Effects of Water-Borne Pollutants on Salmon-Passage at John Day Dam, Columbia River (1982–1984)

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COASTAL ZONE AND ESTUARINE STUDIES

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BACKGROUND

Migrating adult salmonids have been found to delay for an inordinate time before passing John Day Dam on the Columbia River. The fishways and flows there are not substantially different from those at other large dams, in particular those at Bonneville and The Dalles Dams, located downstream, where apparently there are no such passage delays. Recent cooperative studies between the National Marine Fisheries Service (NMFS) and the U.S. Army Corps of Engineers (CofE) have suggested that these migratory delays are related to and may be caused by industrial pollutants in the forebay of the John Day Dam.

In 1982, it was determined, from studies of the distributions of a large number of pollutants, that the reported fish-passage delays might be caused in part by fluorides, free heavy metals (cadmium, copper, lead, and zinc), and/or aromatic hydrocarbons. Each of these pollutants, especially the first and third categories, appeared to be related to activities at the primary aluminum-production plant located on the north shore of the reservoir just upstream from John Day Dam. Because of the apparent relationship of fluoride concentrations around John Day Dam to the reported discharges of fluoride from the aluminum plant, and because of the relative intractability of experimentation with heavy metals and hydrocarbons, it was decided to focus research on the effects of fluoride on the migratory behavior of adult salmon.

The rationale, approach, and methods for the field studies in the John Day Dam region are outlined in Damkaer (1983). Studies on the effects of low levels of fluoride on the behavior of returning salmon were added in the second year of the investigation; these experiments are described in Damkaer and Dey (1984). Both the field and behavioral components were continued in this third and final year of the adult salmon delay investigation at John Day Dam.

1982 Fluoride Levels

The fluoride discharges by the aluminum plant were relatively high in 1982, continuing a several-year pattern. The average daily fluoride discharge in 1982 was 846 lbs, with an average monthly maximum discharge of 1,792 lbs. From April to June 1982, fluoride concentrations in the John Day forebay, particularly along the north shore, were generally above 0.2 ppm, against a likely Columbia River background of 0.1 ppm or less. The maximum fluoride concentrations were usually along the forebay's north shore, close to the aluminum plant outfall, and ranged between 0.3 and 0.5 ppm, although high fluoride concentrations could be rather uniform within the area under the influence of strong westerly winds.

Median passage times for chinook salmon observed at John Day Dam in fall 1982 were comparable to the unacceptably long times of previous years--on the order of a week (Stuehrenberg[1/]). This compared unfavorably with passage times of 2 days and 1 day, respectively, at Bonneville Dam and The Dalles Dam, the two lower dams. Although we did not measure fluorides at John Day Dam before 1982, it is probable that the fluoride concentrations for the previous decade did not differ substantially from the 1982 concentrations of ca. 0.3-0.5 ppm. It had also been noted with alarm that a decreasing proportion of returning chinook salmon were reaching McNary Dam, the next dam above John Day Dam. The 1980-82 3-year average interdam "unaccountable loss" was 55% of upriver-bright fall chinook salmon passing Bonneville Dam (DeVore[2/]).

1/ L. Stuehrenberg, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, WA 98112; pers. commun.

2/ J. DeVore, Washington Department of Fisheries, P.O. Box 999, Battleground, WA 98604; pers. commun.

The large-scale bioassay studies, during 1983 at Big Beef Creek, the University of Washington's Experimental Station on Hood Canal, indicated that the behavior of returning chinook, coho, and chum salmon could be adversely affected by fluoride concentrations of ca. 0.5 ppm (Damkaer and Dey 1984).

1983 Fluoride Levels

The aluminum plant located near John Day Dam began using a pollutant landfill-storage system in January 1983. As a result, the 1983 fluoride discharges to the Columbia River were about one-fourth those of previous years. Disregarding September and October, when the new treatment system malfunctioned, the average daily fluoride discharge in 1983 was 235 lbs, with an average monthly maximum of 635 lbs.

Probably as a consequence of reduced fluoride discharge by the aluminum plant, the 1983 fluoride concentrations in the John Day Dam region were significantly less than in 1982. The general fluoride levels in the forebay were 0.10-0.15 ppm, and even near the aluminum-plant outfall they did not exceed 0.17 ppm. Unfortunately, there were no observations of fish-passage times in 1983. However, the interdam loss of fall chinook salmon to McNary Dam was only 11%, the lowest since 1972(DeVore[2/]).

1984 OBSERVATIONS

The 1984 studies involved monitoring fluorides at critical areas above and below John Day Dam from April through December. In addition, daily fluoride measurements were taken in the adult fishways at John Day Dam (to mid-November). Tests on effects of fluorides on adult salmon behavior were also conducted at Big Beef Creek (August through December).

Nine cruises were completed in the John Day Dam region between 11 April and 14 December:

I.	11-12 April	V.	9-11 July
II.	7-8 May	VI.	30 July-1 August
III.	20-22 May	VII.	15-18 September
IV.	10-12 June	VIII.	16-19 October
		IX.	12-14 December

Physical measurements, taken at the same transects, stations, and depths as in previous years (Fig. 1), included temperature, pH, conductivity, dissolved oxygen, and turbidity (Appendix Table 1; Appendix Figs. 1-16); and fluoride concentrations (Appendix Table 2; Appendix Figs. 17-25).

Daily fluoride and turbidity measurements from each fishway are given in Appendix Table 3. The north/south fishway preference pattern (of salmonids[3/] counted to 10 November) was similar to that reported for 1982 and 1983 (Fig. 2). Until mid-May there were strong fluctuations in preference between the two fishways. After mid-May there was a strong and fairly steady preference for the south fishway. By mid-October the strong preference for the south fishway abated, and for the remainder of the counting period the fishway-preference again fluctuated. The daily percentages of salmonids using the north fishway continue to appear unrelated to the daily fluoride concentrations in either fishway (Damkaer and Dey 1984). The periods of lowest fluoride concentration (mid-June to mid-September) were similar in 1983 and 1984, and were also the periods during which most salmonids used the south fishway. This relationship, however, is believed to be secondary, with both the fluoride concentration and fishway preference related to water flows.

[3/] Includes mostly chinook and coho salmon, and steelhead.

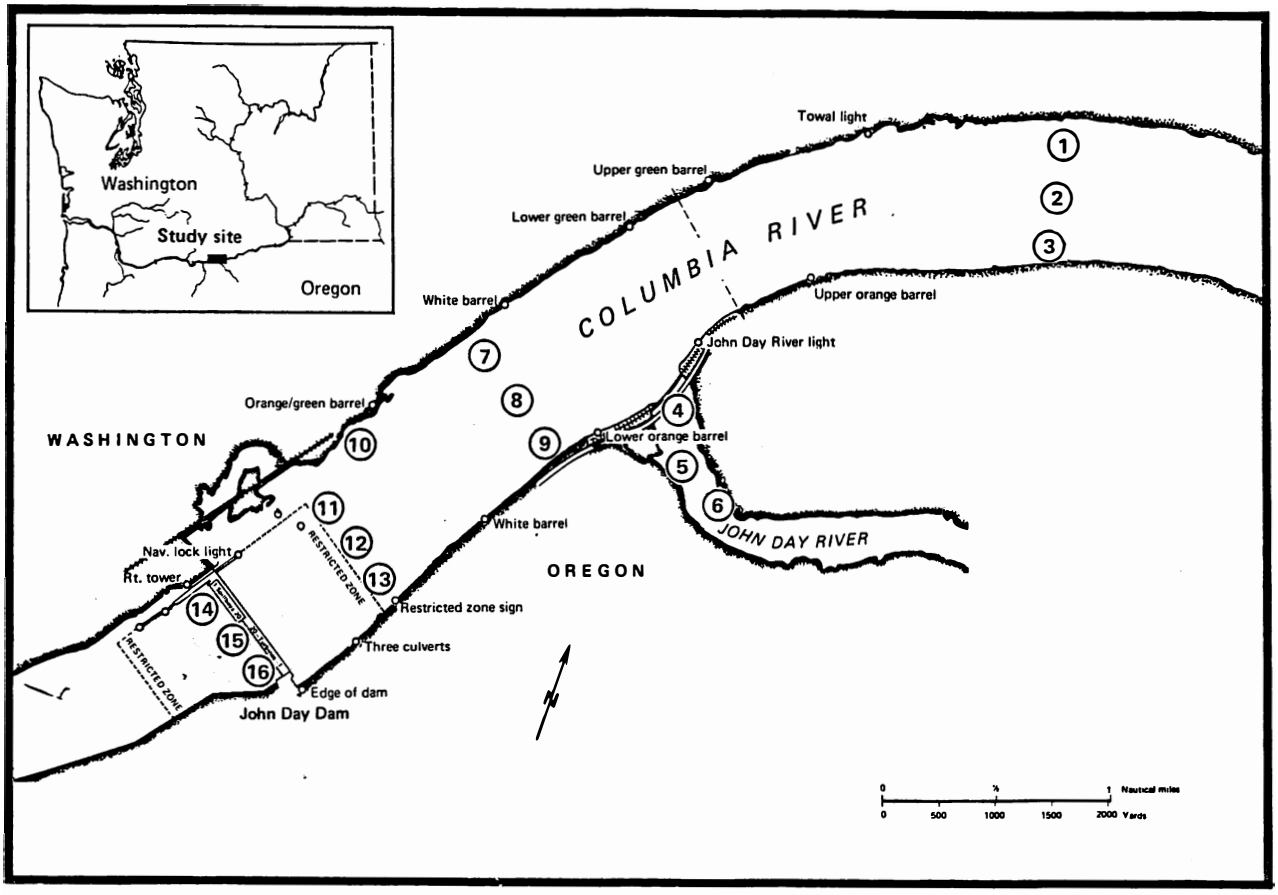

Figure 1.-- Study area for adult salmonid passage-delay program, John Day Dam region, Columbia River. Circled numbers indicate sampling sites (three sites on downstream side of The Dalles Dam not shown).

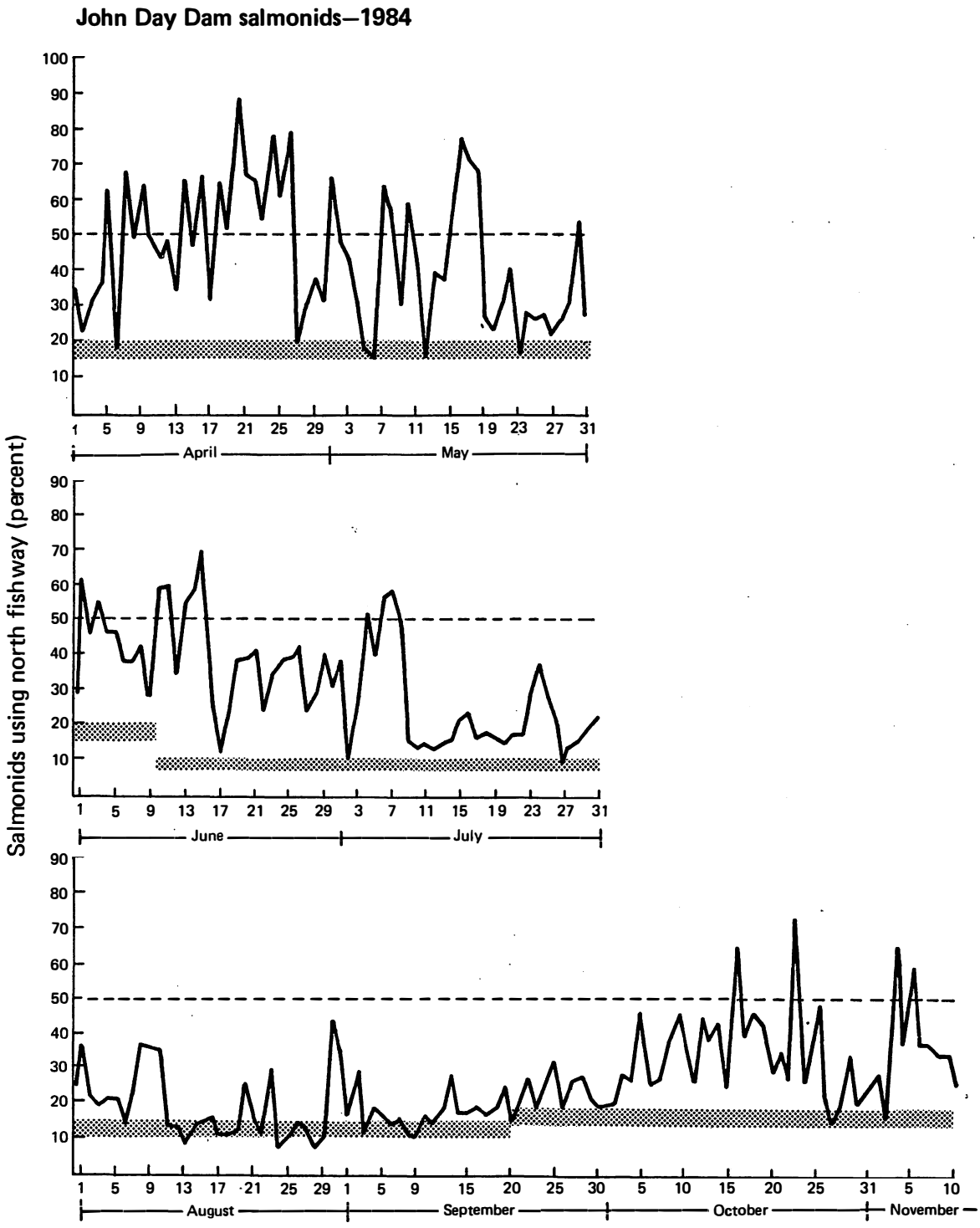

Figure 2.--Returning adult salmonids using north fishway at John Day Dam, Columbia River, 1984; through 10 November 33% passed the north fishway and 67% passed the south fishway. Horizontal bars are ranges of fluoride ion in the north and south fishways ($X\ 10^{-2}$ ppm).

Daily turbidity measurements were not taken before 25 April; preliminary analyses of passage preference and fishway turbidity do not indicate a relationship.

Fluoride Distributions

The fluoride discharges from the aluminum plant at John Day Dam continued to be low during 1984 (Table 1). The average daily fluoride discharge was 282 lbs, with an average monthly maximum of 676 lbs. This is close to the fluoride discharge reported in 1983.

These low fluoride discharges are reflected in the continued low fluoride concentrations in the main Columbia River (Appendix Table 2; Appendix Figs. 17-25). The surface fluoride concentrations rarely approached 0.3 ppm, and were generally 0.1-0.2 ppm, even near the aluminum-plant outfall. The highest fluoride concentration in the fishways was about 0.3 ppm, but by far most observations there also indicated a range of 0.1-0.2 ppm fluoride (Fig. 2; Appendix Table 3). On nearly all days there was no significant difference in fluoride concentrations between fishways.

Fish passage was monitored in spring 1984, and the median passage-time for chinook salmon was 40 hours. Thus there was a very significant decrease in passage time at John Day Dam that relates theoretically and empirically to the decreased fluoride levels in the fishways. The proportion of salmonids reaching McNary Dam was comparable to the high values of 1983, and some up-river stocks returned at higher numbers than in decades.

It should be noted that the fluoride content of two rivulets entering the large lagoon, on the north shore upstream from the dam, is extraordinarily high (up to 10 ppm) (Appendix Table 2). This appears to be unreported, fugitive fluoride, perhaps leaking from the aluminum plant's new discharge

Table 1.--Fluoride discharges reported to Washington Department of Ecology by the aluminum plant at John Day Dam for 1984. Values have been adjusted to allow for a Columbia River background of 10 lbs/d.

Month	At treatment plant[a/] (lbs/d)		Discharge to river (lbs/d)	
	Average	Maximum	Average	Maximum
Jan	0	1.7	402	816
Feb	0	4.3	233	470
Mar	0	3.7	306	897
Apr	0	1.3	418	1,215
May	0	3.4	286	828
Jun	0	1.7	267	1,046
Jul	0	2.4	278	427
Aug	0.9	7.5	286	471
Sep	0	3.1	203	329
Oct	0	12.2	172	247
Nov	2.7	19.6	183	512
Dec	5.3	18.5	353	861[b/]

a/ DOE permit limit at treatment plant: average 25 lbs/d, maximum 50 lbs/d.

b/ Omitting 23-24 December, with 2,848 and 2,192 lbs.

settling pond on the slope above. These concentrations are higher than we generally have noted in the outfall discharge settling ponds. While the total daily fluoride additions through these rivulets are estimated at only 10 lbs/day (ca. 5% of the routine plant discharges), this fluoride enters an area of low flushing and low dispersion. It is expected that the lagoon fluoride concentration, already nearly twice that of the main river (Appendix Table 2), will continue to increase. An equilibrium will be reached that may lead to a significantly high fluoride concentration at the north fishway. This fugitive fluoride discharge, and presumably the associated organic compounds reported from 1982, may also have significant impacts on the CofE public park at the lagoon, since one of the rivulets flows through this public area.

Behavior Experiments

The principal bioassay tests were again conducted at Big Beef Creek (Damkaer and Dey 1984). From September through December 1984, 178 tests were conducted using returning chinook and coho salmon.

One of two branches of Big Beef Creek was furnished with a two-choice flume (Fig. 3). An 8-m partition longitudinally divides this flume. Upstream migrants can choose to proceed into the left or right arms, which are otherwise equivalent. Once a few meters into either side, fish are kept there by a funnel-trap. At the head of this two-choice flume, about 15 m from the starting point (fish acclimating area), a 55-liter carboy empties into the flowing creek water at <u>each</u> of the two arms of the flume. The flow-rates are identical from each carboy, adjusted to empty in about 1 h. Control tests were conducted using <u>no</u> fluoride in either carboy. Most of the other tests were conducted using sodium fluoride in only one carboy (randomly chosen each day). The fluoride concentration was established to result in approximately

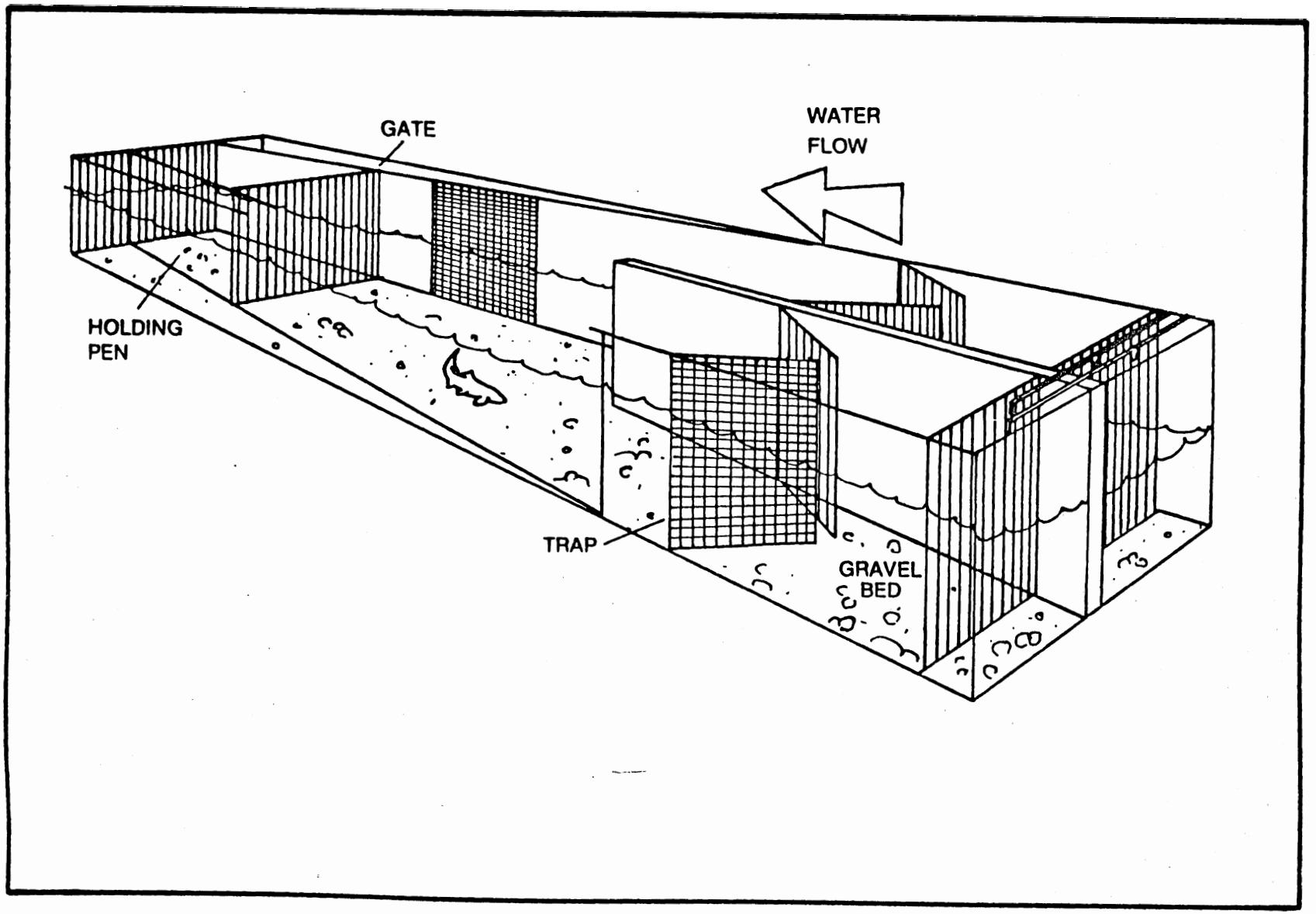

Figure 3.--Two-choice flume for fluoride-gradient salmon-behavior tests, diagrammatic view.

