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DESCHUTES RIVER BASIN SUSPENDED SEDIMENT TRANSPORT STUDY

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INTRODUCTION

The Deschutes River was dammed at its mouth in 1951, forming Capitol Lake, a 220-acre impoundment that is used for salmon culturing (Percival Cove) and a variety of recreational activities. Formation of the lake unfortunately also created an effective settling basin for sediments transported by the river and over the years sediments have accumulated to the point where dredging has been necessary to maintain depth. The State of Washington, which is responsible for maintaining the lake, conducted the first major dredging operation during the 1978-79 winter. This effort will be followed by maintenance dredging every few years.

It became apparent during the planning of the Capitol Lake dredging project that insufficient information was available concerning the sources of the sediments that are reaching the lake. Therefore, during 1976-78, the Department of Ecology conducted sediment monitoring at selected locations in the Deschutes watershed. The study included two objectives: (1) identify sources of sediments transported by the Deschutes River; and (2) determine the quantity and significance of sediments contributed by each of the sources identified.

Drought conditions prevailed during the 1976-77 monitoring period; therefore, the data gathered was considered atypical and not representative. The project was restarted in the spring of 1977 and concluded during January 1978. During this period, typical climatological conditions existed in the Deschutes River drainage. This report presents and discusses the results of the 1977-78 monitoring effort.

DESCHUTES BASIN DESCRIPTION

The Deschutes River originates on Cougar Mountain (3,840 feet) in the Snoqualmie National Forest. From its origin, the river flows in a northwesterly direction for 57 miles, then empties into Budd Inlet at the southern terminus of Puget Sound (Figure 1).

The drainage basin encompasses about 162 square miles with the upper watershed consisting mainly of heavily forested lands and fairly rugged terrain. This changes to rural communities and farm lands in the lower basin. There is some urban development near the river mouth in the Tumwater-Olympia area.

Peak flows occur in the winter months with a maximum of 7,780 cfs (cubic feet per second) recorded on January 15, 1974. Minimum flows occur in the late fall and have ranged from 66 to 100 cfs. The average annual flow is 409 cfs (U.S.G.S., 1962).

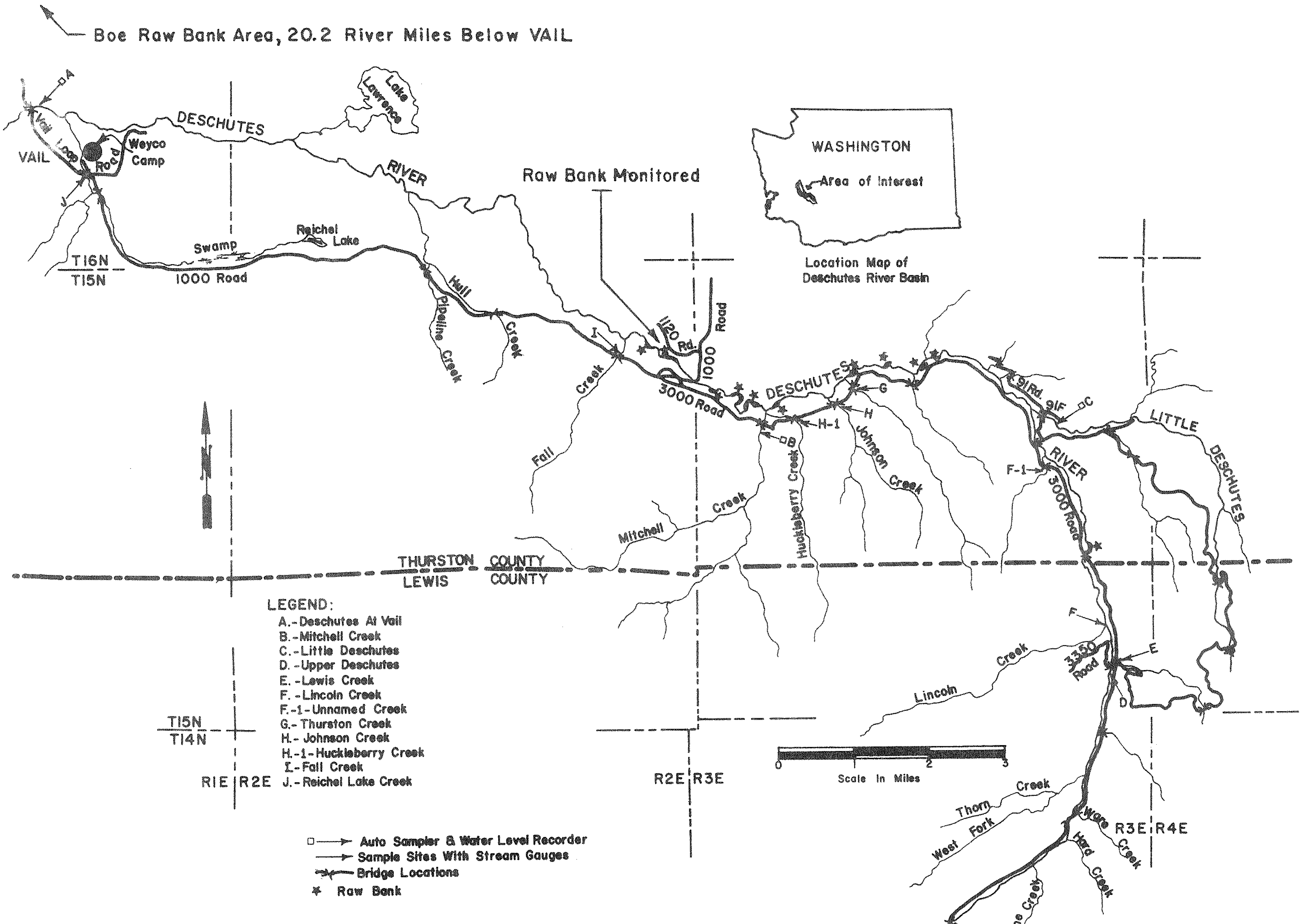

Figure 1
DESCHUTES RIVER – SUSPENDED SEDIMENT STUDY
LOCATIONS OF SAMPLE STATIONS
and
RAW BANK AREAS

MATERIALS AND METHODS

Sediment contributions were determined using two methods. First, suspended sediment transported down the river was measured by water quality monitoring. Second, the total amount of material entering the river from eroding high river banks was calculated using visual survey techniques in the field.

