PRE-AUTHORIZATION ASSESSMENT OF THE PROPOSED SUSITNA RIVER HYDROELECTRIC PROJECTS: PRELIMINARY INVESTIGATIONS OF WATER QUALITY AND AQUATIC SPECIES COMPOSITION

by

JAMES C. RIIS

Fisheries Biologist

Alaska Department of Fish and Game
Sport Fish Division
Anchorage
May 1977

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

JAY S. HAMMOND, GOVERNOR

333 RASPBERRY ROAD
ANCHORAGE 99502

March 13, 1977

Mr. Gordon Watson
Area Director
Fish and Wildlife Service
U.S. Department of the Interior
813 "D" Street
Anchorage, Alaska 99501

Dear Mr. Watson:

The attached progress report summarizes preliminary environmental work related to the Corps of Engineers Susitna River Hydroelectric Project during the fiscal year transition quarter July 1, 1976 to September 30, 1976. This baseline inventory study was conducted by the Alaska Department of Fish and Game, Sport Fish Division, under contract to the U.S. Fish and Wildlife Service. Data collected during this study include water quantity, water quality, and biological information as outlined in Amendment #1 to the Contract Agreement.

I would like to express our appreciation to the U.S. Fish and Wildlife Service for funding this project and renewing the contract for FY-77. The ongoing studies will allow the continuity necessary for baseline investigations to be of value in planning extensive, long-term work. If the Devils Canyon/Watana project is funded, the intensive five year aquatic studies should be initiated at the beginning of FY-78, in order to assess the full impacts of hydroelectric development on the entire Susitna drainage prior to design approval and construction.

Sincerely yours,

James C. Riis
Fishery Biologist
Division of Sport Fish

Attachment

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX A TABLES

APPENDIX A TABLES

APPENDIX A TABLES

ABSTRACT

Biological, water quality, and water quantity investigations were conducted from July 1, 1976 through September 30, 1976 to obtain baseline data on indigenous fish populations and the existing aquatic habitat as part of an ongoing environmental study to assess the potential impacts of the proposed Watana/Devils Canyon hydroelectric project upon the aquatic ecosystem of the Susitna River drainage.

Long term ecological changes to this drainage may be significant. The level and flow patterns of the Susitna River will be altered and will affect the fish and wildlife resources.

INTRODUCTION

The U.S. Army Corps of Engineers has been considering several sites within the Susitna River drainage for construction of a hydroelectric complex. The current plan includes construction of dams and power plants on the Susitna River at Devils Canyon and Watana Creek with transmission lines to the southcentral railbelt. A timetable suggested by the dams' chief advocate, U.S. Senator Mike Gravel, calls for construction authorization in 1981 and Watana Dam completion in 1986. Devils Canyon Dam will be completed in 1990.

The earth fill Watana Dam (river Mile 165) will be 810 feet high. The reservoir, when filled to capacity will have an elevation of 2,200 feet and a surface area of approximately 43,000 acres, extending 54 miles upstream.

The thin arch concrete Devils Canyon Dam (river Mile 134) will be 635 feet high. At maximum pool level, the reservoir will have an elevation of 1,450 feet and a surface area of 7,550 acres, extending upstream approximately 28 river miles to the Watana Dam site.

The estimated cost for the hydroelectric complex was 1.5 billion dollars in 1974. Inflation could increase this estimate to 6 billion dollars (Gabler, 1976). In October, 1976 the 94th Congress Second Session authorized 25 million dollars to become available in October, 1977 for preconstruction planning (Phase I) which includes engineering, economic, and environmental studies. The complex financing scheme for this project beyond Phase I will not be discussed in this report. It is, however, a giant undertaking and it is recommended that the environmental studies proceed on the same scale as the overall project.

Baseline environmental fisheries studies have been conducted over a three-year period by the Alaska Department of Fish and Game (ADF&G) and will be continued in 1977. The projects were financed with federal funding averaging $29,000 per year. In 1974, the National Marine Fisheries Service and U.S. Fish and Wildlife Service (USFWS) contracted ADF&G to conduct a one-year assessment of salmon, (Oncorhynchus spp) populations utilizing the Susitna River in the vicinity of the proposed Devils Canyon dam site. The objectives of these studies were to determine the spawning distribution,

relative abundance, migrational timing and juvenile rearing areas (Barrett, 1974). Additional funding was received in 1975 and 1976 from the USFWS for continuing and expanding these studies downstream and to include physical and chemical parameters associated with the mainstem Susitna River (USFWS 1976). This report covers the period July 1, 1976 through September 30, 1976.

STUDY AREA

The Susitna River is approximately 275 miles long from its source in the Alaska Mountain Range to its point of discharge into Cook Inlet. The major tributaries of the Susitna originate in glaciers and carry a heavy load of silt during the ice free months. There are also many smaller tributaries which are perennially silt free. The Susitna River Basin is one of the largest chinook (O. tshawytscha) and coho (O. kisutch) salmon production areas in Cook Inlet.

The study section is located between Devils Canyon and Willow Creek (Fig. 1). Sampling sites were monitored on the Susitna River and tributaries. Twelve of these sites were clear water sloughs (sites 3c, 8, 10, 11, 13, 14, 15, 16, 17, 18, 19, and 20) adjacent to the Susitna River (Fig. 2). Three sites were on the mainstem of the Susitna River and the remaining locations were clearwater creeks and rivers flowing into the Susitna. Sites were chosen based on their proximity to the Devils Canyon dam area and past Susitna studies documenting fish usage (Barrett, 1974; USFWS, 1976).

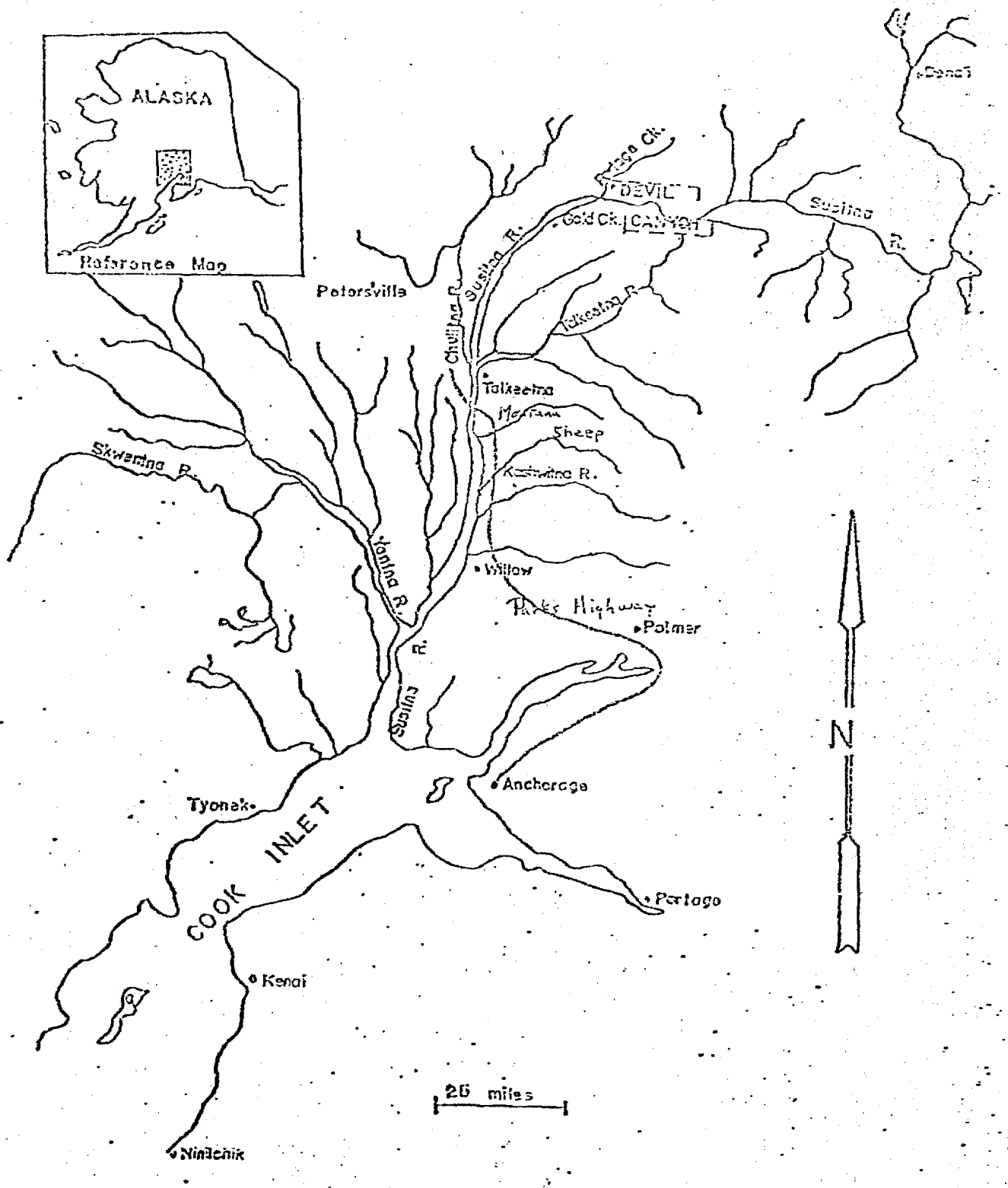


Figure 1. Devils Canyon in reference to the Susitna River watershed and northern Cook Inlet, Devils Canyon Project, 1976.

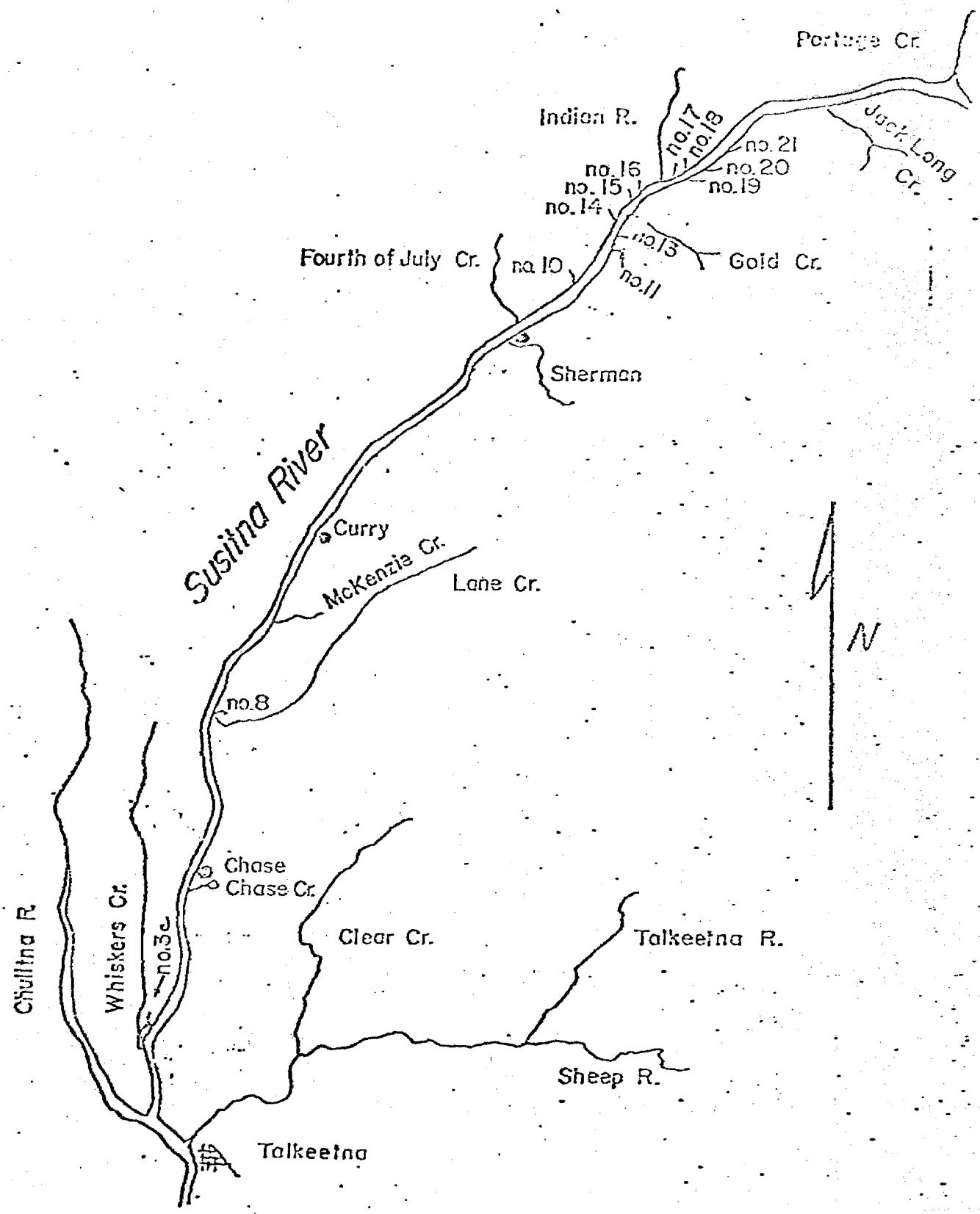


Figure 2. Map of the upper Susitna River study area encompassed in the Devils Canyon Project, 1976.

METHODS

A base camp was established at Gold Creek because of its central location to the sample sites and the logistical advantages offered by the Alaska Railroad. Travel on the Susitna River to the sites was accomplished by a 20-foot riverboat with a jet equipped 85-horsepower outboard motor. Water quantity and biological data were collected biweekly at the sites. Water quality data were collected biweekly at the mainstem Susitna sites and once per month at other site locations.