0.2 ppm fluoride in the treatment arm of the flume. This concentration is similar to the fluoride levels we observed in the Columbia River at John Day Dam during 1983 and 1984.

Fish were tested one at a time and were allowed to acclimate about 10 min in the holding area downstream from the two-choice flume. A gate was then carefully raised from behind a concealed observation area, and each fish was allowed 20 min to move upstream or not.

In the 1983 experiments, using fluoride concentrations of ca. 0.5 ppm, the returning salmon indicated a significant adverse reaction. In 1984, similar experiments were conducted but, as mentioned above, with the fluoride concentration reduced to about 0.2 ppm. As in 1983, tests without fluoride in either side of the flume indicated there was no preference for one side or the other among either the returning chinook or coho salmon (Appendix Tables 4 and 5). The data from 1984 were therefore combined with the no-fluoride data for each species from 1983.

The observations on returning chinook salmon faced with an approximately 0.2 ppm fluoride level suggested that a significant number (54%) delayed even at that low fluoride concentration (Appendix Table 4). It is possible that a number of chinook salmon were sensitive to 0.2 ppm fluoride, but this observation might also have resulted from the shorter observation times for each fish in 1984 (20 min vs about 1 h). Of the chinook salmon which continued upstream within the 20 min (46%), there was no statistically significant difference between their choices of fluoride/non-fluoride sides of the flume. It is believed, therefore, that 0.2 ppm fluoride is at or below the threshold level for fluoride sensitivity in returning chinook salmon at Big Beef Creek.

The observations on returning coho salmon faced with an approximately 0.2 ppm fluoride concentration suggested that they reacted as they would have been expected to if there had been no fluoride at all (Appendix Table 5). Therefore, it is believed that 0.2 ppm fluoride is below the threshold concentration for fluoride sensitivity in returning coho salmon at Big Beef Creek.

SUMMARY AND CONCLUSIONS

1. There is evidence, both empirical and theoretical, that fluoride from the aluminum plant at John Day Dam has a very significant impact on adult salmon passage time and survival over the dam. The 1982 fluoride concentrations of 0.3-0.5 ppm at the dam were probably representative of fluoride levels of the previous several years. During those years the fish-passage times and interdam losses were unacceptably high. Bioassay experiments, on the behavior of returning salmon, suggested that fluoride concentrations ca. 0.5 ppm would adversely affect the migration of adult salmon. Subsequent bioassay experiments indicated that 0.2 ppm fluoride was at or below the threshold for fluoride sensitivity in chinook salmon and below the threshold for fluoride sensitivity in coho salmon. In 1983, the aluminum plant fluoride discharge was significantly reduced, and the fluoride concentrations in the main river were nearly half of those in 1982. Although no passage times were measured at John Day Dam in 1983, the interdam loss was the lowest since 1972. Low fluoride concentrations in the main river continued through 1984. A median passage time of 2 days was observed for spring chinook salmon in April 1984, and the proportion of salmon reaching McNary Dam was comparable to the high value of 1983.

2. There are indications, however, that the present fluoride situation at John Day Dam is only temporary. The current low discharges of fluoride are the result of precipitation and storage of fluoride in adjacent land-fills. We have monitored extraordinarily high fluoride concentrations (to 10 ppm) in free rivulets possibly originating from the land-fills. It is likely that fluoride levels will continue to build in the large lagoon near the north fishway, and ultimately the fluoride concentrations at the fishway may reach previous high levels.

3. In view of the apparent critical role of fluoride in salmonid passage and survival, it would be fruitful to expand the recent studies and prepare a fluoride budget for the entire Columbia River system. There are natural sources of fluoride, but the "natural" fluoride level cannot be determined without extensive sampling. It is obvious that the natural fluoride regime is overwhelmed by the industrial sources, of which there are several, generally in conjunction with hydroelectric projects. The possibilities, then, that fluoride interacts at other fishways are great, although it may prove that it is the relative position of discharge and fishway that is most important. For example, at John Day Dam, the aluminum plant discharge is just upstream of the fishways. For the aluminum plant at The Dalles Dam, the discharge is downstream of the fishways, and the returning salmonids need contend with only one obstacle at a time. There is another aluminum plant in conjunction with a dam at Wenatchee, Washington, and there are aluminum plants alone at Spokane, Vancouver, and Longview, Washington, and Sandy, Oregon. It is not known what the relative impacts of these sources are on the fluoride concentrations of the Columbia River, nor what might be the impact on the salmonids.

4. Besides fluoride there are low and apparently increasing levels of some organic compounds (chlorinated and aromatic hydrocarbons) in the water and sediments around John Day Dam. The aromatic hydrocarbon content of the sediments (average 8,300 ppb) approaches that found in the Duwamish Waterway (Seattle, Washington) (average 11,000 ppb), which is classed as one of the top ten most-polluted areas in the U.S. We have no information yet on the role these organic compounds might have in fish passage, but the existence of the compounds in the area, and their association with the aluminum-production process, is documented.

5. The recently reduced fluoride discharges near John Day Dam have provided a remarkable opportunity to test the early hypothesis that industrial fluorides (on the order of 0.3 ppm) may be implicated in the passage delay of adult salmonids. Field observations of passage times in 1984, coupled with surveys of the continuing lower-level fluoride, have given the best evaluation of this research to date. One must note that while direct fluoride discharges have decreased markedly near John Day Dam, the possible heavy-metal activations and hydrocarbon accumulations may be unchanged. What fraction of salmonid passage-delay, if any, is due to heavy metals and hydrocarbons has yet to be determined. Future work, therefore, should continue to have both pollutant-monitoring and bioassay/behavior components aimed at the specific problem of Columbia River adult salmonid passage-delay.

ACKNOWLEDGMENTS

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APPENDIX

Tables 1-5

Figures 1-25

Appendix Table 1.--Physical characteristics of river water and other aquatic sites in the John Day Dam region, Columbia River, April-December 1984 (see Figure 1 for station locations).

1984 Cruise I
April 11-12
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Turbidity (NTU)
1	11 Apr	1710	37.7	0	8.5	14.0
				15	8.5	15.0
				30	8.2	17.0
2	11 Apr	1655	35.6	0	8.5	16.0
				15	8.3	17.0
				30	8.2	18.0
3	11 Apr	1735	33.2	0	8.4	16.0
				15	8.2	18.0
				30	8.2	18.0
4	11 Apr	1755	18.3	0	8.4	52.0
				10	7.6	88.0
				18	7.8	92.0
6	11 Apr	1815	27.7	0	7.8	86.0
				15	7.5	90.0
				27	7.2	90.0
10	11 Apr	1630	32.6	0	8.5	15.0
				15	8.4	16.0
				30	8.3	16.0
10	12 Apr	0900	32.6	0	8.4	15.0
				15	8.3	15.0
				30	8.2	16.0
14 - J. Day Dam N. Fishway	12 Apr	1340	-	0	9.2	19.0
16 - S. Fishway	12 Apr	1400	-	0	9.5	18.0
17 - The Dalles Dam (N)	11 Apr	1430	-	0	9.3	20.0
19 - The Dalles Dam (S)	11 Apr	1445	-	0	9.3	21.0

Appendix Table 1.--Continued.

1984 Cruise I (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Turbidity (NTU)
Bonneville Dam	11 Apr					
S-end old powerhouse		1315	-	0	9.3	18.0
S-end spillway		1300	-	0	8.9	21.0
S-end new powerhouse		1245	-	0	9.4	20.0
N-end fishway		1205	-	0	-	19.0
Additional Stations:						
Slough N-end J. Day Dam	12 Apr	1145	-	0	8.9	2.0
Shore near Station 11	12 Apr	1155	-	0	9.3	15.0
Lagoon near L-1	12 Apr	1210	-	0	9.9	7.0
Lagoon float near L-2	12 Apr	1000	-	0	8.8	5.0
N-shore below JDD;	12 Apr					
Between tower and nav-lock		1110	-	0	8.4	18.0
Upstream of tower		1120	-	0	8.4	18.0
Downstream of tower		1130	-	0	8.4	19.0
S-shore below JDD;	12 Apr					
Between nav-lock and entrance jetty		1415	-	0	8.6	18.0
End of nav-lock jetty		1425	-	0	8.6	19.0
Opposite tower		1430	-	0	8.7	23.0

Appendix Table 1.--Continued.

1984 Cruise II
May 7-8
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
1	7 May	0840	35.0	0	10.90	0.15	9.4	9.0
				5	10.19	0.15	10.3	-
				10	10.15	0.15	10.6	-
				15	10.13	0.15	10.8	11.0
				20	10.14	0.15	11.0	-
				25	10.16	0.15	11.2	-
				30	10.20	0.15	11.4	11.0
2	7 May	0915	35.0	0	11.38	0.15	9.1	7.0
				5	10.07	0.15	9.8	-
				10	10.06	0.15	10.1	-
				15	10.03	0.15	10.3	10.0
				20	10.03	0.15	10.5	-
				25	10.03	0.15	10.6	-
				30	10.09	0.15	11.1	10.0
3	7 May	0940	35.0	0	10.89	0.15	9.0	8.0
				5	10.07	0.15	9.8	-
				10	10.03	0.15	10.1	-
				15	10.03	0.15	10.3	12.0
				20	10.03	0.15	10.5	-
				25	10.04	0.15	10.7	-
				30	10.08	0.15	10.7	12.0
4	7 May	1250	22.0	0	13.12	0.15	10.3	28.0
				5	11.77	0.15	11.0	-
				10	11.27	0.15	11.3	32.0
				15	10.72	0.15	11.6	-
				20	10.53	0.15	11.9	44.0

Appendix Table 1.--Continued.

1984 Cruise II (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
6	7 May	1330	25.0	0	14.99	0.15	8.8	26.0
				5	11.95	0.15	10.0	-
				10	11.85	0.15	10.4	31.0
				15	11.00	0.15	10.9	-
				20	10.53	0.15	11.2	-
				22	10.62	0.15	11.2	34.0
7	7 May	1000	35.0	0	10.86	0.15	8.9	9.0
				5	10.15	0.15	9.8	-
				10	10.14	0.15	10.1	-
				15	10.16	0.15	10.4	11.0
				20	10.17	0.15	10.5	-
				25	10.19	0.15	10.6	-
				30	10.23	0.15	10.8	10.0
8	7 May	1030	35.0	0	10.68	0.15	8.8	11.0
				5	10.19	0.15	9.7	-
				10	10.15	0.15	10.0	-
				15	10.11	0.15	10.2	11.0
				20	10.12	0.15	10.5	-
				25	10.14	0.15	10.8	-
				30	10.18	0.15	10.8	11.0
9	7 May	1045	35.0	0	11.15	0.15	8.3	15.0
				5	10.14	0.15	9.3	-
				10	10.10	0.15	9.6	-
				15	10.05	0.15	9.9	15.0
				20	10.05	0.15	10.1	-
				25	10.05	0.15	10.3	-
				30	10.11	0.15	10.7	19.0

Appendix Table 1.--Continued.

1984 Cruise II (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
10	7 May	0715	35.0	0	10.31	0.15	10.2	10.0
				5	10.14	0.15	10.9	-
				10	10.15	0.15	11.1	-
				15	10.13	0.15	11.3	14.0
				20	10.10	0.15	11.4	-
				25	10.09	0.15	11.4	-
				30	10.09	0.15	11.5	12.0
10	7 May	1400	35.0	0	11.44	0.16	9.0	11.0
				5	11.45	0.16	9.8	-
				10	10.30	0.16	9.9	-
				15	10.20	0.16	10.2	10.0
				20	10.20	0.16	10.4	-
				25	10.20	0.16	10.5	-
				30	10.22	0.16	10.6	10.0
L-1	7 May	1345	9.0	0	12.05	0.17	11.6	5.0
				5	10.98	0.17	11.7	-
				8	11.09	0.17	11.8	6.0
L-2	7 May	1500	10.0	0	13.42	0.18	11.6	4.0
				5	11.11	0.18	11.9	-
				8	11.26	0.18	12.0	5.0
11	7 May	1100	35.0	0	10.75	0.16	8.3	10.0
				5	10.30	0.15	9.1	-
				10	10.27	0.15	9.4	-
				15	10.19	0.16	9.5	12.0
				20	10.19	0.16	9.9	-
				25	10.21	0.15	10.2	-
				30	10.25	0.15	10.3	12.0

Appendix Table 1.--Continued.

1984 Cruise II (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
12	7 May	1145	35.0	0	10.94	0.16	11.2	12.0
				5	10.18	0.16	11.9	-
				10	10.15	0.16	12.2	-
				15	10.16	0.16	12.5	11.0
				20	10.16	0.16	12.8	-
				25	10.18	0.16	13.1	-
				30	10.21	0.16	13.5	11.0
13	7 May	1210	35.0	0	11.52	0.16	8.7	15.0
				5	10.19	0.16	9.5	-
				10	10.13	0.16	9.8	-
				15	10.10	0.16	10.0	13.0
				20	10.08	0.16	10.4	-
				25	10.10	0.16	10.8	-
				30	10.21	0.16	11.0	12.0
14+1 (downstream JDD)	8 May	0810	18.0	0	10.31	0.16	11.0	10.0
				5	10.34	0.16	12.2	10.0
				10	10.36	0.16	12.4	10.0
				15	10.40	0.16	12.4	10.0
15+1 (downstream JDD)	8 May	0830	15.0	0	10.24	0.16	11.3	11.0
				5	10.25	0.16	12.7	11.0
				10	10.27	0.16	12.9	11.0
16+1 (downstream JDD)	8 May	0900	-	0	10.30	0.16	11.9	12.0
				3.5	-	-	-	11.0

Appendix Table 1.--Continued.

1984 Cruise IV
June 10-12
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
1	11 Jun	0721	35.0	0	13.28	-	0.115	10.3	3.7	14.0
				5	13.18	-	0.115	11.3	3.7	-
				10	13.18	-	0.116	11.6	3.7	-
				15	13.18	-	0.116	11.8	3.7	15.0
				20	13.18	-	0.116	12.0	3.7	-
				25	13.18	-	0.116	12.2	3.7	-
				30	13.18	-	0.115	12.3	3.7	15.0
2	11 Jun	0745	35.0	0	13.27	6.8	0.116	10.5	3.7	13.0
				5	13.25	6.8	0.115	11.3	3.7	-
				10	13.13	6.7	0.116	11.6	3.7	-
				15	13.14	6.7	0.116	11.8	3.7	15.0
				20	13.14	6.7	0.116	11.9	3.7	-
				25	13.14	6.7	0.115	12.1	3.7	-
				30	13.16	6.6	0.116	12.4	3.7	16.0
3	11 Jun	0830	35.0	0	13.26	-	0.116	10.4	3.7	13.0
				5	13.15	-	0.116	11.5	3.7	-
				10	13.14	-	0.116	11.7	3.7	-
				15	13.13	-	0.116	12.0	3.7	14.0
				20	13.15	-	0.116	12.2	3.7	-
				25	13.15	-	0.116	12.5	3.7	-
				30	13.13	6.8	0.116	12.6	3.7	17.0
4	11 Jun	0920	25.0	0	13.86	7.1	0.125	9.7	3.9	26.0
				5	13.64	7.1	0.125	10.7	3.7	-
				10	13.61	7.1	0.126	10.9	3.7	26.0
				15	13.54	7.0	0.126	11.3	3.7	-
				20	13.45	7.0	0.126	11.5	3.7	27.0

Appendix Table 1.--Continued.

1984 Cruise IV (cont).

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
6	11 Jun	1000	25.0	0	14.25	7.1	0.125	10.3	3.7	25.0
				5	14.11	7.1	0.126	10.4	3.7	-
				10	13.92	6.9	0.126	11.3	3.7	25.0
				15	13.81	6.9	0.126	11.6	3.7	-
				20	13.17	6.9	0.126	12.0	3.7	26.0
7	11 Jun	1110	35.0	0	13.35	7.0	0.118	10.3	3.7	13.0
				5	13.25	-	0.118	11.4	3.7	-
				10	13.23	-	0.118	11.8	3.7	-
				15	13.19	-	0.118	12.0	3.7	13.0
				20	13.21	-	0.119	12.4	3.7	-
				25	13.22	-	0.119	12.7	3.7	-
				30	13.28	-	0.118	13.0	3.7	14.0
8	11 Jun	1045	35.0	0	13.24	7.2	0.118	10.2	3.7	13.0
				5	13.12	7.2	0.117	11.3	3.7	-
				10	13.13	7.2	0.118	11.7	3.7	-
				15	13.12	7.1	0.118	11.9	3.7	15.0
				20	13.12	7.2	0.118	12.2	3.7	-
				25	13.13	7.1	0.118	12.5	3.7	-
				30	13.19	7.1	0.118	12.8	3.7	14.0
9	11 Jun	1020	30.0	0	13.48	7.3	0.123	9.8	3.7	21.0
				5	13.35	7.2	0.123	11.0	3.7	-
				10	13.24	7.2	0.121	11.3	3.7	-
				15	13.29	7.0	0.123	11.6	3.7	17.0
				20	13.27	6.9	0.120	11.7	3.7	-
				25	13.18	6.8	0.121	11.9	3.7	-
				28	13.23	6.6	0.120	12.0	3.7	23.0

Appendix Table 1.--Continued

1984 Cruise IV (cont).

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
10	11 Jun	1130	30.0	0	13.28	7.1	0.119	10.3	3.7	13.0
				5	13.22	7.0	0.119	11.3	3.7	-
				10	13.18	7.0	0.119	11.7	3.7	-
				15	13.20	7.0	0.119	12.0	3.7	13.0
				20	13.19	7.0	0.119	12.4	3.7	-
				25	13.22	7.0	0.118	12.5	3.7	-
				29	13.25	6.9	0.118	12.8	3.7	13.0
10	12 Jun	0930	35.0	0	13.45	7.0	0.119	10.4	3.8	12.0
				5	13.36	7.0	0.119	11.4	3.8	-
				10	13.36	6.9	0.119	11.7	3.8	-
				15	13.36	6.9	0.119	12.1	3.8	13.0
				20	13.36	6.9	0.119	12.6	3.8	-
				25	13.36	6.9	0.119	12.9	3.8	-
				30	13.38	6.9	0.119	13.3	3.8	12.0
L-1	12 Jun	1010	10.0	0	14.64	7.2	0.149	10.3	3.8	4.0
				5	14.51	7.2	0.147	11.2	3.8	-
				9	14.01	6.8	0.146	11.4	3.8	6.0
L-2	12 Jun	1030	18.0	0	14.51	7.1	0.151	9.8	3.7	4.0
				5	14.10	-	0.153	11.1	3.8	-
				10	13.72	-	0.154	11.4	3.8	-
				15	13.62	6.8	0.157	11.7	3.8	5.0
11	12 Jun	0910	35.0	0	13.39	7.0	0.119	11.0	3.8	12.0
				5	13.35	6.9	0.118	11.3	3.8	-
				10	13.35	6.9	0.118	11.8	3.8	-
				15	13.35	6.9	0.118	12.0	3.8	13.0
				20	13.35	6.8	0.118	12.3	3.9	-
				25	13.35	6.8	0.118	12.5	3.9	-
				30	13.36	6.7	0.118	12.9	3.9	14.0

Appendix Table 1.--Continued.

1984 Cruise IV (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
12	12 Jun	0845	35.0	0	13.35	7.0	0.118	10.5	3.8	13.0
				5	13.33	7.0	0.118	11.4	3.8	-
				10	13.33	7.0	0.118	11.7	3.8	-
				15	13.33	7.0	0.118	12.0	3.8	13.0
				20	13.34	6.8	0.118	12.3	3.8	-
				25	13.34	6.8	0.118	12.6	3.8	-
				30	13.35	6.8	0.117	13.6	3.9	14.0
13	12 Jun	0800	35.0	0	13.49	-	0.119	10.6	3.8	13.0
				5	13.46	-	0.118	11.4	3.8	-
				10	13.32	-	0.118	11.8	3.8	-
				15	13.27	-	0.118	12.2	3.8	15.0
				20	13.28	7.1	0.118	12.5	3.8	-
				25	13.25	7.2	0.118	12.8	3.8	-
				30	13.24	7.2	0.118	12.9	3.8	15.0
Additional Stations:										
N-shore below JDD;	12 Jun									
End of nav-lock		1140	-	0	14.5	-	-	-	-	14.0
Between nav-lock and tower		1145	-	0	13.8	-	-	-	-	13.0
At tower		1155	-	0	13.9	-	-	-	-	13.0
S-shore below JDD;	12 Jun									
Opposite nav-lock		1220	-	0	13.8	-	-	-	-	-
Opposite tower		1225	-	0	13.6	-	-	-	-	-
Last grassy area before Rufus		1230	-	0	14.5	-	-	-	-	-

Appendix Table 1.--Continued.