Stream Monitoring

Stream monitoring was conducted during November and December 1977 when the majority of the total annual suspended sediment is produced in the basin. This sampling period was selected based on the findings of Orsborn, *et al.*, (1975) which showed that Deschutes flows exceed 1000 cfs only eight (8) percent of the time. Between 80 and 85 percent of the annual sediment load is transported during this high-water period. Investigations by Nelson (1971) and Orsborn, *et al.*, (1975) showed that nearly all of the suspended sediment transported down the Deschutes originates in the upper watershed above the Weyerhaeuser Vail Camp. Therefore, monitoring stations were established at 13 sites in this area:

Station	Location
A	Deschutes at Vail
B	Mitchell Creek
C	Little Deschutes
D	Upper Deschutes
E	Lewis Creek
F	Lincoln Creek
F-1	Unnamed Creek
G	Thurston Creek
H	Johnson Creek
H-1	Huckleberry Creek
I	Fall Creek
J	Reichel Creek
K	Spurgeon Creek

The monitoring station locations are shown in Figure 1.

Two of the tributaries (Little Deschutes and Mitchell Creek) were selected for intensive monitoring. The continuous data from these two stations provided the information needed to estimate suspended sediment contributions on the other intermittantly sampled tributaries. Also, the Little Deschutes was considered as being influenced by on-going logging practices; i.e., road building, maintenance, logging, and log truck traffic, There were no tributaries in the Deschutes basin that would represent conditions undisturbed by man's influence, However, there are a number of subbasins that have been logged, sedimentation processes are stabilizing, and no logging activities are going on at present, Mitchell Creek was selected as a stream representative of this category. It was last logged two or three years previously.

Sediment monitoring data collected at one station near the mouth of the Deschutes River at Tumwater during the study period (November and December 1977) were evaluated to calculate total transport to Capitol Lake. These data were collected by Stanley (unpbl. data, 1977).

Stream Flow Measurements

A staff gage was established at each of the 13 sampling stations in the upper Deschutes River (Figure 1). Station K (Spurgeon Creek) was discontinued early in the study as the creek was found to contribute a minimal amount suspended sediment. Also, flows in this creek could not be measured accurately during high water because of waters backed up by the Deschutes River. Twelve stations were sampled for the remainder of the study.

Stevens type F model 68 level recorders were installed at stations B (Mitchell Creek) and C (Little Deschutes). A Stevens type A model 71 level recorder located at the U.S.G.S. gage house at station A (Deschutes at Vail) was maintained by Weyerhaeuser Company.

Flows were measured at all gaging stations (except A) twice per week, and more frequently during storm events, using a Marsh-McBirney model 201 portable water current meter. The U.S.G.S. method for calculating flows was employed (Buchanan and Somers, 1969). Discharge rating curves were constructed for each station using the measured stream flows and corresponding gage heights (the flows at station A were periodically measured by Weyerhaeuser hydrologists.)

Continuous gage height graphs were constructed for all stations except A, B, and C, which had continuous recording graphs. Graph heights for periods without data were estimated from data obtained at the nearest continuous hydrograph and an analysis of drainage characteristics. This procedure is used routinely by U.S.G.S.

Suspended Sediments

For the intensive sampling, Manning S 4040 sequential water samplers were installed on the Deschutes River at Vail (Station A), Mitchell Creek (Station B), and Little Deschutes (Station C). The intakes were installed midstream, away from excessive turbulence, and six inches above the stream bed as per Wooldridge (personal communication). During non-storm periods, 100 ml samples were taken every hour for six 4-hour composite samples per day. These samples were picked up twice a week. During storm events, the sampling frequency was increased to a 100 ml sample every 15 minutes, for hourly composite samples.

Samples from the nine remaining stations were taken by the grab method according to U.S.G.S. procedures (Guy and Nolman, 1970). These samples were collected once or twice a week except during storm events when the sampling frequency was increased to three- or four-hour intervals. Emphasis was given to sampling on the rising hydrograph.

All of the suspended sediment samples were analyzed for total suspended solids (TSS) and turbidity (NTU) at the DOE analytical laboratory in Tumwater. Total suspended solids were determined by the Gooch crucible method used by U.S.G.S. (Guy, 1969) and reported as mg/l. The U.S.G.S. Gooch crucible method is comparable to that of Standard Methods (1971).

Turbidity was analyzed using a Hach Model 2100A Turbidimeter and recorded as NTU (Nephelometric Turbidity Units).

Continuous suspended sediment curves were drawn for the three stations with the automatic samplers. These curves also were used as aids in determining suspended sediment curves for the stations sampled by hand (Porter and Field, 1972).

Using the continuous stream flow and suspended sediment concentration curves, suspended sediment transport in tons per day was calculated for each of the 12 sampling sites.

Stream Bank Erosion

A review of land and aerial reconnaissance data (Department of Natural Resources and Department of Ecology) indicated substantial numbers of high-bank erosion (slide potential) areas exist along the Deschutes River. Two of these were monitored. One area is located in the upper Deschutes watershed near the Weyerhaeuser 1120 road and the other along the lower river near Boe Sand and Gravel Company (Figure 1).

Using a surveyor's chain and Brunton Pocket Transit, a reference line was established parallel to the river within each survey area, with observation stations spaced every 20 feet along this line. The slope and height of the stream bank was determined at each station using a Sunto, PM5/360 PC clinometer and a surveyor's chain. These areas were re-measured periodically during the April 15, 1977 to January 10, 1978 monitoring period to provide information concerning the amount of material lost over time.

RESULTS

A series of storms passed through the Deschutes watershed during the 1977-78 winter, ranging from moderate to high intensity. On December 3, the flow reached 4710 cfs or about the two-year high flow (Williams, 1976). The winter flows appeared to be fairly typical of the Deschutes River when compared to 1950-1978 discharge data for the U.S.G.S. gaging station at Vail (Figure 2).

Suspended Sediment Monitoring

Deschutes River at Mouth

A total of 23,131 tons of sediment reached Capitol Lake during December 20, 1976 to December 19, 1977 (Stanley, unpbl. data). Of this amount, 18,262 tons (79 percent) were transported during the November-December 1977 period. The monthly sediment discharges far the Deschutes River at Tumwater are given in Table 1.

