Table 2). The greater load could be accounted for in part by bank erosion below the North Fork and South Fork gages, by contribution from Buck Creek, and by the variability inherent in fixed-point sampling. In WY97 the total suspended load at the Umatilla River was lower than North Fork and South Fork combined (North Fork + South Fork was 1.5 times higher than Umatilla River at Corporation). Deposition below the North Fork and South Fork gages would account for the lower total suspended load at Corporation. Floodplain deposition and development of a mid channel bar above the Umatilla River at Corporation were features observed after winter floods in WY96 and WY97.

Table 2. Total Annual Suspended Sediment - Umatilla Barometer Watershed.

	North Fork Umatilla	South Fork Umatilla	Umatilla @ Corporation	Difference (Corp-[NF+SF])
WY 90	2137	1704	5412	+1571
WY 91	1204	3325	8389	+3860
WY 92	1264	855	2165	+46
WY 93	7555	1853	17769	+8362

WY 94	1565	618	2977	+794
WY 95	4479	1330	12899	+7090
WY 96	632	1667	4059	+1760
WY 97	1264	574	1263	-575

Sediment Rating Curves

The focus of many sediment studies is to develop rating equations that link discharge to sediment (Ketcheson, 1986). If acceptable predictive equations can be developed, then continuous streamflow records could be used to estimate sediment transport. In a sediment rating equation, discharge (independent variable) is used to predict sediment (dependent variable). To develop a rating equation, a regression of sediment to discharge is used. The regression yields the equation of the best-fit line and the coefficient of determination (R^2). The coefficient of determination is a ratio between the variance of the predicted values of the dependent variable over the variance of the observed values of the dependent variable. This ratio is converted to a percentage of variance accounted for by the regression. The R^2 describes the extent to which the regression accounts for the variance in observed values of the dependent variable.

To develop suspended sediment rating equations, TSS values are plotted against daily discharge (Ketcheson, 1986). At each station, TSS values were analyzed on an annual, seasonal, and selected runoff event basis. In addition, all data points collected over the sample period were plotted together. None of the R^2 values were above 0.08 at the 95 percent confidence level. All methods of grouping the values showed high variability. A representative plot of TSS to discharge shows a general positive trend of increasing sediment with discharge but wide scatter of data points with many extreme low values of sediment across the range of discharge (Figure 5). Rating equations could not be developed for TSS to discharge because of low explained variance.

Complications to the development of sediment rating equations include hysteresis, where the sediment to discharge relationship changes from the rising limb to the falling limb of a storm hydrograph. Hysteresis results from changing availability of sediment (Dunne and Leopold, 1978). Sediment availability is subject to seasonal influences and watershed conditions (Ketcheson, 1986 and Williams et al, 1988).

Total Suspended Solids (TSS) and Turbidity

TSS was plotted against turbidity values to determine if turbidity could be used as a surrogate measure for TSS. Turbidity measurements can be taken quickly with a turbidimeter, and instream probes are available to measure turbidity continuously. Measuring TSS involves more time-intensive field collection and laboratory analysis procedures. Using turbidity as a surrogate for TSS, all measurements could be made in the field, eliminating the sample collection and lab analysis procedures.

All three stations showed significant (at the 95 percent confidence level) relationships between TSS and turbidity. The Umatilla River at Corporation and the South Fork Umatilla showed significant relationships (R^2 =0.78 and 0.82, respectively, Figures 6 and 7). The period of 1988-1993 showed the strongest relationship between turbidity and TSS for Umatilla River at Corporation, and the period of 1987-1993 showed the strongest relationships for South Fork Umatilla River. Grouping the data points by seasons did not improve the relationships for Umatilla River at Corporation and South Fork Umatilla River.

For North Fork Umatilla River, the R^2 before grouping the data seasonally (1987-1993) was 0.37. The data were next analyzed by season to separate different runoff events: Winter rain-on-snow (November through February), Spring snowmelt (March through June), and Summer low flows (July through October). By grouping the data, the R^2 improved slightly to 0.43 for Winter and 0.45 for Spring (Figure 8). Grouping the data by season attempts to separate differences resulting from different flow conditions (winter storms vs spring snowmelt) and seasonal changes in sediment supply.

The analysis indicates reasonable relationships between TSS and turbidity such that turbidity could used as a predictor for TSS. Relationships were strongest for the Umatilla River at Coporation and the South Fork Umatilla. Confidence limits or error terms should be used with this application.

Peak Flow Analysis

The annual maximum discharge for each year was analyzed to determine the duration, timing, and percent of total suspended load transported during an individual peak flow event (Table 3). In WY96, the maximum flow accounted for 44 percent of the measured load at Umatilla River at Corporation, although the event lasted two percent of the measured days. On the North Fork in WY93, the maximum flow lasted 11 days, accounting for 46 percent of the measured load, but only three percent of the time. On the South Fork in WY91, the maximum discharge lasted 11 days, accounting for 55 percent of the annual suspended load but only three percent of the time.