1984 Cruise V
July 9-11
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
1	9 Jul	1505	35.0	0	18.39	6.5	0.110	12.9	3.6	4.0
				5	18.28	6.4	0.110	13.4	3.6	-
				10	18.01	6.4	0.110	13.5	3.6	-
				15	17.97	6.3	0.110	13.7	3.6	6.0
				20	17.99	6.4	0.111	13.9	3.6	-
				25	17.97	6.5	0.111	13.8	3.6	-
				30	17.99	6.5	0.111	13.8	3.6	6.0
2	9 Jul	1533	35.0	0	18.25	6.5	0.112	12.6	3.6	5.0
				5	18.17	6.5	0.111	13.3	3.6	-
				10	18.10	6.5	0.112	13.7	3.6	-
				15	18.06	6.4	0.112	13.9	3.6	6.0
				20	18.10	6.3	0.112	14.4	3.6	-
				25	18.09	6.3	0.111	14.9	3.6	-
				30	18.14	6.4	0.112	15.2	3.6	6.0
3	9 Jul	1555	35.0	0	18.67	6.6	0.112	12.5	3.6	4.0
				5	18.54	6.5	0.112	13.3	3.6	-
				10	18.03	6.4	0.112	13.4	3.6	-
				15	17.89	6.5	0.113	13.5	3.6	6.0
				20	17.87	6.4	0.113	13.6	3.6	-
				25	17.87	6.5	0.112	13.8	3.6	-
				30	18.03	6.6	0.121	13.9	3.8	6.0
4	9 Jul	1815	25.0	0	22.86	6.9	0.157	10.8	3.6	3.0
				5	20.30	6.9	0.129	12.4	3.6	-
				10	19.40	6.9	0.115	13.2	3.5	4.0
				15	18.24	6.7	0.113	13.5	3.5	-
				20	18.18	6.7	0.112	13.7	3.5	6.0
6	9 Jul	1840	30.0	0	22.53	7.0	0.160	10.6	3.6	4.0
				5	19.47	6.7	0.133	12.3	3.6	-
				10	18.23	6.6	0.117	12.7	3.6	-
				15	18.02	6.6	0.116	12.9	3.6	5.0
				20	18.01	6.6	0.116	13.0	3.6	-
				25	17.86	6.0	0.118	13.2	3.6	5.0

Appendix Table 1.--Continued.

1984 Cruise V (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
7	10 Jul	0750	35.0	0	18.38	6.8	0.116	-	3.6	5.0
				5	18.26	6.7	0.115	-	3.6	-
				10	18.03	6.7	0.115	-	3.6	-
				15	17.98	6.7	0.114	-	3.6	4.0
				20	17.99	6.7	0.115	-	3.7	-
				25	17.98	6.7	0.115	-	3.7	-
				30	17.99	6.7	0.114	-	3.7	6.0
8	10 Jul	0715	35.0	0	18.74	6.8	0.120	-	3.7	4.0
				5	18.49	6.8	0.116	-	3.7	-
				10	18.21	6.7	0.114	-	3.7	-
				15	18.05	6.7	0.114	-	3.7	4.0
				20	17.94	6.7	0.113	-	3.7	-
				25	17.93	6.7	0.113	-	3.7	-
				30	17.90	6.7	0.113	-	3.7	5.0
9	10 Jul	0645	35.0	0	18.97	6.9	0.120	10.5	3.7	4.0
				5	18.67	6.8	0.116	11.4	3.7	-
				10	18.51	6.8	0.114	11.7	3.7	-
				15	17.91	6.7	0.113	11.8	3.7	6.0
				20	17.85	6.7	0.113	11.9	3.7	-
				25	17.85	6.7	0.112	12.1	3.7	-
				30	17.84	6.7	0.113	12.2	3.7	7.0
10	10 Jul	0915	35.0	0	18.21	6.8	0.114	11.1	3.6	4.0
				5	18.13	6.7	0.114	11.2	3.6	-
				10	18.11	6.7	0.114	11.2	3.6	-
				15	18.02	6.6	0.114	11.3	3.6	6.0
				20	18.00	6.6	0.115	11.3	3.6	-
				25	17.99	6.6	0.115	11.4	3.6	-
				30	18.00	6.6	0.115	11.3	3.6	6.0
L-1	10 Jul	1000	18.0	0	19.69	7.0	0.129	10.3	3.6	2.0
				5	18.20	6.6	0.125	9.9	3.7	-
				10	16.08	6.3	0.142	9.8	3.7	-
				15	14.38	6.4	0.162	10.2	3.6	3.0

Appendix Table 1.--Continued.

1984 Cruise V (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
L-2	10 Jul	1030	16.0	0	19.39	6.9	0.131	10.6	3.6	2.0
				5	18.08	6.6	0.131	10.8	3.6	-
				10	15.74	6.6	0.148	9.8	3.7	-
				14	14.68	6.8	0.156	11.0	3.8	3.0
11	10 Jul	0845	35.0	0	18.34	6.7	0.115	11.4	3.6	4.0
				5	18.23	6.7	0.115	11.5	3.6	-
				10	18.21	6.7	0.116	11.6	3.6	-
				15	18.13	6.6	0.115	11.4	3.6	4.0
				20	18.01	6.6	0.114	11.5	3.6	-
				25	18.01	6.6	0.114	11.7	3.6	-
				30	18.02	6.6	0.114	11.8	3.6	6.0
12	10 Jul	0910	35.0	0	18.64	6.8	0.119	10.6	3.6	4.0
				5	18.24	6.7	0.116	11.3	3.6	-
				10	18.21	6.7	0.116	11.5	3.6	-
				15	18.00	6.6	0.115	11.5	3.6	4.0
				20	17.95	6.6	0.115	11.5	3.7	-
				25	17.95	6.6	0.116	11.7	3.7	-
				30	17.96	6.6	0.115	11.9	3.8	6.0
13	10 Jul	0940	35.0	0	18.90	6.8	0.120	10.5	3.6	4.0
				5	18.54	6.7	0.119	10.8	3.6	-
				10	18.42	6.6	0.118	10.8	3.6	-
				15	18.02	6.5	0.116	10.9	3.6	4.0
				20	17.89	6.5	0.116	10.9	3.6	-
				25	17.89	6.5	0.116	11.1	3.6	-
				30	17.88	6.6	0.115	11.6	3.7	7.0

Appendix Table 1.--Continued.

1984 Cruise V (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
14 John Day Dam										
N-fishway	10 Jul	1250	-	0	-	-	-	-	-	6.0
S-fishway	10 Jul	1300	-	0	-	-	-	-	-	5.0
Additional Stations:										
N-shore; end of nav-lock	10 Jul	1345	-	0	18.2	-	-	-	-	6.0
S-shore; opposite nav-lock	10 Jul	1315	-	0	18.8	-	-	-	-	6.0

Appendix Table 1.--Continued.

1984 Cruise VI
July 30-31
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Turbidity (NTU)
1	30 Jul	1620	35.0	0	23.05	3.0
				5	22.20	-
				10	21.40	-
				15	20.75	4.0
				20	20.60	-
				25	20.60	-
				30	20.50	5.0
2	30 Jul	1635	35.0	0	22.35	3.0
				5	22.10	-
				10	21.60	-
				15	21.05	5.0
				20	20.75	-
				25	20.50	-
				30	20.40	5.0
3	30 Jul	1655	35.0	0	22.15	3.0
				5	21.30	-
				10	21.10	-
				15	20.50	5.0
				20	20.45	-
				25	20.35	-
				30	20.35	6.0
7	31 Jul	0800	35.0	0	21.60	3.0
				5	21.40	-
				10	21.10	-
				15	20.70	5.0
				20	20.40	-
				25	20.40	-
				30	20.40	5.0
8	31 Jul	0740	35.0	0	21.55	2.0
				5	21.45	-
				10	21.25	-
				15	20.45	4.0
				20	20.45	-
				25	20.35	-
				30	20.35	5.0

Appendix Table 1.--Continued.

1984 Cruise VI (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Turbidity (NTU)
9	31 Jul	0700	35.0	0	22.10	2.0
				5	21.40	-
				10	21.20	-
				15	20.65	4.0
				20	20.40	-
				25	20.30	-
				30	-	5.0
10	31 Jul	0830	35.0	0	21.45	3.0
				5	21.15	-
				10	20.75	-
				15	20.70	4.0
				20	20.60	-
				25	20.50	-
				30	20.50	4.0
11	31 Jul	0900	35.0	0	21.50	4.0
				5	21.00	-
				10	21.00	-
				15	20.70	3.0
				20	20.50	-
				25	20.45	-
				30	20.50	5.0
12	31 Jul	0920	35.0	0	22.10	3.0
				5	21.35	-
				10	21.15	-
				15	20.60	4.0
				20	20.40	-
				25	20.40	-
				30	20.40	6.0
13	31 Jul	0940	35.0	0	22.25	3.0
				5	21.40	-
				10	21.15	-
				15	20.50	5.0
				20	20.40	-
				25	20.35	-
				30	20.35	5.0

Appendix Table 1.--Continued.

1984 Cruise VI (cont).

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	Turbidity (NTU)
14 John Day Dam						
N-fishway	31 Jul	1230	-	0	-	5.0
S-fishway	31 Jul	1240	-	0	-	5.0
Additional Stations:						
N-shore; nav-lock, JDD	31 Jul	1200	-	0	21.5	-
S-shore; opposite nav-lock, JDD	31 Jul	1245	-	0	21.0	-

Appendix Table 1.--Continued.

1984 Cruise IX
December 12-14
General Physical Characteristics

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
1	14 Dec	0935	35.0	0	-	-	-	-	-	2.0
2	14 Dec	0940	35.0	0	5.32	5.7	0.174	12.2	3.9	3.0
				5	5.33	5.7	0.174	12.6	3.9	-
				10	5.33	5.8	0.175	13.2	3.9	-
				15	5.33	5.9	0.175	13.7	3.9	3.0
				20	5.32	6.0	0.175	14.2	3.9	-
				25	5.30	6.1	0.175	14.2	4.0	-
				30	5.25	6.2	0.175	14.6	3.9	3.0
3	14 Dec	1010	35.0	0	-	-	-	-	-	3.0
4	14 Dec	1015	25.0	0	-	-	-	-	-	0.3
5	14 Dec	1020	25.0	0	4.95	6.1	0.187	7.3	4.0	0.3
				5	4.40	6.3	0.192	6.4	4.0	-
				10	3.02	6.6	0.207	7.5	3.9	0.5
				15	2.87	6.5	0.209	7.9	3.9	-
				20	2.99	6.5	0.210	8.4	3.9	0.6
6	14 Dec	1040	25.0	0	-	-	-	-	-	0.7
7	14 Dec	1110	35.0	0	-	-	-	-	-	0.1
8	14 Dec	1120	35.0	0	-	-	-	-	-	0.1
9	14 Dec	1125	35.0	0	-	-	-	-	-	0.2
10	14 Dec	1130	35.0	0	5.35	5.8	0.181	11.5	4.1	0.15
				5	5.32	5.8	0.182	9.4	4.0	-
				10	5.32	5.8	0.182	10.6	3.9	-
				15	5.32	5.8	0.181	11.5	3.9	0.15
				20	5.32	5.9	0.182	12.2	3.9	-
				25	5.31	6.0	0.181	12.4	3.9	-
				30	5.28	6.1	0.182	12.9	3.9	0.15

Appendix Table 1.--Continued.

1984 Cruise IX (cont.)

Station	Date 1984	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Chloride (ppm)	Turbidity (NTU)
L-1	13 Dec	1600	10.0	0	-	-	-	-	-	0.3
L-2	13 Dec	1610	10.0	0	-	-	-	-	-	0.2
11	13 Dec	1615	35.0	0	-	-	-	-	-	0.2
12	13 Dec	1618	35.0	0	-	-	-	-	-	0.2
13	13 Dec	1625	35.0	0	-	-	-	-	-	0.2
14	14 Dec	1215	-	0	-	-	-	-	-	0.2
16	14 Dec	1210	-	0	-	-	-	-	-	0.2

Appendix Table 2.--Fluoride concentrations of river water and other aquatic sites in the John Day Dam region, Columbia River, April-December 1984 (see Figure 1 for station locations).

1984 Cruise I
April 11-12
Fluoride (ppm)

Station	Bottom	Mid-depth	Surface
1	0.19	0.19	0.19
2	0.20	0.20	0.19
3	0.19	0.19	0.18
4	0.10	0.10	0.19
6	0.11	0.10	0.10
10	0.21	0.20	0.19
10	0.19	0.18	0.19
Outfall pond			3.88
Near 11 (from shore)			0.19
Shore of lagoon (near L-1)			0.32
Lagoon float (near L-2)			0.31
N Fishway			0.21
S Fishway			0.20
"Slough" N end Dam - near CofE storage area			0.20
North Shore below JDD:			
Between tower and nav-lock			0.18
Upstream of tower			0.19
Downstream of tower			0.20
South Shore below JDD:			
Between nav-lock and entrance jetty (looking across)			0.18
Off end of nav-lock jetty		" "	0.19
Tower (WA shore)		" "	0.20

Appendix Table 2.--Continued.

1984 Cruise II
May 7-8
Fluoride (ppm)

Station	Bottom	Mid-depth	Surface
1	0.16	0.16	0.16
2	0.15	0.15	0.13
3	0.16	0.14	0.15
4	0.12	0.12	0.09
6	0.08	0.08	0.09
7	0.15	0.15	0.16
8	0.16	0.15	0.15
9	0.16	0.11	0.17
10	0.16	0.15	0.15
10	0.18	0.16	0.16
L-1	0.22	-	0.24
L-2	0.25	-	0.26
11	0.16	0.16	0.17
12	0.18	0.18	0.17
13	0.16	0.15	0.17
14+1 (downstream JDD)	0.16	0.17	0.17
15+1 " "	-	0.17	0.17
16+1	0.18	-	0.16
17 (The Dalles Dam)	-	-	0.16
19 " "	-	-	0.17

Appendix Table 2.--Continued.

1984 Cruise II (cont.)

Station	Bottom	Mid-depth	Surface
Bonneville Dam			
S - side old powerhouse			0.19
S - side spillway			0.17
S - side 2nd Powerhouse			0.18
N - side fishway			0.17

Additional Stations:

1.	"Rivulet" near L-2	5.48
2.	Culvert by entrance to Lagoon parking lot	0.30
3.	Outfall pond (nearest river)	3.21
4.	Outfall pond (N of above)	3.14
5.	Outfall "falls"	2.90
6.	Nav-lock (empty)	0.18

Appendix Table 2.--Continued.

1984 Cruise III
May 20-22
Fluoride (ppm)

Station	Surface	Station	Surface
1	0.21	9	0.14
2	0.23	10	0.23
3	0.22	10	0.23
4	0.10	L-1	0.23
5	0.07	L-2	0.22
6	0.12	11	-
7	0.21	12	-
8	0.19	13	-

Additonal Stations	Surface
1. Estuary pond near L-2 (and rivulet)	4.41
2. Rivulet near L-2	5.05
3. "Outfall pond"	3.29
4. S - side park near JDD	0.19
5. S - side downstream	0.37
6. S - side downstream further	0.14
7. Scum Pond (near slag heap)	1.51
8. N - side, nav-lock channel, "pipe pier"	0.24
9. N - side downstream	0.20
10. N - side downstream farther	0.20
11. N - side downstream farther	0.18
12. Mile 117.5	0.20

Appendix Table 2.--Continued.

1984 Cruise III (cont.)

Additonal Stations	Surface
13. Mile 128, Sundale Park, Lagoon	0.19
14. Roosevelt, WA	0.19
15. RR mile 160; mile post 147.5	0.21
16. Mile 161.9; near Glade Creek	0.18
17. Vernita (left bank C.R.)	0.15
18. Priest Rapids Reservoir (pump sta. upriver from dam)	0.19
19. Wanapum Dam (tailrace)	0.14
20. Vantage Bridge (1 mile downstream left bank C.R.)	0.13
21. Rock Island Dam; upstream and across from Al plant	0.13
22. Rock Island Dam; lagoon between tracks & highway	0.34
23. Douglas County Park; downstream from Wenatchee	0.12
24. Lincoln Rock St. Park; above Rocky Reach Dam (E. side C.R.)	0.13

Appendix Table 2.--Continued.

1984 Cruise IV
June 10-12
Fluoride (ppm)

Station	Bottom	Mid-depth	Surface
1	0.13	0.13	0.13
2	0.13	0.13	0.12
3	0.13	0.12	0.12
4	0.07	0.06	0.06
6	0.06	0.07	0.09
7	0.13	0.14	0.13
8	0.11	0.12	0.12
9	0.09	0.12	0.10
0	0.13	0.13	0.13
10	0.12	0.13	0.13
L-1	0.15	-	0.23
L-2	0.22	-	0.24
11	0.11	0.12	0.12
12	0.12	0.12	0.13
13	0.09	0.26[Sic]	0.08
14 John Day N Fishway	-	-	0.12
16 S Fishway	-	-	0.11
17 The Dalles Dam (N)	-	-	0.18
19 " " " (S)	-	-	0.21
Bonneville Dam; S-end old powerhouse			0.16
S-end spillway			0.13
S-end new powerhouse			0.13
N-end fishway			0.13

Appendix Table 2.--Continued.

1984 Cruise IV (cont.)

Additional Stations		Surface (ppm F-)
1. "Scum pond", Al-plant		3.03
2. "Outfall pond"	West	3.27
	East	3.32
3. Rivulet (L-2)		5.10
4. WA shore; downstream from J.D. Dam		
(end of Nav-lock)		0.16
Farther downstream (1/2 way to tower)		0.13
Farther downstream (at tower)		0.15
5. OR shore; downstream from J.D. Dam		
(opposite Nav-lock)		0.12
Farther downstream (opp. tower)		0.12
Farther downstream		0.10
6. Rufus Station (NMFS) water		0.55

Appendix Table 2.--Continued.

1984 Cruise V
July 9-11
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.08	0.08	0.08
2		0.08	0.08	0.08
3		0.09	0.08	0.08
4		0.08	0.06	0.05
6		0.07	0.06	0.06
7		0.07	0.09	0.07
8		0.08	0.08	0.08
9		0.07	0.08	0.08
10		0.08	0.08	0.08
L-1		0.16	-	0.14
L-2		0.18	-	0.16
11		0.08	0.07	0.08
12		0.08	0.06	0.14
13		0.06	0.08	0.07
14	John Day N. Fishway	-	-	0.13
16	S. Fishway	-	-	0.13
17	The Dalles Dam N. Fishway	-	-	0.08
19	The Dalles Dam S. Fishway	-	-	0.07
	Bonneville Dam;	S-end old powerhouse		0.08
		S-end spillway		0.09
		S-end new powerhouse		0.07
		N-end fishway		0.09

Appendix Table 2.--Continued.

1984 Cruise V (cont.)

Additional Stations	Surface (ppm F-)
1. Rivulet (L-2)	4.72
2. Rivulet (L-1/L-2)	6.86
3. OR shore opposite N-lock	0.14
4. OR shore opposite tower	0.09
5. OR shore last turn before Rufus	0.09
6. "Outfall pond" (west)	6.03
7. WA shore N-lock	0.12
8. WA shore 1/2 way to tower	0.10
9. WA shore tower	0.10

Appendix Table 2.--Continued.

1984 Cruise VI
July 30-31
Fluoride (ppm)

Station	Bottom	Mid-depth	Surface
1	0.21	0.23	0.11
2	0.10	0.12	0.08
3	0.11	0.10	0.09
"5" Off dock, John Day River	-	-	0.08
7	0.05	0.08	0.05
8	0.10	0.06	0.29
9	0.10	0.10	0.10
10	0.08	0.11	0.08
11	0.08	0.06	0.07
12	0.08	0.08	0.09
13	0.09	0.09	0.09
14 John Day Dam N. Fishway	-	-	0.06
16 John Day Dam S. Fishway	-	-	0.08
17 The Dalles Dam (N)	-	-	0.08
19 The Dalles Dam (S)	-	-	0.07
Bonneville Dam: S-end old powerhouse			0.09
S-end spillway			0.10
S-end new powerhouse			0.13
N-end fishway			0.10

Additional Stations:

1. Rivulet (L-2)	4.86
2. Rivulet (L-1/L-2)	9.05

Appendix Table 2.--Continued.

1984 Cruise VI (cont.)

	Surface
3. Lagoon (off boat ramp near L-2)	0.15
4. Outfall pond	2.66
5. N-shore, nav-lock channel	0.09
6. N-shore, tower	0.08
7. S-shore, opposite nav-lock	0.09
8. S-shore, opposite tower	0.11

Appendix Table 2.--Continued.

1984 Cruise VII
September 17-18
Fluoride (ppm)

Station	Surface
1	0.20
2	0.18
3	0.18
7	0.17
8	0.16
9	0.16
10	0.19
11	0.16
12	0.17
13	0.16

Additional Stations:

1. Rivulet (L-2)	5.51
2. Rivulet (L-1/L-2)	6.54
3. Lagoon (off boat ramp near L-2)	0.21
4. Outfall pond	2.39
5. John Day River boat ramp	0.16
6. N-shore, nav-lock channel	0.15
7. N-shore, tower	0.15
8. S-shore, opposite nav-lock	0.16
9. S-shore, opposite tower	0.16

Appendix Table 2.--Continued.

1984 Cruise VIII
October 16-17
Fluoride (ppm)

Station	Surface
1	0.18
2	0.18
3	0.18
4	0.17
6	0.17
7	0.17
8	0.17
9	0.17
10	0.21
10	0.20
L-1	0.26
L-2	0.25
11	0.18
12	0.17
13	0.18
Bonneville Dam: N-end fishway	0.18
Additional Stations:	
1. Rivulet (L-2)	5.39
2. Rivulet (L-1/L-2)	9.59
3. Outfall pond	1.84
4. River at outfall	0.30
5. N-shore, nav-lock channel	0.21

Appendix Table 2.--Continued.

1984 Cruise VIII (cont.)

Additional Stations:

6.	N-shore, tower	0.18
7.	S-shore, opposite nav-lock	0.18
8.	S-shore, opposite tower	0.17
9.	Mayer St. Park	0.18
10.	Rooster Rock St. Park	0.13

Appendix Table 2.--Continued.