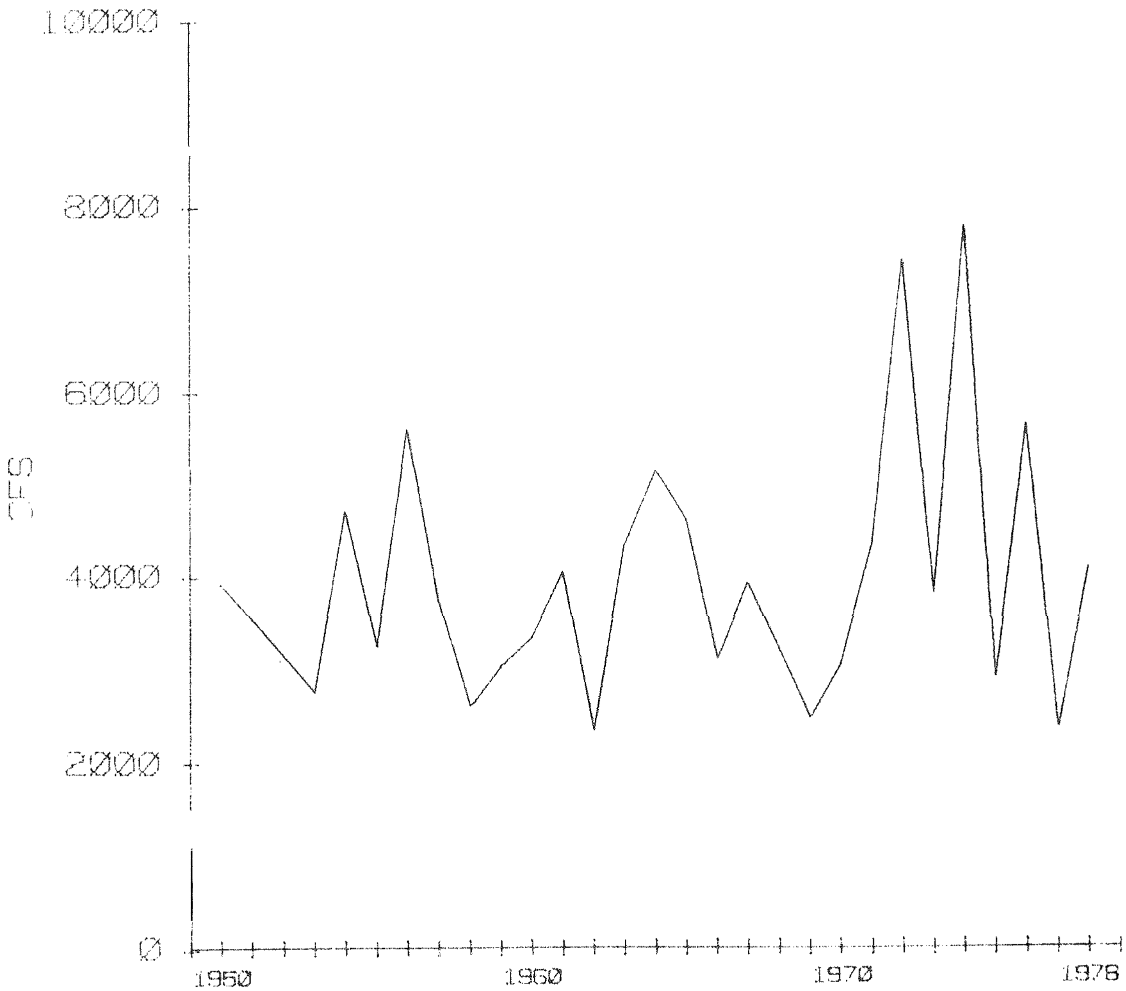

FIGURE 2 . DESCHUTES RIVER BASIN SUSPENDED SEDIMENT TRANSPORT STUDY. ANNUAL PEAK DISCHARGES OF THE DESCHUTES RIVER STA. A (USGS GAGE), WATER YEAR OCT 1-SEPT 30.

Table 1. Total Tons of Suspended Sediment Contributed by each Station with Average Daily Peak Flows for each Station. *

	Station	Suspended Sediment Transport (Tons) November	December	Total	Ranking	Average Daily Peak Flow (Nov.-Dec. 197 flows (cfs)	Ranking
A	Deschutes River at Vail	1990	10,243	12,233	1	860	1
B	Mitchell Creek	53	617	670	2	116	3
C	Little Deschutes	83	293	376	4	92	4
D	Upper Deschutes	39	215	254	7	194	2
E	Lewis Creek	9	56	65	11	24	11
F	Lincoln Creek	158	418	576	3	89	5
F-1	Unnamed Creek	4	9	13	12	13	12
G	Thurston Creek	33	341	374	5	65	6
H	Johnson Creek	27	99	126	10	35	9
H-1	Huckleberry Creek	13	138	151	8	31	10
I	Fall Creek	14	290	304	6	38	8
J	Reichel Lake Creek	38	96	134	9	48	7
Deschutes Mouth				18,262			
Total of all Stations above Station A				3,043			
Suspended Sediment at the Mouth Excluding Tributary Stations				15,219			
Raw Bank (January 1977-78)							
Boe Sand and Gravel				1,310			
Weyerhaeuser 1120 Road				304			

"Ranking of Stations According to Tons of Suspended Sediment and Average Daily Peak Flows. Total Suspended Sediment in Tons at Mouth of Deschutes River, all Stations Above "A" and at Mouth, Excluding Tributary Stations, November-December 1977. Total Tons of Suspended Sediment Contributed by Two Raw Areas, January 1977-1978.

Tributary Contributions (Upper Deschutes)

Suspended sediment transport for the 11 tributaries monitored during November and December 1977 were calculated at 3,043 tons. This was estimated to represent some 90 to 95 percent of the contribution from all tributaries in the Deschutes system during these two months. During this same period, 12,233 tons of suspended sediment passed station A (Deschutes at Vail) which is downstream of these tributaries. Thus, only about 25 percent of the suspended sediment at station A could be attributed to the 11 feeder streams monitored. The balance of the sediment had to originate either from the stream bed or banks of the Deschutes mainstem (Table 1).

A regression line was developed from the total suspended solids and flow data collected at each of the streams monitored. These data provided a means to compare each station in terms of sediment output and flow (Figure 3). The results for each stream follow.

The Upper Deschutes (Station D) at 194 cfs had the second highest average flow, but suspended sediment transport was extremely low at 254 tons (Table 1 and Figure 3). This low sediment output seems reasonable because a visual survey of the mainstem indicated much less soil was available for erosion above this station than below. The stream bed and banks downstream of Station D are mainly a mixture of sand, gravel, and cobbles but bedrock, large boulders, and cobbles prevail upstream of this station. Very few areas of stream bank erosion were evident above Station D. It should be noted that this stream was excluded from the regression analysis due to extremely low sediment output.