Water Quantity

Discharge data were collected by ADF&G personnel at many of the slough and tributary sites. Flows were measured with a Pygmy Gurley current meter. Leupold stage gauges were installed in the sloughs and one of the tributaries. Permanent bench marks were established on the river banks, adjacent to the gauges, for future location reference (Appendix A, Tables 19-31). Channel cross sections were measured with a wading rod and tape measure.

Mainstem Susitna River flow regimen were continually monitored by the U.S. Geological Survey (USGS) gauge station downstream from Gold Creek.

Water levels of the sloughs and one tributary were correlated with mainstem Susitna River discharges using a Wang 462 advanced statistical calculator.

Water Quality

Turbidity, conductivity, pH, alkalinity, hardness and dissolved oxygen were measured with a Hach chemical kit, model DR-EL/2, using the methods outlined by the Hach Chemical Company. Temperature data were continually recorded with Ryan thermographs, Model D-30, at three sites on the Susitna River and one at Birch Creek. A pocket thermometer was used at the remaining sites. Analysis of water samples for total suspended solids was adapted from Standard Methods (APHA, et al., 1971; USFWS, 1976).

Benthic Invertebrates

Benthics were collected with artificial substrates which consisted of a wire vegetable basket lined with nylon cloth (210 micrometre mesh) and filled with 40 rocks taken from the streambed following the procedures described by the USGS (McCoy, 1974). The basket remained in the water for 75 days.

Fisheries

Adult salmon escapement and rearing fry were enumerated by ground survey with the exception of chinook salmon counts, which were done with a Bell-47 helicopter and fixed wing aircraft. Fry samples were taken with a dip net or minnow trap and preserved with a 10% formalin solution (Brown, 1971).

Angling (using spinning and fly rods) was employed to capture grayling for tagging studies. Grayling were tagged with Floy anchor (T) tags.

FINDINGS

Flow Regimens

Between May 12, 1976 and June 12, 1976 the unregulated flow of the Susitna River increased from 11,900 cubic feet per second (cfs) to a peak discharge of 33,300 cfs (Fig. 3; Appendix A, Table 18). By June 19, the flow had decreased to 19,400 cfs and remained at approximately 20,000 cfs through August 19. The flow again declined, and by September 30, 1976 was 5,800 cfs. Based upon flow data obtained between 1965 and 1975, the Susitna flow regimen continues to decrease through November and stabilizes at approximately 1,300 cfs, until it begins to increase during the spring runoff in April (USGS Water Resources Data for Alaska 1965-1975). The fluctuating flows and associated stage heights of the unregulated mainstem Susitna are compared to the projected daily 7,000 cfs discharge of the proposed regulated system in Fig. 4.

Stage fluctuations within the clearwater sloughs of the Susitna related directly to mainstem discharge variations (Figures 5-10; Appendix A, Tables 4-9. Nine (75%) of the 12 sloughs were isolated pools or completely dry when mainstem flows were 7,000 cfs. Attempts to measure flows of the sloughs were unsuccessful because of low velocities.

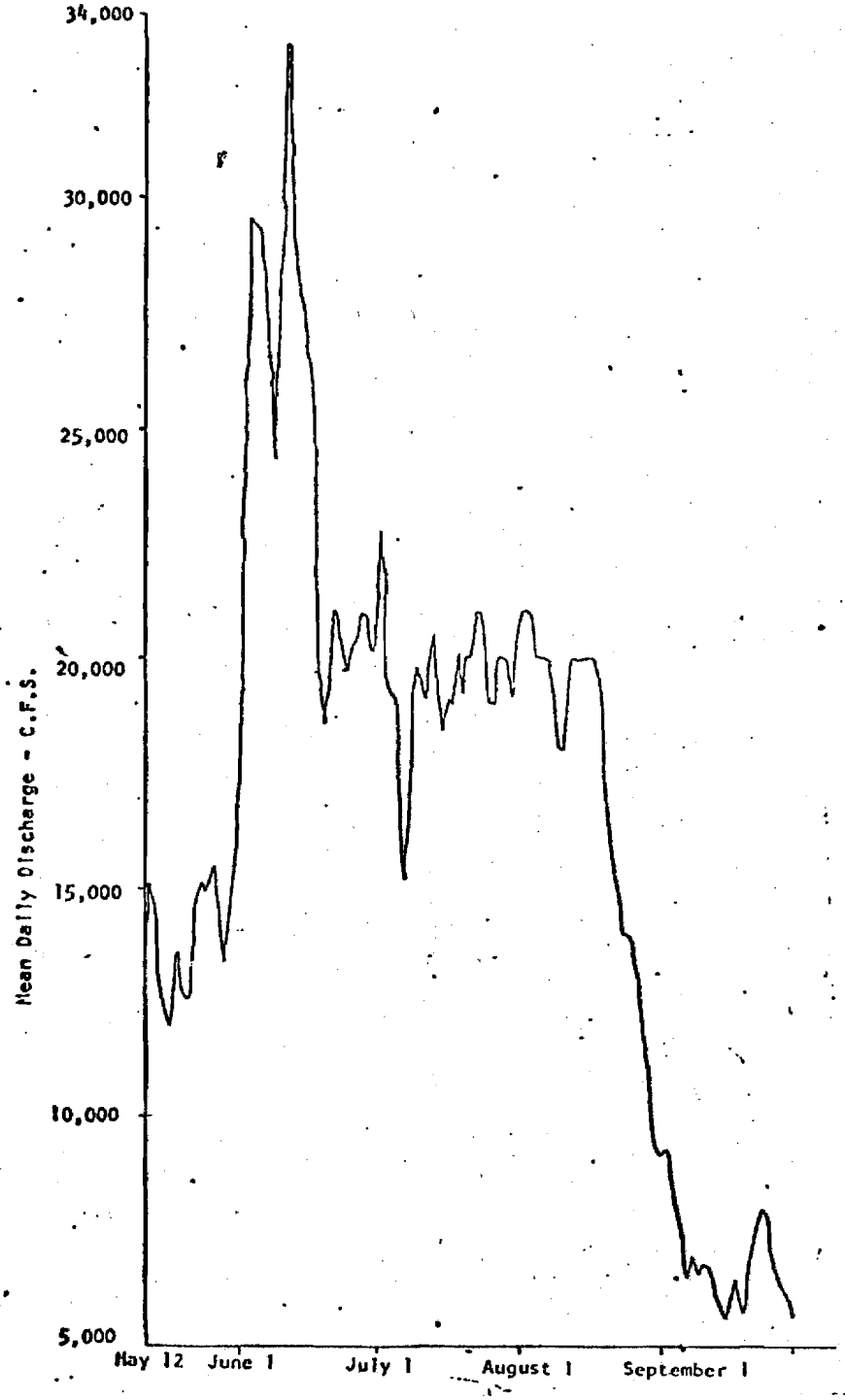


Figure 3. Susitna River Discharge at Gold Creek, USGS Provisional Records, 1976.

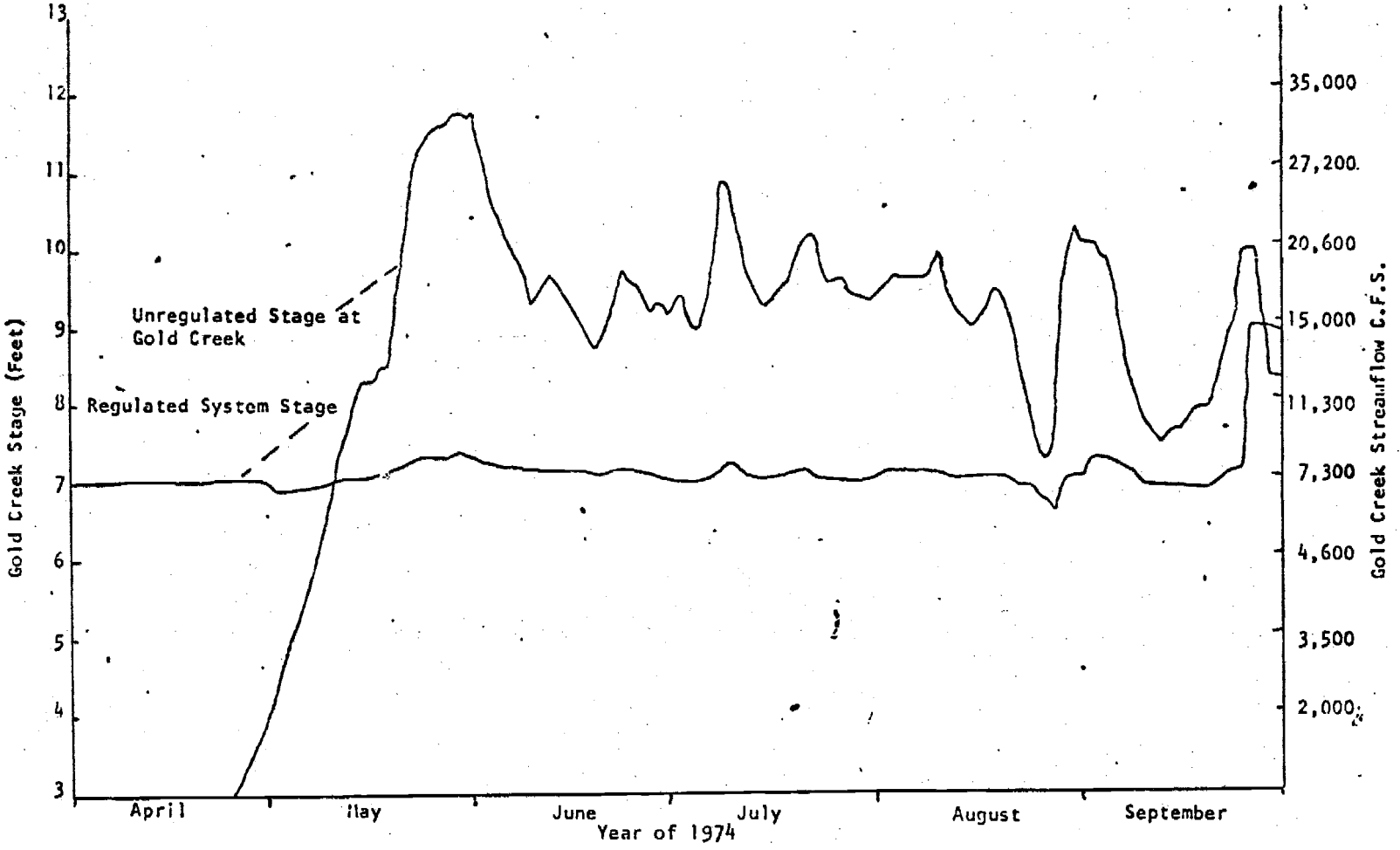
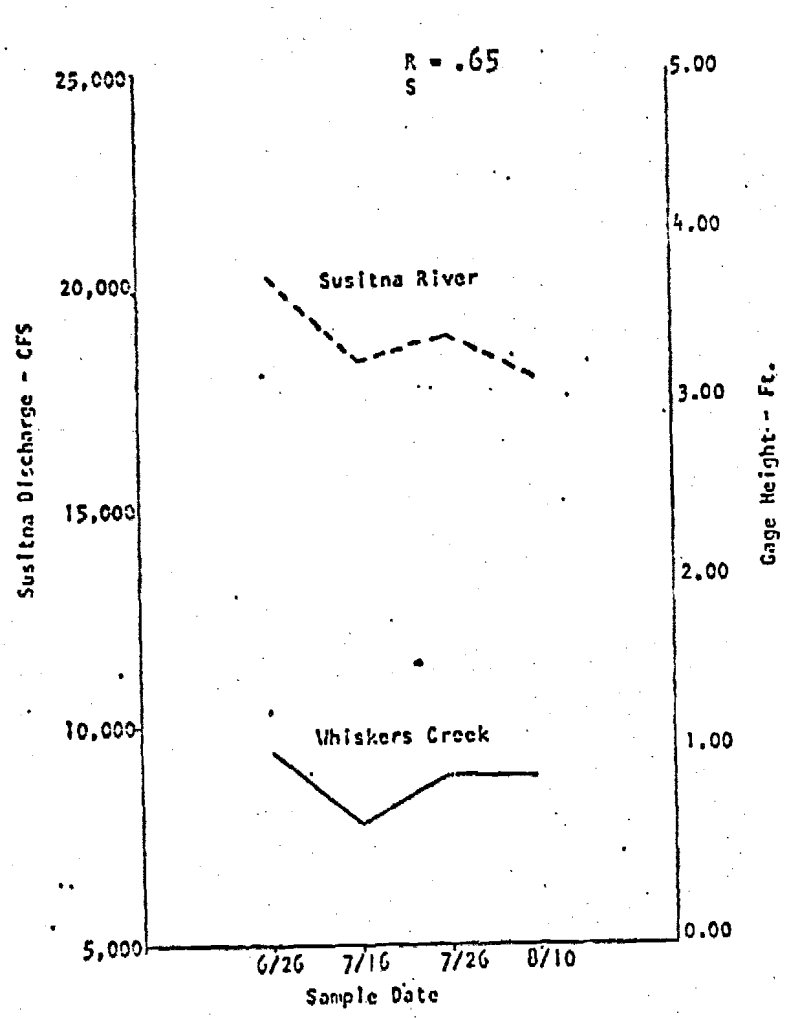


Figure 4. Devils Canyon and Watana Dams Regulated and Unregulated Daily Streamflow, U.S. Army Corps of Engineers, 1975.



