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A PROGRESS REPORT ON SUSPENDED SEDIMENT SAMPLING IN SEVERAL WESTERN OREGON AND WESTERN WASHINGTON STREAMS

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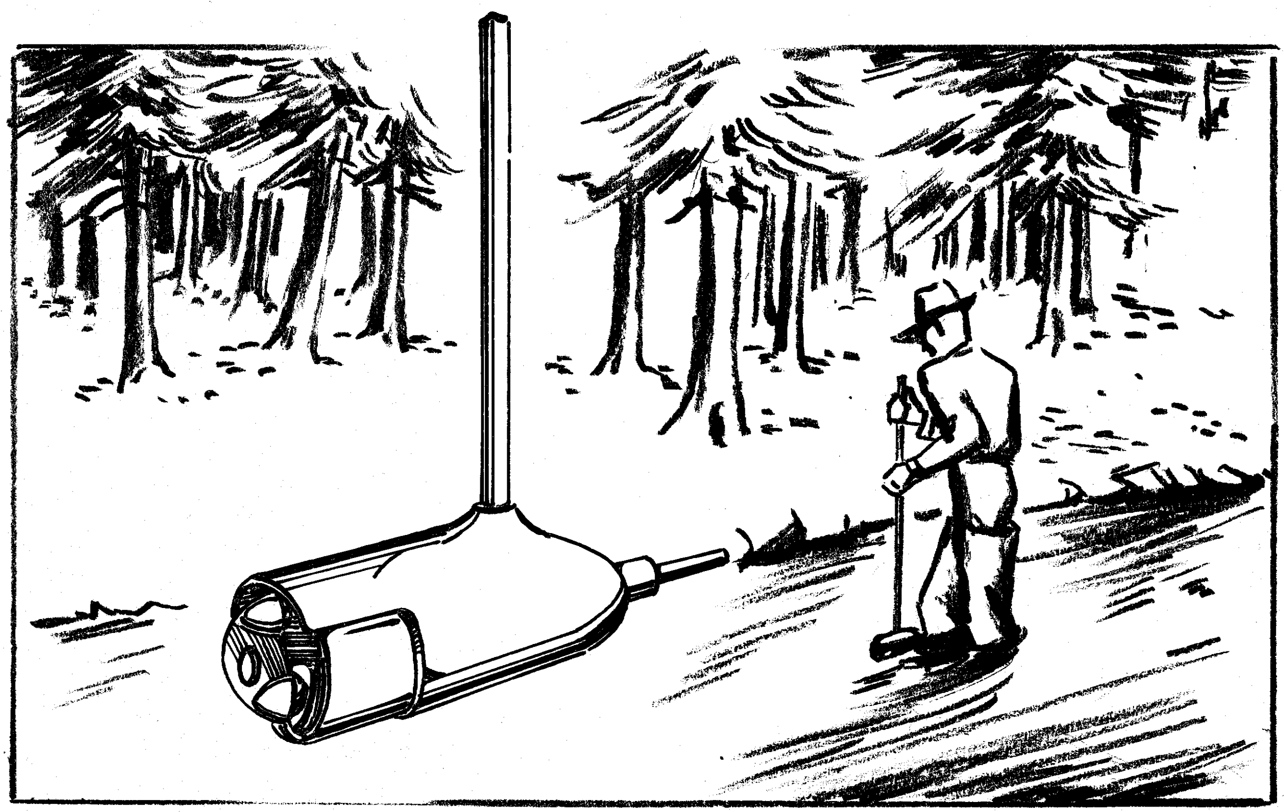

INTRODUCTION

Streams transport their loads by traction [1] (the bed load) in suspension (the suspended load) and as salts in solution (the solution load). The total load is the sum of these three and is commonly called the water quality. The amounts of and variation in stream flow and water quality have become in the past few years accepted criteria for evaluating watershed conditions. Although many of the fundamental relationships between soil, cover and water are known, much remains to be ascertained. Such is the case with suspended sediment loads. That is why the Division of Flood Control Surveys, Pacific Northwest Forest and Range Experiment Station in cooperation with the Siskiyou-Cascade Research Center and others conducted a suspended sediment load study of fifteen streams in Oregon and Washington during the first nine months of the 1951 water year.

Specifically, the study was made to determine:

(1) the concentration of suspended sediment carried by a selected group of western Oregon and western Washington streams;

(2) the maximun, minimun, and average suspended sediment loads carried by these streams; and

(3) the relationship between stream flow and suspended sediment loads.

This paper summarizes the data obtained from this study and details the methods by which they were obtained. It makes some interpretation of these data along the lines mentioned above. It is hoped that the information contained in it may be useful to watershed managers and planners, state and municipal authorities, and industrial concerns in this region.

The author's thanks are extended to all who assisted in this study, particularly the personnel of the Siskiyou-Cascade Research Center and southwestern Oregon Ranger Districts for their cooperation in collecting samples.

Summary

Analysis of the data obtained from a suspended sediment load study of fifteen western Oregon and Washington streams during the first nine months of the 1951 water year indicated:

1. Seasonal trends in sediment loads.

2. A range in suspended sediment loads from 38,200 ppm. to 0 ppm. in Oregon streams and 304 ppm. to a trace in Washington streams.

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[1] Traction is defined as the pushing, rolling, and saltation (skipping) of rock particles by the stream current along the stream bed.

3. A curvilinear relationship between discharge and sediment loads.

4. Differences in stream flow accounted for 4%-64% of the variation in sediment load in two Washington streams.

Field Sampling Procedure

Prior to October 1, 1950, twenty sampling sites were established in fifteen Oregon and Washington streams (see map on page 4). Their location was determined by considering the distance and road condition to the site from the collector's headquarters, the availability of stream flow data, the availability of structures such as bridges and retaining walls for convenient sampling, and watershed conditions and characteristics. The sampling began October 1, 1950 and ended June 1, 1951.

A DH depth-integrating sampler[2] was used to collect the samples. The accessory equipment used with the sampler varied among the collectors. In general, two arrangements were most common. One was the sampler outfitted with an aluminum tail fin, six feet of stainless steel rod and twenty-five feet of light rope. The other setup consisted of the sampler and fin connected to twenty-five feet of rope by means of an eyebolt. Pint milk bottles with standard size mouths were used in the sampler.