1984 Cruise IX
December 12-14
Fluoride (ppm)

Station	Bottom	Mid-depth	Surface
1	-	-	0.19
2	0.21	0.20	0.22
3	-	-	0.20
4	-	-	0.19
5	0.15	0.16	0.20
6	-	-	0.13
7	-	-	0.20
8	-	-	0.20
9	-	-	0.20
10	0.21	0.19	0.23
L-1	-	-	0.34
L-2	-	-	0.33
11	-	-	0.21
12	-	-	0.21
13	-	-	0.18
14 John Day Dam N. Fishway	-	-	0.20
16 John Day Dam S. Fishway	-	-	0.21
17 The Dalles Dam (N)	-	-	0.21
19 The Dalles Dam (S)	-	-	0.21
Bonneville Dam: S-end old powerhouse			0.19
S-end spillway			0.20
S-end new powerhouse			0.24
N-end fishway			0.20

Appendix Table 2.--Continued.

1984 Cruise IX (cont.)

Additional Stations:		Surface
1.	Rivulet (L-2)	5.50
2.	Rivulet (L-1/L-2)	8.98
3.	Outfall pond	1.78
4.	N-shore, tower	0.20
5.	S-shore, opposite tower	0.20
6.	Mayer St. Park	0.19
7.	Rooster Rock St. Park	0.17
8.	Sauvies Island (slough)	0.06
9.	Trojan nuc. plant (slough)	0.06
10.	Longview Bridge	0.11
11.	Jones Beach	0.14
12.	Young's Bay	0.21
13.	Hammond Field Station	0.23
14.	Astoria Bridge (N-end)	0.17
15.	Upstream (3 miles) from Astoria Bridge (N-side)	0.15

Appendix Table 3.--Daily fluoride concentration and turbidity in John Day Dam fishways, 1984.

Date (1984)	Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU)a/ (N)	Turbidity (NTU)a/ (S)
Apr 2	0.24	0.24	-	-
3	-	-	-	-
4	0.24	0.19	-	-
5	0.20	0.21	-	-
6	0.20	0.18	-	-
7	-	-	-	-
8	-	-	-	-
9	0.19	0.17	-	-
10	0.20	0.19	-	-
11	0.19	0.18	-	-
12	0.19	0.18	-	-
13	0.16	0.11	-	-
14	-	-	-	-
15	-	-	-	-
16	-	-	-	-
17	0.16	0.14	-	-
18	0.15	0.15	-	-
19	0.20	0.14	-	-
20	0.17	0.13	-	-
21	0.14	0.15	-	-
22	0.17	0.16	-	-
23	0.17	0.17	-	-
24	0.19	0.13	-	-
25	0.18	0.32[Sic]	14.0	20.0
26	0.14	0.13	14.0	26.0
27	0.18	0.15	12.0	20.0
28	0.16	0.15	11.0	15.0
29	0.17	0.15	12.0	12.0
30	0.17	0.17	11.0	13.0
May 1	0.17	0.17	11.0	14.0
2	0.15	0.14	11.0	13.0
3	0.16	0.15	11.0	14.0
4	0.16	0.16	11.0	13.0
5	0.16	0.16	11.0	14.0
6	0.18	0.16	11.0	14.0
7	0.19	0.17	09.0	14.0
8	0.16	0.15	-	-
9	0.18	0.15	10.0	12.0
10	0.17	0.15	09.0	12.0
11	0.16	0.13	10.0	12.0
12	0.17	0.14	11.0	12.0
13	0.16	0.14	11.0	14.0
14	0.14	0.14	12.0	14.0
15	0.16	0.13	12.0	20.0
16	0.14	0.14	13.0	22.0
17	0.19	0.14	15.0	30.0
18	0.16	0.15	14.0	21.0
19	0.16	0.16	15.0	23.0

Appendix Table 3.--Continued.

Date (1984)	Fluoride (ppm) (N)	(S)	Turbidity (NTU) a/ (N)	(S)
May 20	0.17	0.17	15.0	18.0
21	0.16	0.18	18.0	14.0
22	0.19	0.16	12.0	17.0
23	0.17	0.17	12.0	15.0
24	0.14	0.15	12.0	15.0
25	0.18	0.15	15.0	15.0
26	0.15	0.14	16.0	19.0
27	0.16	0.15	20.0	18.0
28	0.14	0.14	20.0	12.0
29	0.18	0.16	14.0	18.0
30	0.15	0.12	13.0	14.0
31	0.14	0.14	14.0	14.0
June 1	0.15	0.12	14.0	19.0
2	0.16	0.14	17.0	20.0
3	0.15	0.16	14.0	18.0
4	0.16	0.14	14.0	18.0
5	0.16	0.15	12.0	16.0
6	0.15	0.13	12.0	17.0
7	0.15	0.14	13.0	16.0
8	0.14	0.13	11.0	15.0
9	0.13	0.12	13.0	17.0
10	0.13	0.12	13.0	14.0
11	0.10	0.10	13.0	16.0
12	0.10	0.10	12.0	14.0
13	0.10	0.10	11.0	13.0
14	0.10	0.09	11.0	13.0
15	0.09	0.20	10.0	15.0
16	0.13	0.11	11.0	18.0
17	0.10	0.10	12.0	15.0
18	0.09	0.10	11.0	12.0
19	0.10	0.09	10.0	10.0
20	0.09	0.10	08.0	10.0
21	0.12	0.11	09.0	11.0
22	0.11	0.10	08.0	11.0
23	0.11	0.09	09.0	10.0
24	0.10	0.09	10.0	09.0
25	0.10	0.10	08.0	12.0
26	0.10	0.09	10.0	10.0
27	0.09	0.09	10.0	08.0
28	0.10	0.09	07.0	08.0
29	0.11	0.08	09.0	08.0
30	0.19	0.08	09.0	09.0
July 1	0.07	0.31	08.0	08.0
2	0.07	0.08	10.0	08.0
3	0.08	0.09	08.0	-
4	0.09	0.09	08.0	07.0
5	0.09	0.08	08.0	06.0
6	0.09	0.09	06.0	07.0

Appendix Table 3.--Continued.

Date (1984)	Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU)[a/] (N)	Turbidity (NTU)[a/] (S)
July 7	0.09	0.08	6.0	5.0
8	0.09	0.09	5.0	5.0
9	0.09	0.09	7.0	7.0
10	0.11	0.09	6.0	5.0
11	0.09	0.08	6.0	5.0
12	0.09	0.09	5.0	5.0
13	0.09	0.10	5.0	6.0
14	-	-	-	-
15	0.11	0.09	5.0	4.0
16	0.09	0.09	9.0	9.0
17	0.09	0.10	6.0	6.0
18	0.11	0.10	4.0	4.0
19	0.09	0.09	4.0	6.0
20	0.09	0.10	4.0	4.0
21	0.09	0.10	4.0	3.0
22	0.09	0.09	3.0	3.0
23	0.09	0.09	3.0	3.0
24	0.10	0.10	3.0	3.0
25	0.10	0.09	3.0	3.0
26	0.09	0.09	4.0	3.0
27	0.09	0.09	2.0	2.0
28	0.10	0.10	4.0	4.0
29	0.08	0.08	4.0	4.0
30	0.08	0.09	4.0	4.0
31	0.17	0.08	5.0	5.0
Aug 1	0.12	0.12	4.0	4.0
2	0.12	0.12	4.0	3.0
3	0.12	0.12	4.0	4.0
4	0.15	0.11	4.0	5.0
5	0.12	0.12	4.0	4.0
6	0.12	0.11	5.0	6.0
7	0.12	0.12	4.0	6.0
8	0.12	0.12	4.0	5.0
9	0.12	0.12	4.0	4.0
10	0.11	0.13	4.0	4.0
11	0.12	0.12	4.0	4.0
12	0.13	0.13	4.0	4.0
13	0.12	0.13	4.0	4.0
14	0.10	0.12	6.0	6.0
15	0.12	0.12	4.0	5.0

Appendix Table 3.--Continued.

Date (1984)		Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU)[a/] (N)	Turbidity (NTU)[a/] (S)
Aug	16	0.12	0.12	5.0	6.0
	17	0.12	0.12	5.0	6.0
	18	0.12	0.13	5.0	6.0
	19	0.12	0.12	5.0	6.0
	20	0.12	0.12	4.0	6.0
	21	0.12	0.10	4.0	4.0
	22	0.13	0.13	5.0	5.0
	23	0.15	0.16	5.0	5.0
	24	0.13	0.14	5.0	7.0
	25	0.13	0.14	5.0	6.0
	26	0.13	0.13	-	-
	27	0.13	0.13	4.0	4.0
	28	0.13	0.13	5.0	7.0
	29	0.14	0.13	4.0	8.0
	30	0.13	0.14	5.0	6.0
	31	0.11	0.13	6.0	6.0
Sep	1	0.13	0.13	5.0	6.0
	2	-	-	-	-
	3	-	-	-	-
	4	0.13	0.14	4.0	5.0
	5	0.13	0.13	4.0	5.0
	6	0.12	0.13	5.0	6.0
	7	0.13	0.13	4.0	5.0
	8	-	-	-	-
	9	-	-	-	-
	10	0.14	0.14	5.0	6.0
	11	0.14	0.14	5.0	6.0
	12	0.14	0.14	5.0	5.0
	13	0.13	0.14	5.0	6.0
	14	-	-	-	-
	15	-	-	-	-
	16	-	-	-	-
	17	0.14	0.14	4.0	4.0
	18	0.14	0.14	-	-
	19	0.15	0.16	4.0	4.0
	20	0.16	0.16	3.0	3.0
	21	0.15	0.16	5.0	5.0
	22	-	-	-	-
	23	-	-	-	-
	24	0.17	0.17	3.0	3.0
	25	0.16	0.16	2.0	3.0

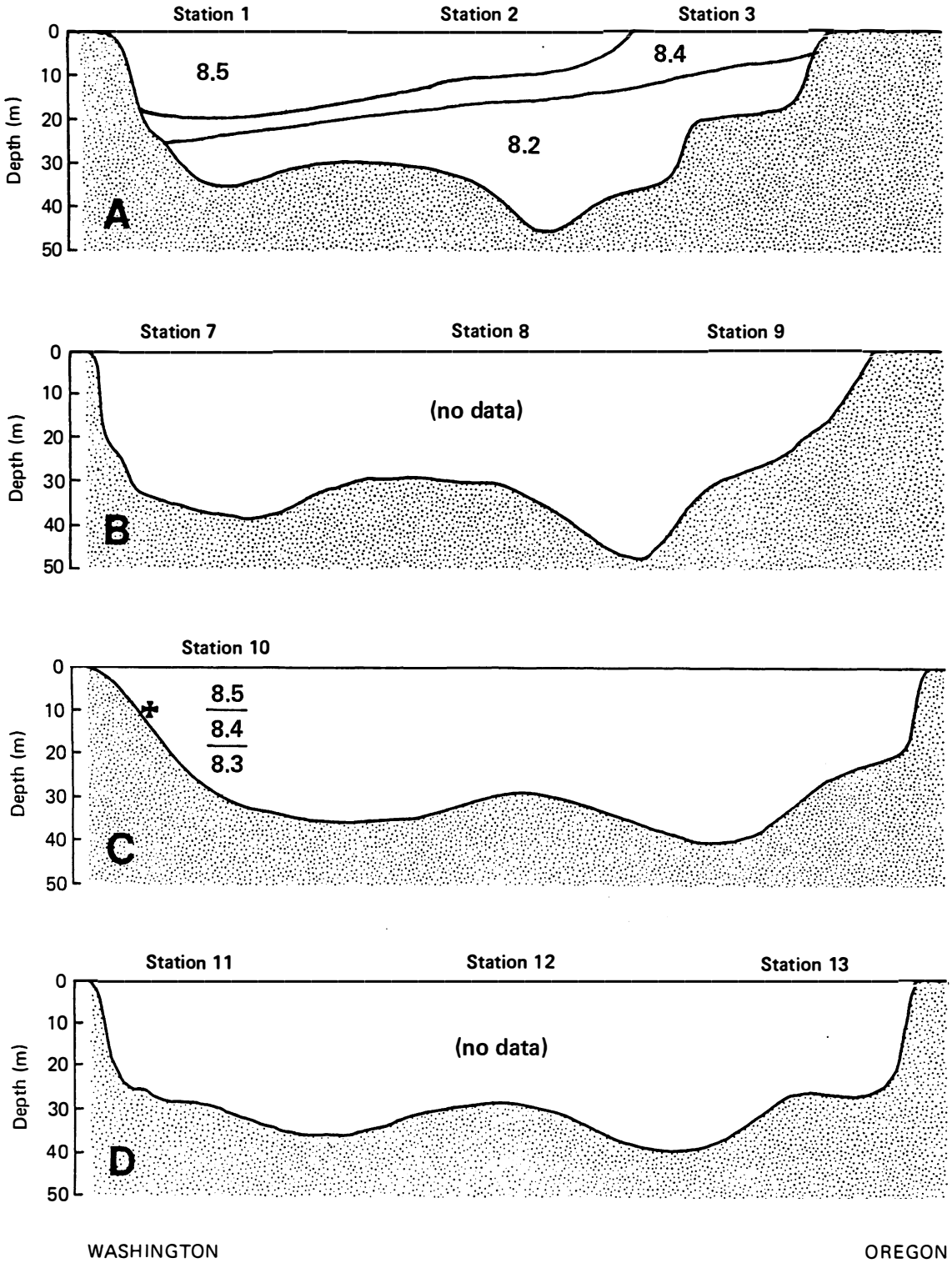
Appendix Table 3.--Continued.

Date (1984)		Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU)[a] (N)	Turbidity (NTU)[a] (S)
Sep	26	0.16	0.17	2.0	2.0
	27	0.16	0.16	2.1	3.0
	28	0.16	0.16	3.0	3.0
	29	–	–	–	–
	30	–	–	–	–
Oct	1	0.16	0.16	3.0	3.0
	2	0.16	0.16	2.0	4.0
	3	0.16	0.16	2.0	3.0
	4	0.16	0.16	1.5	1.5
	5	0.17	0.16	2.0	4.0
	6	–	–	–	–
	7	–	–	–	–
	8	–	–	–	–
	9	0.17	0.17	3.0	4.0
	10	–	–	–	–
	11	0.17	0.16	3.0	4.0
	12	0.16	0.16	4.0	4.0
	13	–	–	–	–
	14	–	–	–	–
	15	0.17	0.17	3.0	4.0
	16	0.16	0.16	4.0	4.0
	17	0.16	0.15	4.0	4.0
	18	0.15	0.15	4.0	4.0
	19	0.16	0.16	4.0	4.0
	20	–	–	–	–
	21	–	–	–	–
	22	0.17	0.20	4.0	5.0
	23	0.17	0.18	4.0	4.0
	24	–	–	–	–
	25	–	–	–	–
	26	0.17	0.16	4.0	4.0
	27	–	–	–	–
	28	–	–	–	–
	29	0.17	0.17	4.0	4.0
	30	0.17	0.17	4.5	3.5
	31	0.17	0.17	–	–
Nov	1	0.17	0.17	4.0	4.5
	2	0.18	0.19	3.0	5.0
	3	–	–	–	–
	4	–	–	–	–
	5	0.18	0.18	4.0	4.0
	6	0.18	0.18	3.0	3.0

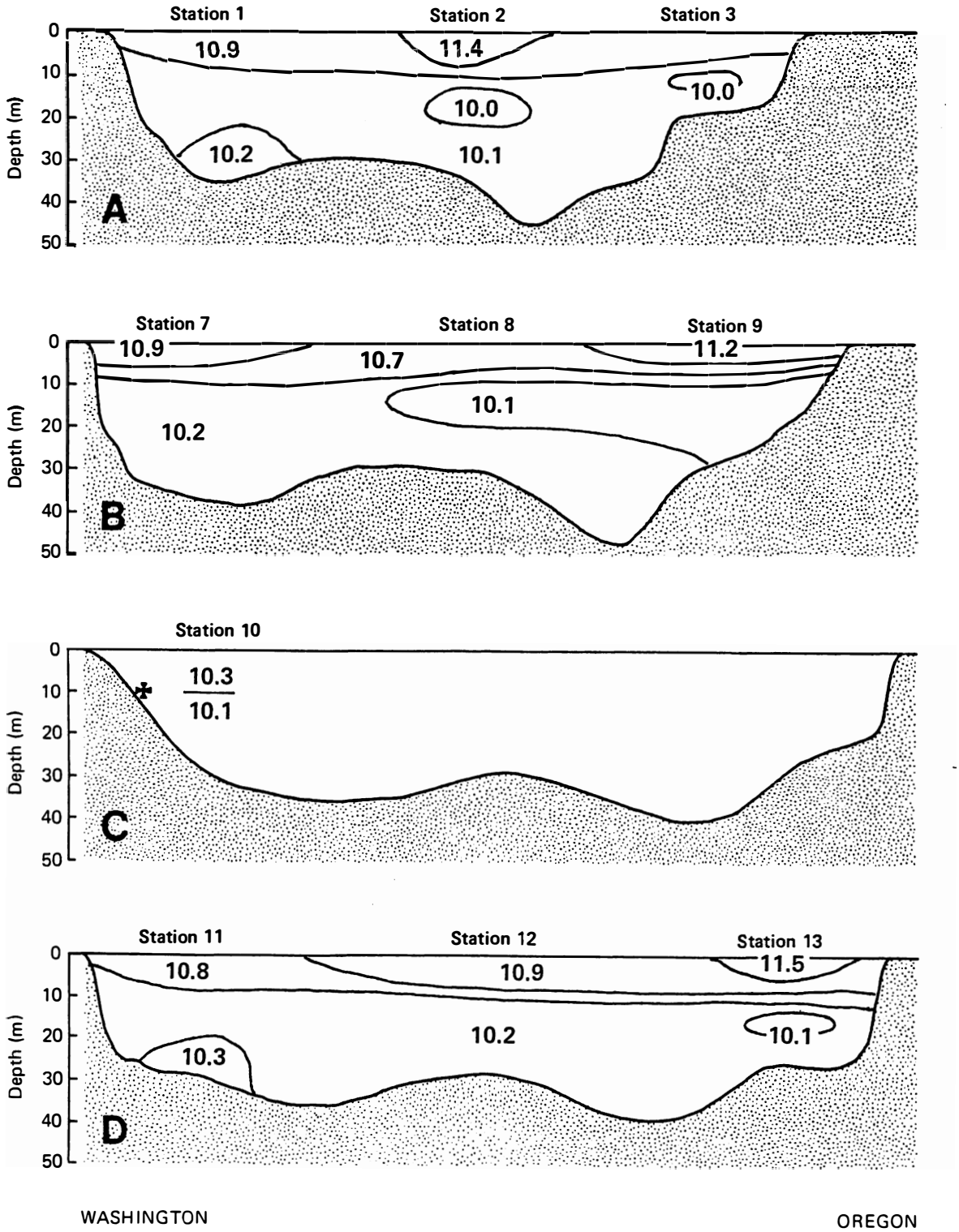
Appendix Table 3.--Continued.

Date (1984)		Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU)[a] (N)	Turbidity (NTU)[a] (S)
Nov	7	0.18	0.18	3.0	3.0
	8	0.19	0.19	4.0	4.0
	9	0.20	0.19	4.0	4.0

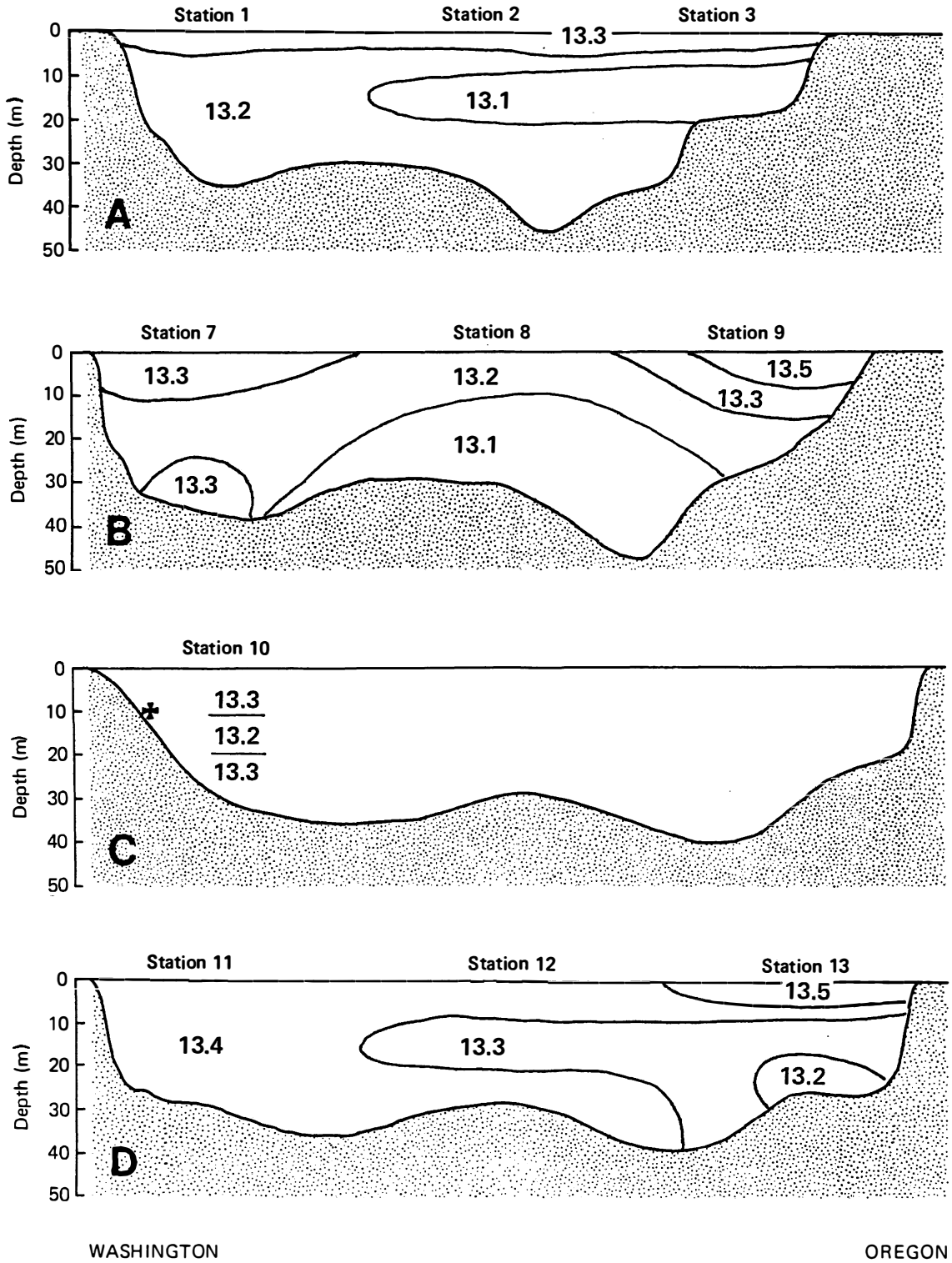
[a] From 15 May through 7 June a different turbidity meter was used and the data were not adjusted.