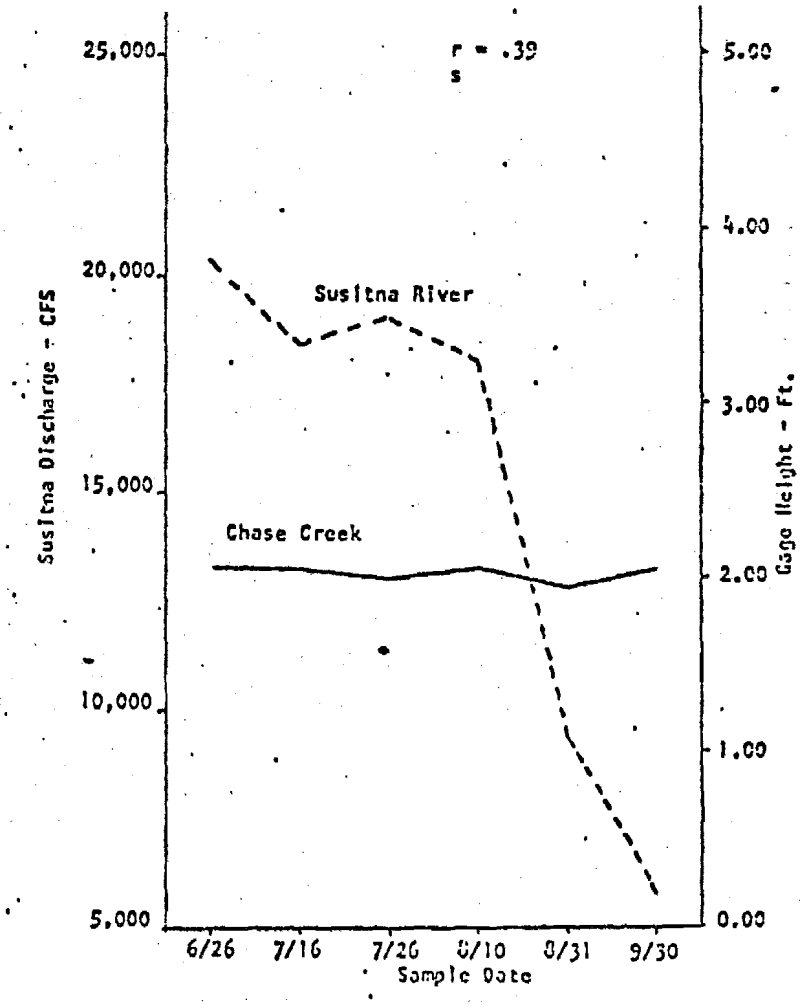
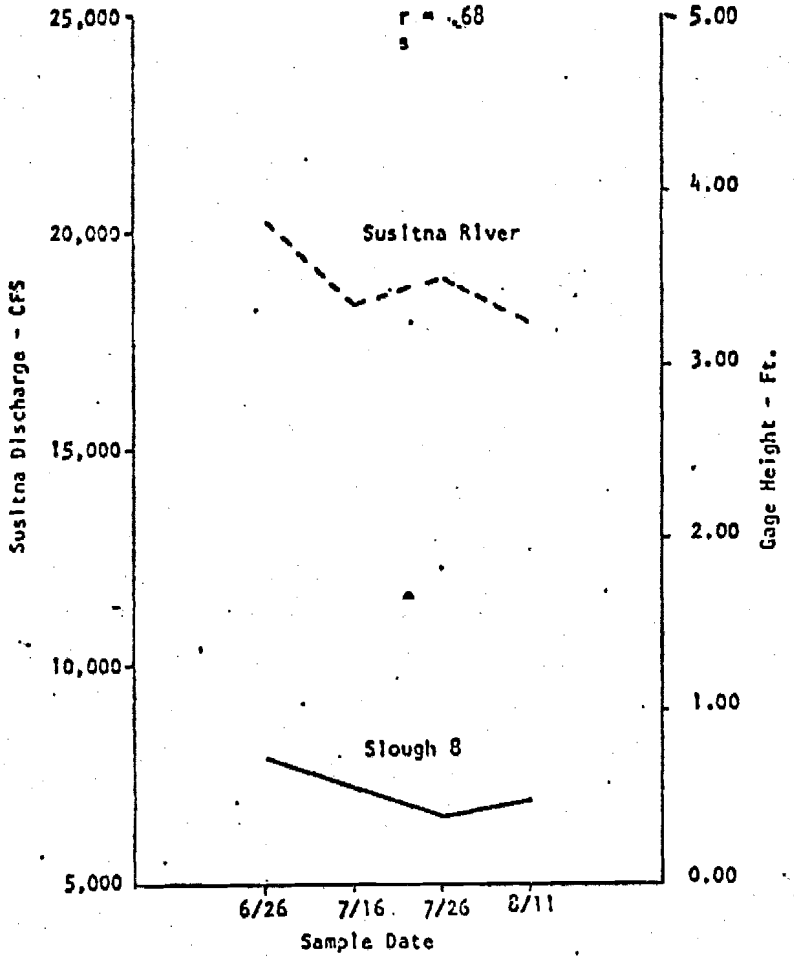


Figure 5. Correlation of Susitna River Discharge with Water Stage in Slough 3C and Chase Creek, Devils Canyon Project, 1976.

S = Non Significant



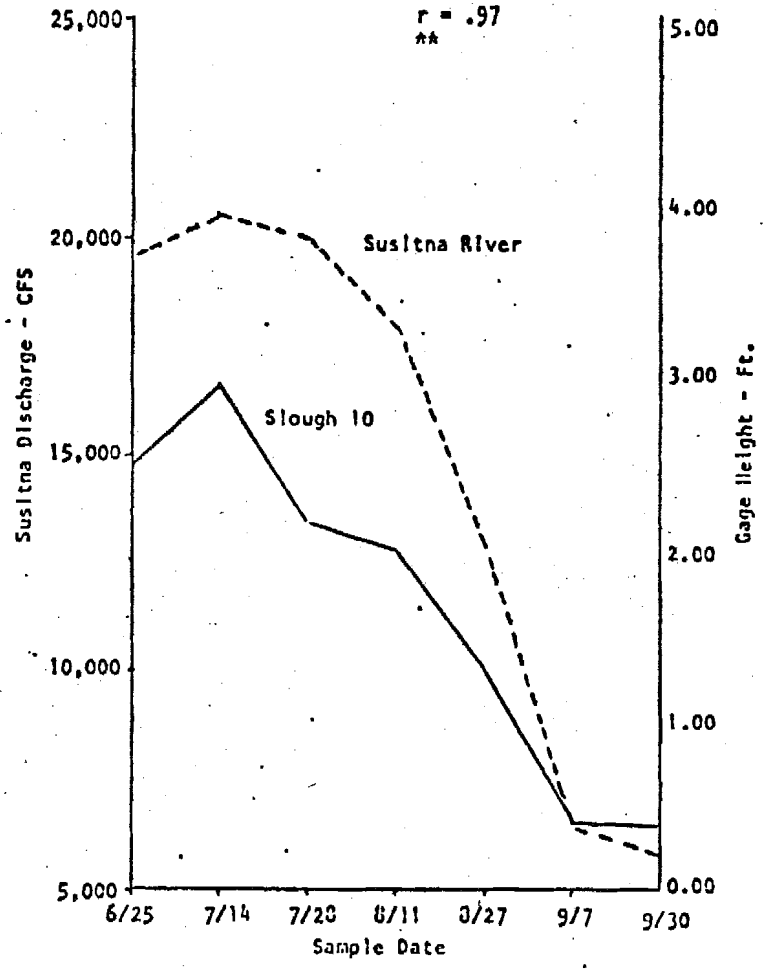
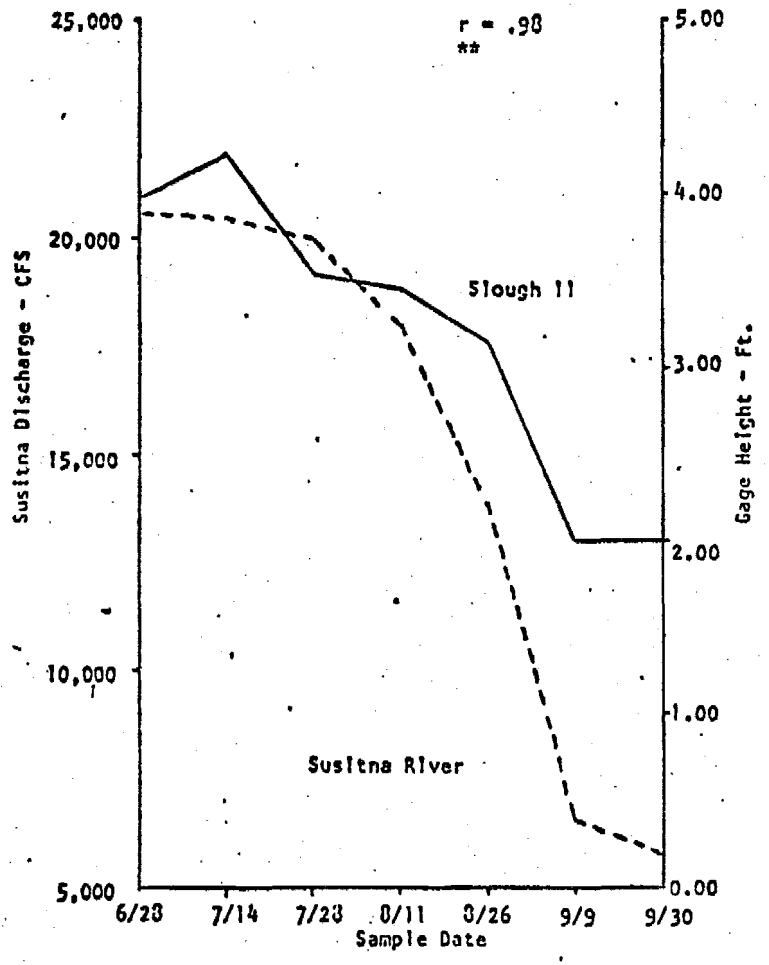


Figure 6. Correlation of Susitna River Discharge with Water Stage in Sloughs 8 and 10, Devils Canyon Project, 1976.

** = .01 Significant
S = Not Significant



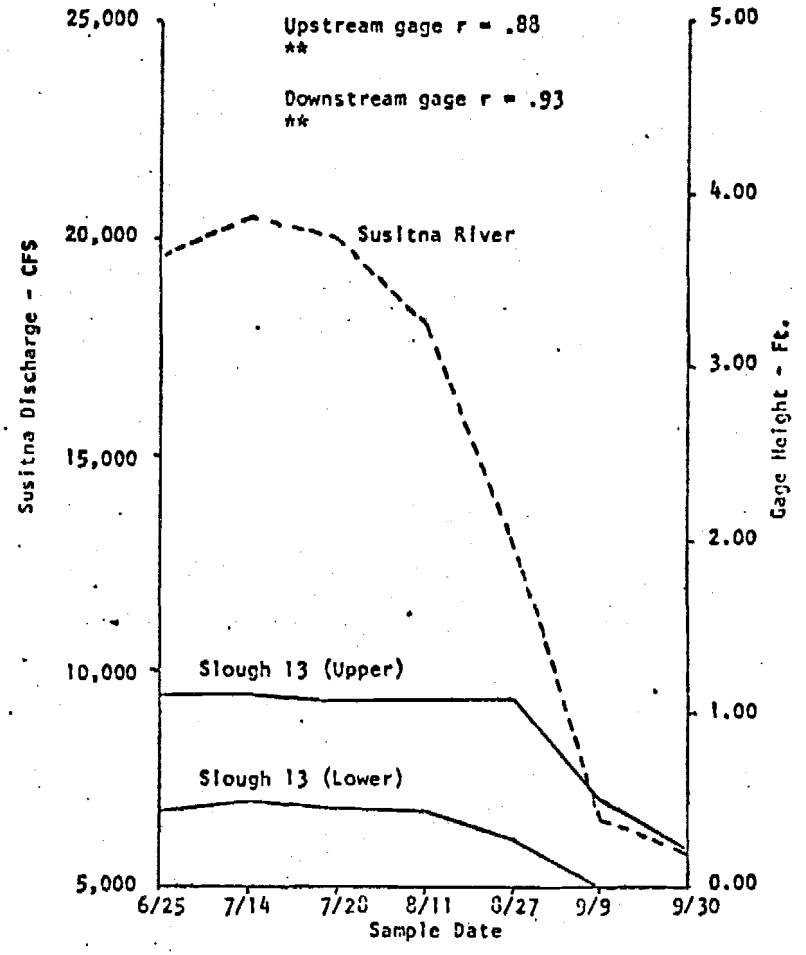


Figure 7. Correlation of Susitna River Discharge with Water Stage in Sloughs 11 and 13, Devils Canyon Project, 1976.