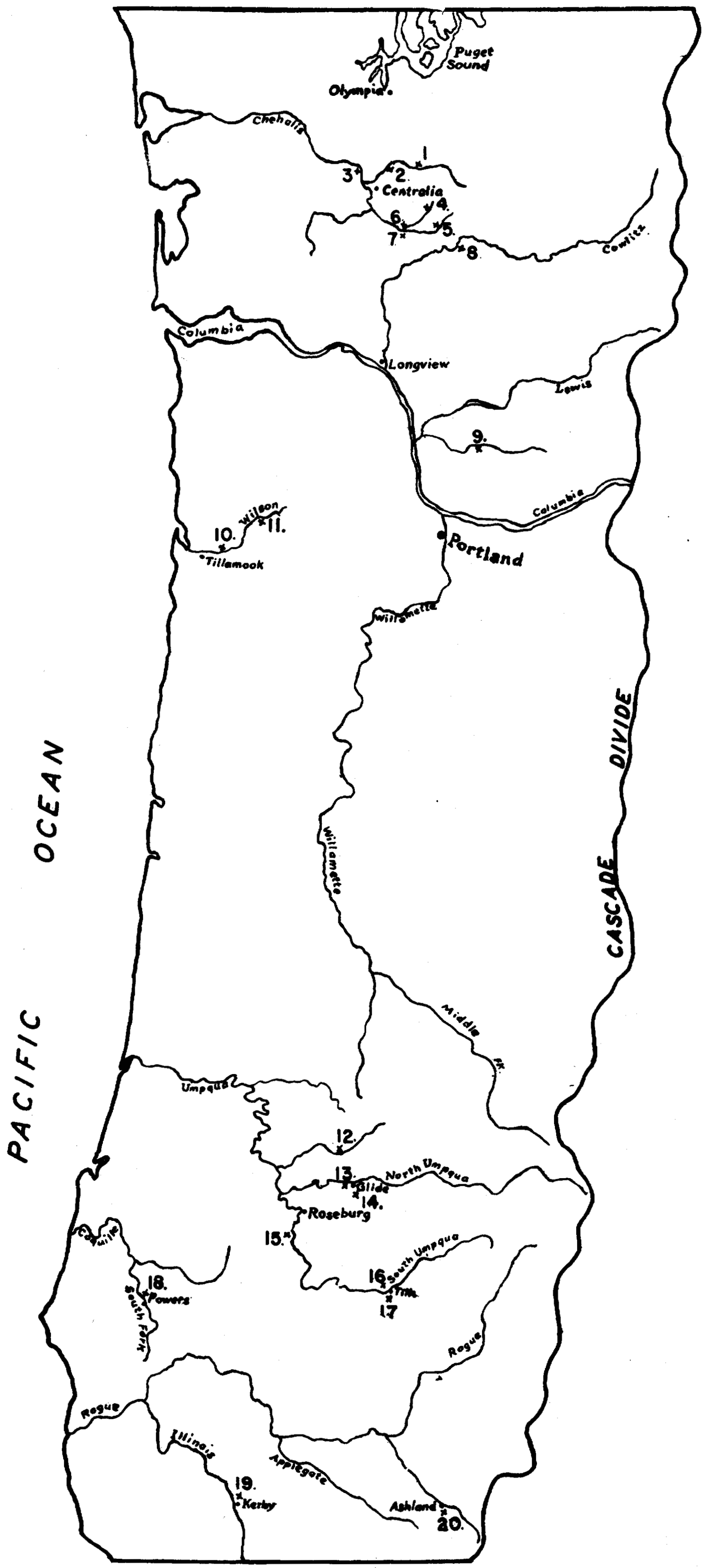
A sample was collected in the following manner. The outfitted sampler with a bottle inserted was lowered and then raised in such a way as to traverse the stream vertically from top to bottom to top at a uniform rate of speed without completely filling the bottle. The bottle was then removed from the sampler, sealed with two milk bottle caps and a rubber cap (Davol #120 anti-germ), labeled and placed in a special cardboard container for mailing to the laboratory.

One depth-integrated sample was collected bi-weekly at each sampling station, provisions were also made to sample whenever there were sharp changes in stream stage or turbidity.

Sources of Error

The principal sources of error in this field sampling procedure were: (1) the tendency of the sampler to revolve and swing in the stream current; (2) overfilling of the container; (3) sampling too near the stream bottom; (4) the disturbance of the flow characteristics of the stream by the sampler; and (5) the irregular rate of movement of the sampler.

2/ The DH-48 sampler was developed by the Corps of Engineers, U. S. Army, in cooperation with the University of Iowa and the University of Minnesota. It is the standard hand sampler and is now being used by the USGS Water Quality section in shallow streams of the Colorado and Rio Grande river basins.



SUSPENDED SEDIMENT
SAMPLE LOCATIONS

1. Skookumchuck River
(Stony Pt. School)

2. Skookumchuck River
(Bucoda, Wash.)

3. Chehalis River
(Grand Mound, Wash.)

4. N. Fk. Newaukum River
(Chehalis intake)

5. S. Fk. Newaukum River
(Alpha P.O., Wash.)

6. N. Fk. Newaukum River
(near Forest, Wash.)

7. S. Fk. Newaukum River
(near Forest, Wash.)

8. Cowlitz River
(at Mayfield, Wash.)

9. E. Fk. Lewis River
(Heisson, Wash.)

10. Wilson River
(Tillamook, Oregon)

11. Wilson River
(Lee's Bridge)

12. Calapooya Creek
at Nonpareil

13. N. Umpqua River
(Glide, Oregon)

14. Little River
(Fall Creek Bridge)

15. S. Umpqua River
(Brockway, Oregon)

16. S. Umpqua River
(Tiller, Oregon)

17. Elk Creek
(Tiller, Oregon)

18. S. Fk. Coquille River
(Powers, Oregon)

19. Illinois River
(Kerby, Oregon)

20. Ashland Creek
(Ashland, Oregon)

The tendency of the sampler to rotate and swing in the stream current was eliminated by adding a tail fin and additional weights. The tail fin served as a stabilizing rudder, utilizing the stream current so as to keep the water intake nozzle facing upstream. The additional weight of the stainless steel rod was usually sufficient enough to reduce the downstream swing of the sampler. When the turbulence of the stream current was great, the error was minimized by the more uniform distribution of sediment throughout the water.

Studies have shown that overfilling the container results in too much of one or more vertical portions of the stream contributing to the so-called representative sample (3). This was eliminated by filling the container only to about an inch from the top.

Sampling too near the bottom resulted in collecting some of the bed load. To eliminate this, the collector first determined the depth of the stream, and then lowered the sampler no closer than six inches to the channel bottom.

Undoubtedly there was a disturbance of the flow characteristics of the stream due to such factors as the shape of the intake nozzle, the shape of the sampler and of the stainless steel rod. There was no way to determine the extent of this disturbance. Since equipment of the same design was used by most collectors, it was assumed that the flow disturbance error introduced would be uniform for this study.

The error introduced by moving the sampler at irregular rates of speed was eliminated by advising the collector to take several practice samples. In this way he could determine how fast the water entered the sampler and then gauge the rate accordingly.

Laboratory Procedure

A total of 241 samples were analyzed for suspended sediment concentration during the course of the study. The results obtained have been presented graphically on pages 6-13 . The analyses were made in the laboratory at the Forest Service departmental shops in Portland, Oregon, using the filtration-suction method similar to that used by the Tennessee Valley Authority (1). This method was chosen because of the large number (40) of samples which could be analyzed per man day.

On arrival of a sample at the laboratory the tare weight, bottle number [3] and sampling information were recorded. The sampling information

