UNITED STATES DEPARTMENT OF THE INTERIOR
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Retrospective Report on Bottom-Sediment Studies: NAWQA Surface Water Study, Yakima River Basin, Washington

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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Abstract

In this report existing studies of bottom sediment geochemistry conducted in the Yakima River Basin are reviewed. Data from these studies has been evaluated for use in the National Water Quality Assessment (NAWQA) study to be carried out in this area. Sources of data, sampling protocols, analytical methods and the applicability of diverse sets of data to the study of water-quality issues in the basin were considered. Existing studies were found to be inadequate for use in a basin wide evaluation of the relationship between water quality and bottom-sediment geochemistry.

INTRODUCTION

Bottom sediments were selected as one of the water quality study topics for the Yakima River Basin because of the part they play as a source of trace elements in the aquatic environment. Bottom sediments may also serve as a record of trace element levels and contribute to the transport of trace elements, especially during period of high flow.

This report summarizes existing bottom sediment data for this study area and covers Wilderness Resources Assessment Program studies conducted by the Geologic Division of the USGS, environmental, mining and mineral assessment studies conducted by state and private organizations and hydrogeochemical and stream sediment reconnaissance (HSSR) surveys conducted under the National Uranium Resources Evaluation (NURE) program.

Information sources which were reviewed for this report included the USGS Rock Analysis and Storage System (RASS), USGS PLUTO data base, USGS Assessment of Mineral-Resource Potential in U.S. Forest Service Lands by Marsh and others (1984), Washington State Water Resources Abstracts, bibliographies and indices of geology and mineral resources of Washington by Bennett (1939), Reichert (1960, 1969), Manson and Burnetti (1983) and Manson (1987), a compilation of theses on Washington geology by Manson (1986), the Bibliography and Index of Geology and the USGS National Uranium Resources Evaluation data base.

These sources revealed a large volume of information regarding sediment loads and water-quality issues in the region. However, there is virtually no existing data on trace elements carried by bottom sediments. The bottom sediment studies conducted in this area have historically been for mineral-resource investigations focused in the mountainous regions of the Yakima River Basin. Sediment studies conducted in the more populous agricultural area have apparently focused on water-quality issues without regard to trace element contributions from bottom sediments.

Bottom Sediment Studies

A search of existing data bases and literature indicated that no comprehensive study of trace element geochemistry in bottom sediments has been conducted in the Yakima River Basin. Virtually all existing data has been generated either during USGS mineral-resource potential studies of forest service lands by Gualtieri and others (1973,1975), Simmons and others (1974) and Church and others (1983) or in a compilation of stream sediment data by Moen (1969).

The USGS mineral potential studies included approximately 1300 stream sediment samples from sites within the Yakima River Basin. These studies were designed with mineral exploration as the primary goal. Although extensive sampling was done, these studies included only isolated portions of four sub-basins (Cle Elum Lake, Easton, Upper Naches, Tieton) covering less than 10 percent of the area drained by the Yakima River Basin. (fig. 1).

The Moen report includes samples from parts of eight sub-basins (Cle Elum Lake, Easton, Upper Naches, Tieton, Teanamway Creek, Taneum Creek, Manastash Creek and Swauk Creek) including several in which no USGS sampling was done. Within the Yakima Basin the Moen compilation includes 182 sites concentrated in the mountainous portion of the basin (fig. 2). The area covered by the Moen report is much larger than that covered in the USGS studies but the sample density is much lower. Two of the sub-basins, Taneum Creek and Manastash Creek, are represented by four and two samples respectively.

The review of bottom sediment studies began with a search of the PLUTO data base, maintained by the Geologic Division of the USGS. This data base contains analyses performed from 1967 to present by the Branch of Analytical Chemistry. Analyses of 81 samples taken within the boundaries of the Yakima River Basin were found during this search. These samples, taken from areas around Yakima, Sunnyside and Richland, were all identified as either rocks or soils and are not included in this report.

A generalized search was conducted on the Rock Analysis Storage System (RASS), currently maintained by the Geologic Division of the USGS. This data base includes data generated from 1965 to present. The search found samples from sites in the Yakima Basin, taken during a study conducted in the Goat Rocks wilderness area by Church and others (1983). Church's study was conducted in the area of Old Snowy Mountain, southwest of Rimrock Lake. All sites for this study were identified by latitude and longitude as well as by Universal Transverse Mercator (UTM) coordinates. Only 48 of the 141 sediment samples taken came from the drainages under study here. Contamination from pyroclastic and air-fall volcanic deposits as a result of the May 18, 1980 eruption of Mount St. Helens complicated the sampling of this area. Additional studies were also conducted to evaluate the effect of volcanic debris on the analytical results for stream sediments.