** = .01 Significance

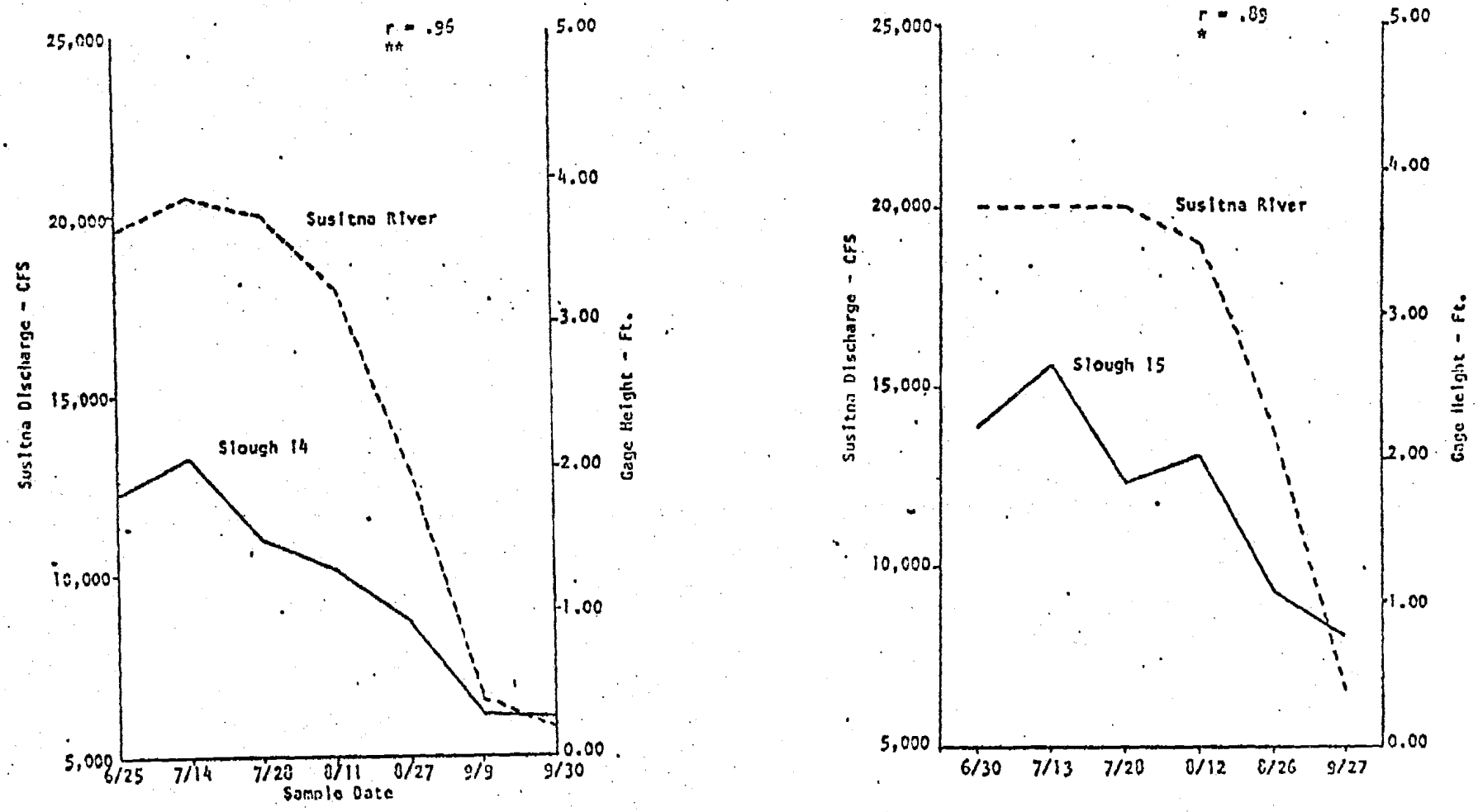
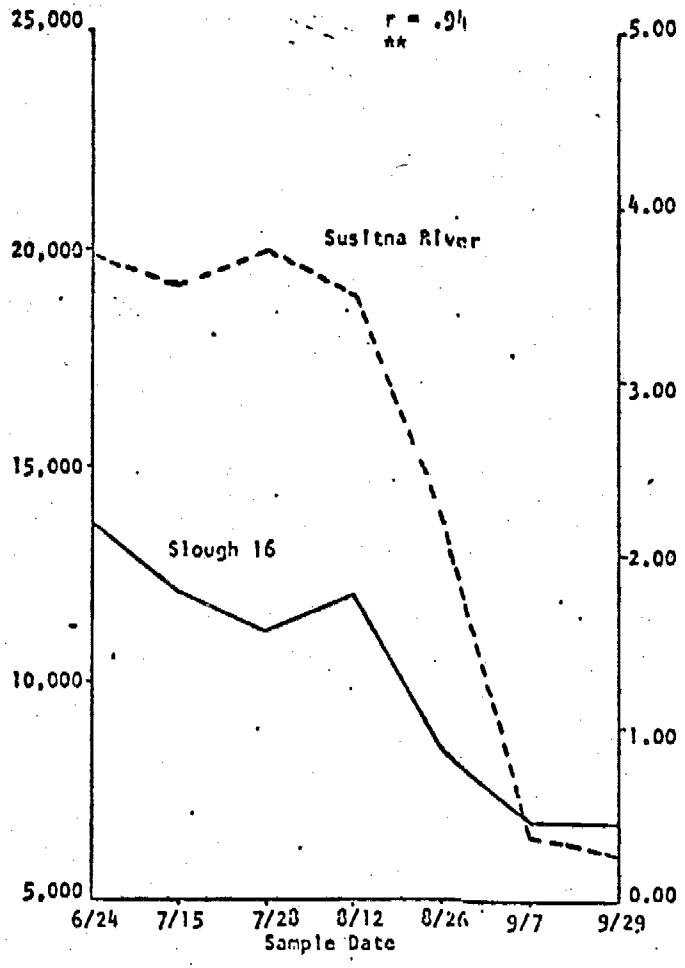


Figure 8. Correlation of Susitna River Discharge with Water Stage in Sloughs 14 and 15, Devils Canyon Project, 1976.

* = .05 Significance
** = .01 Significance



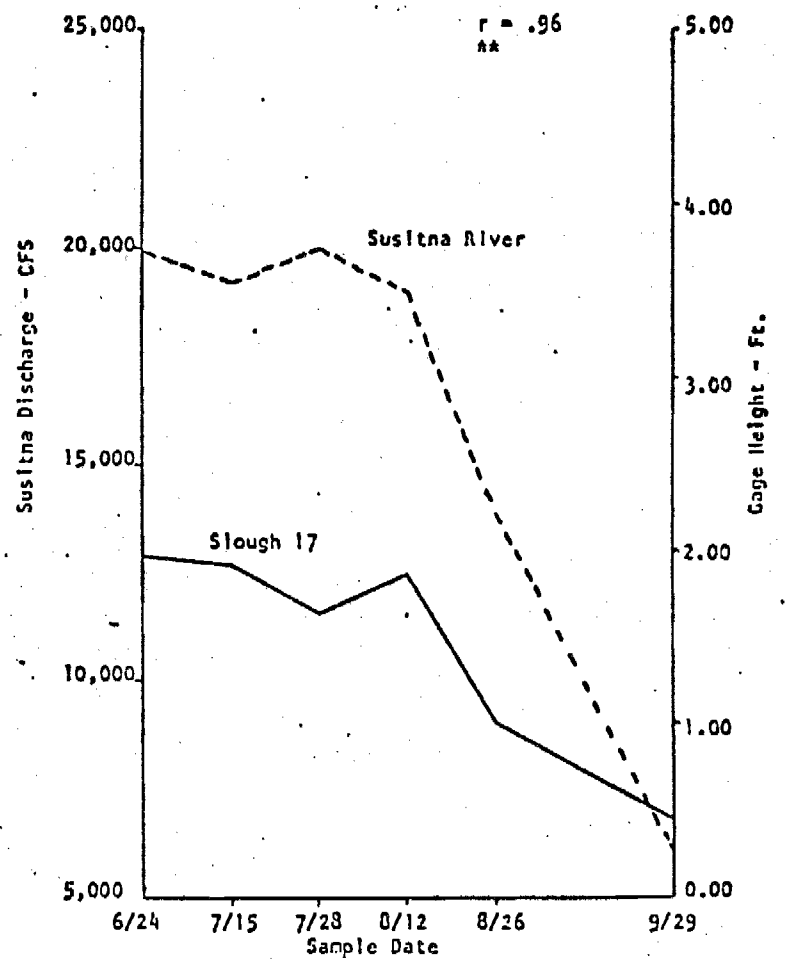
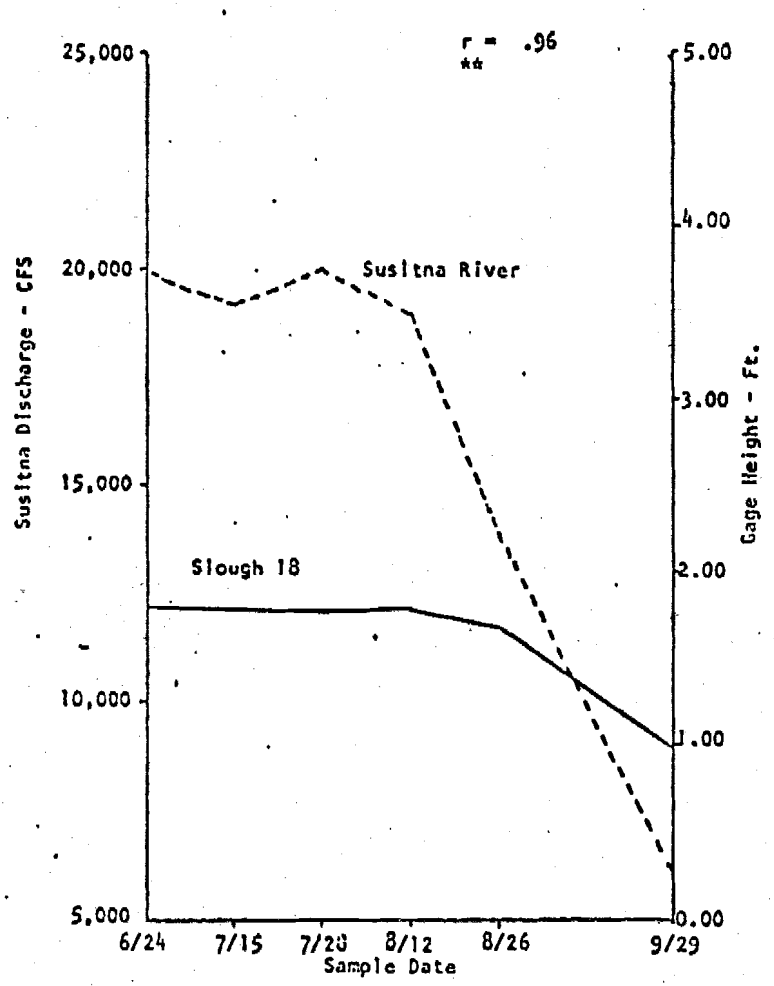


Figure 9. Correlation of Susitna River Discharge with Water Stage in Sloughs 16 and 17, Devils Canyon Project, 1976.

** = .01 Significance



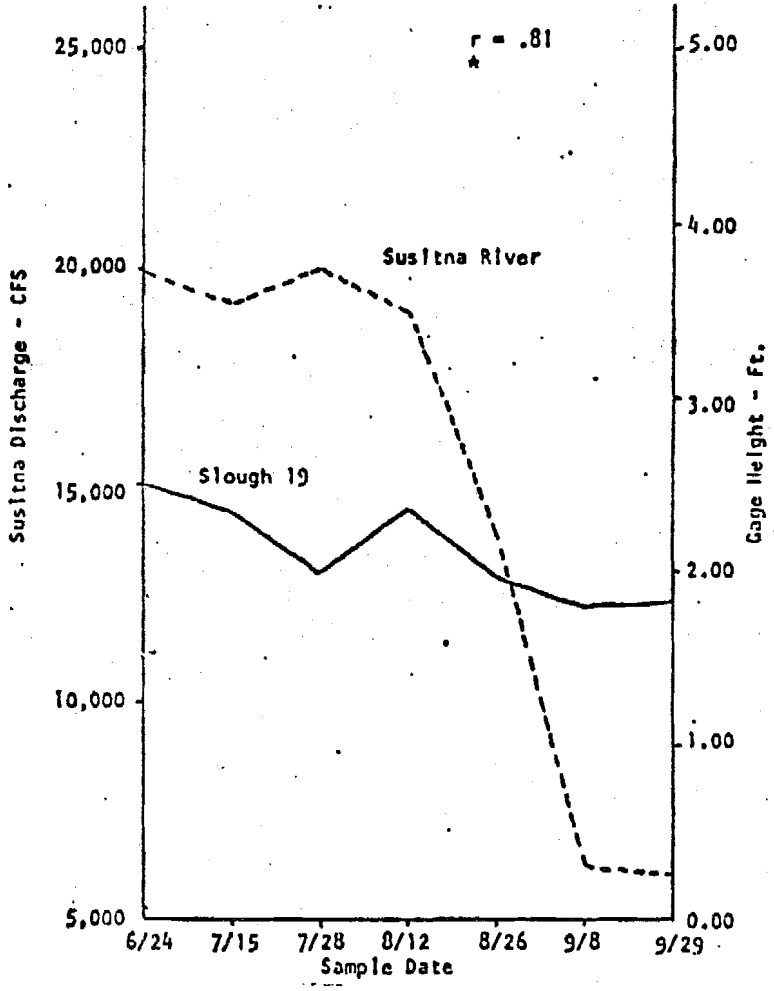


Figure 10. Correlation of Susitna River Discharge with Water Stage in Sloughs 18 and 19, Devils Canyon Project, 1976.

** = .01 Significance
* = .05 Significance

Flows of Portage, Gold, Fourth of July, Chase and Whiskers creeks are presented in Appendix A, Table 32. Insufficient data were collected to analyze trends.

Temperature

Thermographs were located on the Susitna River at the Parks Highway bridge, upstream of Chase Creek, and between Devils Canyon and Portage Creek. Temperature trends were similar at the three sites. Temperatures at the Parks Highway Bridge site varied from 54 F on June 26 to 56 F on July 11 and August 4, and decreased to 32 F by October 26 (Fig. 11; Appendix A, Table 14). Temperatures at the Chase Creek location ranged from 51 F on June 21 to 59 F on July 30, 31, August 1, and 3, and dropped to 41 F by September 29 (Fig. 12, Appendix A, Table 15). Temperatures at the station between Devils Canyon and Portage Creek varied from 50 F on June 22 to 58 F on August 2 and decreased to 31 F by October 30 (Fig. 13, Appendix A, Table 16). Temperatures at Birch Creek (a potential future fish facility location) were also monitored and averaged 10 F higher than those recorded in the Susitna (Figure 14). Temperatures were also recorded at the thermograph and other study sites with a pocket thermometer (Tables 3-8). Slough water temperatures were more stable than those of the mainstem Susitna.