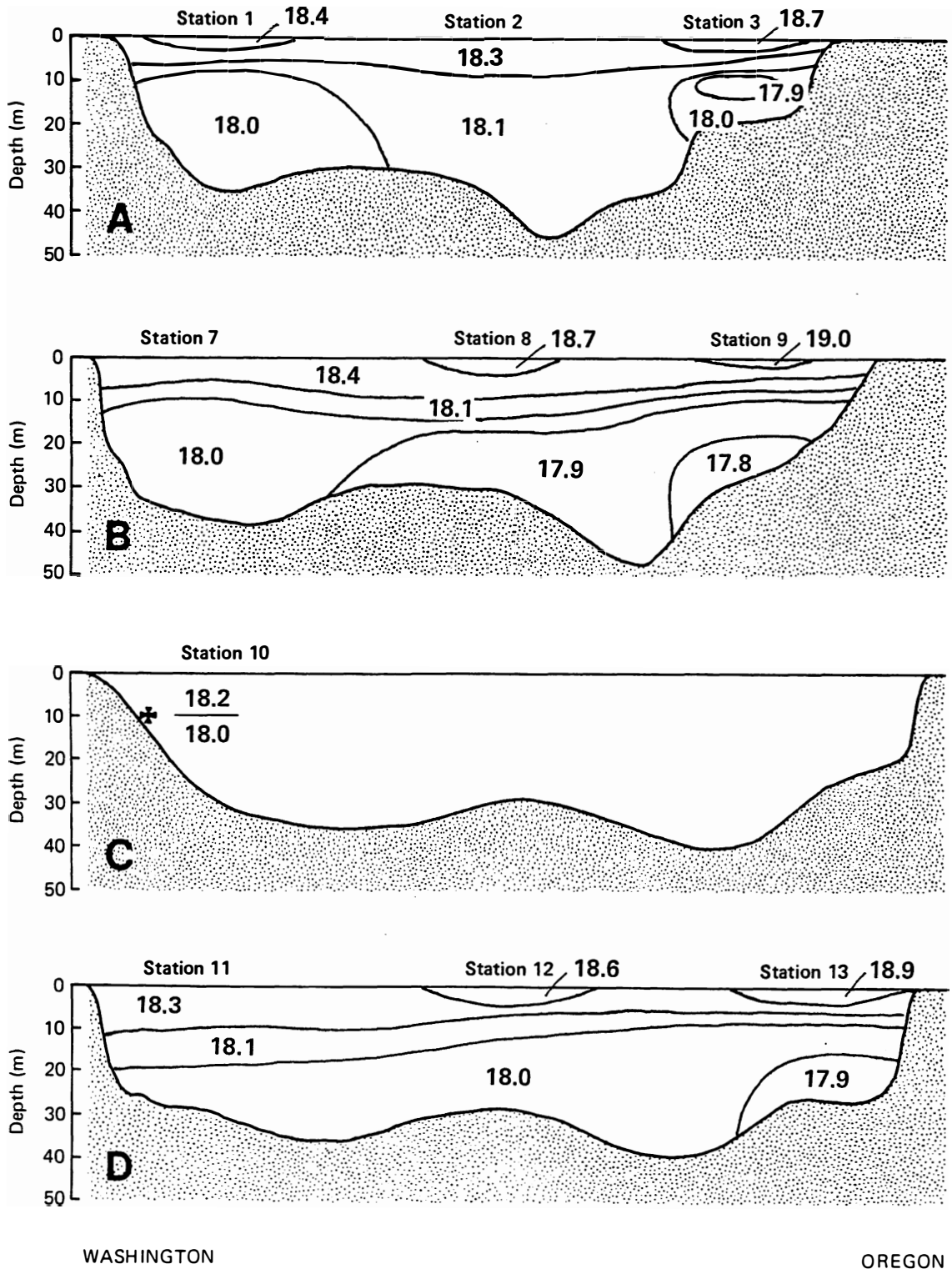
Appendix Figure 1.--Temperature contours (°C), 11-12 April 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



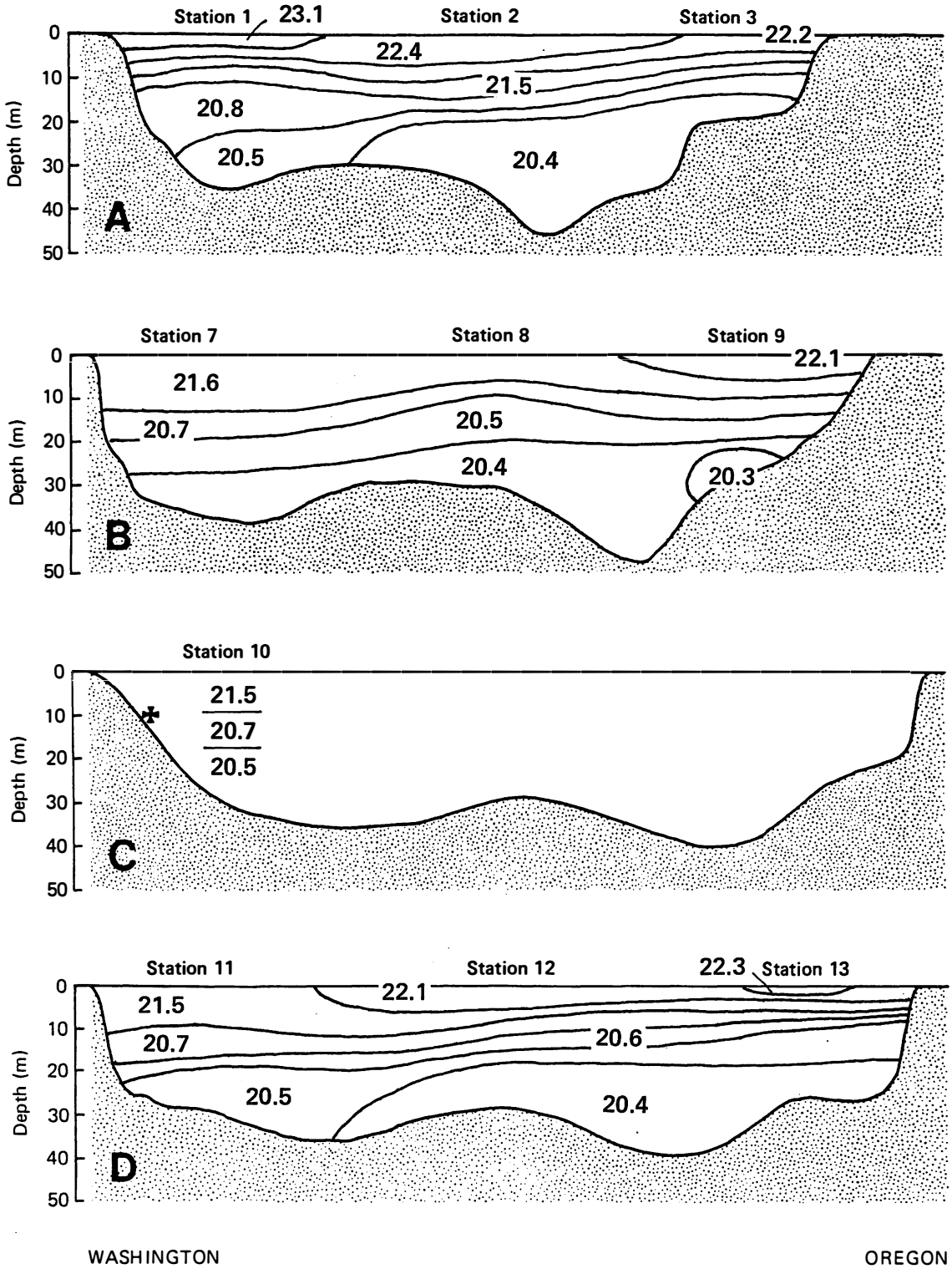
Appendix Figure 2.--Temperature contours (°C), 7-8 May 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



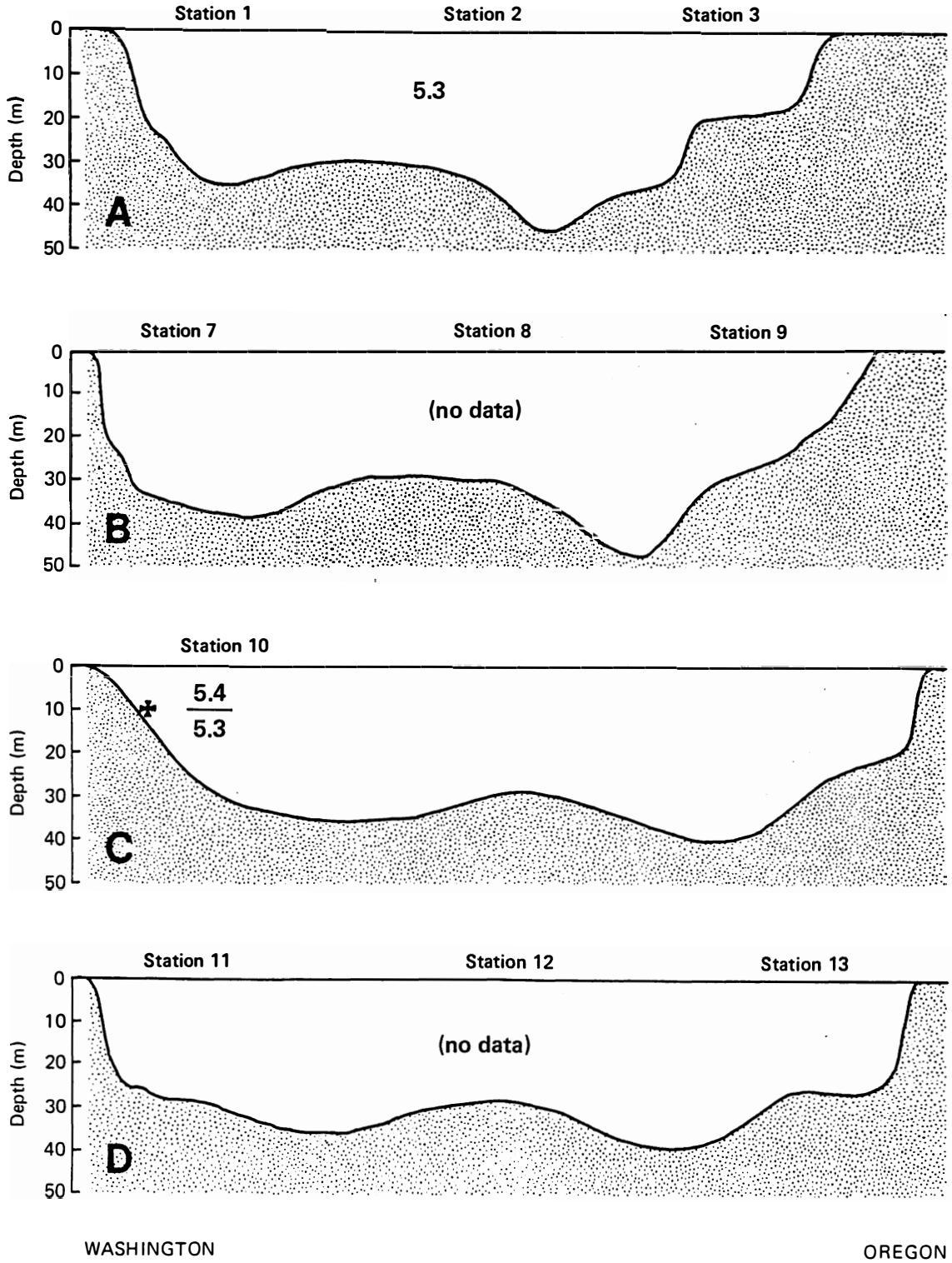
Appendix Figure 3.--Temperature contours (°C), 10-12 June 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



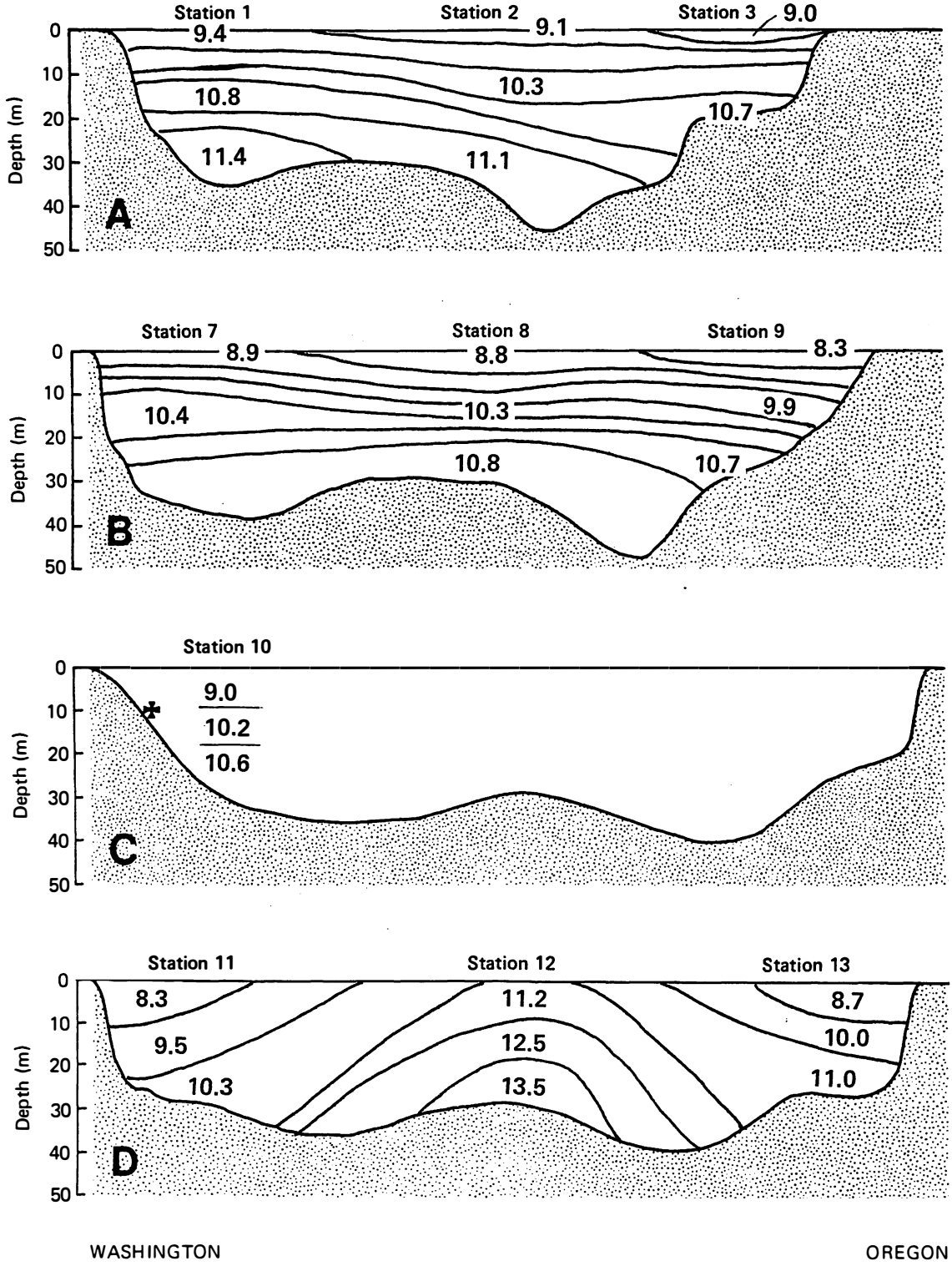
Appendix Figure 4.--Temperature contours (°C), 9-11 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



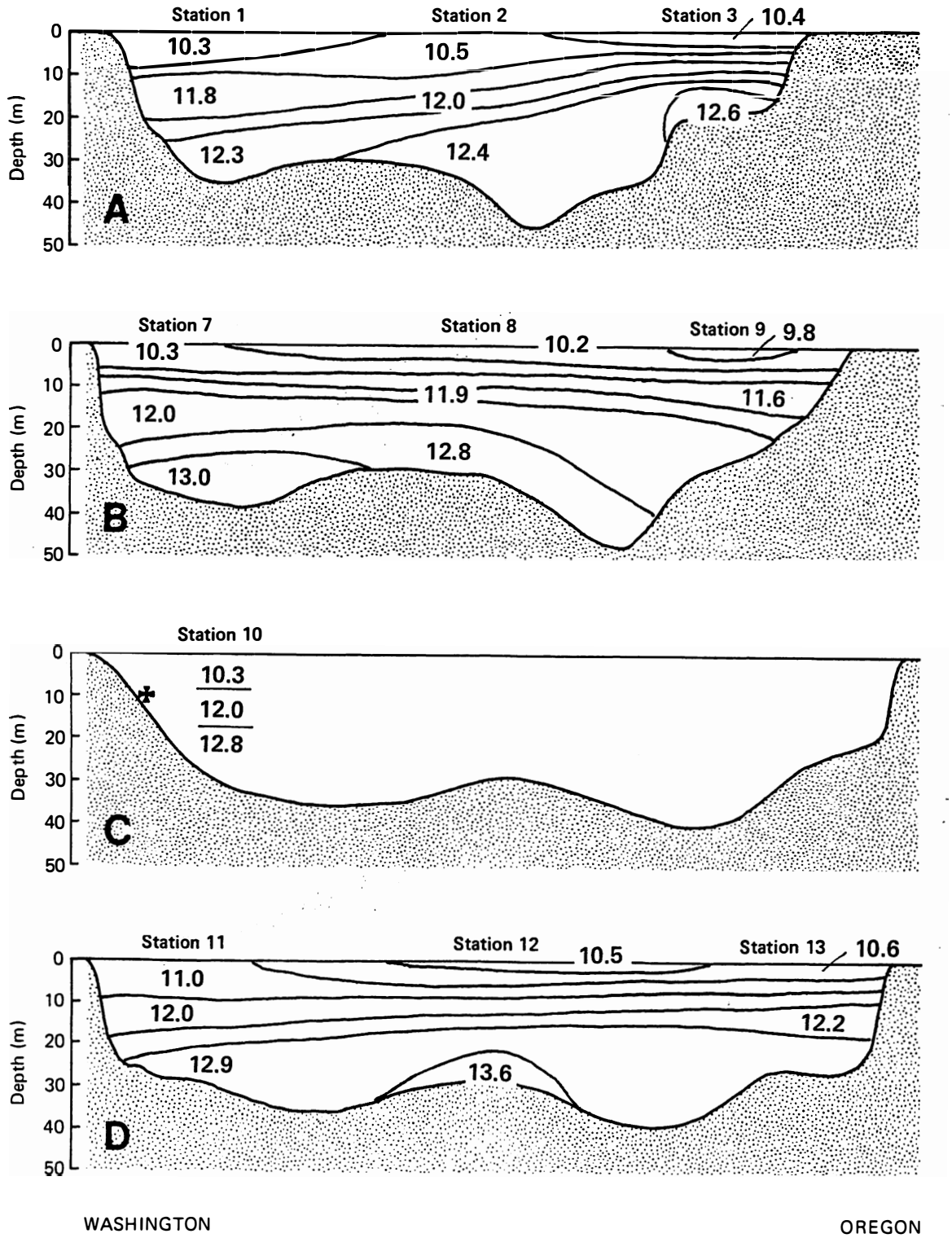
Appendix Figure 5.--Temperature contours (°C), 30-31 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