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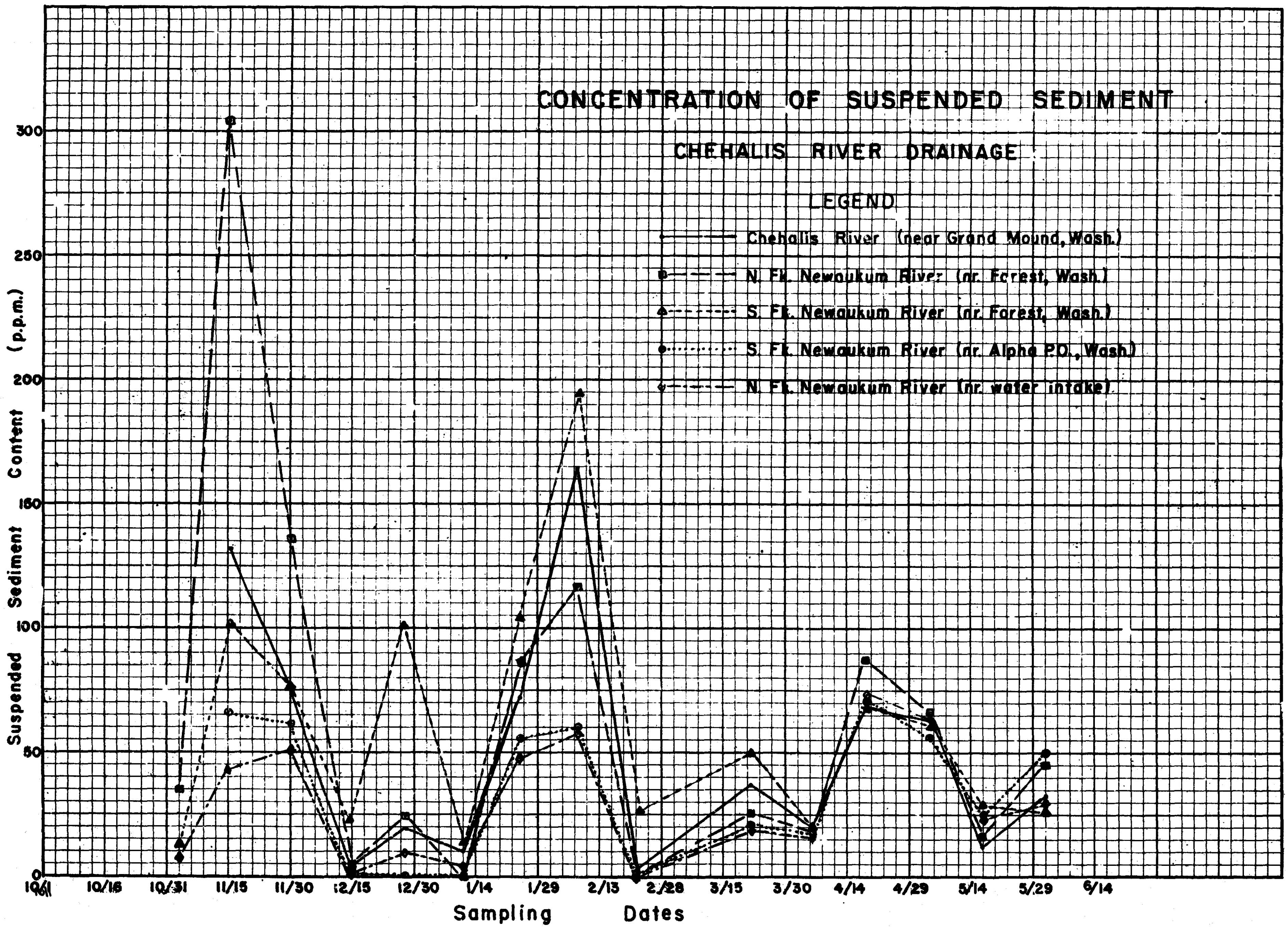
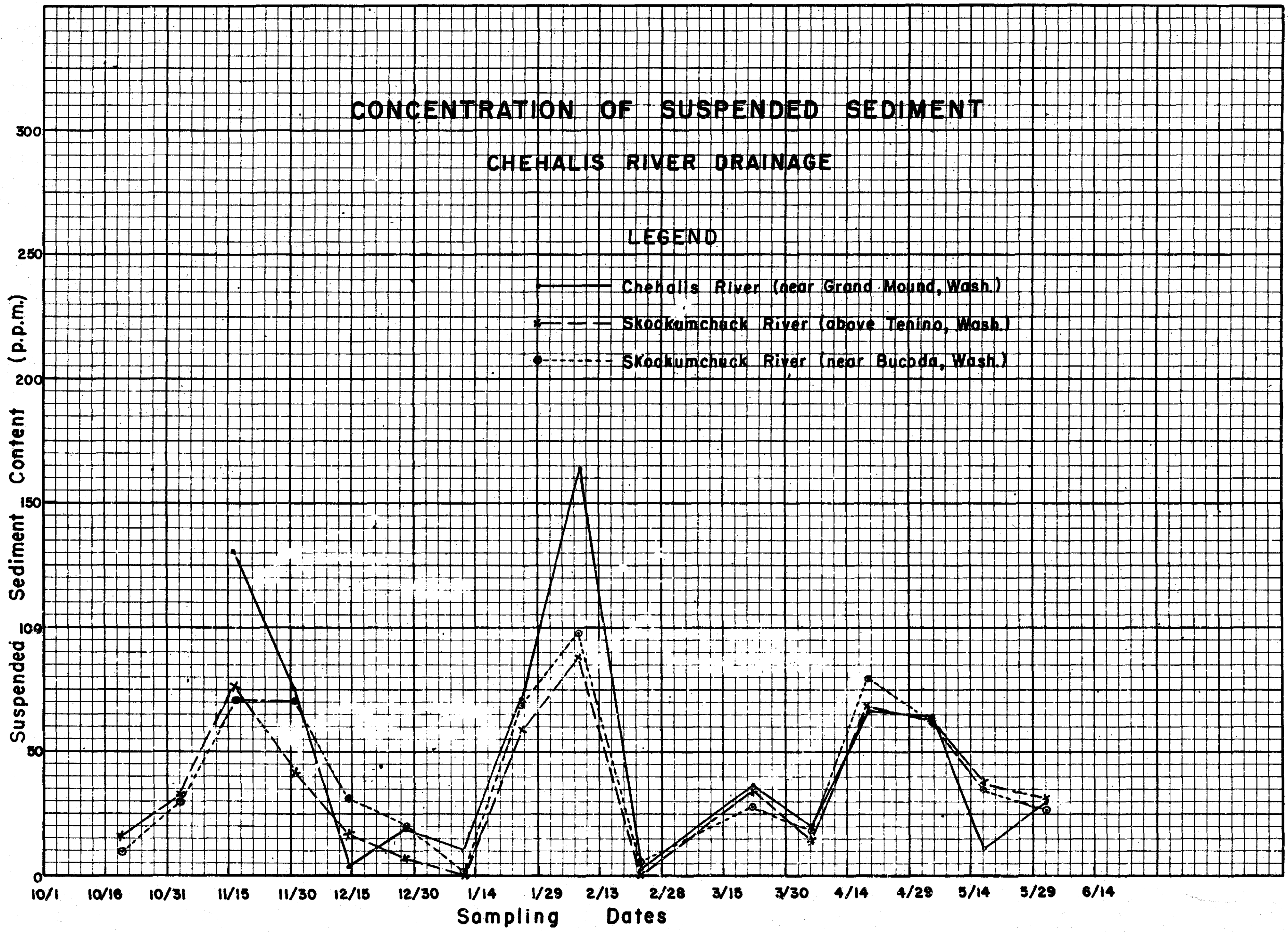
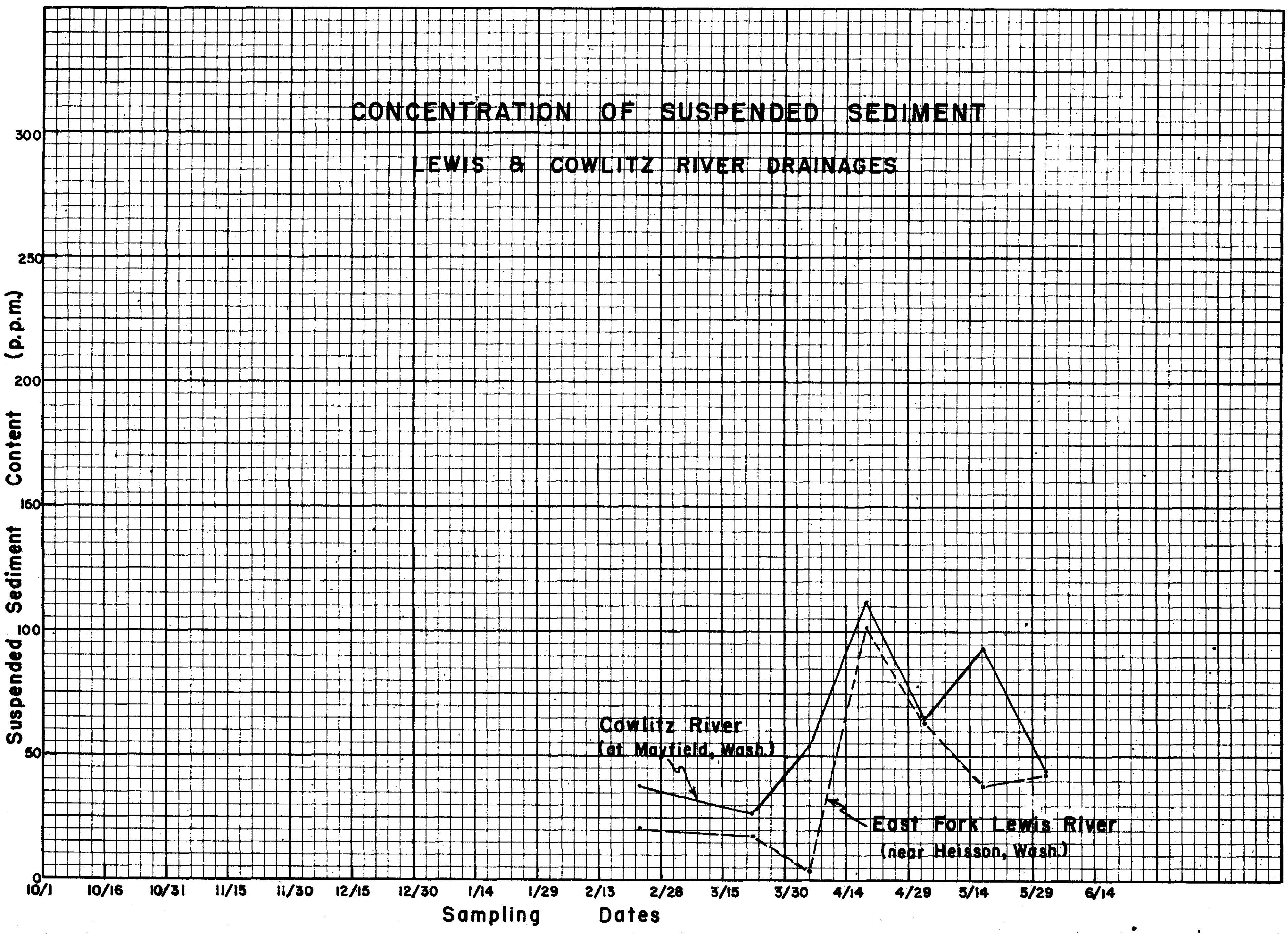