Suspended Solids and Turbidity

Total suspended solids (TSS) levels, measured immediately downstream from Devils Canyon, varied from 1,300 milligrams per liter (mg/l) on July 16 to

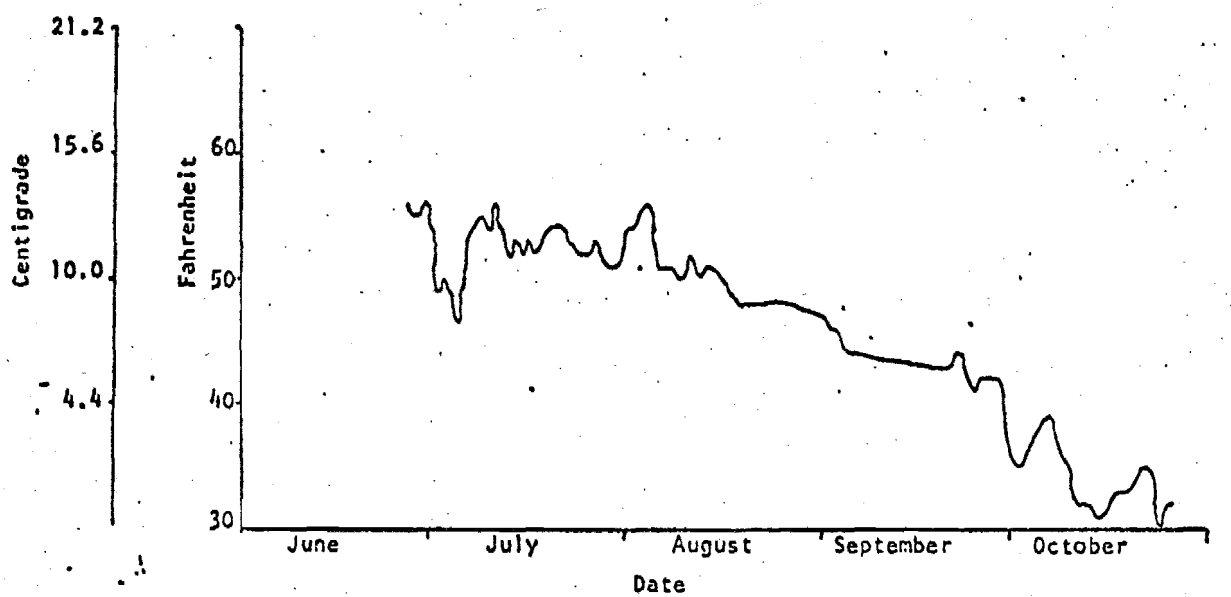


Figure 11. Maximum Daily Water Temperatures of Susitna River at Parks Highway Bridge, Devils Canyon Project, June 27 to October 26, 1976.

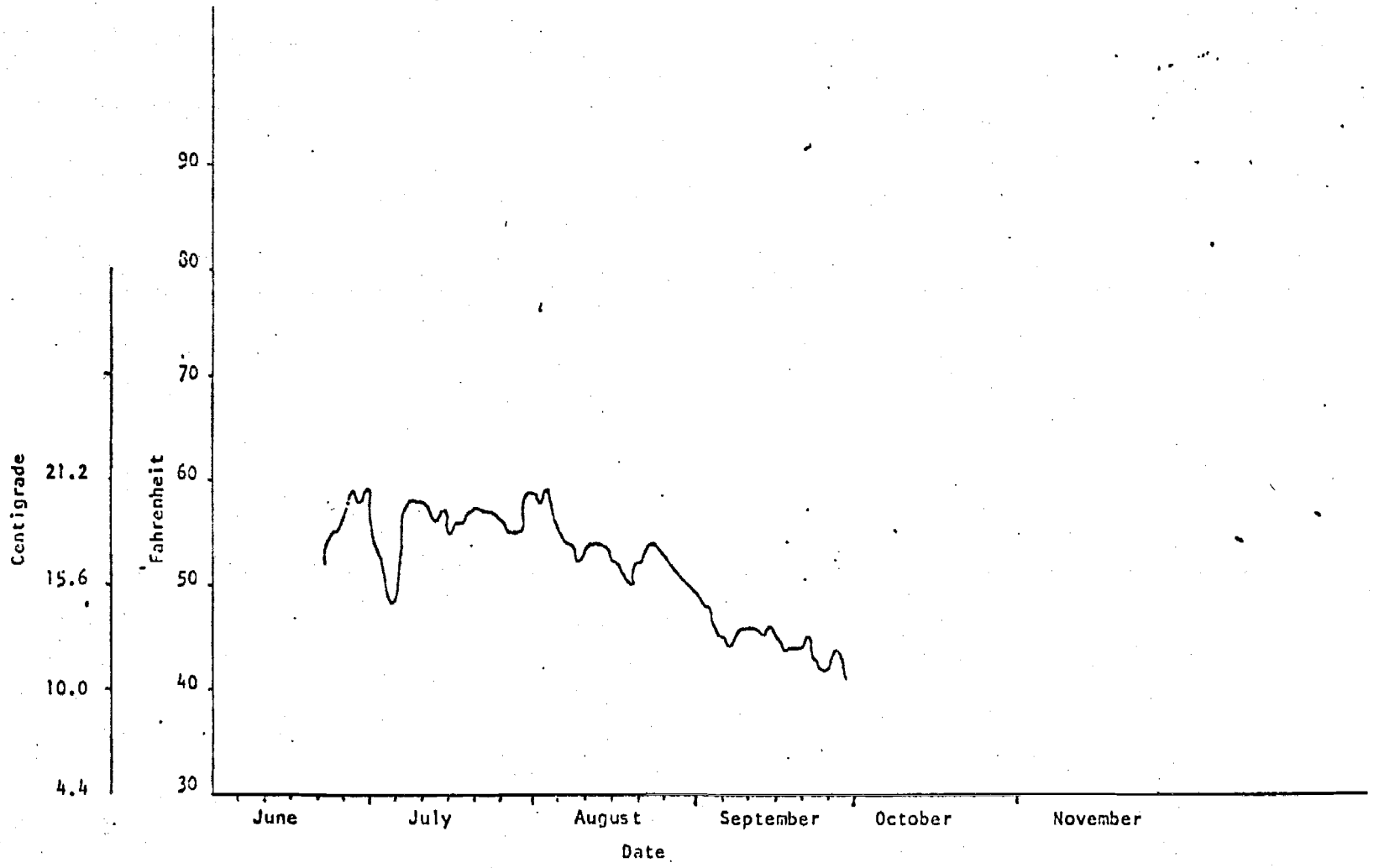


Figure 12. Maximum Daily Water Temperatures of Susitna River Upstream from Chase Creek, Devils Canyon Project, June 22 to September 29, 1976.

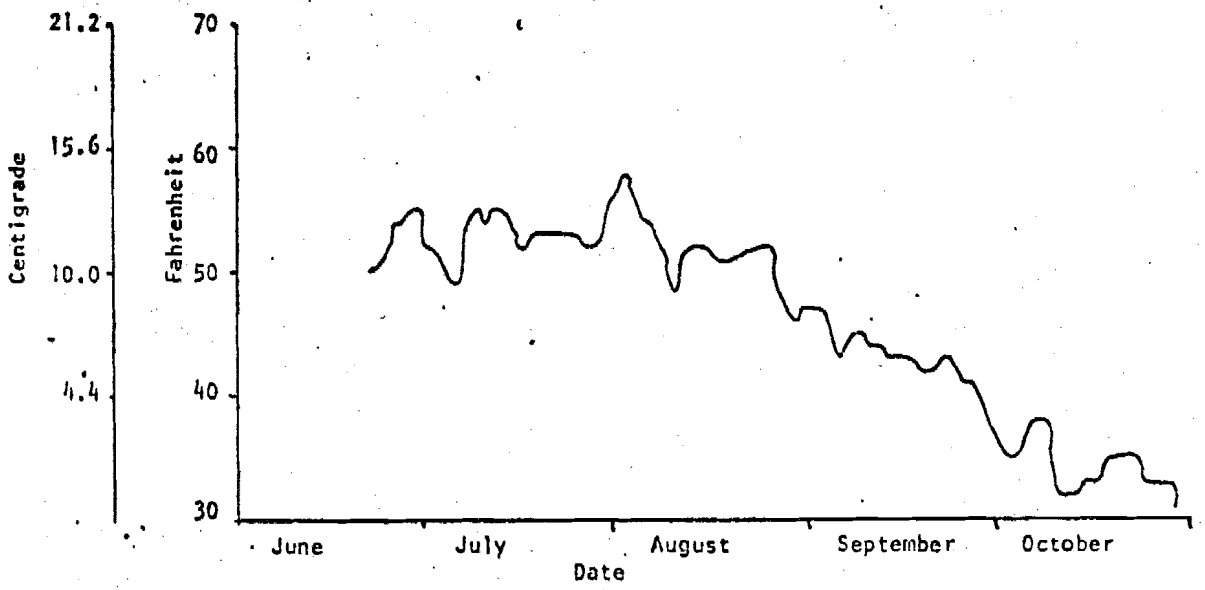


Figure 13. Maximum Daily Water Temperatures of Susitna River between Devils Canyon and Portage Creek, Devils Canyon Project June 22 to October 30, 1976.