The stream sediment portion of the Goat Rocks study was conducted by determining the concentration of 30 elements in the minus 80 mesh portion (particles less than 177 microns in diameter) of the sample. (table 1.). Analysis of these samples was performed using six-step semiquantitative direct current emission spectrography (table 2). Additional analytical studies were conducted on the plus 80 mesh to minus 30 mesh portion (particles with diameters between 177 and 590 microns) and plus 30 mesh to minus 10 mesh portion (particles with diameters between 590 and 2000 microns). In addition to the spectrographic technique, selected samples were also subjected to an aqua regia leach and the resulting leachate was analyzed using inductively coupled plasma atomic emission spectrometry (ICPAES)

A literature search found several other studies which included information that is relevant to the study of bottom sediment contributions to water-quality in the Yakima River Basin. These studies fell into the categories of wilderness studies conducted by the USGS, mineral-resources mapping conducted by state agencies, and finally sediment transport and load studies conducted by various agencies and institutions. The latter studies did not include analytical data on the stream sediment samples and are not included in this report.

In addition to the data from the Goat Rocks study, which was included in the RASS data base retrieval, the literature search found four additional studies of wilderness areas in or bordering the Yakima River Basin. These wilderness study areas run from the northern tip of the Yakima basin, along its western border as far south as Mount Adams. Areas covered by the wilderness studies which overlap or border the Yakima study area include studies of the Alpine Lakes area of Chelan, King and Kittitas counties by Gualitieri and others (1973), a later study of additions to the Alpine Lakes area by Gualitieri and others (1975), a study of the Cougar Lakes-Mount Aix area of Yakima and Lewis counties by Simmons and others (1974), and a study of the Mount Adams Wilderness by Hildreth and Fierstein (1982). Although more than 3500 stream sediment samples were taken during these studies, fewer than 1300 fall within the Yakima River Basin. These reports, including the previously mentioned Goat Rocks study, represent less than 10 percent of the drainage basin. (fig. 1).

The two Alpine Lakes studies included 2,657 stream sediment samples. Approximately 420 of these were collected from locations within the boundaries of the Yakima basin. Samples of stream sediments were taken along all the major and medium sized stream drainages with analytical work performed in the field. There was apparently no quality control or quality assurance program included and published reports included data only for those samples determined to be geochemically anomalous. Because these samples are identified only by field number, with no associated latitude or longitude information, they can be located only by manually searching them out on the maps provided with the Open-File reports. The lack of latitude and longitude information explains why these areas did not appear in the RASS data base search.

Samples for the Alpine Lakes studies were taken from the finest material available but where fine grained sediment could not be obtained, material from underwater bank sediment was taken instead. In steep-gradient streams it was sometimes impossible to obtain a sample for some types of analyses. Samples were sieved and the minus 80-mesh portion (particles with diameter less than 177 microns) was used for analyses. All samples were analyzed by six-step semiquantitative direct current arc emission spectrography (table 2). Samples which contained elevated levels of certain elements were subjected to further analysis for Pb, Zn, Sb, Mo, and Au.

The Cougar Lake-Mount Aix study included 779 stream sediment samples of which nearly 100% fall within the Yakima basin. This study was carried out in a manner which was virtually identical to that used in the Alpine Lakes studies with respect to sampling and analytical methods. One important difference is that, although not identified by latitude and longitude, samples do carry UTM coordinates to specify location. As in the Alpine Lakes studies published reports include data only for geochemically anomalous samples and because samples were not originally identified by latitude and longitude they did not appear in the RASS search.

The area included in the Mount Adams study shares its eastern border with the Yakima study area and parts of it may be drained by the Yakima River Basin. However, the report from this area indicates that no stream sediment samples were taken because of heavy contamination from the then-recent eruption of Mount St. Helens.