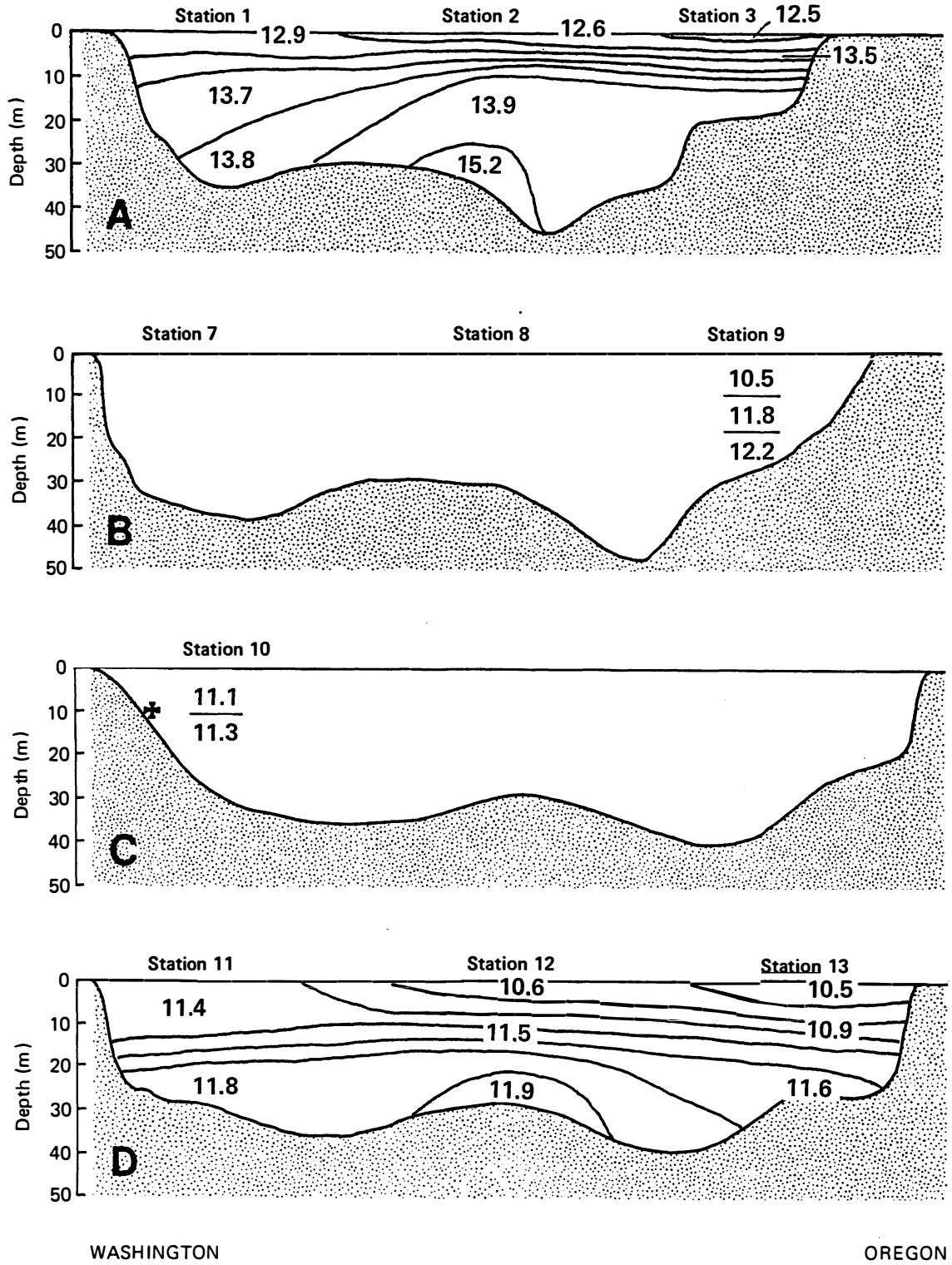
Appendix Figure 6.--Temperature contours (°C), 12-14 December 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



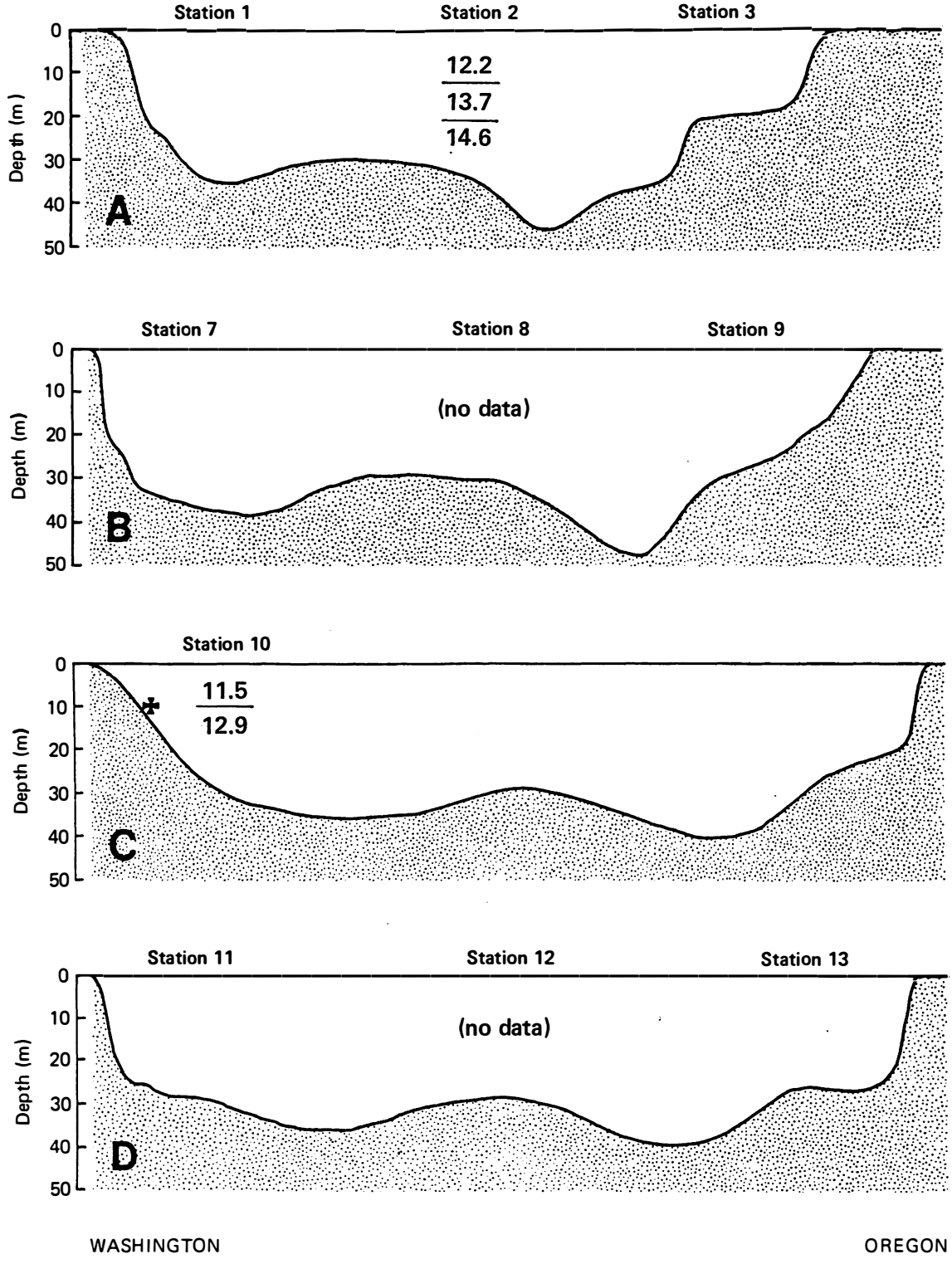
Appendix Figure 7.--Dissolved oxygen contours (ppm), 7-8 May 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



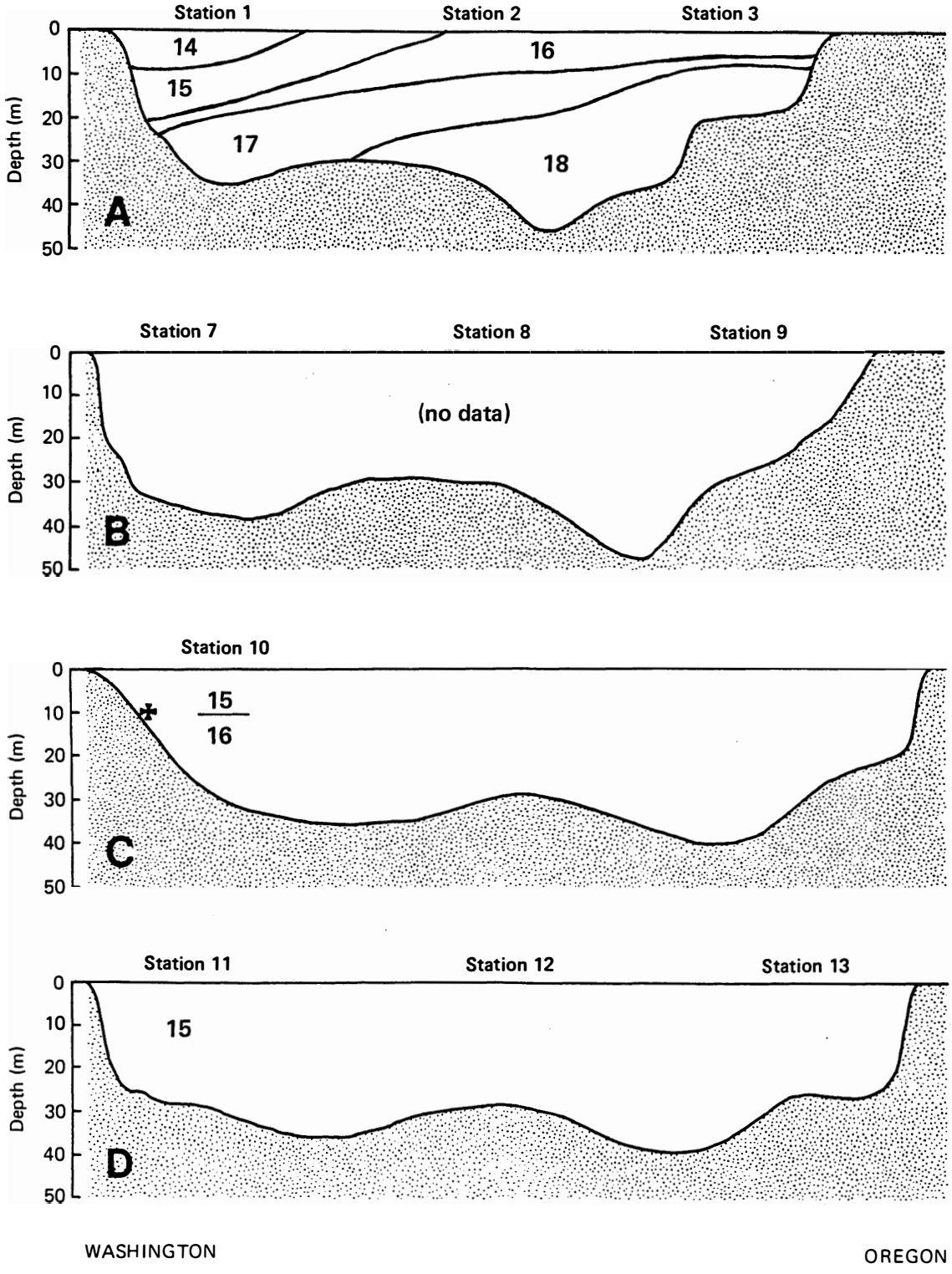
Appendix Figure 8.--Dissolved oxygen contours (ppm), 10-12 June 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



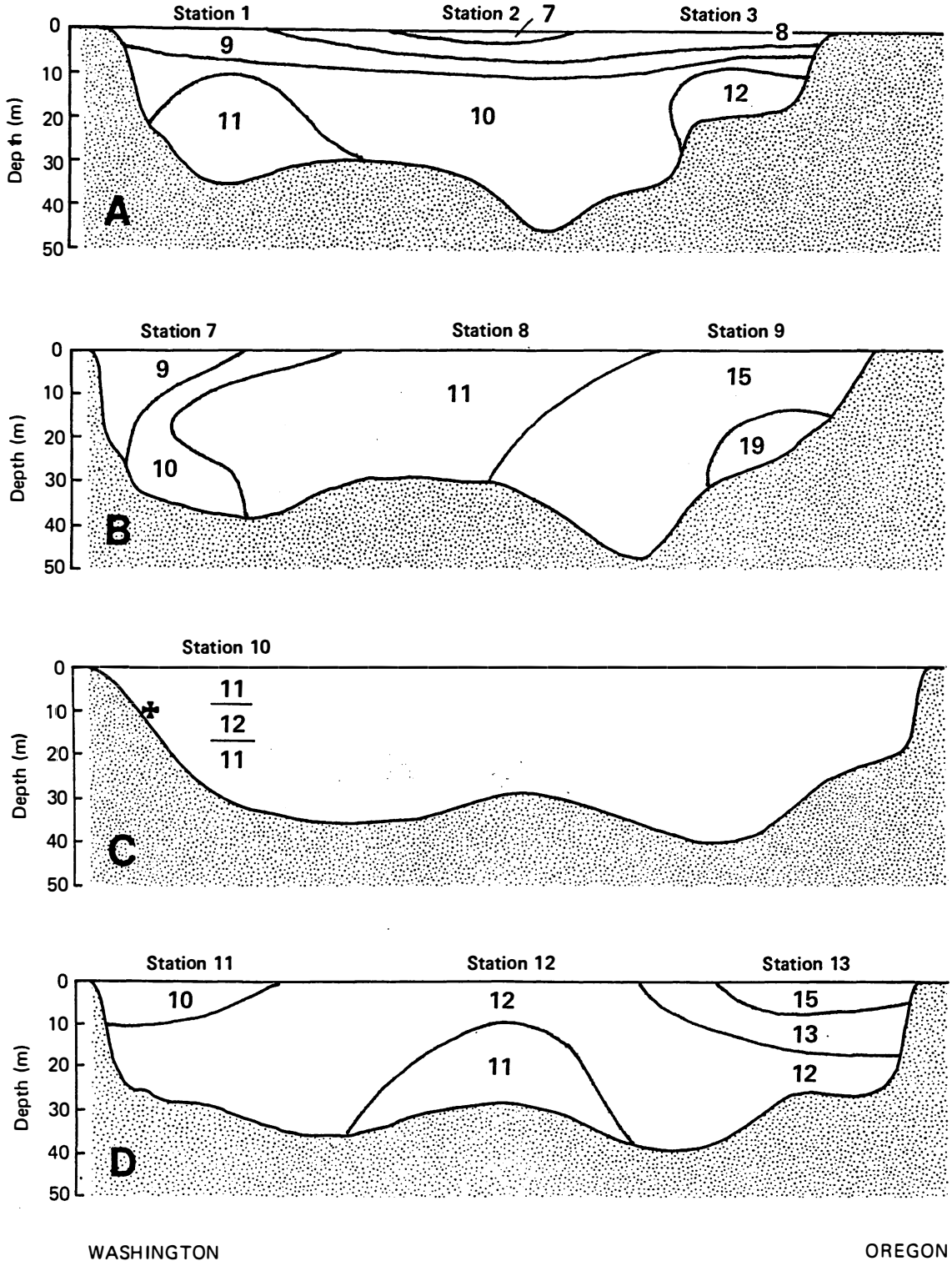
Appendix Figure 9.--Dissolved oxygen contours (ppm), 9-11 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



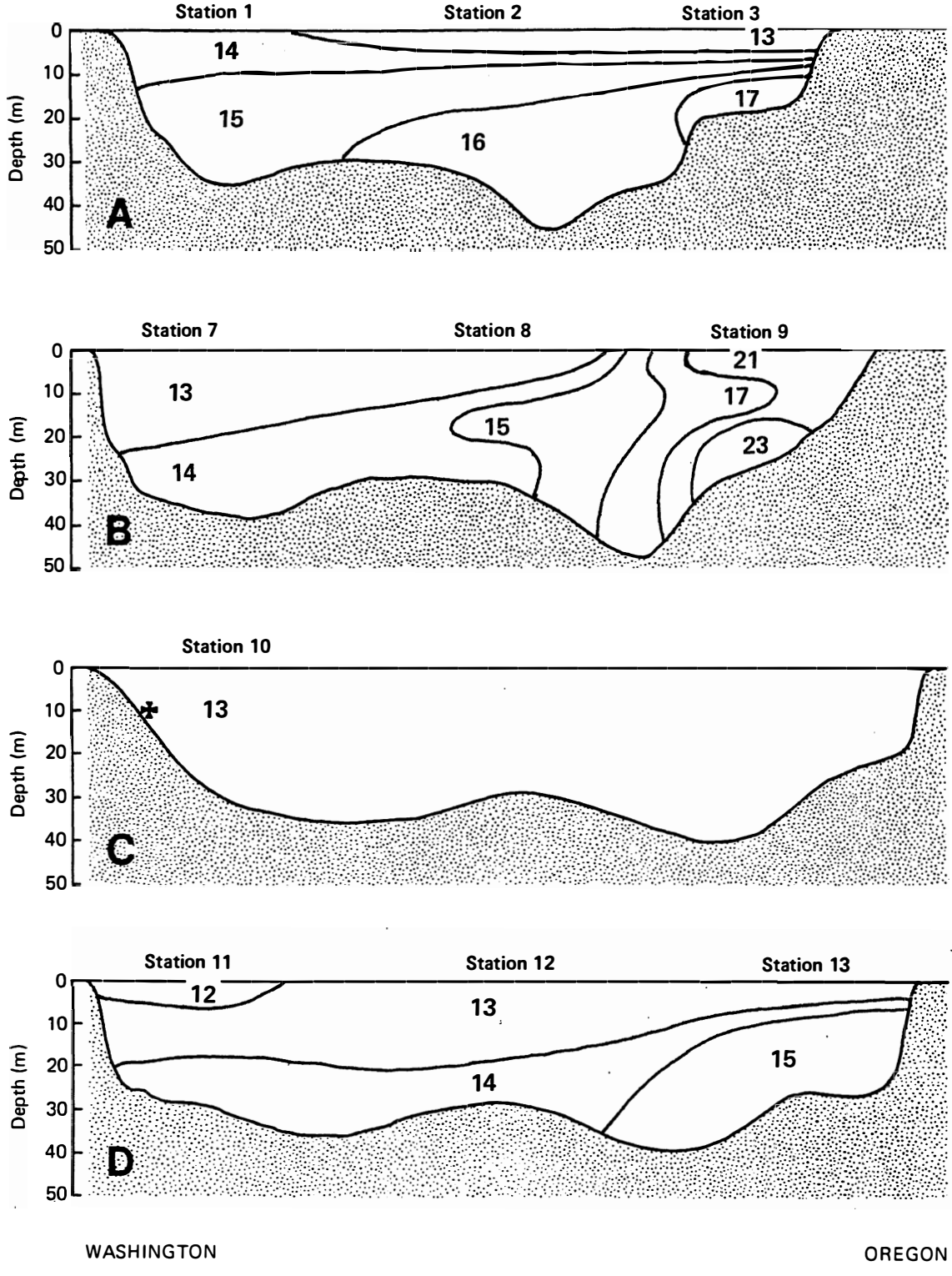
Appendix Figure 10.--Dissolved oxygen contours (ppm), 12-14 December 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



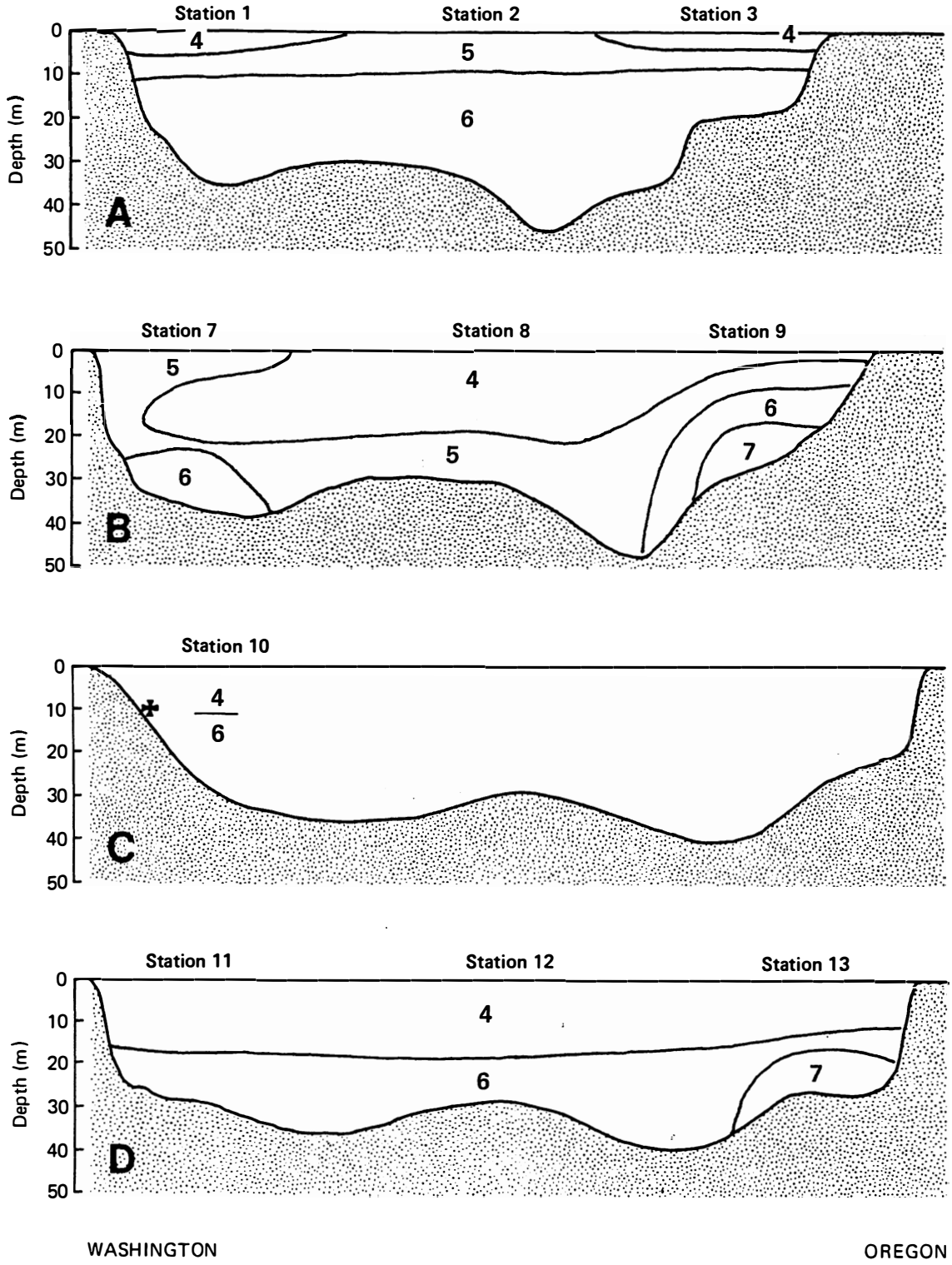
Appendix Figure 11.--Turbidity contours (NTU), 11-12 April 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