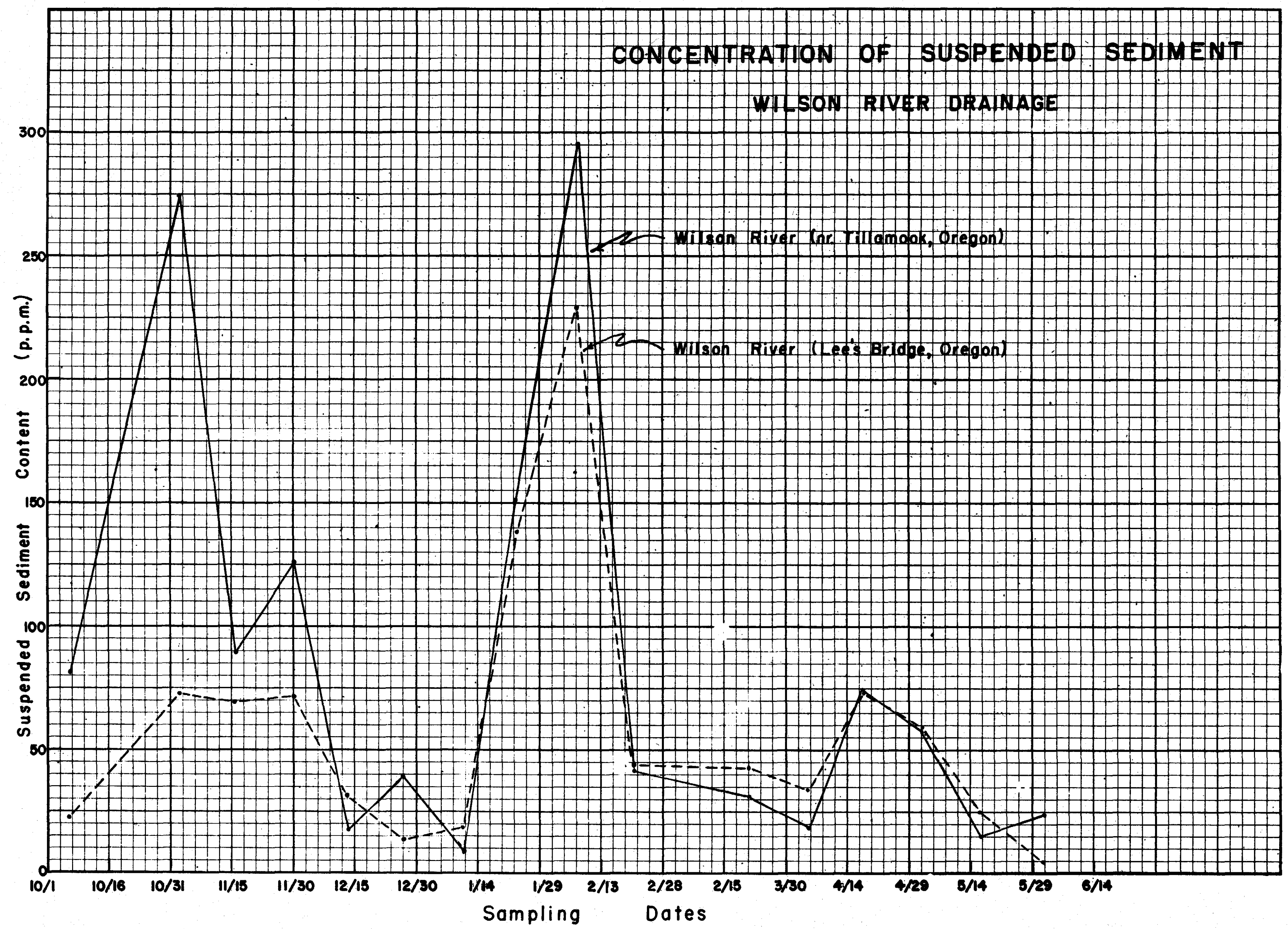
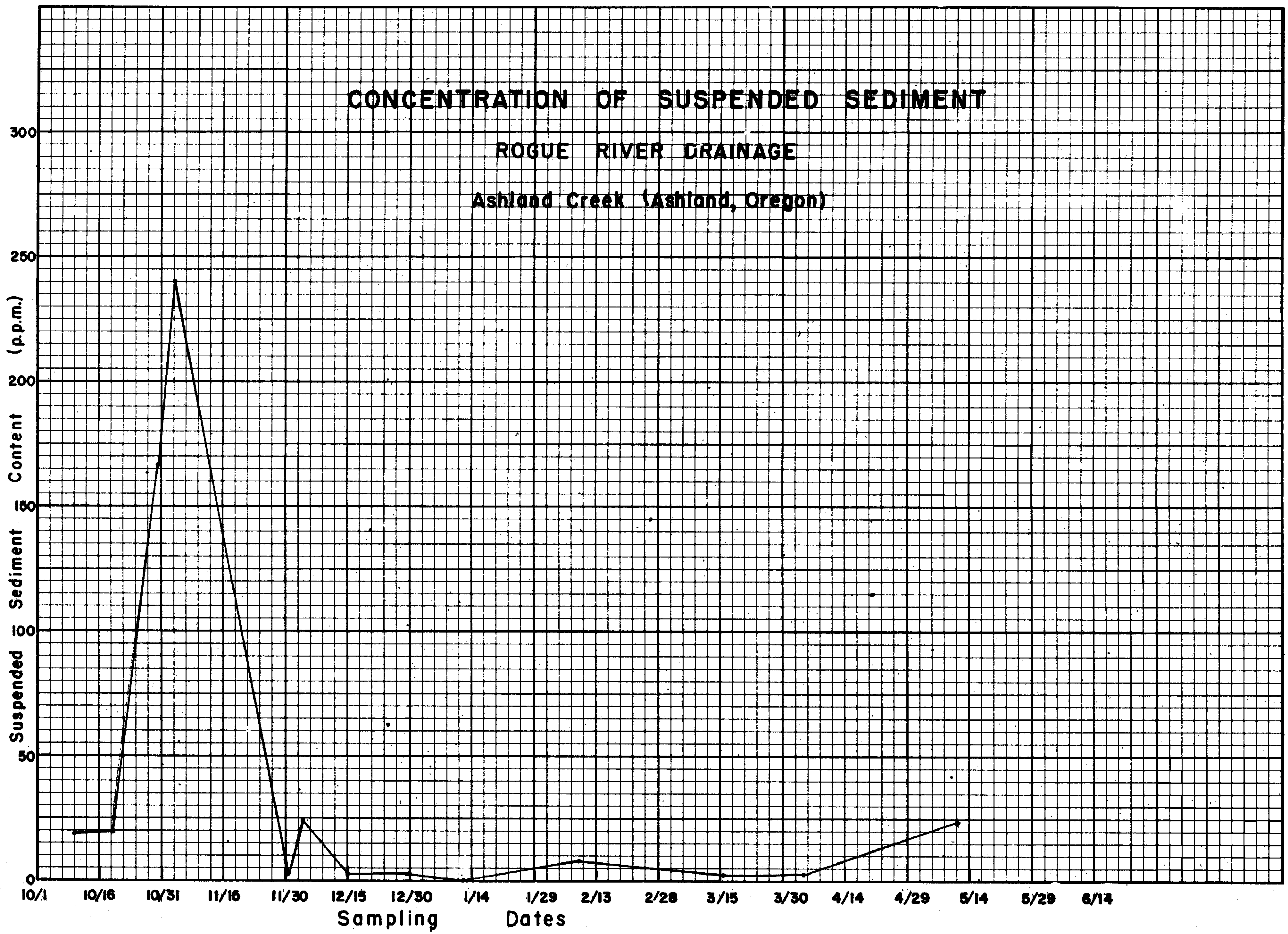
3/ The bottle number and tare weight were inscribed on most bottles prior to distribution.