Several other reports regarding mineral-resources in the area were also found during the literature search. The majority provide information on locations of known mineral resources based on existing mining activity or on the development of new resources. These reports included references on the mineral and water resources of Washington prepared by the USGS (1966), an inventory of Washington minerals by Hunting (1956), mineral resource maps of Washington by Moen (1978), a compilation of stream sediment data from various sources by Moen (1969), environmental impact reports and exploration and development reports for mining operations. These reports may be useful in planning future detailed studies of areas pinpointed by a reconnaissance study. In general, they do not include bottom sediment data relevant to water-quality issues.

Only the 1969 report by Moen contains a significant amount of data on stream sediments. In this study, data is presented for 1,916 stream sediment samples collected throughout Washington by a number of teams. Samples for this study consist of spot geochemical samples taken at major stream intersections, generally near road crossings. Of the samples listed in this compilation 182 fall within the Yakima study area and are concentrated in the north western third of the basin, exclusively in the Cascade range (fig 2). The sample locations are described by township and range and locations cannot be converted to latitude and longitude. Analytical data is presented for Cu, Mo, Pb, Zn, and cold extractable heavy metals (cxHM) (table 3). The data for cold extractables was obtained using a citrate/dithizone extraction. The elemental determinations were performed using atomic absorption spectrophotometry and colorimetry.

A search of the HSSR surveys conducted during the National Uranium Resource Evaluation (NURE) program was also conducted. This search found that both the Cascade Range and the Columbia Plateau physiographic provinces, which contain the boundaries of the Yakima study area, fell into a low priority category. As a result no stream sediment samples were taken from the Yakima River Basin as a part of the NURE program.

Finally, unpublished data, for samples collected in 1986 by McKenzie, of the Water Resources Division of the USGS, was reviewed. (table 4) This data represented samples from 8 sites covering the Yakima River Basin.(fig. 2) Sampling at two of the sites was replicated and the material was sieved to less-than 125 micron diameter. The determination of 40 elements in these samples was performed using ICPAES and a mixed acid, total digestion sample preparation.

SUMMARY

The historical data regarding bottom sediments in the Yakima River Basin is extremely limited in terms of spatial and temporal coverage and existing studies are incompatible in terms of sampling protocol, analytical methods, site identification and quality assurance. They may provide some historical insight over the last 20 years into land and water use, relevant natural factors or land and waste management practices in isolated areas. However, the goal of describing, in a nationally consistent manner, water-quality conditions related to constituents in bottom sediments and trends in the concentrations of these constituents is not served by existing data for the Yakima River basin.

The available data comes from studies designed primarily to detect areas of mineral-resource potential rather than to evaluate water-quality conditions. Because the few existing stream sediment studies focus on relatively small areas of known mining activity and mineral potential, only limited information relating water-quality conditions to basin geology could be inferred. No data exists which can be used to evaluate the relationship between land use, or point and non-point source discharges, and constituent concentrations is stream sediments affecting the water quality in the Yakima River Basin.

Because of the limited extent of historical bottom sediment data for the Yakima River Basin and the even more limited applicability of the existing data to the description of water-quality conditions, a study of trace elements in bottom material, as described by McKenzie and Rinella (1987) has been proposed for this area.

Such a study should establish a regional geochemical characterization of stream bed sediments in the basin to provide a basis for defining relationships between bottom sediment chemistry and water quality. This can be accomplished by using several sampling approaches and applying proven analytical techniques, including multi-element methods, to the determination of a wide range of geochemically important constituents in the samples.

The sampling and analytical program required to overcome the lack of stream sediment data in this basin would be extensive. To determine the magnitude and source of elemental variations in stream bed sediments a reconnaissance survey involving sampling of the entire basin would be required. Such a reconnaissance survey, with random samples collected from grids covering the basin, should include provisions for analysis-of-variance and must provide for quality assurance in the analytical portion of the study. Where detailed historical water-quality data is available more intensive sampling should be conducted, as should temporal sampling of bottom sediments in these areas. Finally, areas of interest, including those highlighted during the reconnaissance phase, should be selected for more detailed study. Provisions for statistical evaluation of sampling and analysis should also be provided for these last two approaches.