The Little Deschutes (Station C) had 377 tons suspended sediment and a 92 cfs flow (Table 1). This tributary originates in an area that was being logged during the survey period. A partial explanation for the "low" sediment contribution (Figure 3) may be that more bedrock is exposed along the lower reaches of this stream than the other tributaries, resulting in less source material being available for suspended sediments.

Reichel Lake Creek (Station J) had a "low" suspended sediment yield of 134 tons (Table 1) relative to flow (Figure 3). This stream is unlike the other tributaries in this area because of its very low gradient. It originates at Reichel Lake, then flows through a series of swamps and pasturelands. No areas of active streamside erosion were visible above the sampling station. Because much of its source waters enter from pastures, swamps, and Reichel Lake, its peak flows are considerably delayed compared to the rest of the river system. Also, flows decline much more slowly than the other tributaries after rainfall (Figures 4 and 5).

Fall Creek (Station I) at 304 tons had a "higher" than expected sediment transport (Table 1). This stream seemed to respond very quickly to rainfall, indicating a quick runoff along its length (Figures 4 and 5). High peaks of suspended sediment would be expected in this case.

Lincoln Creek (Station F) would be expected to supply a large amount of suspended sediment; however, its suspended sediment transport of 576

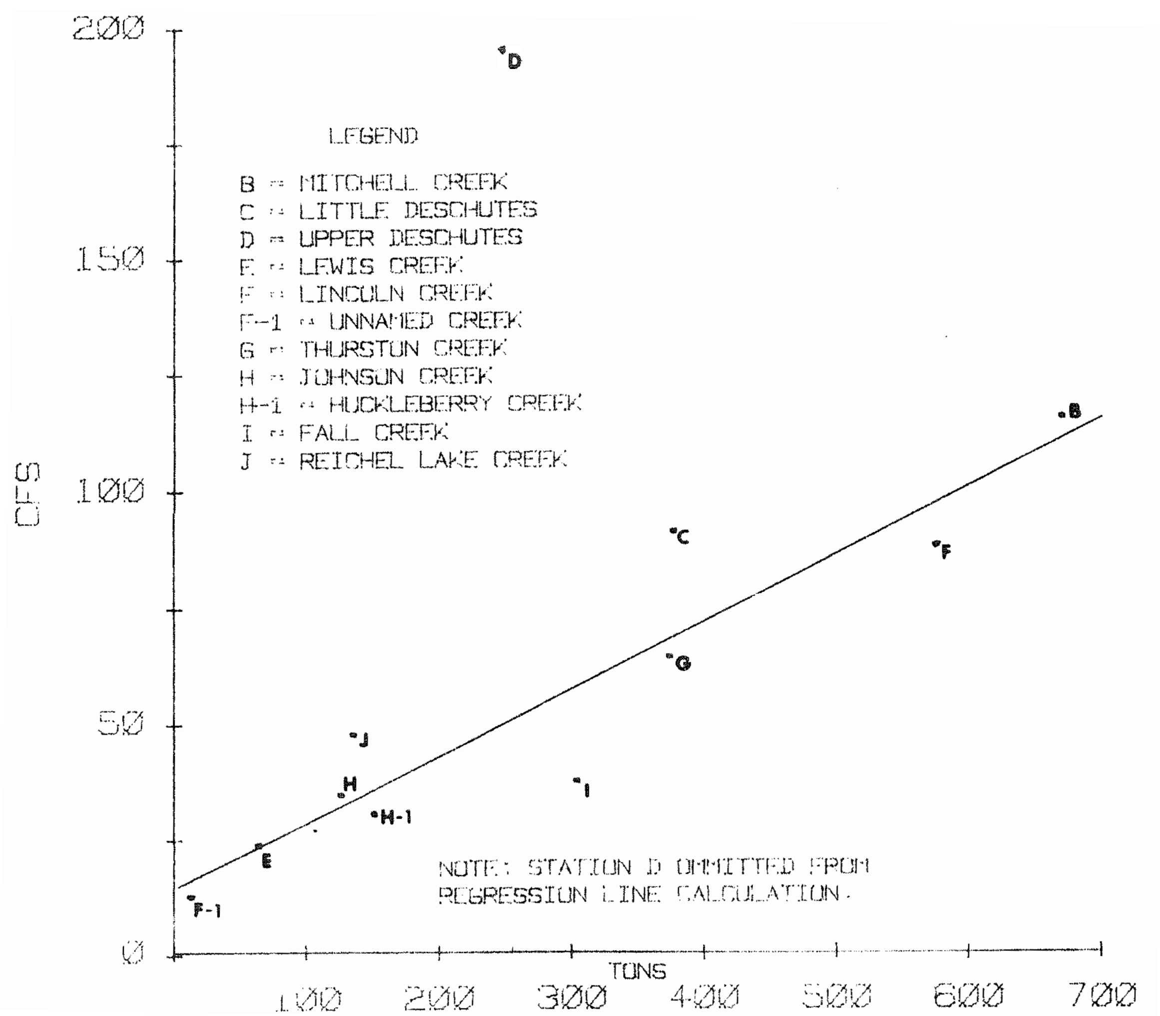

FIGURE 3 . DESCHUTES RIVER BASIN SUSPENDED SEDIMENT TRANSPORT STUDY* TOTAL SUSPENDED SEDIMENT TRANSPORT IN TONS VS AVERAGE DAILY PEAK FLOW IN CFS (CUBIC FEET PER SECOND) NOV-DEC 1977. REGRESSION LINE DRAWN.