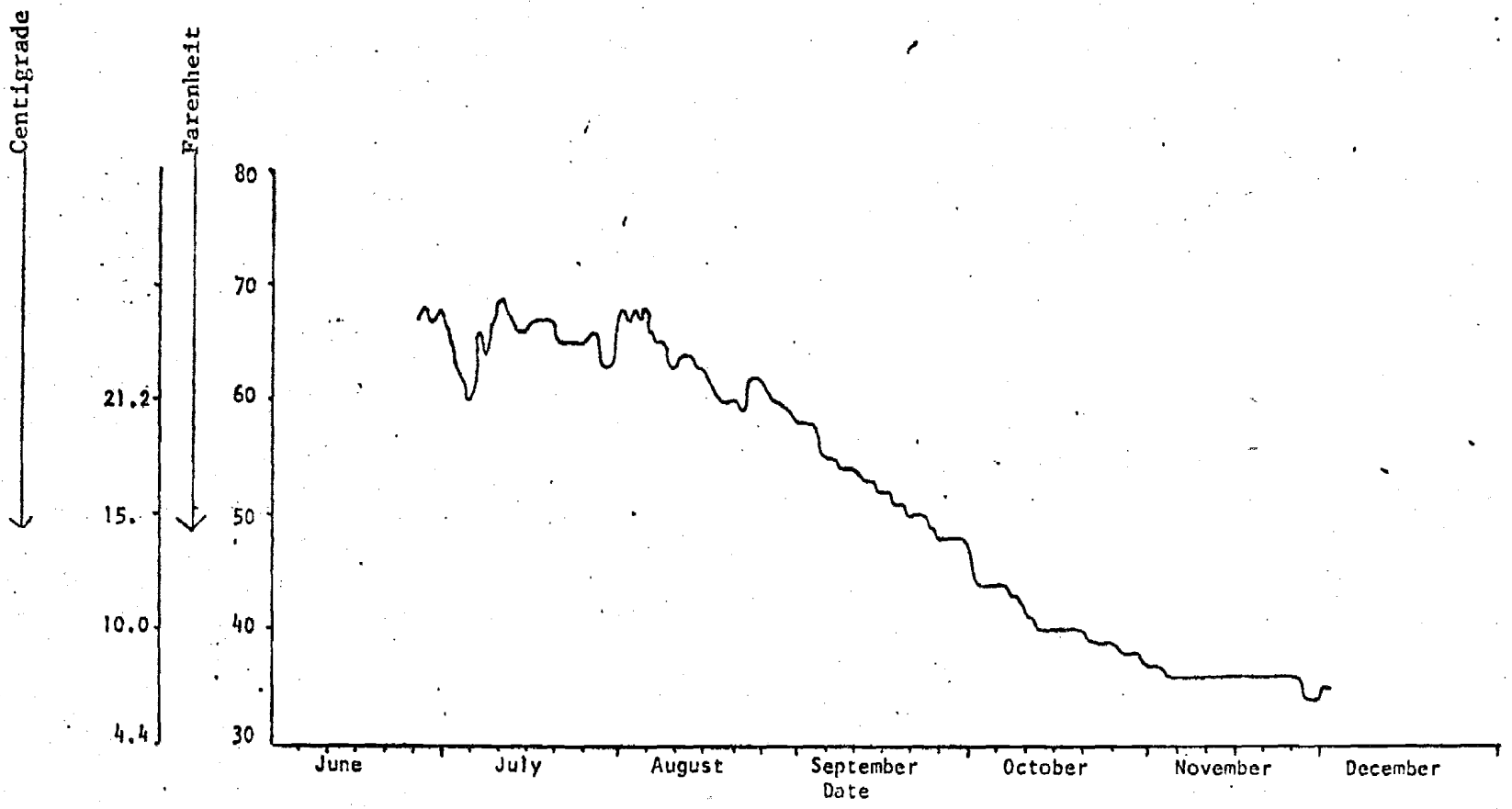


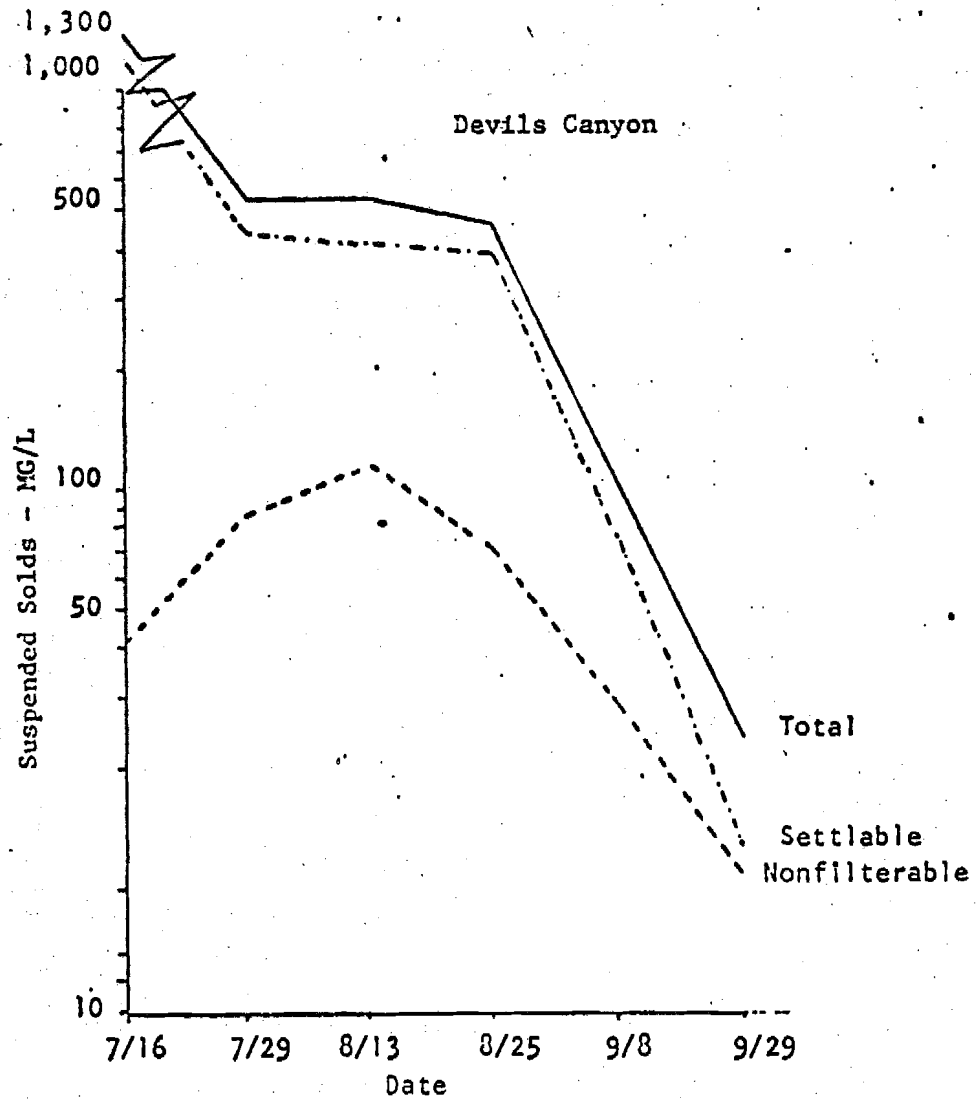
Figure 14. Maximum Daily Water Temperatures of Birch Creek Below Highway Crossing, Devil s Canyon Project, June 26 to December 1, 1976.

500 mg/1 by the end of July and remained constant throughout August (Fig. 15). The TSS decreased to 30 mg/1 during September. Formazin turbidity unit (Ftu) measurements followed a similar trend between July and September, ranging from 300 to 20 Ftu's (Fig. 16). TSS levels and turbidity levels correlated with Susitna River discharge fluctuation trends. Based upon past observations, the TSS and Ftu levels continue to decrease as flow decreases, stabilizing between November and April, and begin to increase with the increased flow in spring.

Water Chemistry

Field analyses of dissolved oxygen, pH, hardness, total alkalinity, and specific conductance are presented in Appendix A, Tables 1 through 13. Measurements of these parameters expands the Susitna River data base considerably and will be valuable in future studies and post-impoundment comparisons if the dams are built.

Oxygen concentrations were close to saturation throughout the study, ranging from 10 to 13 parts per million (ppm) in the Susitna River, 6-12 ppm in the sloughs, and 9 to 14 ppm in the tributaries. The dissolved oxygen concentrations exhibited a tendency to rise during the summer. Hydrogen ion (pH) concentrations ranged from 7.6 to 8.3 in the Susitna, 6.6 to 8.0 in the sloughs, and 7.0 to 8.3 in the tributaries. The range in pH at each station remained relatively stable for the three months of monitoring. Hardness, as $CaCO_3$, varied from 40 to 60 ppm in the Susitna River, from 20 to 95 ppm in the sloughs, and from 10 to 105 ppm in the tributaries. These readings all fall within the soft to medium water hardness classification.



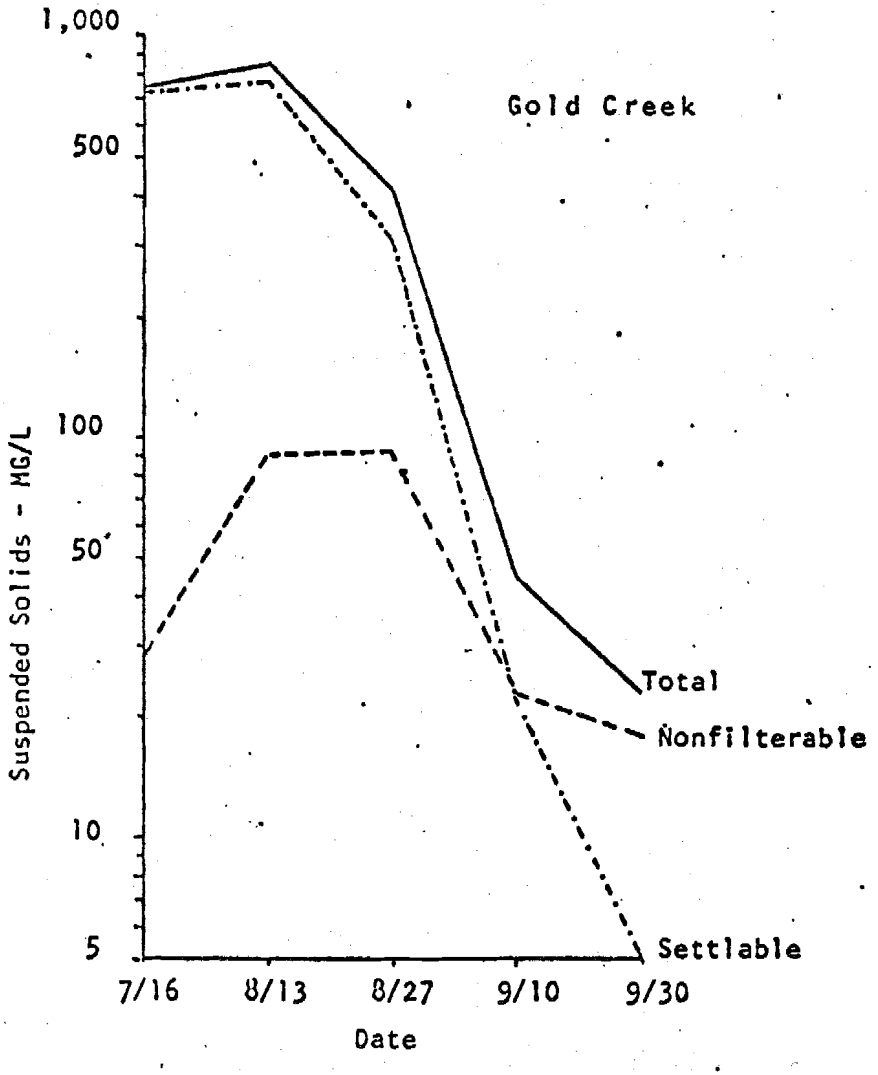


Figure 15. Susitna River Suspended Solids Collected Downstream of Devils Canyon and Below Gold Creek Railroad Bridge, Devils Canyon Project, 1976.

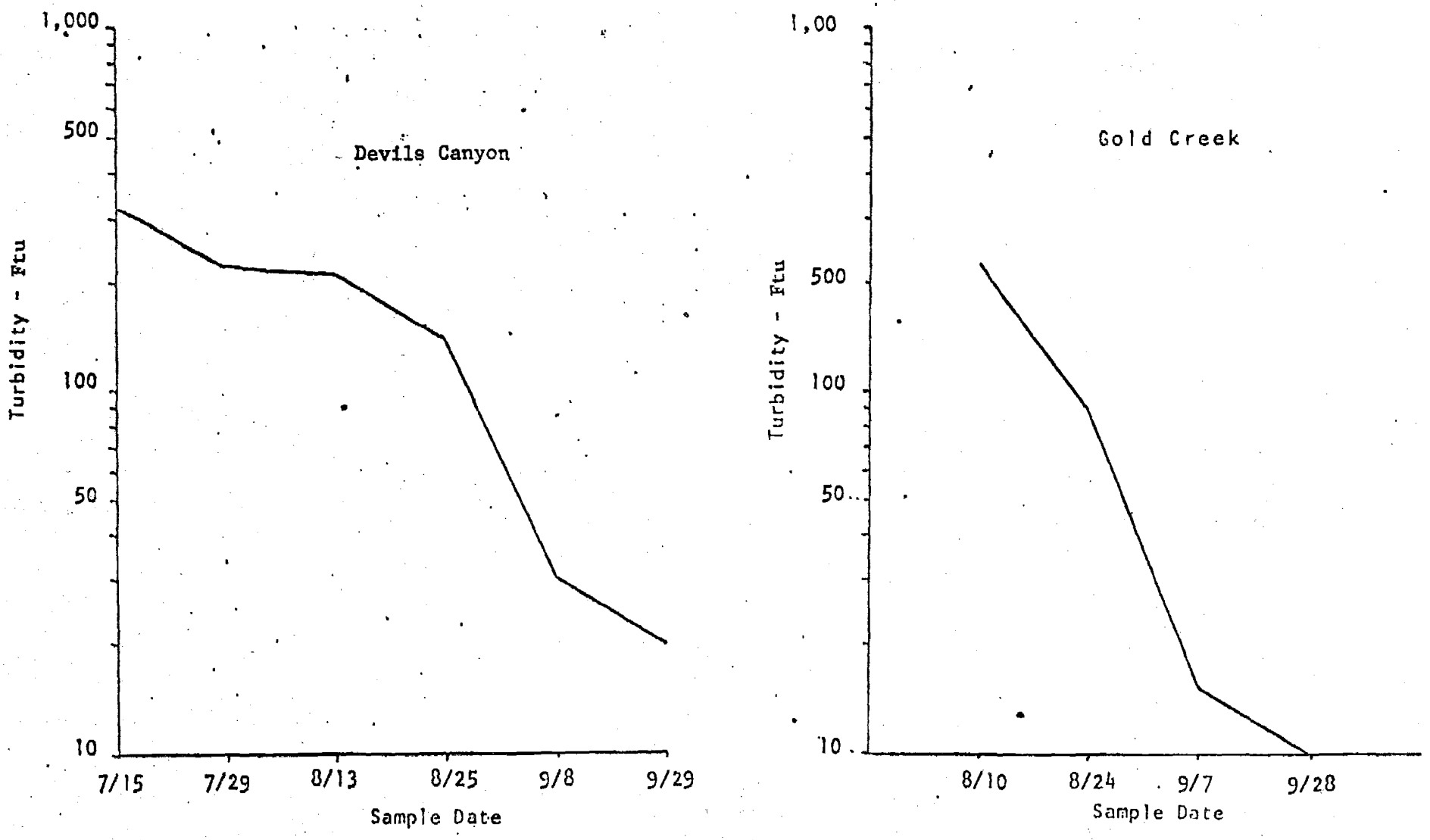


Figure 16. Susitna River Turbidity (Ftu) Levels Downstream of Devils Canyon and Below Gold Creek Railroad Bridge, Devils Canyon Project 1976.

Total alkalinity measurements were fairly uniform at each site during the study. Concentrations ranged from 30 to 55 ppm in the Susitna, from 10 to 105 ppm in the sloughs, and from 10 to 80 ppm in the tributaries. Conductivity readings, which were standardized to 25 C, ranged from 105 to 170 micro mhos per centimeter (micro mhos/cm) ranged from 105 to 170 micro mhos/cm in the Susitna, 55 to 230 micro mhos/cm in the sloughs, and 25 to 120 micro mhos/cm in the tributaries.

Benthic Invertebrates

Seven artificial substrate baskets were installed in the mainstem Susitna River on July 14, 1976. Two were located under the Gold Creek railroad bridge on the north side of the river and four on the south side of the river (two upstream of Gold Creek and two downstream of Gold Creek). One substrate was also placed in the Susitna upstream of Chase Creek on the east side of the river. Only the two baskets under the Gold Creek railroad bridge on the north side of the river can be discussed because the four on the south side were vandalized; and the water level dropped below the one at Chase Creek immediately preceding the recovery date. At the point where the two baskets remained in the water, the bottom material ranged in size from course gravel to large boulders (Wickett, 1959). The baskets were retrieved on September 30, 1976 and each rock was examined in the field for benthic invertebrates. The insects were keyed to order in the laboratory and of the 118 specimens (Plecoptera 77, Diptera 55, and Ephemeroptera 66), 63% were classifed as being "sensitive". *(In this report the orders of mayflies [Ephemeroptera] and stoneflies [Plecoptera] are considered to be "sensitive" to changes in water quality while the order of the true flies*

[Diptera] is considered to be "tolerant" to such changes. This admittedly is a fairly general categorization, but it is a widely used practice, particularly when taxonomic breakdown are not available to the researcher. A healthy stream section would therefore contain a large number of insects, a high percentage of which would be pollution "sensitive". Any reduction in total numbers or in the percentage of sensitive organisms from a control station would indicate stream degradation when more than one sample is collected).

Fisheries

The Susitna River drainage is utilized by all five Pacific salmon species, as well as resident species such as rainbow trout (Salmo gairdneri), and Arctic grayling (Thymallus arcticus). Aerial and ground escapement surveys were conducted in 1976 on Susitna River sloughs and its tributaries (Tables 1, 3, 4, 5, 6, 7, and 8). These escapement counts indicate the relative abundance of fish observed, and should not be interpreted to be total counts.