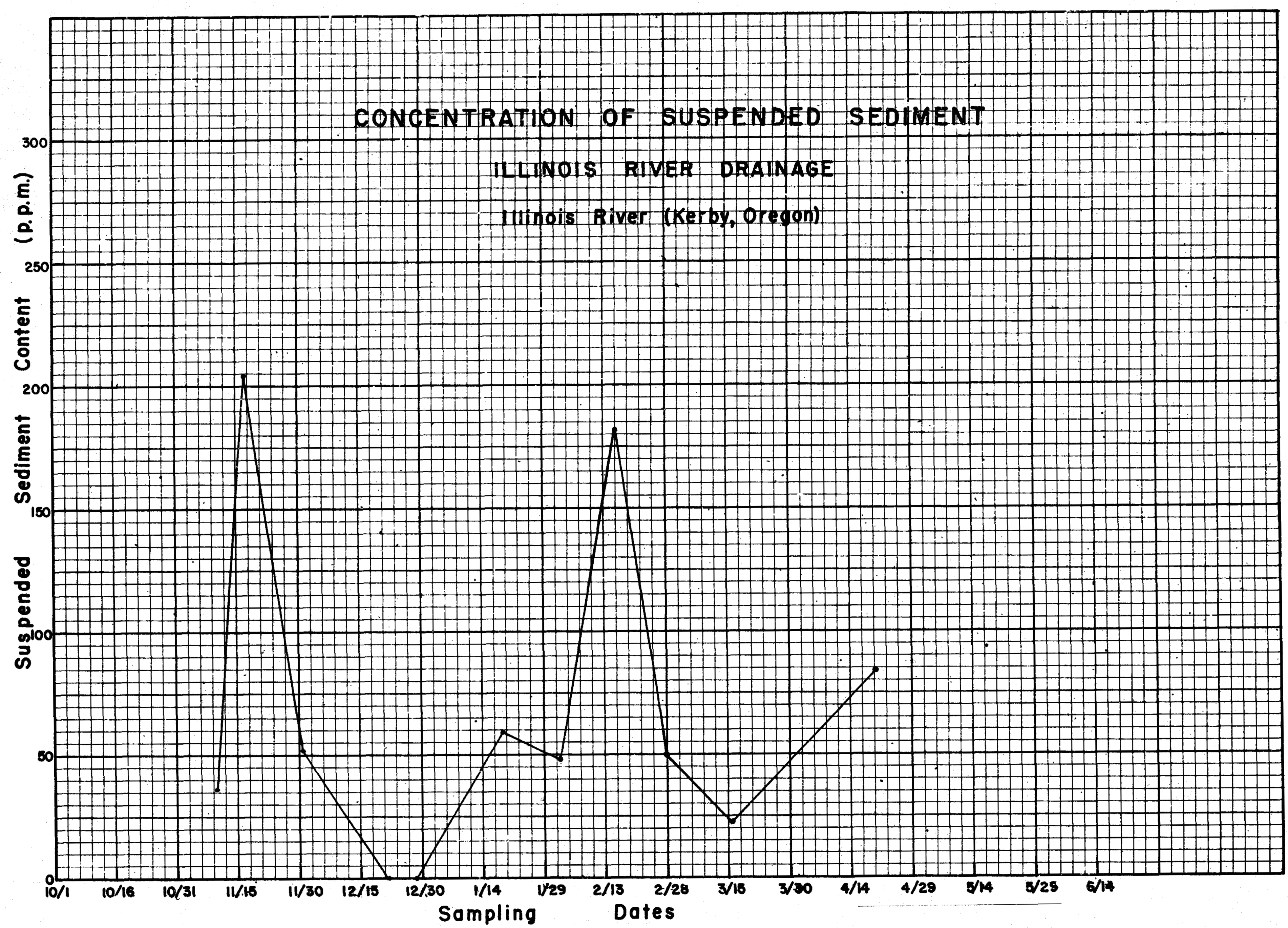

CONCENTRATION OF SUSPENDED SEDIMENT
CHEHALIS RIVER DRAINAGE
LEGEND
Chehalis River (near Grand Mound, Wash.)
N. Fk. Newaukum River (nr. Forest, Wash.)
S. Fk. Newaukum River (nr. Forest, Wash.)
S. Fk. Newaukum River (nr. Alpha P.O., Wash.)
N. Fk. Newaukum River (nr. water intake)
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates