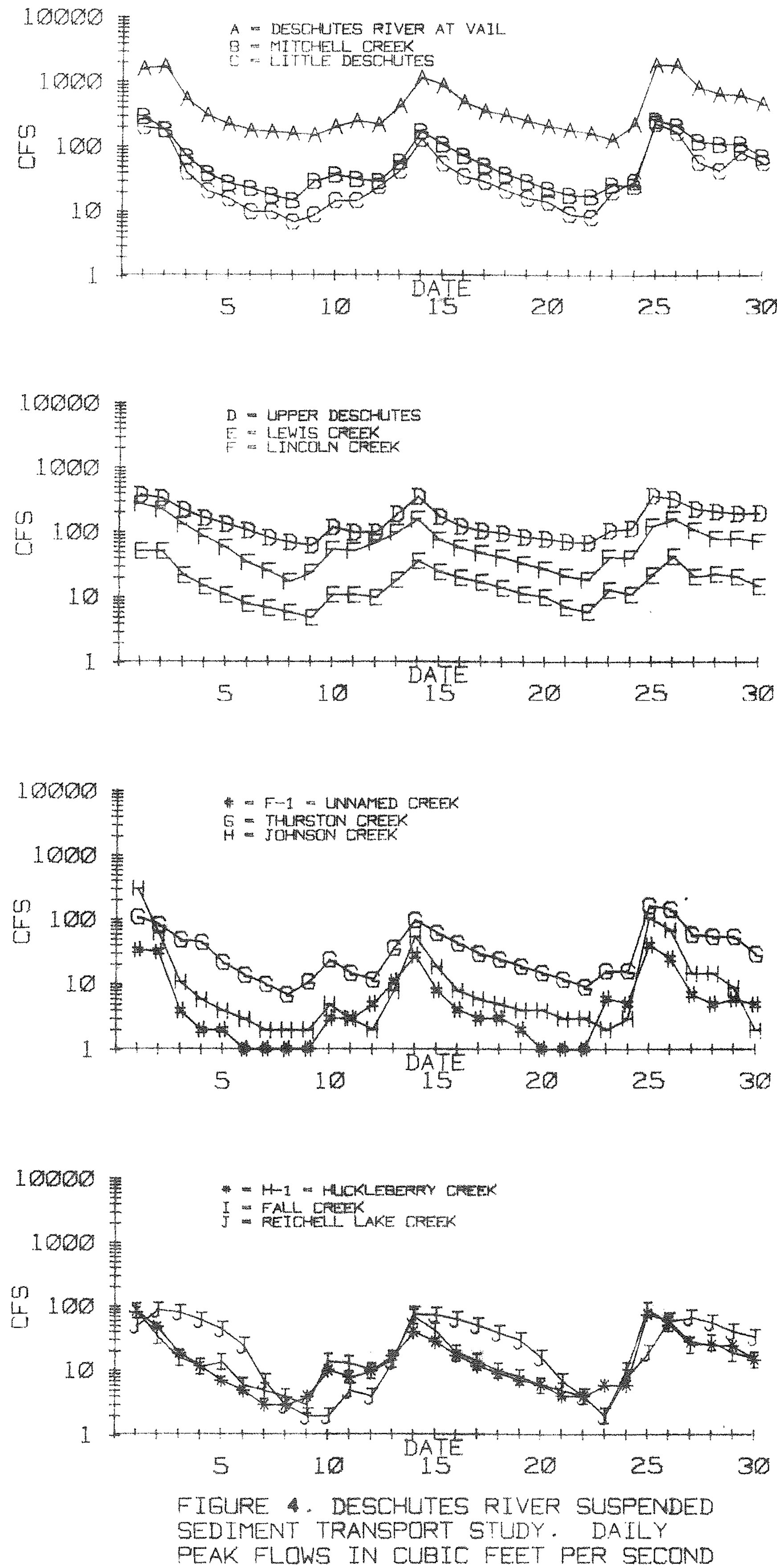

FIGURE 4. DESCHUTES RIVER SUSPENDED SEDIMENT TRANSPORT STUDY. DAILY PEAK FLOWS IN CUBIC FEET PER SECOND (CFS) FOR EACH STATION, NOV. 1977.

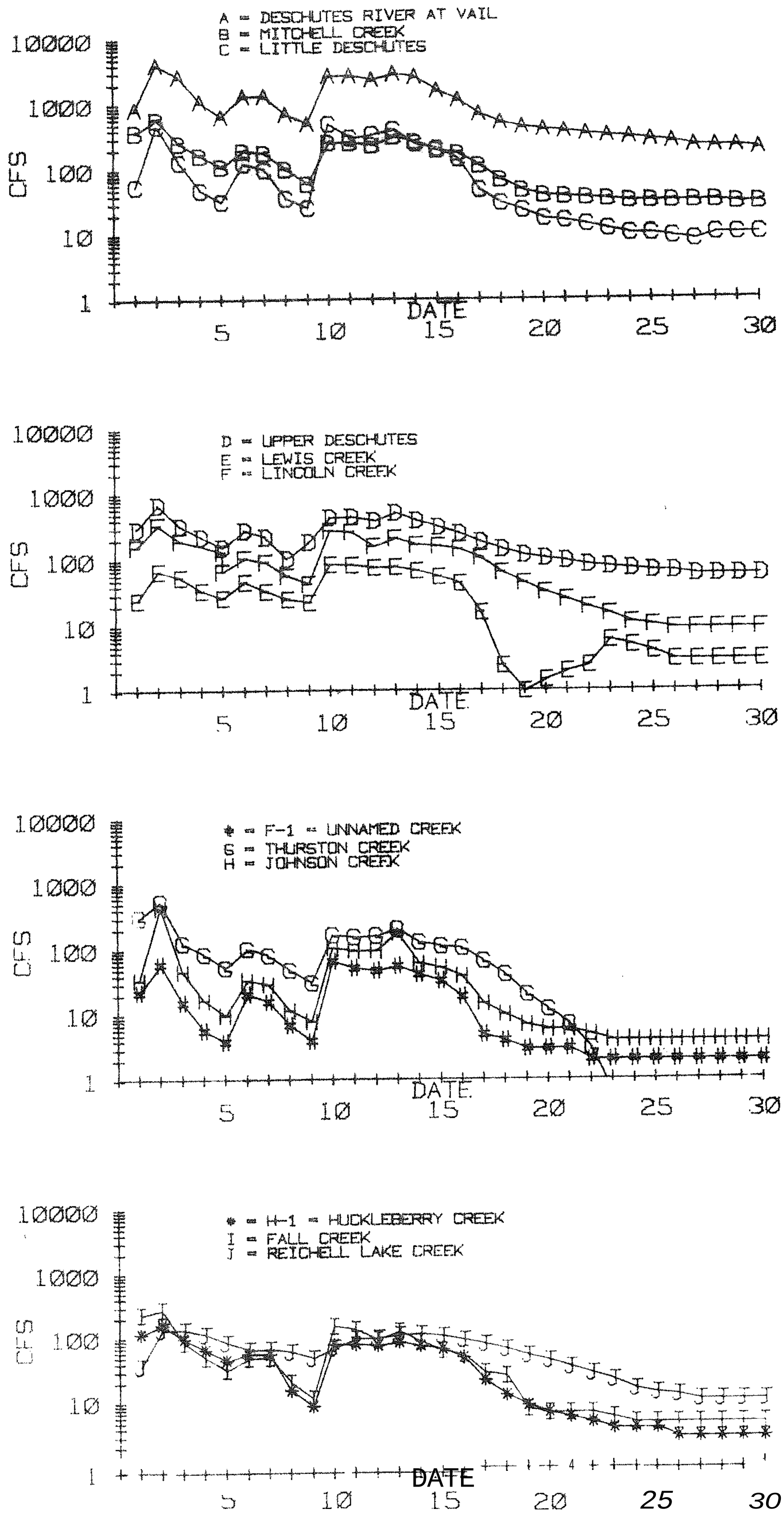

FIGURE 5. DESCHUTES RIVER SUSPENDED SEDIMENT TRANSPORT STUDY. DAILY PEAK FLOWS IN CUBIC FEET PER SECOND (CFS) FOR EACH STATION. DEC. 1977.