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WILDERNESS REPORT AREAS COINCIDENT
WITH THE YAKIMA RIVER BASIN

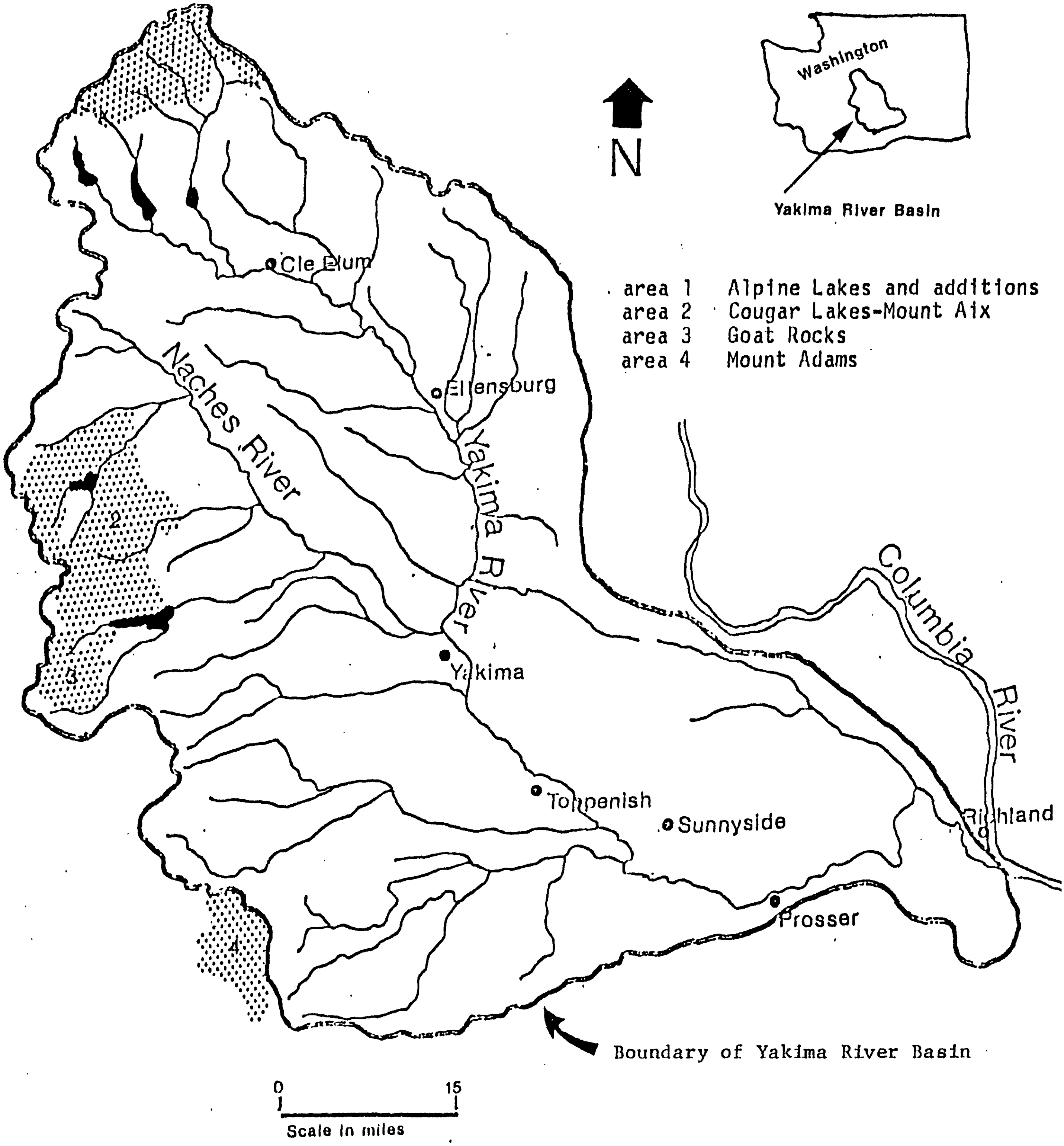

Figure 1.