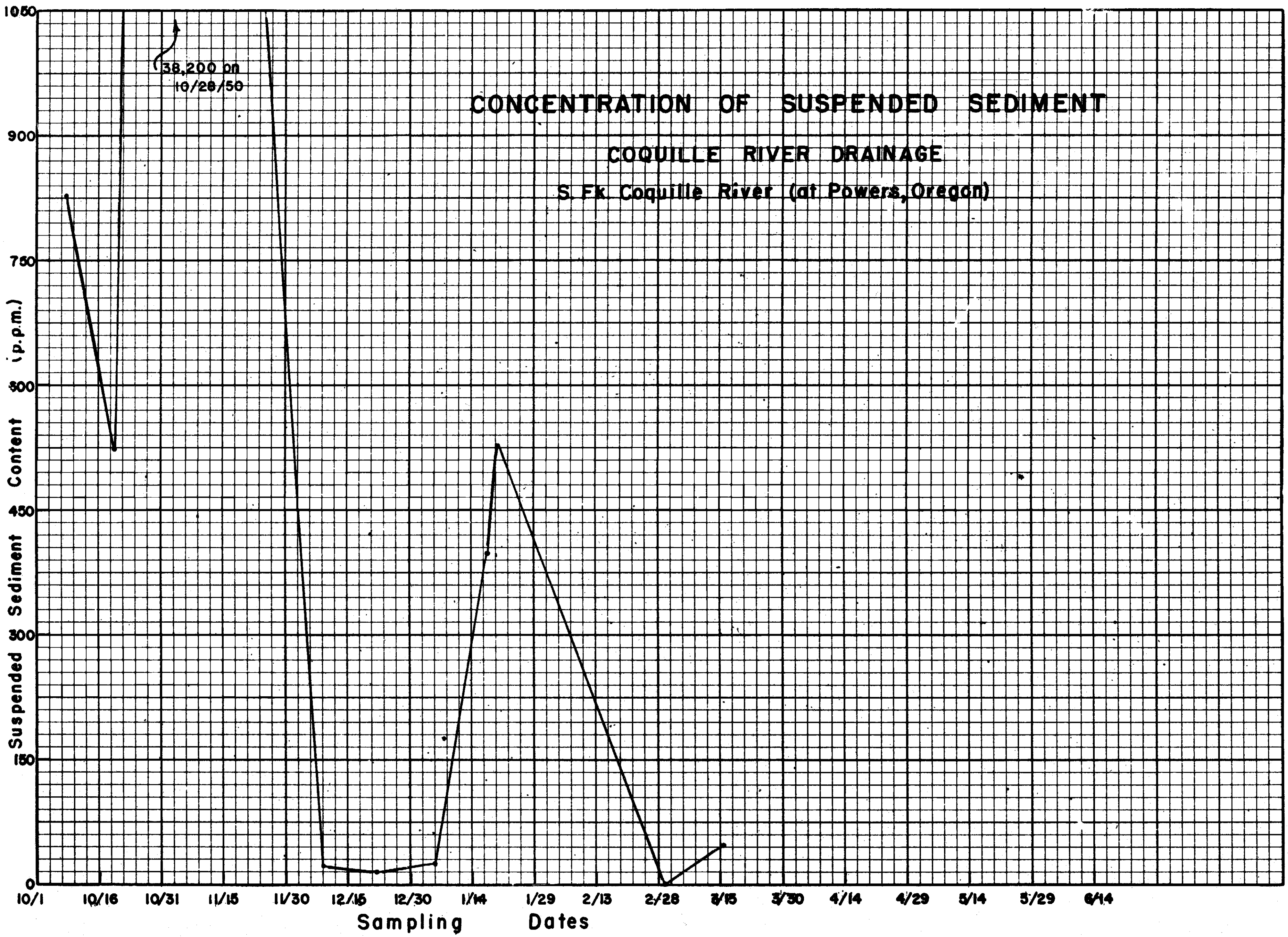

CONCENTRATION OF SUSPENDED SEDIMENT
CHEHALIS RIVER DRAINAGE
LEGEND
Chehalis River (near Grand Mound, Wash.)
Skookumchuck River (above Tenino, Wash.)
Skookumchuck River (near Bucoda, Wash.)
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates

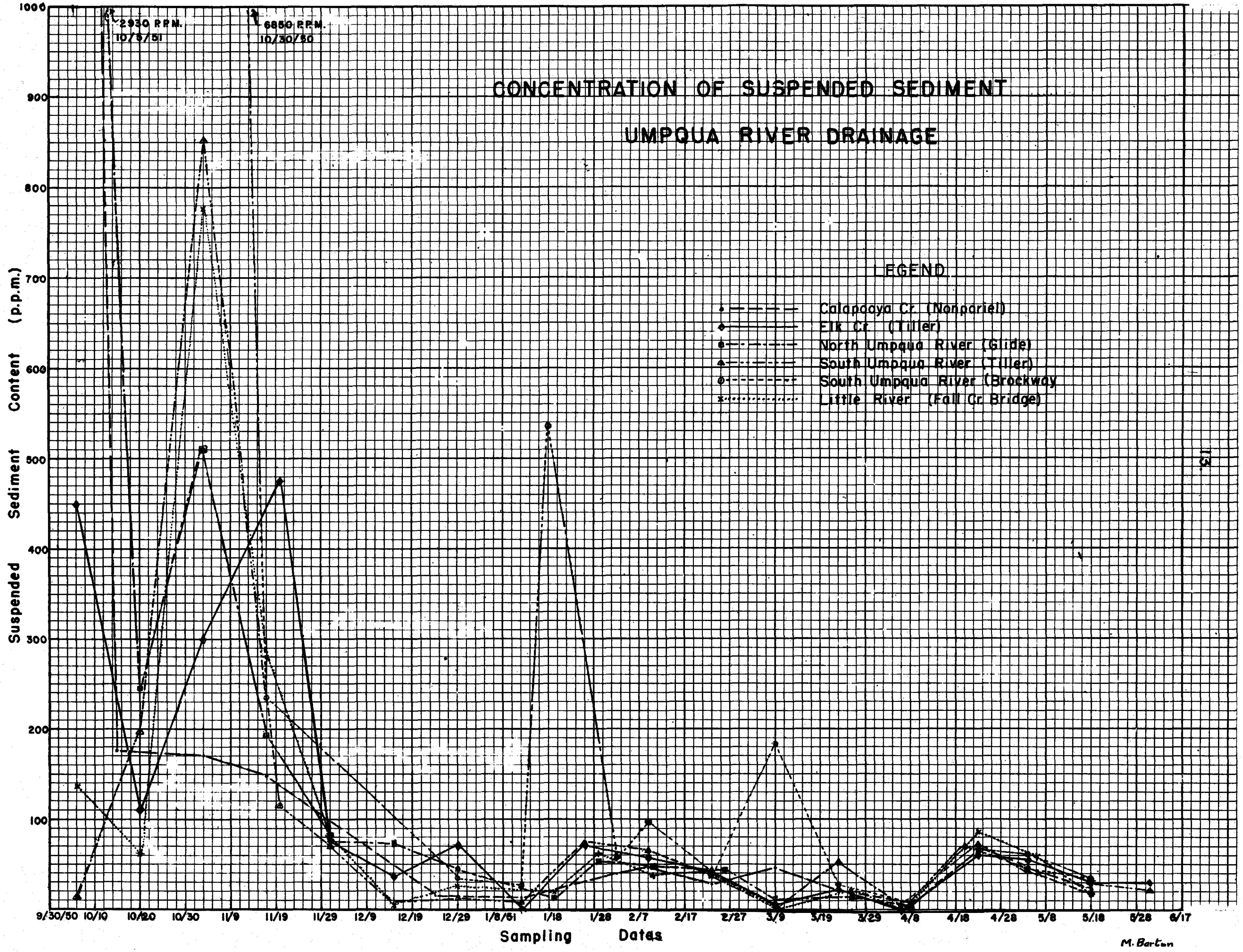

CONCENTRATION OF SUSPENDED SEDIMENT
LEWIS & COWLITZ RIVER DRAINAGES
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates
Cowlitz River
(at Mayfield, Wash.)
East Fork Lewis River
(near Heisson, Wash.)