The highest peak runoff events occur during Spring snowmelt (March-May) and during Winter rain-on-snow events (Dec-Feb). Overall, on an annual basis, spring snowmelt appears to be the dominant sediment transport process because snowmelt is an annual event, where major winter storms may not occur every year. Figures 9, 10, and 11 show daily suspended load over the sample period. For most years at all stations, the highest loads occur during the beginning of spring snowmelt.

Table 3. Peak flow duration, timing, and percent of total annual suspended load.

	Umatilla @ Corp			North Fork Umatilla			South Fork Umatilla		
	# days	% load	Start Date	# days	% load	Start Date	# days	% load	Start Date
WY 88	6	28	3/27	5	14	4/21	9	21	4/12
WY 89	no data for peaks			9	26	4/19	11	21	4/13
WY 90	5	9	4/26	9	12	5/2	11	13	4/28
WY 91	8	41	5/17	10	4	5/17	11	55	5/17
WY 92	4	5	12/6	8	5	12/6	8	4	12/6
WY 93	11	20	5/3	11	46	4/29	11	10	4/29
WY 94	9	40	3/1	6	7	3/1	9	14	3/1
WY 95	13	27	1/31	10	50	5/11	9	28	1/31
WY 96	7	44	2/7	6	7	2/7	no data for peaks		

Discussion

Fixed-point automated pumping samplers offer high sampling frequency with low maintenance, yet there are problems associated with using these devices. The intake of the sampler is small relative to the cross section, located at a single point, and does not vary with stage height. One assumption with automatic samplers is the sampled point represents the entire cross section. Since concentration gradients occur throughout the cross section, fixed point sampling only estimates the actual sediment transported through the cross section. Generally, the most representative point is above the thalweg, at least 10 cm above the streambed (Thomas, 1985).

When pumping a sample, the fixed point automatic sampler intake alters the water velocity, potentially altering the sediment concentration of the sample (Thomas, 1985). Automatic samplers should be calibrated with depth-integrated samples at each site over a wide range of streamflows to determine the relationship between cross sectional suspended sediment concentration and fixed point suspended sediment concentration.

Fixed-interval sampling may miss peak flow events in quick response streams. Since storm events span days, setting the sampling interval at six hours is a reasonable approximation of the daily suspended sediment contribution.

In low flow conditions, the initial backflushing of the intake line to purge any collected water or sediment may actually stir up sediment or algae on the streambed prior to pumping the water sample. During low flow conditions, the intakes at the three Umatilla stations are located in flowing water, minimizing this potential error source.

Operations problems often contribute to data gaps; for example instrument and battery malfunctions, and in the winter, the intake line occasionally freezes. Deep snow occasionally prevents access to the South Fork Umatilla sampler. The November 1995 flood washed out the footbridge across the South Fork, making it difficult to access the sampler at high flows.

Summary and Recommendations

The objectives of this report included: characterizing the annual and seasonal suspended sediment loads on the Upper Umatilla River; comparing the suspended loads for the three mainstem stations; determining the viability of sediment rating curves; identifying relationships between turbidity and total suspended solids; and, determining the contribution of suspended sediment from individual runoff events.

High year-to-year and between station variability in sediment yields was evident from the analysis. For example, the Umatilla River at Corporation ranged from 14 to 196 tons/ mi^2, an order of magnitude difference in annual unit sediment loads. Comparing the tributary streams, the North Fork produces more sediment than the South Fork, even though the South Fork is a larger watershed and exhibits greater peak flows. The majority of the annual suspended load is contributed during spring snowmelt. Rating equations for TSS to discharge were not developed because of high variability. Predictive equations for turbidity and TSS were developed for the Umatilla River at Corporation and South Fork Umatilla River (Figures 6 and 7).

Recommendations include: evaluating the accuracy of fixed-point sampling with concurrent depth-integrated measurements; determining the frequency of sampling needed to characterize the sediment parameters; and, measuring bedload to determine transport rates and contributions to total sediment loads.

Acknowledgments

The Umatilla Barometer Watershed project was maintained through the dedication of Ed Calame and Greg Holden (retired USFS). We thank Bruce McCammon (Region 6), John Potyondy (Stream Systems Technology Center), and John Williams (Agricultural Research Service) for their review of an earlier draft. This work was supported in part through an interagency agreement with the Environmental Protection Agency, Seattle WA.

REFERENCES

American Public Health Association, 1992. Standard methods for the examination of water and wastewater. 18th edition.

Clifton, C. 1996. Watershed hydrology: Ecosystem analysis of the Umatilla and Meacham watersheds. Report on file Umatilla National Forest, Pendleton, Oregon.