AREAS OF YAKIMA RIVER BASIN INCLUDED IN MOEN'S 1969 STREAM SEDIMENT STUDY AND SITES SAMPLED IN 1986 BY McKENZIE

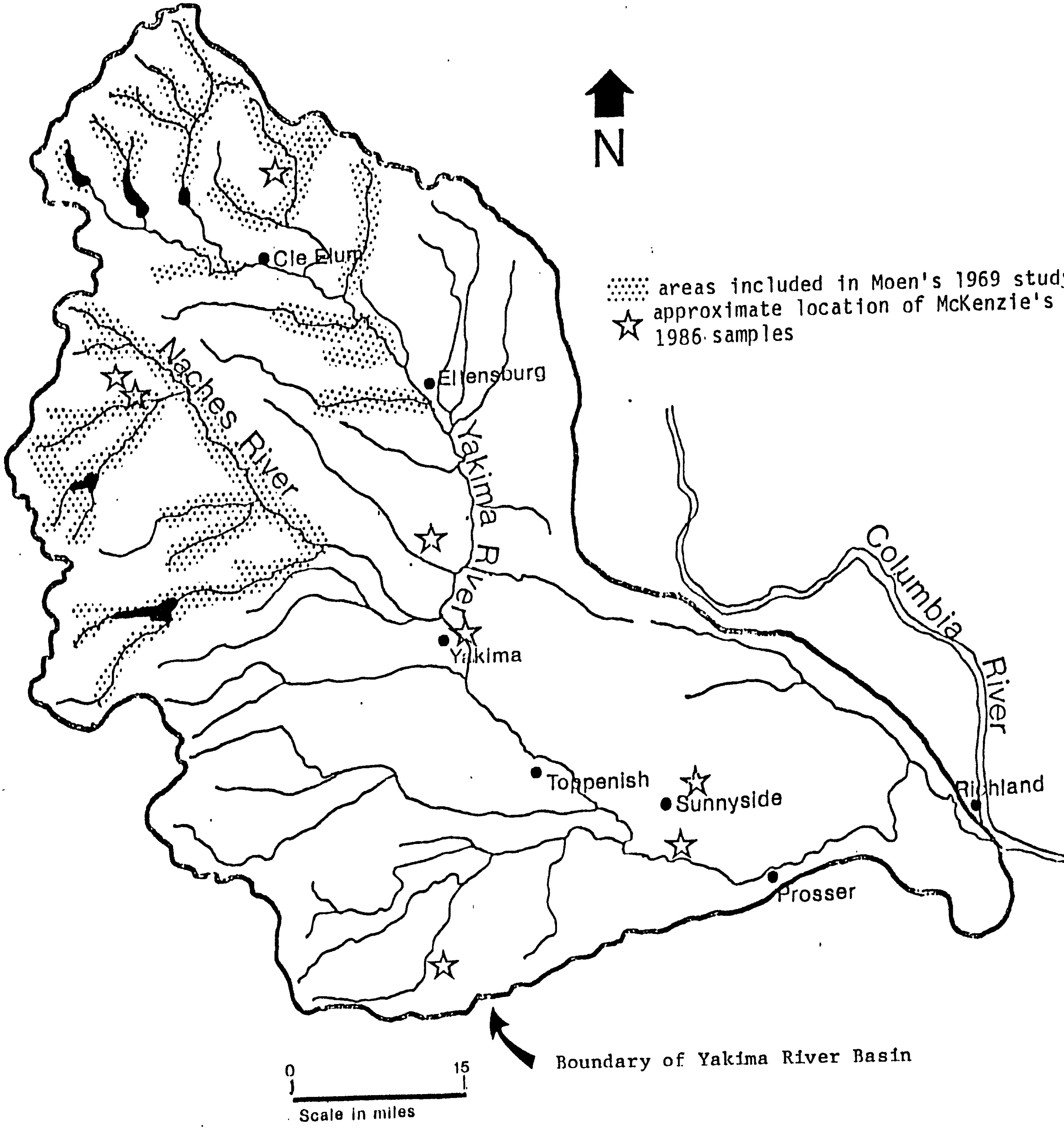

Figure 2.

Table 1.

Summary of Descriptive Statistics for Data from the Goat Rocks Wilderness Study (Church and others)

Element		Minimum	Maximum	Range	Mean	Deviation	N
Fe	%	2	10	8	7	2.5	48
Mg	%	0.5	2	1.5	1.4	0.5	48
Ca	%	1	3	2	2.0	0.5	48
Ti	%	0.1	> 1	na	na	na	48
Mn	µg/g	300	2000	1700	1100	377	48
B	µg/g	< 10	100	100	na	na	48
Ba	µg/g	150	1000	850	414	190	48
Be	µg/g	< 1	2	1	na	na	48
Co	µg/g	5	50	45	31	15	48
Cr	µg/g	10	200	190	96	51	48
Cu	µg/g	7	100	93	44	19	48
La	µg/g	< 30	30	na	na	na	48
Nb	µg/g	< 20	30	10	na	na	48
Ni	µg/g	< 5	100	95	na	na	48
Pb	µg/g	< 10	20	10	na	na	48
Sc	µg/g	5	30	25	18	5	48
Sr	µg/g	100	500	400	355	122	48
V	µg/g	20	500	480	182	77	48
Y	µg/g	10	30	20	17	3.2	48
Zn	µg/g	< 200	300	100	na	na	48
Zr	µg/g	70	500	430	181	104	48