CONCENTRATION OF SUSPENDED SEDIMENT
WILSON RIVER DRAINAGE
Wilson River (nr. Tillamook, Oregon)
Wilson River (Lee's Bridge, Oregon)
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
2/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates


CONCENTRATION OF SUSPENDED SEDIMENT
ROGUE RIVER DRAINAGE
Ashland Creek (Ashland, Oregon)
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates


CONCENTRATION OF SUSPENDED SEDIMENT
ILLINOIS RIVER DRAINAGE
Illinois River (Kerby, Oregon)
Suspended Sediment Content (p.p.m.)
0
50
100
150
200
250
300
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates


CONCENTRATION OF SUSPENDED SEDIMENT
COQUILLE RIVER DRAINAGE
S. Fk. Coquille River (at Powers, Oregon)
38,200 on 10/28/50
Suspended Sediment Content (p.p.m.)
1050
900
750
600
450
300
150
0
10/1
10/16
10/31
11/15
11/30
12/15
12/30
1/14
1/29
2/13
2/28
3/15
3/30
4/14
4/29
5/14
5/29
6/14
Sampling Dates


CONCENTRATION OF SUSPENDED SEDIMENT
UMPQUA RIVER DRAINAGE
LEGEND
Calapooya Cr. (Nonpariel)
Elk Cr. (Tiller)
North Umpqua River (Glide)
South Umpqua River (Tiller)
South Umpqua River (Brockway
Little River (Fall Cr. Bridge)
2930 P.P.M. 10/5/51
6850 P.P.M. 10/30/50
Suspended Sediment Content (p.p.m.)
1000
900
800
700
600
500
400
300
200
100
9/30/50
10/10
10/20
10/30
11/9
11/19
11/29
12/9
12/19
12/29
1/8/51
1/18
1/28
2/7
2/17
2/27
3/9
3/19
3/29
4/8
4/18
4/28
5/8
5/18
5/28
6/17
Sampling Dates
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consisted of stream name, location, date, time, flow, and stage. The gross weight of the sample was obtained by weighing it on a beam balance to an accuracy of $\pm$ 0.1 gram. To separate the sediment from the water, a high-grade filter paper was used. The filter paper was numbered for handling purposes and weighed on a chainomatic balance to an accuracy of $\pm$ 0.0001 gram to obtain its tare weight. The filter paper was placed in a four-inch Buchner funnel which was then inserted in a flask connected to an aspirator. The contents of the sample bottle were poured on the filter paper. The bottle was then washed out carefully to remove all the sediment clinging to its surface. When all the water had been filtered, the filter paper and sediment were removed from the funnel and placed on an electric oven to dry. The filter paper was dried on top of the oven to eliminate charring due to direct heat in the oven. After drying, the filter paper and sediment were weighed to obtain the gross weight. The net weights of the total sample and sediment were obtained by subtracting their tare weights from their respective gross weights. The net weight of sediment was divided by the net weight of the total sample multiplied by one million (10^6) to give the suspended sediment load expressed in parts per million (ppm).

Sources of Error

Although the filtration-suction method of analyzing samples was very satisfactory for the mass handling of a large number of samples, there were several disadvantages. These were: (1) the hygroscopic action of the filter paper; (2) the loss of sediment through the filter paper; and (3) the tendency of the sediment to cling to the sample container's surface. Of the three, the hygroscopic action of the filter paper was the most serious. It was a source of error because temperature and humidity variations in the laboratory changed the tare weight of the filter paper following the completion of an analysis. To minimize this error, a correction factor was applied to the tare weight prior to the final calculation. The correction factor was determined by separately weighing a control set of three filter papers before and after the completion of an analysis. The total weight of the control set before the analysis was subtracted from the total weight of the control set after the analysis; this difference was then divided by the total weight of the control set before the analysis to obtain a $\pm$ percentage correction factor for the tare weight.

The loss of sediment through the filter paper was negligible. Visual examination of the filtrates revealed them to be very clear. It has been pointed out in other studies that such loss of sediment can often be eliminated by the addition of predetermined weights of kaolin or fullers earth (1).

When a sediment sample was transferred from the milk bottle container to the Buchner funnel a small amount of the sediment often remained on the surface of the bottle. This condition was easily corrected by additional washing of the bottle to flush out the clinging sediment.

Findings

Once a month during the course of this study a stream sediment sampling record was sent to sample collectors, cooperators, state and federal agencies and others. The sediment load data contained in these records have been presented graphically on pages 6-13. Instead of plotting the data for each sampling site separately, the data were grouped by major watersheds. Visual analysis of such charting indicated that the grouped streams, in general, have the same trends. For example, high sediment loads in one stream at a given date were accompanied by high sediment loads in others of the group for the same date. It also showed a common tendency for the streams to produce very high sediment loads during the months of October through December. This might be explained in part by the high stream flows in the grouped streams which were produced by storms during October, November and December. Also early in the water year, moderate stream flows flushed out sediment which had been dropped by decreasing summer and fall flows, or produced by caving of stream banks.

The Maximum, Minimum, and Average Suspended Sediment Loads

A table giving maximum, minimum, and average suspended sediment loads carried by the selected streams is shown on page 16. The most notable of these data was from the sampling station on the south fork of the Coquille (at Powers, Oregon) having a 169 sq. mile watershed. On October 28, 1950, a discharge of 22,520 cfs transported a suspended load of 38,200 ppm (3.8%).

Stream Flow - Suspended Sediment Load Relationship

The suspended sediment quantities carried by the Wilson River near Tillamook, Oregon and the South Umpqua River at Brockway, Oregon during the first nine months of the 1951 water year were plotted against their transporting stream flows (pages 17-18). From the curves obtained, it appears that the stream flow-sediment load relationship was curvilinear. Studies which have been made concerning capacity 4/ and stream discharge seem to support this observation. In these studies, it was found that capacity increases as the 3rd to 4th power of the velocity (2).

A statistical analysis of the stream flow-suspended sediment load relationship using the data from the two lower sampling sites on the north and south forks of the Newaukum and the flow data from the USGS gage on the main Newaukum gave correlation coefficients of .60 and .81. This explained only 36% and 66% of the variation in sediment loads due to differences

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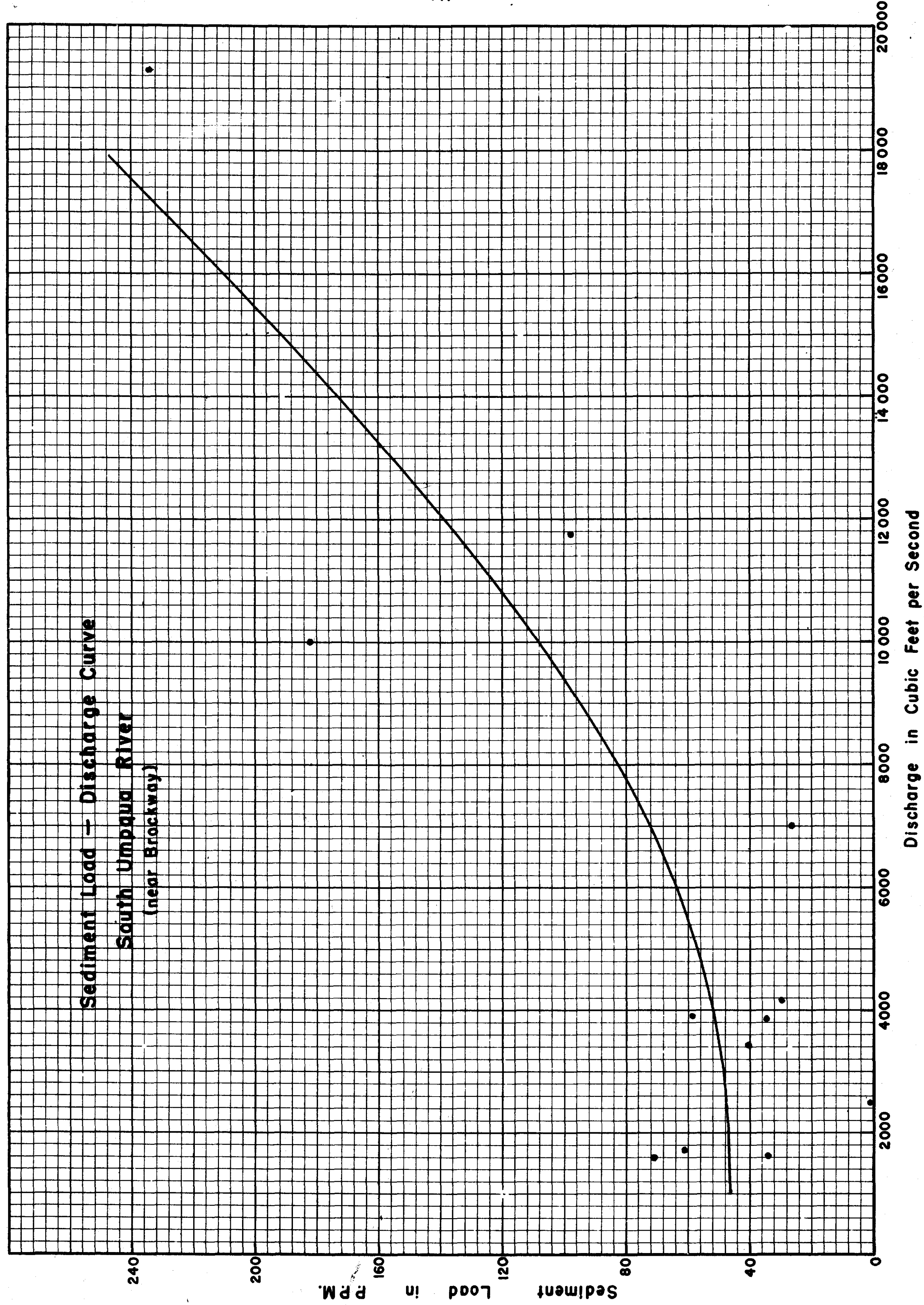
4/ Capacity is defined as the ability of a current to transport in terms of quantity.