52 p.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning. San Francisco: W.H. Freeman and Co. 818 p.

Helvey, J.D. and W.B. Fowler. 1996. Effects of timber harvest on the hydrology and climate of four small watersheds. Report on file Umatilla National Forest, Pendleton, Oregon. 128 p.

Ketcheson, G.L. 1986. Sediment rating equations: an evaluation for streams in the Idaho batholith. INT-213, Intermountain Research Station, Ogden, Utah. 12 p.

Lambert, B. and R. Harris. 1998. Total Maximum Daily Load (TMDL) Winter 1998 sediment monitoring Final Report, total suspended solids. Report on file Umatilla National Forest, Pendleton, Oregon. 21 p.

Rantz, S. E. and others, 1982. Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge, and Volume 2. Computation of discharge. U. S. Geological Survey Water Supply Paper 2175. 631 p.

Ross, R.N. and M.R. Moore. 1965. Watershed analysis: Umatilla River Barometer Watershed. Report on file Umatilla National Forest, Pendleton, Oregon. 145 p.

Spangenberg, N.E. 1971. Umatilla Barometer Watershed Survey-Analysis-Plan. Report on file Umatilla National Forest, Pendleton, Oregon. 98 p.

Thomas, R.B. 1985. Measuring suspended sediment in small mountain streams. Gen. Tech. Rep. PSW-83. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Williams, O.R., Thomas, R.B., and R.L. Daddow. 1988. Methods for collection and analysis of fluvial-sediment data. WSDG-TP-00012, U.S.D.A. Forest Service, Washington, D.C. 85 p.

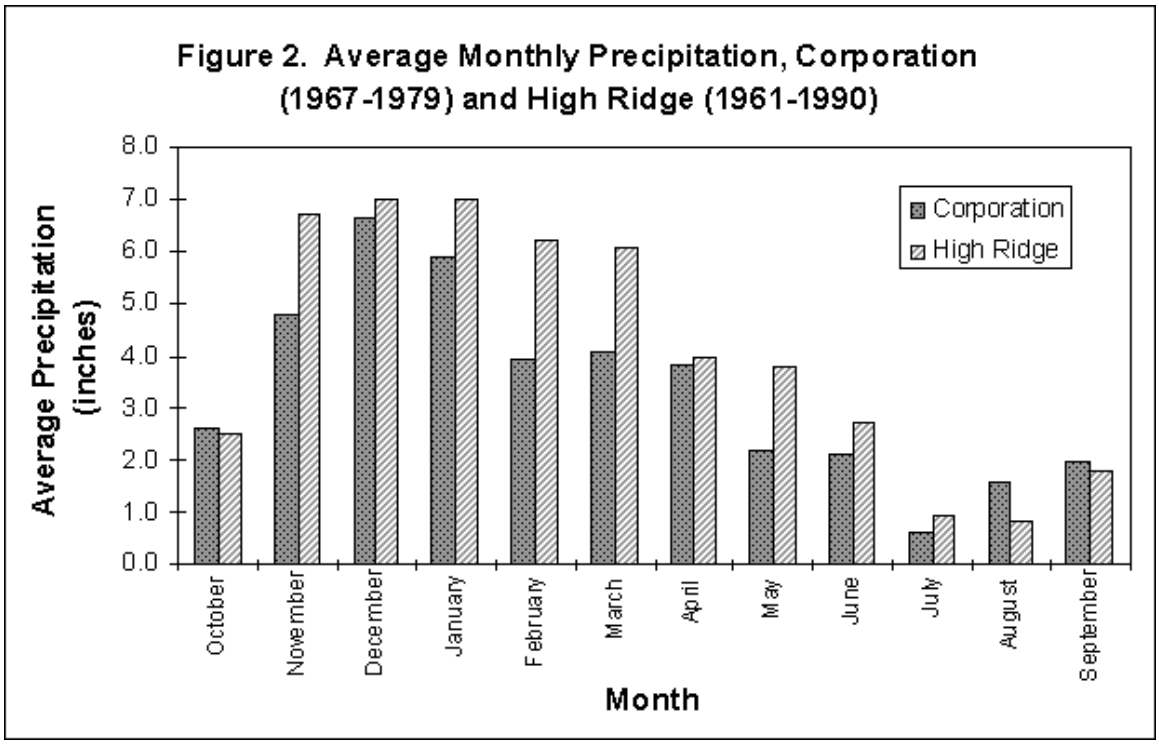
Figure 2. Average Monthly Precipitation, Corporation (1967-1979) and High Ridge (1961-1990)
Average Precipitation (inches)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Corporation
High Ridge
October
November
December
January
February
March
April
May
June
July
August
September
Month