N indicates number of measurements

Percentiles

Element		10th	25th	50th	75th	90th
Fe	%	5	5	7	10	10
Mg	%	1	1	1.5	2	2
Ca	%	1.75	1.75	2	2	3
Ti	%	0.5	0.5	0.7	1	> 1
Mn	µg/g	700	1000	1000	1500	1500
B	µg/g	< 10	10	10	20	50
Ba	µg/g	300	300	400	500	600
Be	µg/g	< 1	1	1	1	1.5
Co	µg/g	20	20	30	50	50
Cr	µg/g	30	50	100	150	150
Cu	µg/g	20	30	50	50	70
La	µg/g	< 20	< 20	< 20	< 20	< 20
Nb	µg/g	< 20	< 20	< 20	< 20	< 20
Ni	µg/g	30	30	40	50	50
Pb	µg/g	< 10	< 10	< 10	10	10
Sc	µg/g	10	15	20	20	20
Sr	µg/g	250	300	300	500	500
V	µg/g	150	150	200	200	300
Y	µg/g	15	15	15	20	20
Zn	µg/g	< 200	< 200	< 200	< 200	200
Zr	µg/g	100	100	150	250	300

Table 2.

Elements Determined and Lower Limits of Determination for the Direct Current Arc Method Used in U.S.G.S. Wilderness Area Stream Sediment Surveys (six-step semiquantitative determination)

Element	Lower Limits of Determination µg/g	Element	Lower Limits of Determination µg/g
Ag	0.5	Mn	10
As	200	Mo	5
Au	10	Ni	2
B	10	Nb	10
Ba	5	Pb	10
Be	1	Sb	100
Bi	10	Sr	50
Ca	500	Sn	10
Cd	20	Sc	5
Co	5	Ti	10
Cr	5	V	10
Cu	2	W	50
Fe	500	Y	10
La	20	Zn	200
Mg	200	Zr	20

Values reported are spaced geometrically over any given order of magnitude in six steps, for example 100, 70, 50, 30, 20, 15, 10. The precision of the method is approximately plus or minus one reporting unit at the 83 percent confidence level and plus or minus two reporting units at the 96 percent confidence level. Thus the range for a reported value of 30 ppm Cd at the 96 percent confidence level would be from less than the limit of determination to 70 ppm.

Table 3.

Summary of Descriptive Statistics for Cu, Mo, Pb, Zn and cxHM Data for the Yakima River Basin