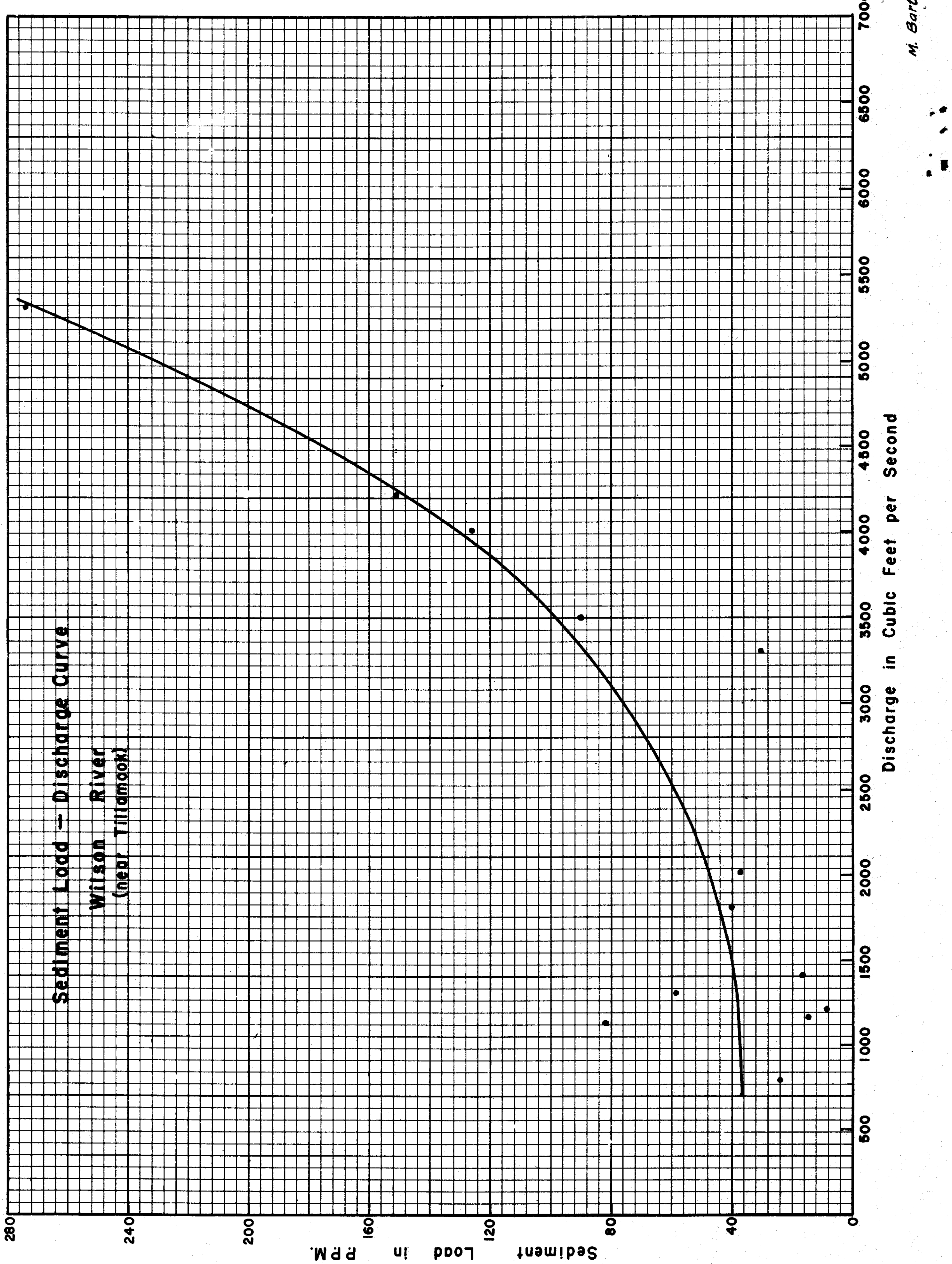
RANGE IN SUSPENDED SEDIMENT LOADS*

Stream	Maximum	Minimum	Average**
OREGON			
Illinois River	204	Trace	67
So. Fk. Coquille	38,200	1/4	4,061 (267)
Ashland Creek	2,410	2	401 (97)
Wilson (USGS)	295	9	84
So. Umpqua (Brockway)	6,850	Trace	552 (102)
Calapooya Creek	2,930	1/2	252 (61)
So. Umpqua (Tiller)	853	1/4	94 (49)
No. Umpqua (Glide)	2,100	3	220 (94)
Elk Creek (Tiller)	450	Trace	106
Little River	777	2	104 (56)
Wilson (Lee's Bridge)	229	4	59
WASHINGTON			
Chehalis	164	3	50
Skookumchuck (Bucoda)	98	2	41
Cowlitz	112	27	62
E. Fk. Lewis	102	4	42
Skookumchuck (Tenino)	88	1	37
So. Fk. Newaukum (Forest)	195	13	60
" " " (Alpha)	71	Trace	33
No. Fk. " (Water Intake)	65	Trace	30
" " " (Forest)	304	1/2	65

* In ppm.

** The averages were based on approximately 15 samples per station. Averages in parentheses were obtained by eliminating the maximum sediment load from the computation.


Sediment Load — Discharge Curve
South Umpqua River
(near Brockway)
Discharge in Cubic Feet per Second
Sediment Load in P.P.M.
0
2000
4000
6000
8000
10 000
12 000
14 000
16000
18000
20 000
40
80
120
160
200
240


Sediment Load — Discharge Curve
Wilson River
(near Tillamook)
Discharge in Cubic Feet per Second
Sediment Load in P.P.M.
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
0
40
80
120
160
200
240
280
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in stream flow. The following factors probably would account for much of the variation not explainable by stream discharge:

(1) Intensity and amount of precipitation.
(2) Vegetal cover.
(3) Season of year.
(4) Condition and kind of surface soil.
(5) Topography.
(6) Size of stream.
(7) Stability of channel.
(8) Intensity of land use.

Literature Cited

(1) Anonymous, "A study of methods used in the measurement and analysis of sediment load in streams," Report No. 4. Published at the St. Paul U. S. Engineer Sub-office, Hydraulic Laboratory, University of Iowa, Iowa City, Iowa. 1940.

(2) Gilbert, G. K., "The transportation of debris by running water," U. S. Geological Survey, Prof. Paper 86. 1914.

(3) Anonymous, "A study of methods used in the measurement and analysis of sediment load in streams," Report No. 1. Published at the St. Paul U. S. Engineer Sub-office, Hydraulic Laboratory, University of Iowa, Iowa City, Iowa. 1940.