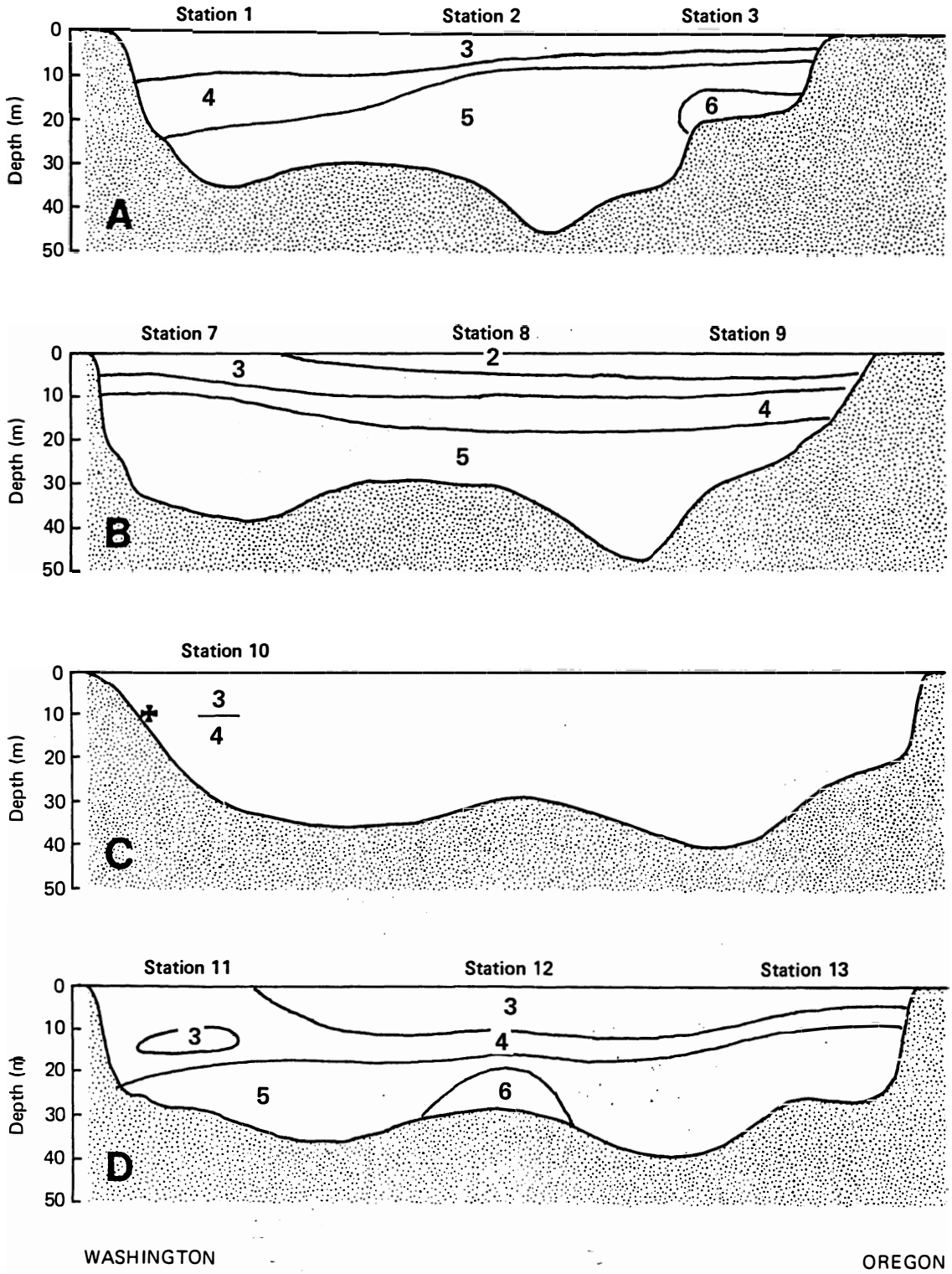
Appendix Figure 12.--Turbidity contours (NTU), 7-8 May 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



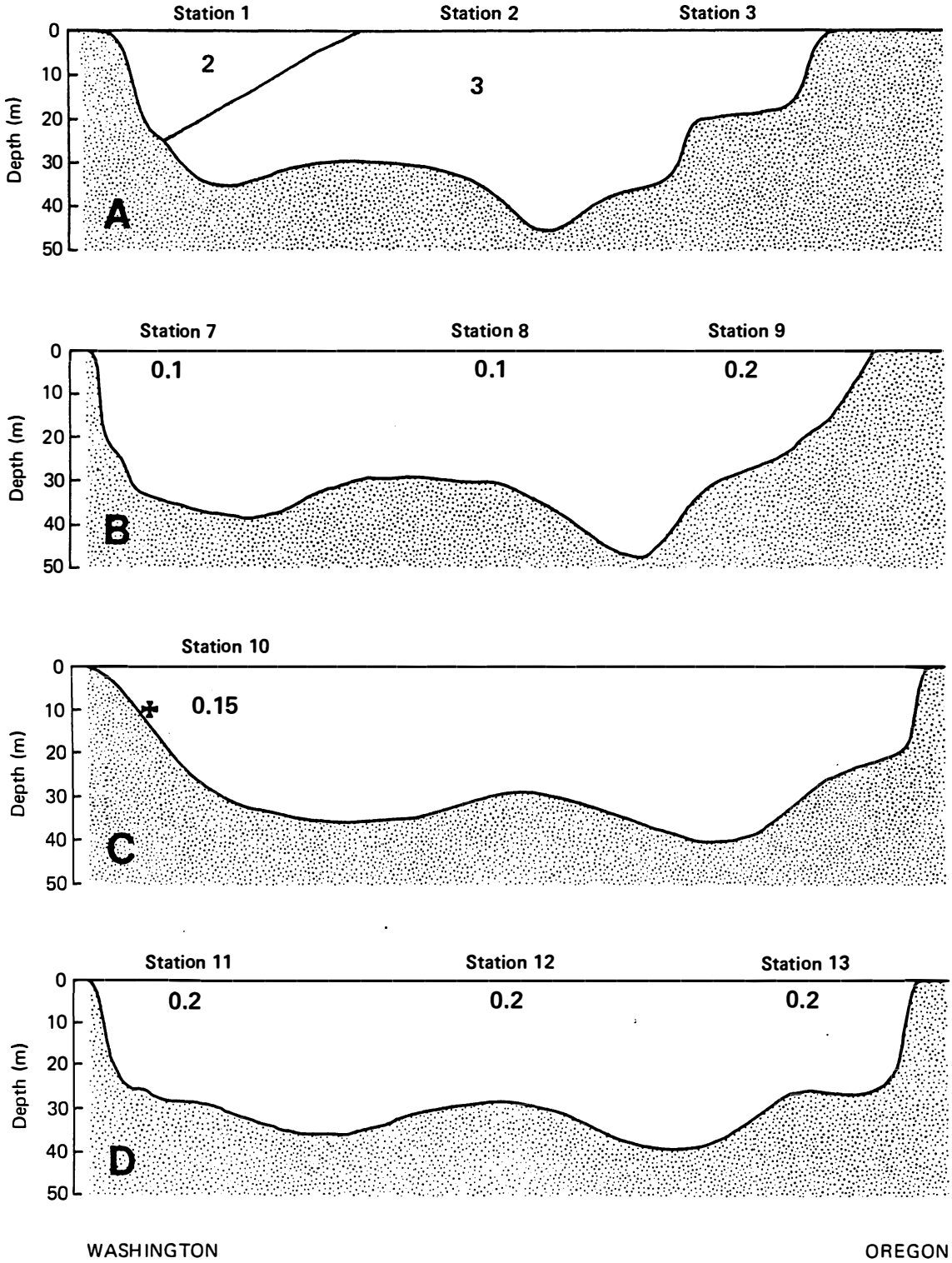
Appendix Figure 13.--Turbidity contours (NTU), 10-12 June 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



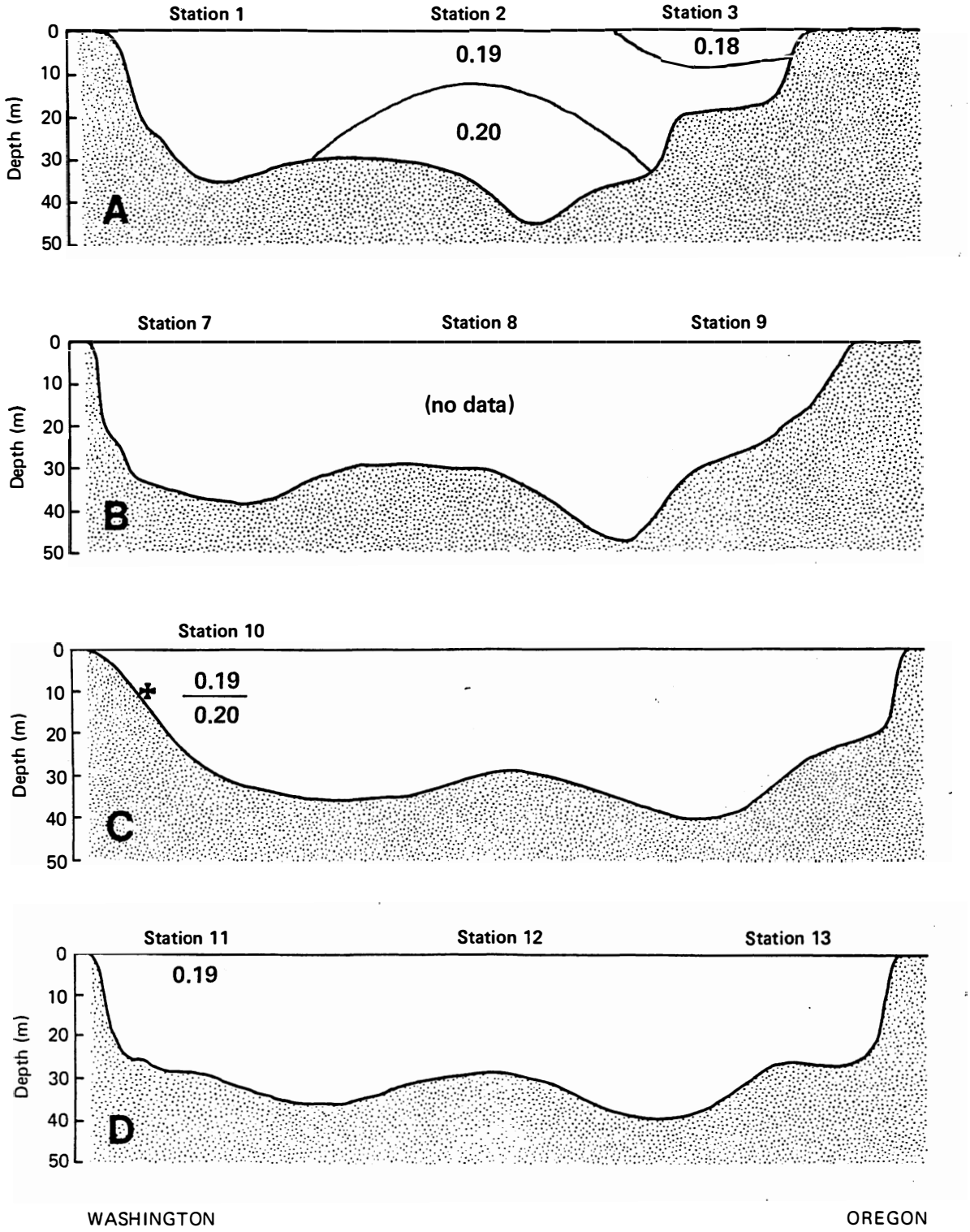
Appendix Figure 14.--Turbidity contours (NTU), 9-11 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



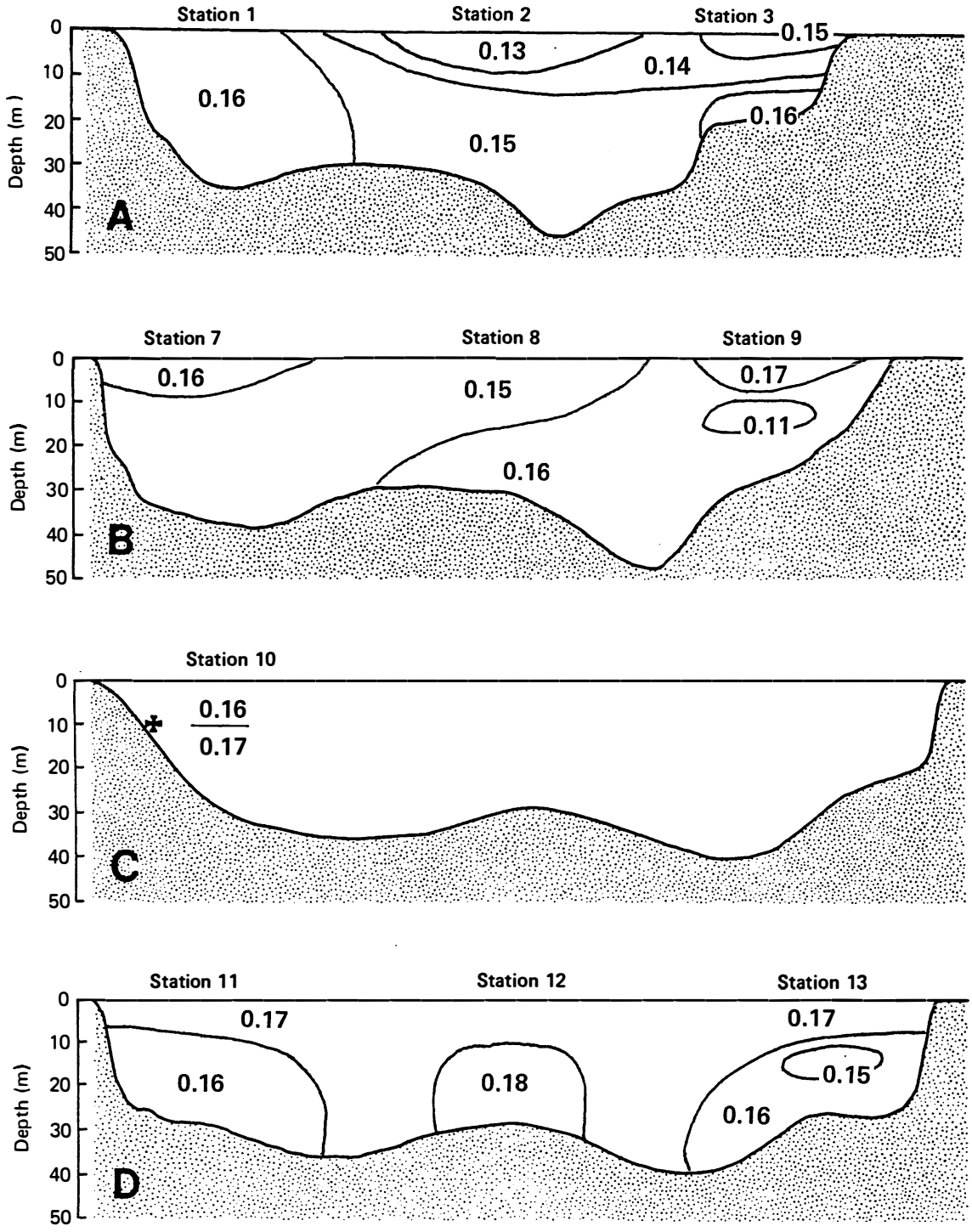
Appendix Figure 15.--Turbidity contours (NTU), 30-31 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



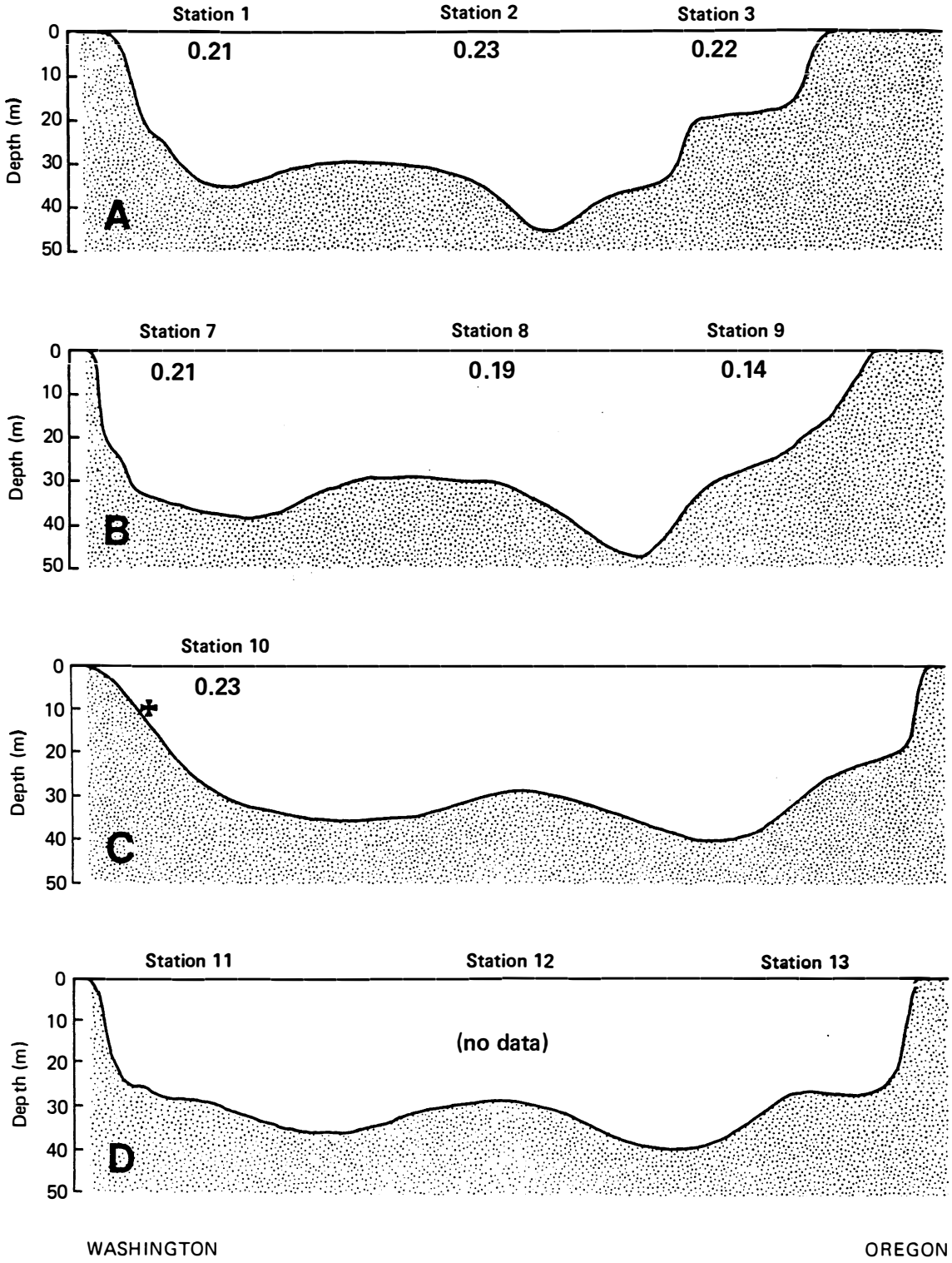
Appendix Figure 16.--Turbidity contours (NTU), 12-14 December 1984, John Day Dam region, Columbia River (see Figure 1 for station locations).