	[--------------Moen data by sub-basin--------------]									
	Cle Elum Lake	Teanaway Creek	Easton	Upper Naches	Tieton	Swauk Creek	Manastash Creek	Taneum Creek	all Moen data	Goat Rocks	McKenzie
Cu (µg/g)											
Minimum	5	5	15	5	10	5	10	5	5	7	15
Maximum	88	30	206	385	50	10	15	20	385	100	570
Range	83	25	191	380	40	5	5	15	380	93	555
Mean	22	14	34	31	19	8	12	11	24	44	96
Deviation	22	6	47	53	12	3	4	6	39	19	179
# of Measurements	22	23	15	76	31	9	2	4	182	48	8
10th percentile	8	8	16	8	11	na	na	na	8	20	na
25th percentile	11	11	20	19	14	na	na	na	12	30	na
50th percentile	17	14	22	20	17	na	na	na	18	50	na
75th percentile	28	18	34	31	26	na	na	na	24	50	na
90th percentile	84	27	200	79	45	na	na	na	43	70	na
Mo (µg/g)											
Minimum	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	5
Maximum	5	< 5	5	5	5	< 5	< 5	< 5	5	5	15
Range	na	na	na	na	na	na	na	na	na	na	10
Mean	na	na	na	na	na	na	na	na	na	na	8.5
Deviation	na	na	na	na	na	na	na	na	na	na	3
# of Measurements	22	23	15	76	31	9	2	4	182	48	8
10th percentile	< 5	< 5	< 5	< 5	< 5	na	na	na	< 5	< 5	na
25th percentile	< 5	< 5	< 5	< 5	< 5	na	na	na	< 5	< 5	na
50th percentile	< 5	< 5	< 5	< 5	< 5	na	na	na	< 5	< 5	na
75th percentile	< 5	< 5	< 5	< 5	< 5	na	na	na	< 5	< 5	na
90th percentile	< 5	< 5	< 5	< 5	< 5	na	na	na	< 5	< 5	na
Pb (µg/g)											
Minimum	< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 10	5
Maximum	29	37	50	150	< 25	< 25	< 25	< 25	150	20	68
Range	4	12	25	125	na	na	na	na	125	10	63
Mean	na	na	na	na	na	na	na	na	na	na	23
Deviation	na	na	na	na	na	na	na	na	na	na	20
# of Measurements	22	23	15	76	31	9	2	4	182	48	8
10th percentile	< 25	< 25	< 25	< 25	< 25	na	na	na	< 25	< 10	na
25th percentile	< 25	< 25	< 25	< 25	< 25	na	na	na	< 25	< 10	na
50th percentile	< 25	< 25	< 25	< 25	< 25	na	na	na	< 25	< 10	na
75th percentile	< 25	< 25	< 25	26	< 25	na	na	na	< 25	10	na
90th percentile	< 25	< 25	< 25	49	< 25	na	na	na	33	10	na
Zn (µg/g)											
Minimum	20	30	45	20	45	40	50	40	20	< 200	73
Maximum	110	110	101	1000	125	65	65	75	1000	300	610
Range	90	80	56	980	80	25	15	35	980	100	537
Mean	49	58	67	117	73	57	58	52	85	na	193
Deviation	21	18	15	142	24	10	11	16	98	na	170
# of Measurements	22	23	15	76	31	9	2	4	182	48	8
10th percentile	26	41	50	45	52	na	na	na	40	< 200	na
25th percentile	36	49	56	62	59	na	na	na	53	< 200	na
50th percentile	48	59	69	78	68	na	na	na	66	< 200	na
75th percentile	62	69	82	97	84	na	na	na	84	< 200	na
90th percentile	90	98	98	330	120	na	na	na	119	200	na
cxHM											
Minimum	0	1	1	0	1	1	1	1	0	na	na
Maximum	9	5	20	20	7	2	2	2	20	na	na
Range	9	4	19	20	6	1	1	1	20	na	na
Mean	2	2	3	3	2	1	1.5	1	2	na	na
Deviation	2	1	5	4	2	0.3	0.7	0.5	3	na	na
# of Measurements	22	23	15	76	31	9	2	4	182	na	na
10th percentile	0.5	1	1	1	1	na	na	na	1	na	na
25th percentile	1	1	1	1	2	na	na	na	1	na	na
50th percentile	2	2	2	2	2	na	na	na	2	na	na
75th percentile	3	2	2	3	3	na	na	na	3	na	na
90th percentile	6	4	20	8	5	na	na	na	5	na	na

Table 4.

Summary of Descriptive Statistics for McKenzie Data

Element	Minimum	Maximum	Range	Mean	Deviation	N
Fe %	4.2	9	4.8	6.8	1.4	8
Mg %	0.89	1.9	1.01	1.4	0.3	8
Ca %	1	3.9	2.9	3.0	0.9	8
Ti %	0.46	1.6	1.14	0.9	0.4	8
Mn µg/g	660	1800	1140	1223	322	8
Ba µg/g	310	600	290	468	95	8
Be µg/g	< 1	2	2	na	na	8
Co µg/g	16	41	25	26	7.9	8
Cr µg/g	26	110	84	71	25	8
Cu µg/g	18	540	522	96	168	8
La µg/g	16	48	32	27	9.1	8
Nb µg/g	6	14	8	8.7	2.6	8
Ni µg/g	8	50	42	27	12	8
Pb µg/g	6	64	58	23	19	8
Sc µg/g	12	25	13	21	4.8	8
Sr µg/g	150	360	210	299	60	8
V µg/g	87	310	223	188	81	8
Y µg/g	19	30	11	23	3.5	8
Zn µg/g	74	600	526	193	159	8

N indicates number of measurements