tons approximated the "expected" amount (Table 1 and Figure 3). This drainage is steep, fairly unstable, and has deep clay soils (Thorson and Othberg 1978). A number of natural slumps were evident throughout this drainage, indicating unstable soils. During December 1977, a dirtslide flowed about 100 yards into the creek about 3/4 mile above its mouth. The amount of suspended sediments measured was considerably more than the Little Deschutes (Station C). However, unlike the Little Deschutes which has exposed bedrock in its lower reaches, and consequently less material available for erosion, Lincoln Creek has large quantities of material readily available for suspended sediment transport.

Mitchell Creek (Station B), the stream considered representative of a "stable" area or not being actively logged, had both the highest average flow of the tributaries samples (116 cfs) and largest suspended sediment load at 670 tons (Table 1). The continuous suspended sediment record showed no abnormal events such as earth slides to increase suspended sediment. During storm events, this stream was altered more at the point of sampling than any of the other tributaries. The high flow rate, coupled with the loose sand, gravel, and cobble bottom, were major factors for the streambed erosion at this point. Other significant factors were the relatively straight channel in this area and the narrowing at the bridge structure, both of which accelerate flow velocity and increase erosional forces.

Lewis Creek (Station E), was initially identified as having a high potential for sediment production (Thorson and Othberg, 1978). However, during the survey this stream transported a "normal" amount of suspended sediment at 65 tons (Figure 3). Even though this stream was identified as steep and narrow with unstable soils, the flows during the survey period apparently were not great enough to cause excessive erosion.

The remaining creeks monitored (Unnamed Creek, F-1; Thurston Creek, G; Johnson Creek, H; and Huckleberry Creek, H-1) did not have any unusual features and, according to Figure 3, were fairly "normal" for the Deschutes in terms of suspended sediment production.

Further information on daily production of sediments at the 12 survey sites during the two-month monitoring period is given in Figures 6 and 7,

Stream Bank Erosion

Stream bank erosion appeared to be the major source of sediment in the Deschutes River Basin (Table 1). The raw bank area near Weyerhaeuser 1120 road (Figure 1) contributed an estimated 609 tons of material to the river during the 12-month monitoring period. Assuming 50 percent of this material was fine enough to be transported as suspended sediment during high flow, this bank could have contributed about 304 tons of suspended sediment during the November and December 1977 period. This represents about 12 percent of the total amount of suspended sediment which the upstream tributaries had delivered to this point.

The 50 percent estimate is considered conservative compared to figures developed by Thorson and Othberg (1978). They estimated the composition

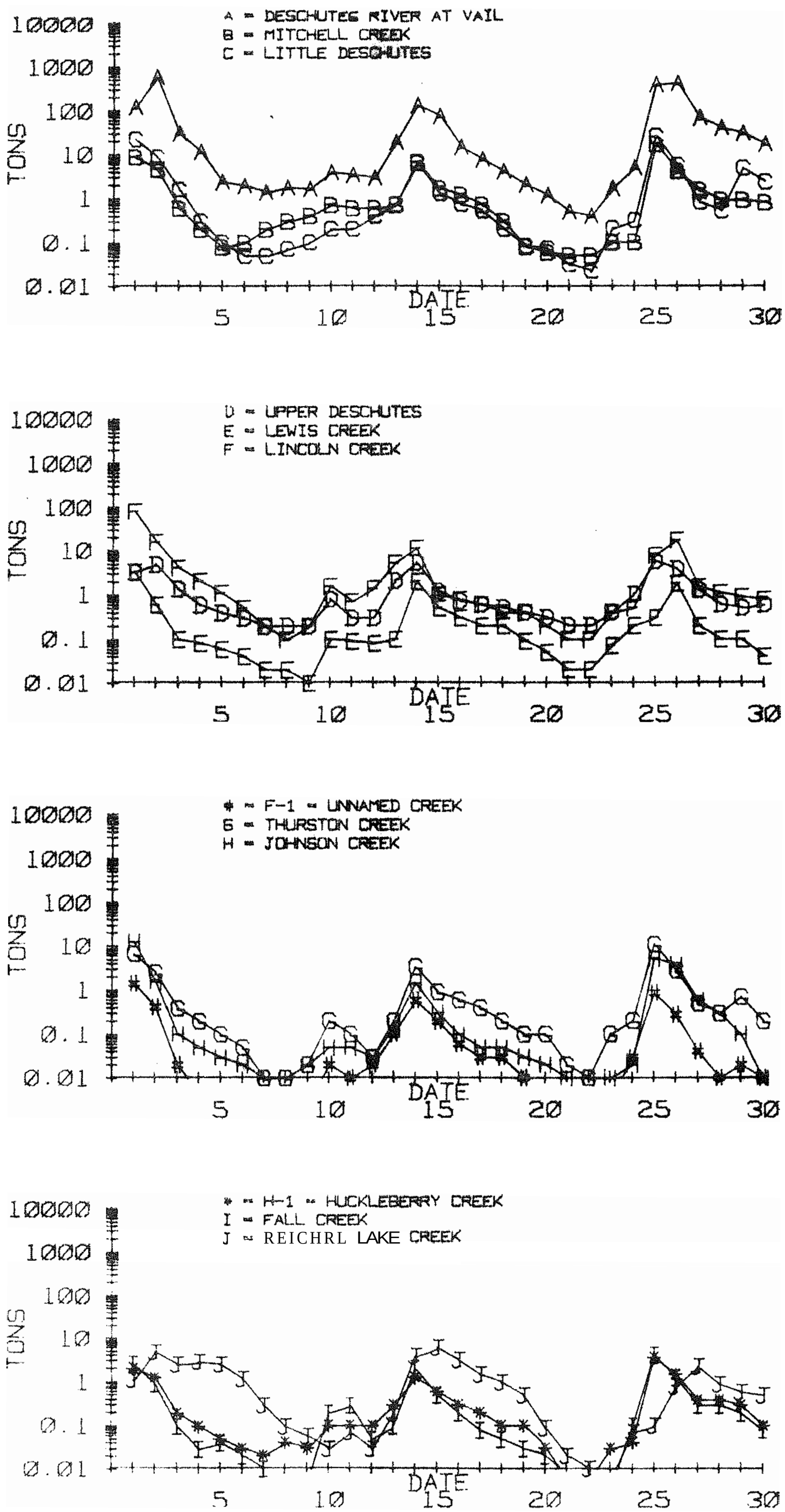

FIGURE 6. DESCHUTES RIVER SUSPENDED SEDIMENT TRANSPORT STUDY. TONS OF SUSPENDED SEDIMENT TRANSPORTED DAILY BY EACH STATION, NOV. 1977.