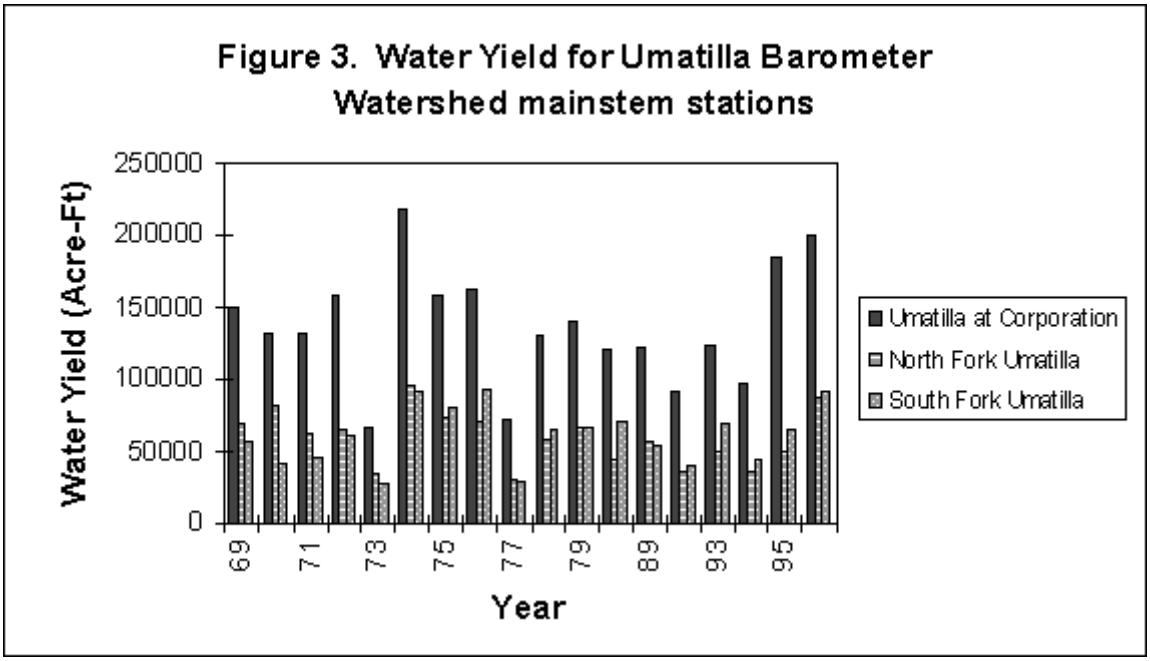
Figure 3. Water Yield for Umatilla Barometer Watershed mainstem stations
Water Yield (Acre-Ft)
250000
200000
150000
100000
50000
0
Umatilla at Corporation
North Fork Umatilla
South Fork Umatilla
69
71
73
75
77
79
89
93
95
Year

APPENDIX A: Average Daily Value Tables and Annual Hydrographs

Average daily Total Suspended Solids (mg/L) for Umatilla Barometer Watershed mainstem stations

	Umatilla @ Corp	North Fork Umatilla	South Fork Umatilla
WY 87	no data	30	35
WY 88	limited data	61	3.4
WY 89	15	90	8.4
WY 90	27	31	50
WY 91	26	22	35
WY 92	14	26	14
WY 93	39	55	14
WY 94	15	29	11
WY 95	27	77	25
WY 96	17	8.9	27
WY 97	23	10	37

Average daily Turbidity (NTU) for Umatilla Barometer Watershed mainstem stations

	Umatilla @ Corp	North Fork Umatilla	South Fork Umatilla
WY 87	no data	3.3	4.7
WY 88	limited data	9.9	2.1
WY 89	2.3	8.8	3.1
WY 90	4.7	4.0	9.4
WY 91	4.6	3.2	5.0
WY 92	3.0	3.8	3.5

WY 93	6.4	6.8	3.5
WY 94	2.8	2.5	2.5
WY 95	0.9	1.5	0.9
WY 96	0.6	0.5	1.3
WY 97	4.2	1.1	3.9

Average daily Conductivity (uS/cm) for Umatilla Barometer Watershed mainstem stations

	Umatilla @ Corp.	North Fork Umatilla	South Fork Umatilla
WY 87	no data	152	152
WY 88	limited data	127	124
WY 89	93	94	88
WY 90	81	82	70
WY 91	77	76	70
WY 92	84	84	71
WY 93	79	80	67
WY 94	76	78	66
WY 95	62	65	60
WY 96	50	52	94
WY 97	82	69	72

APPENDIX B: Streamflow and Sediment Data Summary

Umatilla River at Corporation, WY 1988-1997

North Fork Umatilla River, WY 1987-1997

South Fork Umatilla River, WY 1987-1997

(Appendix B [> 250 pages] available upon request, in electronic format or paper copy. A sample year from each station is included here.)

To receive a paper copy of this report, complete with graphs, contact Robin Harris or Caty Clifton.