A chinook escapement of 50,499 (enumerated via aerial survey) is tabulated in Table 1. Coho adults were observed (via ground survey) in various tributaries prior to spawning; however, it was not possible to enumerate them to the extent chinook salmon were, because they utilize and disperse throughout many tributaries rather than congregating in the larger tributaries. Large numbers of pink salmon (O. gorbuscha) were located near the mouths of tributaries (Tables 7 and 8).

Table 1. Aerial enumeration of Chinook Salmon Escapements in the Susitna River Tributaries, Devils Canyon Project, 1976.

Stream (West Side)		Stream (East Side)	
Alexander Creek	5,412	Willow Creek	1,660
Deshka River	21,693	Montana Creek	1,445
Peters Creek	1,489	Chunilna Creek	1,237
Martin Creek	791	Kashwitna River (North Fork)	303
Lake Creek	3,735	Little Willow Creek	833
Talachulitna River	1,319	Sheep Creek	455
		Indian River	537
		Portage Creek	702
		Chulitna River (East Fork)	112
		Chulitna River (Middle Fork)	1,870
		Chulitna River (Main stem)	124
		Prairie Creek	6,513
		Honolulu Creek	124
		Byers Creek	53
		Troublesome Creek	92

Table 2. Grayling Tagged at Indian River and Portage Creek, Devil s Canyon Project, 1976.

Location	Date	Tag Number	Length-Inches (Total Length)
Portage Creek	6/22	06379	11.5
		06378	11.5
		06365	13.0
		06359	12.0
		06105	14.0
		06108	13.0
		06109	14.0
	6/24	06110	14.0
		06110	14.0
		06118	15.0
		06119	13.0
		06120	15.0
		06121	15.0
		06122	12.0
		06123	15.0
		06125	12.0
	7/15	06133	8.0
	7/29	06137	15.0
	8/25	26107	13.0
		26108	11.0
		06139	14.0
Indian River	6/22	06112	15.0
		06113	11.5
		06114	12.5
		06115	12.5
		06116	13.0
	7/14	06130	14.0
		06131	13.0
		06132	15.0

Table 3. Fish Surveys Conducted on Susitna River Sloughs 8, 10, and 11, Devils Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Water	Weather Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Slough #8	6/26	1200	62	46	Excellent	200		x					0	0	0	0	0
	7/16	1130	58	44	Poor	50		x									
	7/26	935		42	Good	300		x									
	8/11	1540	65	54	Good	300		x									
Slough #10	6/26	1200	60	52	Excellent	0							0	0	0	0	0
	7/14	1230	61	49	Poor	0											
	7/28	1000	63	38	Fair	1		x									
	8/11	1745	63	42	Fair	0											
	8/27	1200	58	43	Good	0 1/											
	9/7	1410		42	Excellent	5		x									
	9/30	1500		40	Excellent	0											
Slough # 11 2/	6/23	1405	60	45	Excellent	0							0	0	0	0	0
	7/14	1545	74	51	Good	0											
	7/25	1100	60	46	Fair	0											
	8/11	1900	59	47	Good	0										12	
	8/26	1230			Excellent	0									28	57	1
	9/4	1620	45	39	Good	0									78	66	
	9/30	1220	42	38	Excellent	0											

1/ Approximately 300 coho fry observed in clear water channel between Slough 10 and Susitna main channel, water temperature was 52°F.

2/ Slough No. 11 was excellent rearing habitat prior to this year. An ice jam in the spring of 1976 destroyed this slough.

Table 4. Fish Surveys Conducted on Susitna River Sloughs, Devils Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Temperature (°F) Water	Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Slough No. 13	6/25	1100		41	Excellent	100		x	x	x		x	0	0	0	0	0
	7/14	1630	72	44	Good	150		x		x							
	7/28			43	Fair	200		x									
	8/11	2000	55	40	Good	250		x									
	8/27				Good	250		x									
	9/9	1735	52	47	Good	3		x									
	9/30	1345	48	36	Excellent	0		x									
Slough No. 14	6/25	1650		46	Excellent	10		x					0	0	0	0	0
	7/14	1800	63	45	Good	10		x									
	7/28	1300		43	Fair	0		x									
	8/11	2050	49	43	Good	25		x									
	8/27	1300	57	43	Fair	20		x									
	9/9	1840	49	44	Good	4		x									
	9/30	1405	47	44	Excellent	1		x									
Slough No. 15	6/30		66	43	Excellent	250	x	x		x			0	0	0	0	0
	7/13	2030	54	47	Poor	100	x	x		x							
	7/28	1500		50	Fair	200	x										
	8/12	1002	52	44	Poor	200	x										
	8/26	1900	57	47	Excellent	50	x								1		
	9/7	1720	47	41	Fair	50	x				x						

Table 5. Fish Surveys Conducted on Susitna River Sloughs 16, 17, and 18, Devils Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Water	Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Slough No. 16	6/24	1330		54	Excellent	200	x	x					0	0	0	0	0
	7/15	1930	52	49	Poor	200	x	x									
	7/28	1530		50	Fair	500	x	x									
	8/12	1050	51	45	Poor	225	x	x									
	8/26 1/	1700	60	49	Excellent	75	x	x									
	9/7	1830	47	42	Fair	0											
	9/29	1740	41	47	Excellent	0											
Slough No. 17	6/24	1550		48	Excellent	100		x					0	0	0	0	0
	7/15	1845	64	40	Fair	100		x									
	7/28	1600		42	Fair	100		x									
	8/12	1340	51	38	Fair	2		x									
	8/26	1600	60	41	Excellent	60		x			x						
	9/29	1550	43	41	Excellent	0											
Slough No. 18	6/24			53	Excellent	50		x					0	0	0	0	0
	7/15	1900	60	48	Poor	25		x									
	7/28	1630		49	Fair	25		x									
	8/12	1535	54	48	Fair	5		x									
	8/26	1630	54	42	Excellent	10		x									
	9/29 2/	1635	50	47	Excellent	0											

1/ Flow and water level dropped considerably.

2/ Entry and exit to Susitna blocked.

Table 6. Fish Surveys Conducted on Susitna River Sloughs 19, 20, and 21; Devils Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Temperature (°F) Water	Weather Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Slough No. 19	6/29	1700		43	Excellent	100		x	x	x			0	0	0	0	0
	7/15	1700	64	49	Good	100		x		x							
	7/28	1700		49	Fair	100		x		x							
	8/12	1850	55	45	Fair	300		x		x							
	8/25 1/			47	Good	200		x							32		
	9/8	1710	47	44	Poor	0									30		
	9/24	1510	44	42	Excellent	0											
Slough No. 20	6/29		62	49	Good	1000		x			x						
	7/15	1600	76	55	Good	1000		x			x						
	7/28	1800		52	Fair	200		x			x						
	8/12	2000	53	50	Fair	85		x			x					2	
	8/26	1900			Good	0											
	9/8	1605	47	43	Poor	0											
	9/29		48	39	Excellent	100					x						
Slough No. 21	8/25	1300			Good	200	x	x		x	x				10	30	
	9/18	1400		40	Good	200	x	x			x				23	6	
	9/29 2/	1600		40	Fair	450	x	x			x				15		

1/ Entry and exit to Susitna blocked at mouth of slough.

2/ Fry trapped in small pools.

Table 7. Escapement Surveys Conducted on Susitna River Tributaries, Devil s Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Temperature (°F) Water	Weather Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Whisker's Creek	6/26	1350		58	Excellent	1000+	x	x									
	7/16	1330	66	54	Good	1000+	x	x					4				
	7/26	1635	60	56	Good	1000+	x	x					8				
	8/10	1130	75	56	Excellent	1000+	x	x					2				75
	9/1	1010	35	37	Excellent												
Chase Creek	6/26	1245	68	56	Excellent	1000+	x	x									
	7/16	1300	64	54	Poor	1000+	x	x									
	7/26	1930			Good	1000+	x	x									
	8/10	1310	70	58	Excellent	1000+	x	x									50
	8/31	1545	59	50	Good	1000+	x	x									
	9/30	1700	43	41	Excellent	0											
Fourth of July Cr.	7/14	1130	63	50	Good								14				
	7/27			54	Excellent								14				30
	8/11	907	59	53	Good								1			8	4000
	8/27	1100	57	47	Excellent									17		78	3 live 3000 dead
	9/19	1130	62	45	Excellent												
Gold Cr.	8/10	1130		46	Good	50					x						32
	8/26	1030		43	Good												20

Table 8. Escapement Surveys Conducted on Susitna River Tributaries, Devils, Canyon Project, 1976.

Location	Date	Time (Military)	Temperature (°F) Air	Temperature (°F) Water	Weather Conditions	No. Fry Observed	Fry Species Identified: Chinook	Coho	Chum	Sockeye	Grayling	Whitefish	Adult Salmon Density: Chinook	Coho	Sockeye	Chum	Pink
Indian R.	6/22				Good	10					x						
	7/14	1730	67	42	Good								537				
	8/12	1200	50	48	Fair									18		134	5000
	8/26	1300		46	Excellent								8	30	2		300
	9/28	1755		44	Fair												
Portage Creek	6/22	1200			Good	45					x						
	7/15	1330	76	44	Good								702				
	8/13	1130	68	47	Excellent									75		250	3000
	8/25	1200		50	Excellent									100		300	200
	9/8	1240	45	43	Poor												

Fry salmon observations were conducted in the sloughs and tributaries of the Susitna (Tables 3-8). Fry were located in clearwater sloughs during the early summer when stage heights of the water were highest. As the summer progressed and water depth within the sloughs decreased, so did the number of fry observed.

A tagging program was initiated to determine grayling movements within the Susitna and its tributaries. Twenty-nine fish were captured, measured (length), and released at the mouths of Portage Creek and the Indian River (Table 2). One tagged grayling was recaptured and released by an angler one and one-half miles above the mouth of Portage Creek one month after it was tagged. The angler did not record the tag number.

DISCUSSION

Flow Regimens

The effects of flow regulation on various fish and wildlife resources in the Susitna River basin is a primary concern of the Alaska Department of Fish and Game. Depth, width, and velocity of the flow determine the quality and quantity of habitat available to aquatic organisms. High discharges associated with spring run-off result in a number of physical actions which are important to aquatic life in the Susitna River. A flushing or scouring action is produced which removes deposited sediments and fines,

resulting in an annual cleansing of the river bottom. This is an important aspect of river ecology, particularly for rivers like the Susitna, which transport large amounts of sediment. Deposition of sediment without the annual scouring could change the overall productivity of the river, eventually suffocating all aquatic organisms within the system.

High spring flows may trigger upstream spawning migrations of salmon and resident fish species to spawning areas in sloughs and tributaries of the Susitna. The tributaries and sloughs of the Susitna also serve as rearing habitat for salmon and resident fish fry. Upstream movements of some fish species to these areas may be restricted or blocked by reduced flows. Successful salmonid egg incubation is dependent upon adequate flows to maintain flow-percolation-intragravel water movements within a redd (Stalnaker and Arnette, 1976).

Water velocity and stage determine the availability of wetted areas necessary for benthic species production. Discharges which would alter and reduce the benthic population and composition of the Susitna would also reduce its carrying capacity.

Aquatic populations in free flowing rivers have evolved to their current levels due to extreme flow variations (very high to very low). Some aquatic species may be present only because the particular hydrologic regime exists.

Water Quality

Dissolved oxygen, pH, alkalinity, hardness, temperatures and conductivity were within acceptable limits for fish life and were in the range of expected results for natural waters in southcentral Alaska (Bauers, personal communication).

Relationships between temperature and the aquatic environment are intimate. Fish and other aquatic organisms are directly affected by changes in water temperature. Salmonids are sensitive to the slightest changes in temperature. Releases from a hydroelectric power plant and reduced flows could result in abrupt temperature changes during critical life history stages of aquatic life. Dissolved oxygen decreases as water temperature increases; yet, aquatic animals require higher dissolved oxygen levels as temperatures increase. Higher temperatures and lower dissolved oxygen concentrations could limit the diversity of organisms present.

Unregulated flowing waters dilute and transport natural and man-generated pollutants. In a relatively undeveloped river system, such as the Susitna, any alteration to the natural balance of the system may reduce the biological productivity and quality of the river.

Fisheries

The Susitna drainage, in its natural state, is a viable fishery for salmon and other freshwater species. It is known to be one of the largest chinook and coho production areas in Cook Inlet. Thus, it is essential to define

the life history (spawning, incubation, rearing, and migration) habitat requirements of indigenous fish species and other aquatic biota to sustain the existing Susitna drainage fishery.

Data collected this year indicate that in the early summer, when salmon rearing conditions are poor in the mainstem Susitna (because of high discharge and sediment loads), the clear water sloughs and tributary habitat areas are utilized by fry. As the season progresses, discharge and sediment loads of the mainstem Susitna begin to decrease. By fall and winter, the silt load and discharge appear to be low enough to transform the mainstem Susitna into suitable fry rearing habitat to replace slough areas (which are eliminated when mainstem discharge decreases), and tributaries that freeze in the winter.

Apparently these seasonably wide fluctuations of water velocity, depth, temperature, chemical composition, and clarity of the mainstem Susitna, its sloughs and tributaries determine to some extent the intrasystem migrations of fish seeking more desirable environments. Thus, any alterations to the existing aquatic ecosystem which restrict or reduce the availability of required habitat, will also reduce fish production.

CONCLUSION

Baseline inventory studies, to date, emphasize the need to initiate a comprehensive study to properly assess the potential environmental impacts

to the aquatic ecosystem of the Susitna drainage by the proposed Watana/ Devils Canyon hydroelectric project prior to final design approval and construction authorization.