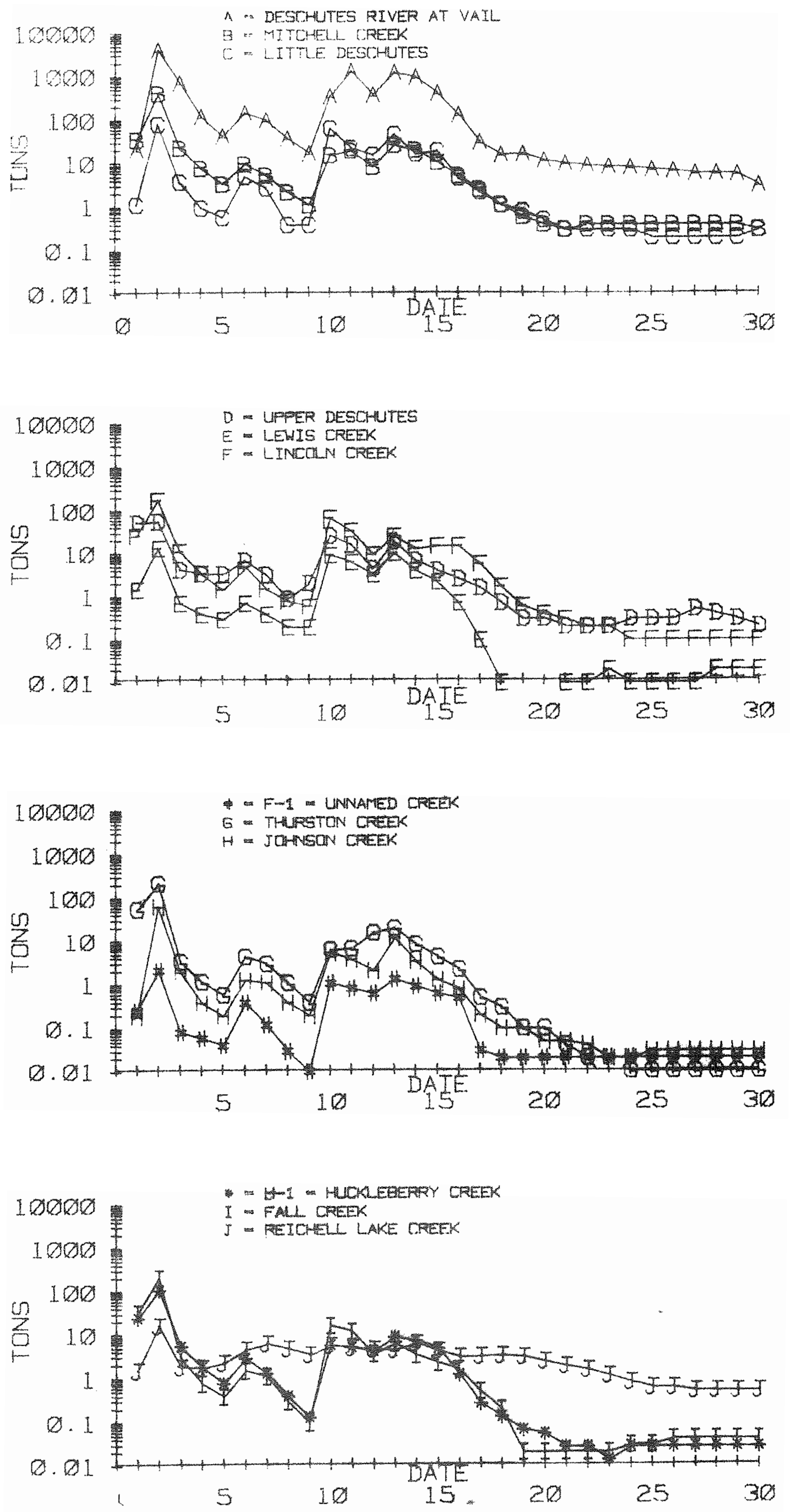

FIGURE 7. DESCHUTES RIVER SUSPENDED SEDIMENT TRANSPORT STUDY. TONS OF SUSPENDED SEDIMENT TRANSPORTED DAILY BY EACH STATION. DEC 1977.

of a 90-foot high raw bank one-half mile below the mouth of Mitchell Creek to be 10 percent gravel, cobbles, and boulders; 30 percent coarse sand; 40 percent fine sand; and 20 percent silt. All of the fine sands and silt and some of the coarse sand could become suspended sediment during high flows.

The large raw bank area along the Boe Sand and Gravel, Inc. property (Figure 1) delivered an estimated 2,620 tons of material to the Deschutes River during the survey period (Table 1). Like the 1120 road river bank, the river eroded the base of the bank only during high flows. Much of this undercut bank material entered the river through a ravelling process.

This process appeared to occur throughout the year, with winds, wetting and drying, and freezing and thawing being contributing factors. Accelerated cutting, sliding, and slumping appeared to occur during high flows. Assuming 50 percent of the Boe raw bank material became suspended sediment during the high flows of November and December 1977, about 1,310 tons were contributed during this period. This represented some 22 percent of the total amount of sediment added to 21.6-mile section of the Deschutes between Vail and the mouth.

There are more than 12 erosion banks along the Deschutes River. Also, several raw banks in addition to the Boe site were identified along the lower Deschutes. These do not include eroding banks less than about 15 feet high. Thorson and Othberg (1978) identified ten major raw bank areas in about a five-mile stretch of the Upper Deschutes between Fall Creek and Deschutes Falls (Figure 1).

Turbidity Monitoring

The Deschutes mainstem at Station A had the highest values of all stations while the upper Deschutes (Station B) had the lowest values. The tributaries and mainstem streambed between Stations A and D appeared to be the main factors contributing to the higher values found at Station A. Figure 8 shows daily turbidity values for all stations for December 1 through December 26, 1977.