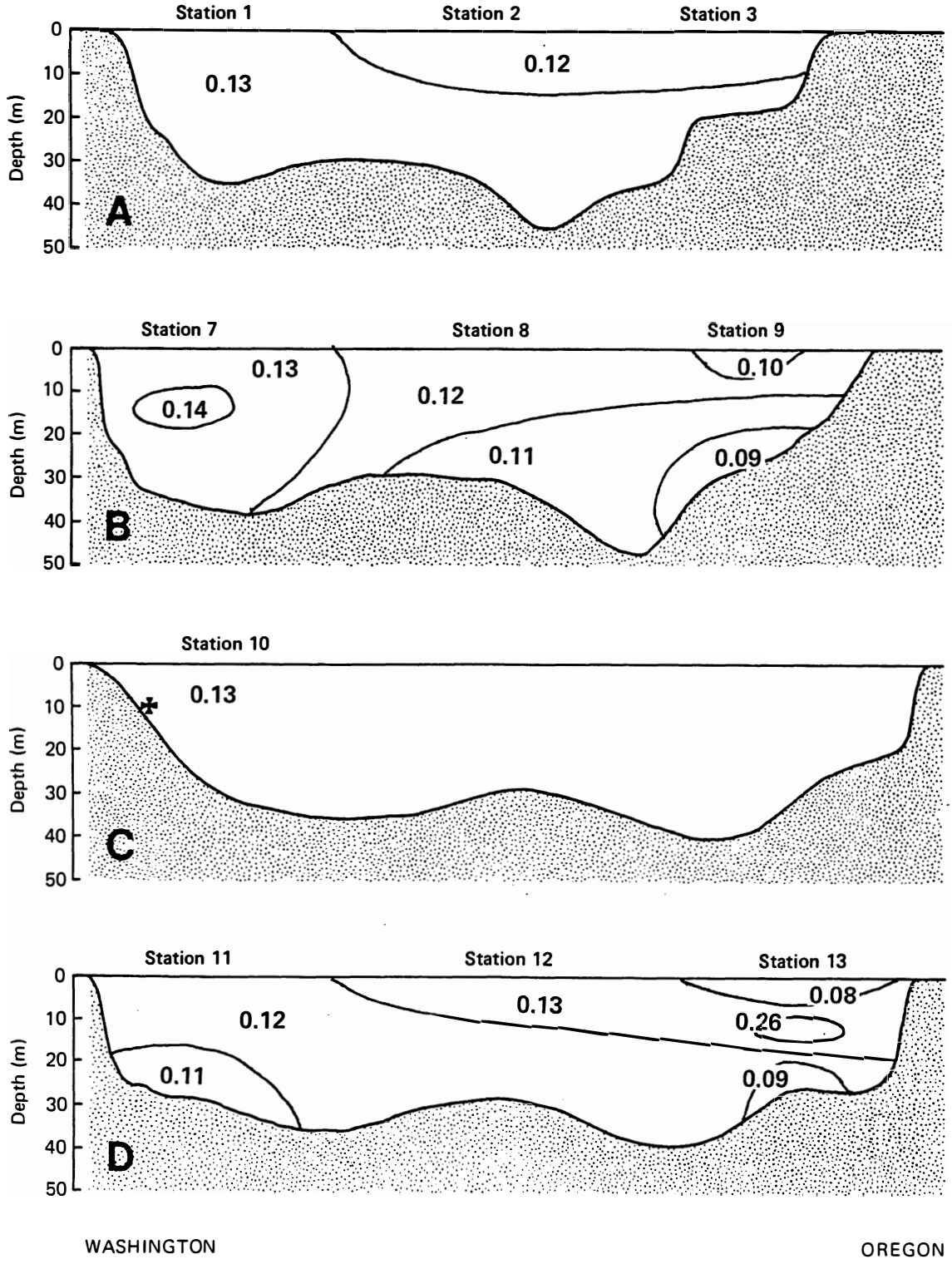
Appendix Figure 17.--Fluoride contours (ppm), 11-12 April 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



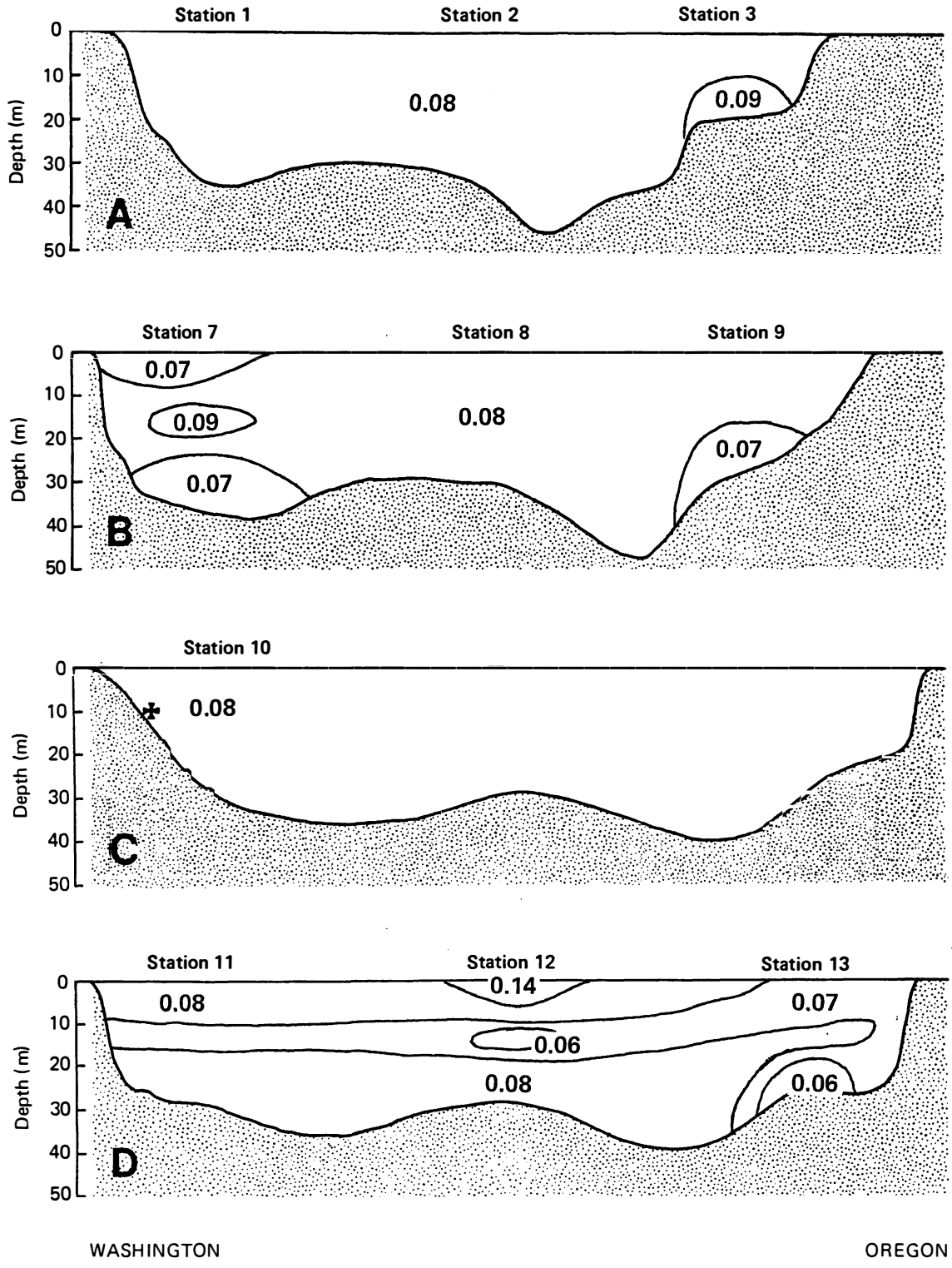
Appendix Figure 18.--Fluoride contours (ppm), 7-8 May 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



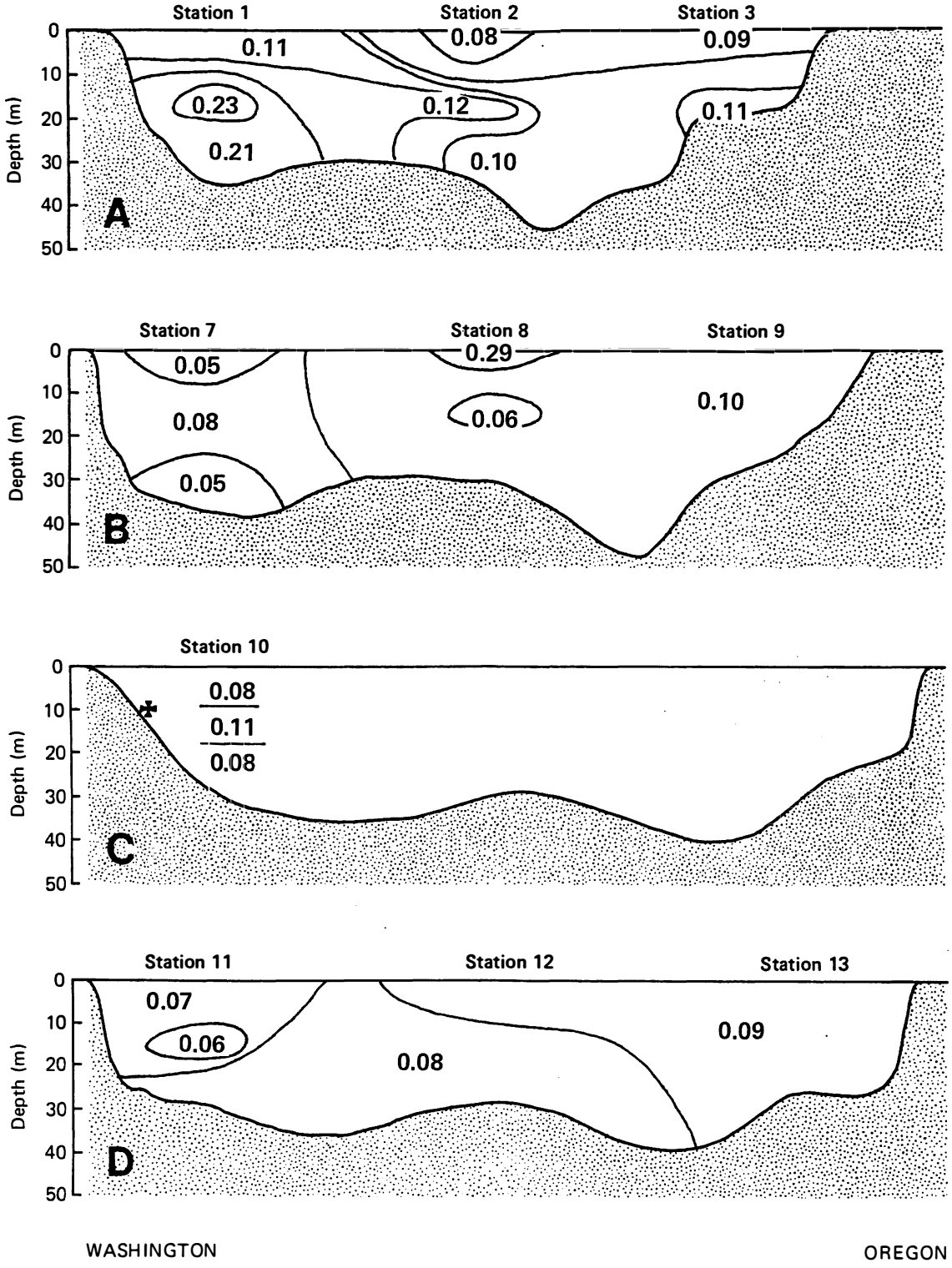
Appendix Figure 19.--Fluoride contours (ppm), 20-22 May 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



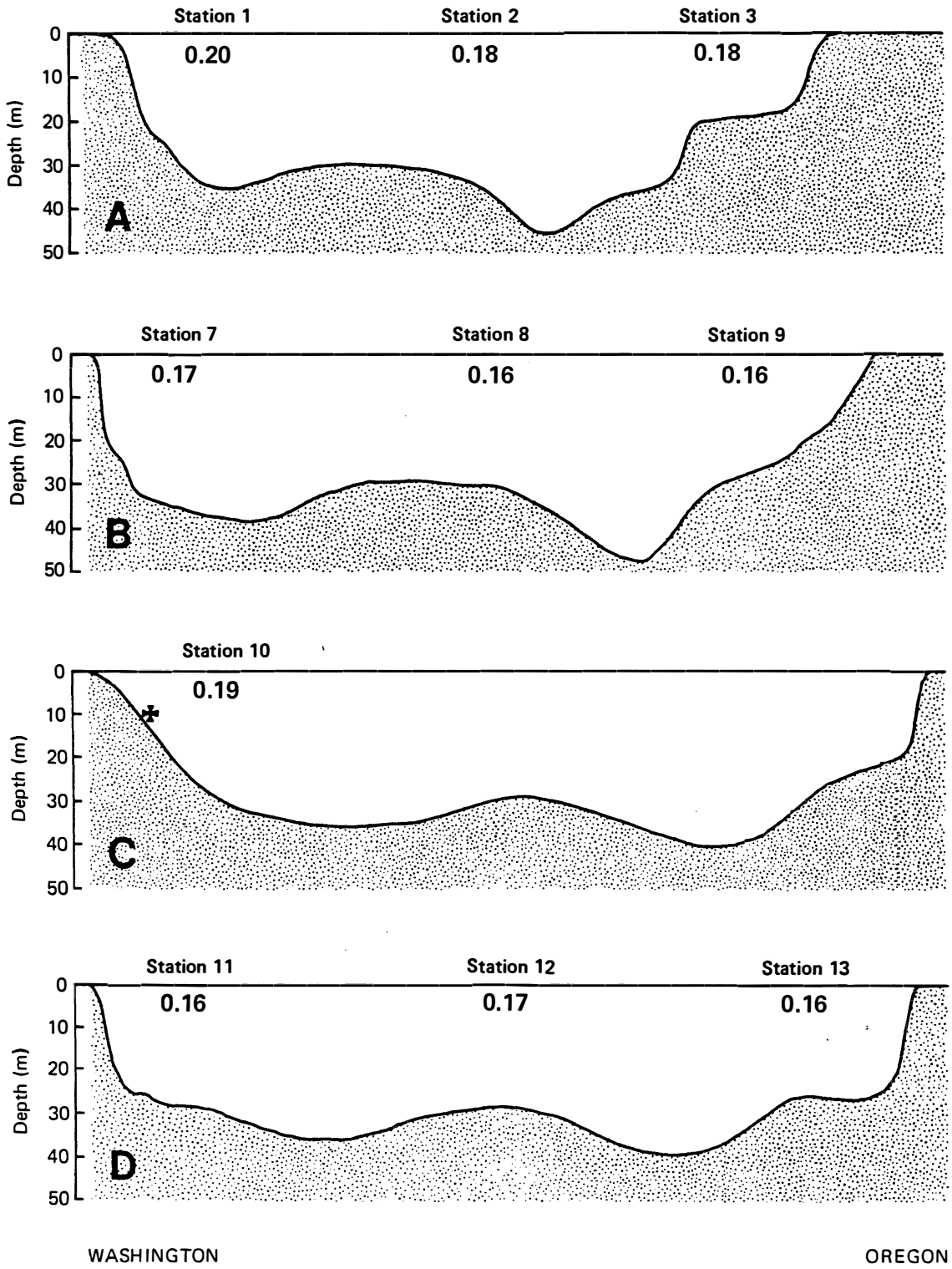
Appendix Figure 20.--Fluoride contours (ppm), 10-12 June 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



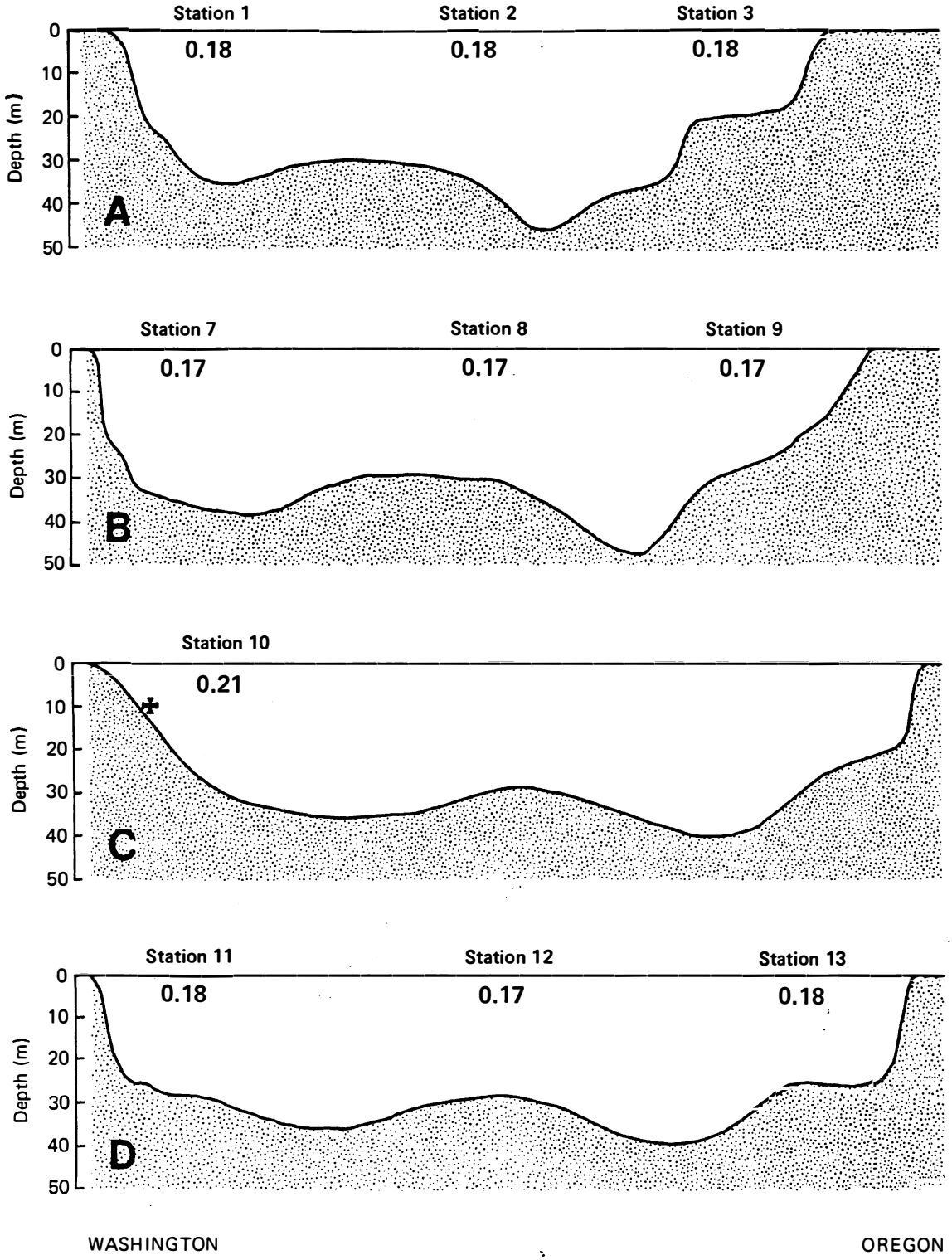
Appendix Figure 21.--Fluoride contours (ppm), 9-11 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



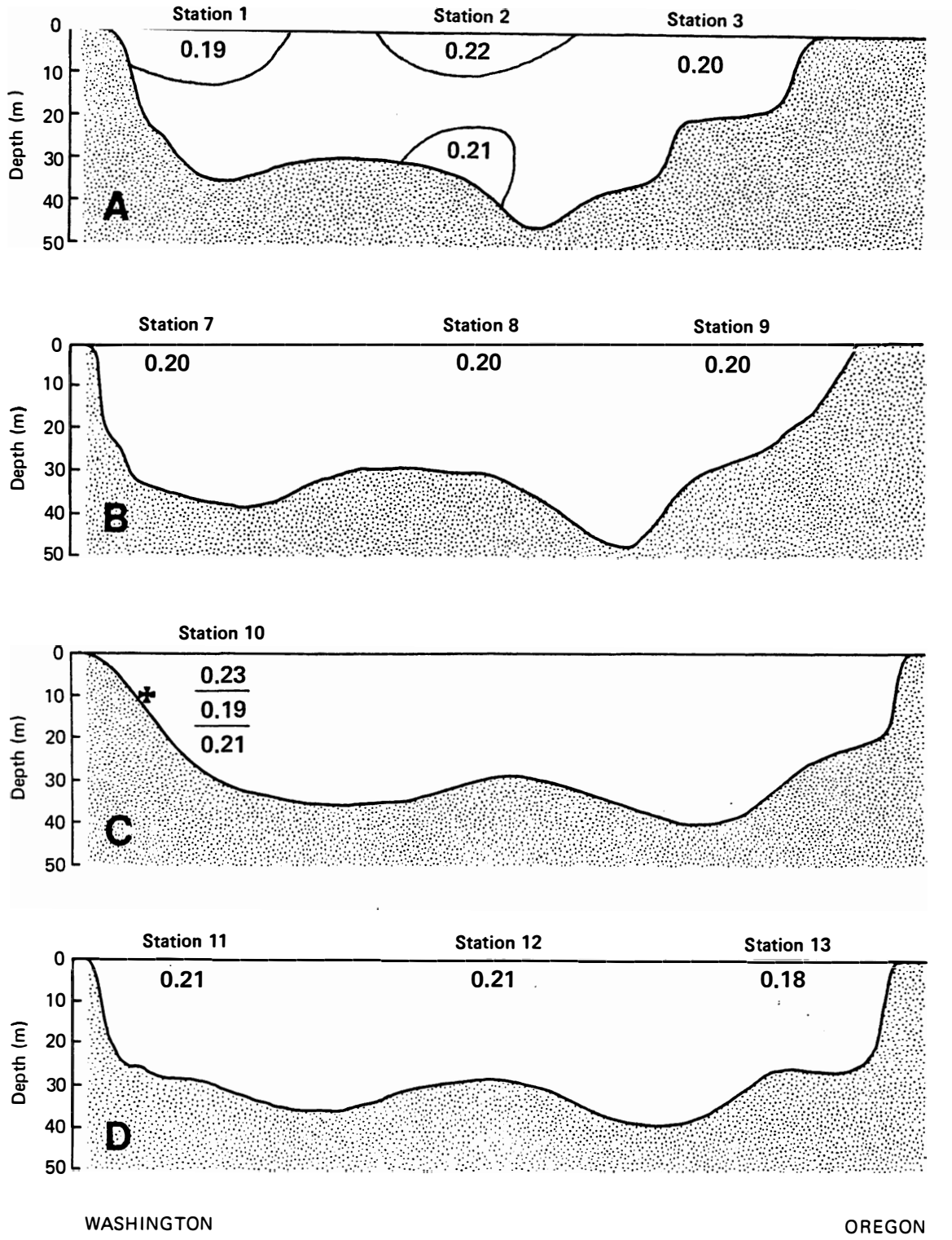
Appendix Figure 22.--Fluoride contours (ppm), 30-31 July 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



Appendix Figure 23.--Fluoride contours (ppm), 17-18 September 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



Appendix Figure 24.--Fluoride contours (ppm), 16-17 October 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.



Appendix Figure 25.--Fluoride contours (ppm), 12-14 December 1984, John Day Dam region, Columbia River (see Figure 1 for station locations). Maltese cross indicates location of aluminum plant outfall.