DISCUSSION AND CONCLUSIONS

An estimated 3,043 tons (25 percent) of the 12,233 tons of suspended sediment originating from the upper Deschutes basin during November and December 1977 came from the tributaries monitored. The stream banks and channel appeared to account for the 9,190 ton (75 percent) difference. Another 6,029 tons was picked up along the lower Deschutes, nearly all of which appeared to come from the mainstem. These results indicate that the majority of the 18,262 tons (67 percent) of suspended sediments transported to Capitol Lake by the Deschutes River during the two-month monitoring period originated from the streambed and banks along the mainstem itself,

At least 12 large actively eroding banks are known to exist along the river, Eleven of these documented banks are located in the upper basin.

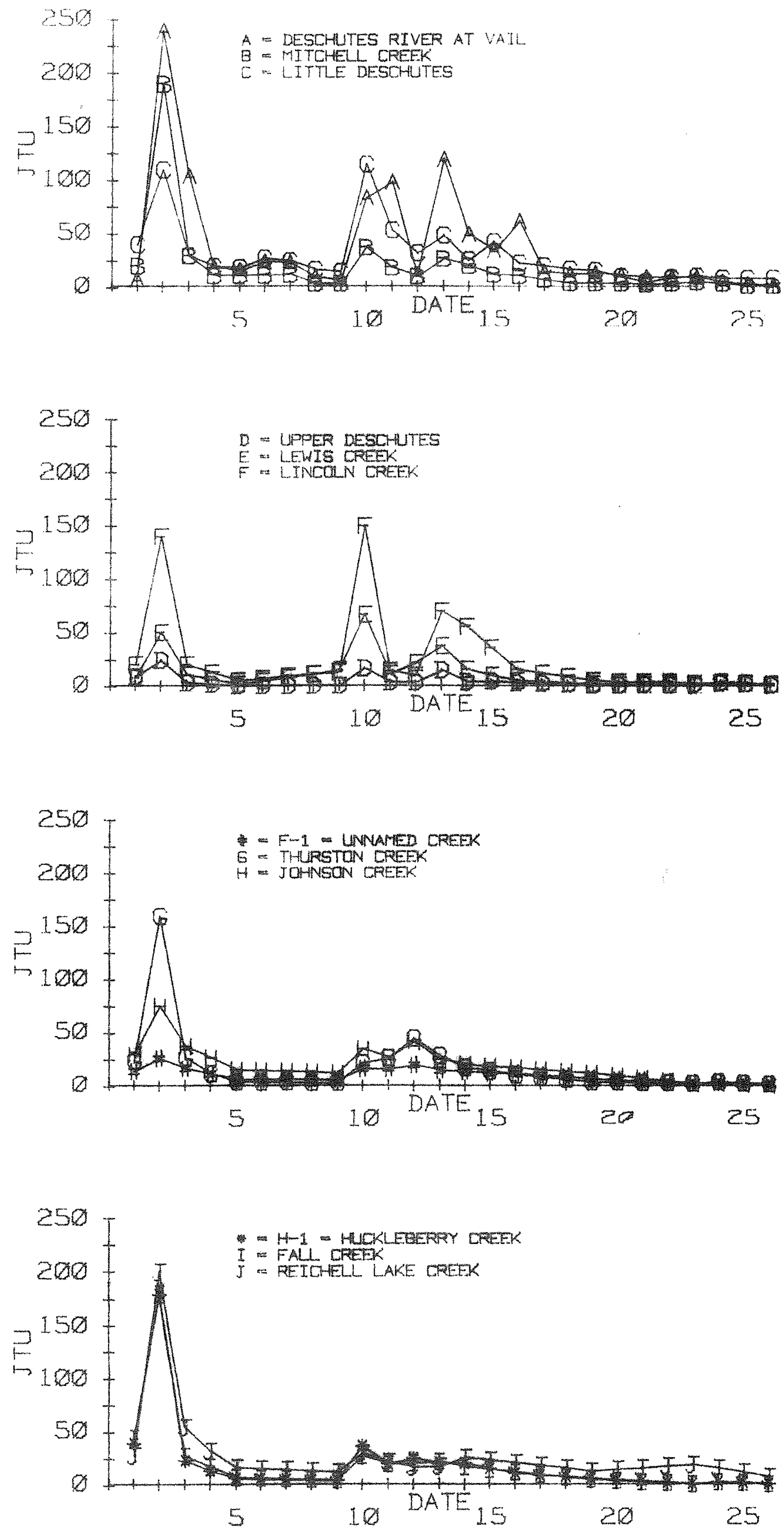

FIGURE 8. DESCHUTES RIVER SUSPENDED SEDIMENT TRANSPORT STUDY. TURBIDITY IN JACKSON TURBIDITY UNITS (JTU) FOR ALL STATIONS, DEC. 1 - 26 1977.

The banks studied in this area contributed about 304 tons between January 1977 and January 1978. A twelfth bank, located in the lower basin, contributed an estimated 1,310 tons to the river between April 1977 to January 1978. These two banks accounted for about 7 percent of the total amount of sediment transported to Capitol Lake (23,131 tons) during the year.

The effects of forest practices did not appear to have a large impact upon the river's suspended sediments if the tributaries are considered to be the source of logging originated sediments. However, as logging continues in the watershed such tools as slope and soil stability studies and other protective measures should be employed to avoid excessive sediment production. Fishery reproduction and rearing habitat in a stream susceptible to erosional problems may be adversely affected under certain conditions even though the stream does not substantially contribute to sediment transport in the mainstem below.

The dominant erosional force appears to be natural erosion of the mainstem banks and channel. These processes could be controlled to a certain extent. The Federal Soil Conservation Service proposes that if the Deschutes River were protected by rock riprap that suspended sediments entering Capitol Lake could be reduced by about 25 to 30 percent (Limeberry, 1970).

The tributaries in the upper Deschutes all empty into the same river, however, their flow and suspended sediment production characteristics are quite different. Mitchell Creek was considered to be the "stable" area and the Little Deschutes the actively logged area. As the study progressed it became evident that it is extremely difficult to directly compare the cause of one stream's suspended sediment output with another. The large number of variables such as soil types, flow volumes, stream gradients, and associated flow speeds and exposure to storm fronts make cause-and-effect relationships almost impossible to determine, at least for a short-term study. Causes possibly could be understood if a specific stream were studied and one or two conditions varied, such as a land use. It might also be possible to definitively determine causes of sediment if a large sample of stream types were used.

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