The Susitna River is a product of its tributaries. All aquatic habitat and populations (within the power transmission corridor site, construction road routes, and above and below the proposed dam sites) which would be directly or indirectly affected during construction and after completion of the project must be carefully evaluated. It is imperative to thoroughly investigate the interrelationships between the aquatic biology, water quantity and water quality of the existing free flowing Susitna River system. Recreational, social, economic, and aesthetic considerations should also be included.

With this information the Alaska Department of Fish and Game will be able to provide the input for preventing unnecessary losses of the fisheries and related resources.

ACKNOWLEDGEMENTS

Funding for this study was provided by the U.S. Fish & Wildlife Service.

The author wishes to acknowledge the technical assistance of Jeffrey D. Hock, Fisheries biologist with the Department of Fish and Game.

Special credit is due Larry Engel and Stan Kubik, area biologists with the Sport Fish Division, for conducting the aerial chinook salmon escapement counts.

LITERATURE CITED

APHA, et al. 1971. Standard methods for the examination of water and waste water. 13th edition. American Public Health Association, Washington, D.C. pp. 539-540.

Barrett, B.M. 1974. An assessment study of the anadromous fish populations in the upper Susitna River watershed between Devils Canyon and the Chulitna River. Alaska Dept. of Fish and Game, Div. of Commercial Fisheries (unpublished). 56 pp.

Bauers, Harvey. 1976. Personal communication. U.S. Geological Survey.

Brown, C.J.D. 1971. Fishes of Montana. Big Sky Books, Bozeman, Montana. 207 pp.

Gabler, A. 1976. Susitna Dam cost going up. Anchorage Times. December 12,
1976.

McCoy, G.A. 1974. Preconstruction assessment of biological quality of the Chena and Little Chena rivers in the vicinity of Chena Lakes flood control project near Fairbanks, Alaska. U.S. Geological Survey Water-Resources Investigations 29-74: 84 pp.

Stalnaker, C.B. and J.C. Arnette (eds.). 1976. Methodologies for the determination of stream resource flow requirements: An assessment. Prepared for U.S. Fish and Wildlife Services Office of Biological Services Western Water Allocation by Utah State Univ. 199 pp.

U.S. Fish and Wildlife Service. 1976. Southcentral railbelt area-Susitna River Basin. Fish and Wildlife studies related to the Corps of Engineers Devils Canyon-Watana Reservoir hydroelectric project. Studies conducted by the Alaska Dept. of Fish and Game under contract agreement with the U.S. Fish and Wildlife Service. Feb. 158 pp. and appendices.

Wickett, W.P. 1959. Effects of siltation on success of fish spawning. Proceedings of the 5th Pacific Northwest Symposium on Water Pollution Research. U.S. Public Health Service, Water Supply and Water Pollution Control Program. Portland, OR. March 23-24. pps. 16-22.

APPENDICES

Appendix A

Table 1. Water Quality Data Collected from the Susitna River at the Parks Highway Bridge Between July 21 and October 1, 1976, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Temperature (°F) Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (µmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Suspended Solids (mg/l) Settlable	Suspended Solids (mg/l) Total
7/21		11:10 a.m.	mostly sunny	52	68	10	8.1	50	45	122		96	465	561
7/27		1:30 p.m.	mostly sunny									163	424	587
9/1	29.95	11:00 a.m.	mostly sunny	43	53	11	8.0	50	50	132	85	79	237	316
10/1		2:00 p.m.	mostly sunny									26	78	104
10/12	30.10	12:45 p.m.	mostly	35	38	13	7.6	60	50	160	10	3	17	20

Appendix A
Table 2. Water Quality Data Collected from the Susitna River at the Gold Creek Railroad Bridge Between July 13 - October 1, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (μmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Settlable	Total
7/13		12:00 noon	Cloudy Rain	50	54		7.9	40	30	105				
7/16		2:00 p.m.										28	725	753
8/10		2:20 p.m.	Clear	53	75	11	8.3	50	45	125	230			
8/13		2:50 p.m.	cloudy Rain									90	769	859
8/24		7:00 p.m.	clear	51	63	11	8.0	50	40	125	90			
8/27		2:45 p.m.	mostly sunny									92	325	417
9/7	29.45	4:20 p.m.	Cloudy	43	53	12	8.0	58	45	146	15			
9/10		10:50 a.m.	Cloudy									23	22	45
9/28	29.15	4:25 p.m.	Mostly cloudy	44	49	13	8.3	45	30	132	10			
9/30		1:20 p.m.	Mostly sunny									18	5	23

Appendix A
Table 3. Water Quality Data Collected from the Susitna River Upstream of Portage Creek between July 15 and September 29, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (µmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Settlable	Total
7/15	-	12:30 p.m.	partly cloudy-rain	49	76	11	7.9	50	45	125	320	41	1,232	1,273
7/29	-	11:30 a.m.	partly cloudy	50	65	11	8.0	55	55	140	220	86	443	529
8/13	29.50	9:30 a.m.	mostly sunny	48	55	12	8.0	55	40	115	210	117	412	529
8/25	29.45	11:45 a.m.	partly cloudy	50	57	12	8.0	50	45	120	140	71	387	458
9/8	29.30	11:55 a.m.	overcast rain	-	49	12	8.0	60	50	165	30	29	76	105
9/29	29.25	11:30 a.m.	partly cloudy	41	39	12	8.0	60	50	170	20	11	13	24

Appendix A
Table 4. Water Quality Data Collected from Sloughs 8 and 10, between June 25 and September 30, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height(FT)	Susitna Flow (CFS)
Slough 8													
6/26	-	-	clear	46	62	-	-	-	-	-	-	0.72	20,300
7/16	-	11:30 a.m.	rain	44	58	9	7.0	30	40	88	0	0.55	18,400
7/26	-	9:35 p.m.	partly cloudy	42	-	-	-	-	-	-	-	0.39	19,000
8/11	-	2:40 p.m.	partly cloudy	54	65	9	6.9	40	35	98	0	0.48	18,000
Slough 10													
6/25	-	-	clear	52	-	-	-	-	-	-	-	2.44	19,600
7/14	-	12:30 p.m.	partly cloudy	49	60	9	7.5	75	50	175	50	2.91	20,500
7/28	-	10:00 a.m.	cloudy	38	61	-	-	-	-	-	-	2.11	20,000
8/11	-	5:45 p.m.	mostly cloudy	42	63	10	7.5	75	65	230	0	1.95	18,000
8/27	-	12:00 noon	clear	43	63	-	-	-	-	-	-	1.27	13,000
9/7	29.75	2:10 p.m.	mostly sunny	42	58	11	7.3	60	50	150	0	0.38	6,480
9/30	-	3:00 p.m.	clear	40	-	-	-	-	-	-	-	0.37	5,800

Appendix A
Table 5. Limnological Data Collected from Slough 11 and 13 between June 23 and September 30, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height(FT)	Susitna Flow (CFS)
Slough 11													
6/23	-	2:05 p.m.	clear	45	60	-	-	-	-	-	-	4.00	20,600
7/14	-	3:45 p.m.	partly cloudy	51	74	10	7.5	85	105	55	193	4.24	20,500
7/28	-	11:00 a.m.	cloudy	46	60	-	-	-	-	-	-	3.66	20,000
8/11	-	7:00 p.m.	partly cloudy	47	59	12	7.6	90	55	230	8	3.47	18,000
8/26	-	12:30 p.m.	mostly sunny	-	-	-	-	-	-	-	-	3.17	13,900
9/9	29.85	4:20 p.m.	partly cloudy	39	45	12	7.4	95	70	210	0	2.01	6,570
9/30	-	12:20 p.m.	clear	38	42	-	-	-	-	-	-	2.00	5,800
Slough 13													
6/25	-	-	clear	41	-	-	-	-	-	-	-	0.85/0.44	19,600
7/14	-	4:30 p.m.	partly cloudy	44	72	10	6.7	90	70	200	55	0.86/0.49	20,500
7/28	-	-	cloudy	43	-	-	-	-	-	-	-	0.82/0.45	20,000
8/11	-	8:00 p.m.	partly cloudy	40	55	10	7.4	80	65	170	0	0.83/0.43	18,000
8/27	-	-	-	-	-	-	-	-	-	-	-	0.84/0.27	13,000
9/9	29.75	5:35 p.m.	partly cloudy	47	51	12	7.6	85	60	200	0	0.51/dry	6,570
9/30	-	1:45 p.m.	clear	36	48	-	-	-	-	-	-	0.22/dry	5,800

Appendix A
Table 6. Water Quality Data Collected from Sloughs 14 and 15 between June 25 and September 30, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height (FT)	Susitna Flow (CFS)
Slough 14													
6/25	-	4:50 p.m.	-	46	-	-	--	-	-	-	-	1.82	19,600
7/14	-	6:00 p.m.	partly cloudy	45	63	12	6.8	35	20	85	-	2.07	20,500
7/28	-	1:00 p.m.	cloudy	43	-	-	-	-	-	-	-	1.49	20,000
8/11	-	8.50 p.m.	partly cloudy	43	49	9	6.9	45	15	90	-	1.28	18,000
8/27	-	1:00 p.m.	cloudy	43	57	-	-	-	-	-	-	0.93	13,000
9/9	29.80	6:40 p.m.	partly cloudy	44	49	9	6.9	35	40	95	0	0.29	6,570
9/30	-	2:05 p.m.	clear	44	47	-	-	-	-	-	-	0.27	5,800
Slough 15													
6/30	-	-	clear	43	66	-	-	-	-	-	-	2.23	20,000
7/13	-	8:30 p.m.	cloudy-rain	47	54	9	6.8	25	30	68	-	2.65	20,000
7/28	-	3:00 p.m.	cloudy	50	-	-	-	-	-	-	-	1.83	20,000
8/12	-	10:00 a.m.	rain	44	52	7	6.7	30	10	72	0	2.02	19,000
8/26	-	7:00 p.m.	clear	47	57	-	-	-	-	-	-	1.08	13,900
9/27	29.40	5:20 p.m.	overcast	41	47	9	6.7	25	30	68	0	0.76	6,480

Appendix A
Table 7. Water Quality Data Collected from Sloughs 16 and 17 between June 24 and September 29, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height(FT)	Susitna Flow (CFS)
Slough 16													
6/24	-	1:30 p.m.	clear	54	62	-	-	-	-	-	-	2.17	19,900
7/15	-	7:30 p.m.	rain	49	52	10	7.2	35	20	85	-	1.77	19,200
7/28	-	3:30 p.m.	cloudy	50	-	-	-	-	-	-	-	1.55	20,000
8/12	29.50	10:50 a.m.	rain	45	51	10	7.1	45	35	80	0	1.75	19,000
8/26	-	5:00 p.m.	clear	49	60	-	-	-	-	-	-	0.81	13,900
9/7	29.40	6:30 p.m.	overcast	42	47	6	6.2	20	30	60	0	0.45	6,480
9/29	-	5:40 p.m.	clear	47	41	-	-	-	-	-	-	0.44	6,060
Slough 17													
6/24	-	3:50 p.m.	clear	48	-	-	-	-	-	-	-	1.97	19,900
7/15	-	6:45 p.m.	partly cloudy	40	64	10	7.0	30	35	80	-	1.92	19,200
7/28	-	4:00 p.m.	cloudy	42	-	-	-	-	-	-	-	1.64	20,000
8/12	29.55	1:40 p.m.	cloudy	38	51	9	6.6	25	30	66	0	1.87	19,000
8/26	-	4:00 p.m.	clear	41	60	-	-	-	-	-	-	1.01	13,900
9/29	29.30	3:50 p.m.	mostly sunny	41	43	11	6.9	25	20	75	0	0.45	6,060

Appendix A
Table 8. Water Quality Data Collected from Sloughs 18 and 19 between June 15 and September 29, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height(FT)	Susitna Flow (CFS)
Slough 18													
6/24	-	-	-	53	-	-	-	-	-	-	-	1.80	19,900
7/15	-	7:00 p.m.	rainy	48	60	8	7.0	60	50	118	-	1.78	19,200
7/28	-	4:30 p.m.	cloudy	49	-	-	-	-	-	-	-	1.77	20,000
8/12	29.55	3:35 p.m.	cloudy	48	54	9	7.3	40	45	105	0	1.78	19,000
8/26	-	4:30 p.m.	clear	42	54	-	-	-	-	-	-	1.68	13,900
9/29	29.30	4:35 p.m.	mostly sunny	47	50	11	8.0	55	50	135	0	0.98	6,060
Slough 19													
6/24	-	-	-	43	-	-	-	-	-	-	-	2.49	19,900
7/15	-	5:00 p.m.	partly cloudy	49	64	10	7.5	60	40	140	-	2.39	19,200
7/28	-	5:00 p.m.	cloudy	49	-	-	-	-	-	-	-	1.98	20,000
8/12	29.55	6:50 p.m.	cloudy	45	55	9	7.1	70	50	142	-	2.37	19,000
8/26	-	7:30 p.m.	cloudy	47	-	-	-	-	-	-	-	1.96	13,900
9/8	29.40	5:10 p.m.	overcast-rain	44	47	12	7.8	60	60	150	-	1.80	6,240
9/29	-	3:10 p.m.	mostly sunny	42	44	-	-	-	-	-	-	1.82	6,060

Appendix A
Table 9. Water Quality Data Collected From Slough 20 between June 24 and September 29, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height (FT)	Susitna Discharge (CFS)
Slough 20													
6/24	-	-	-	49	62	-	-	-	-	-	-	2.78	19,900
7/15	-	4:00 p.m.	partly cloudy	55	76	11	7.7	40	35	105	5	above gauge	19,200
7/28	-	6:00 p.m.	cloudy	52	-	-	-	-	-	-	-	2.66	20,000
8/12	29.55	8:00 p.m.	cloudy	50	53	11	7.7	35	40	95	0	2.64	19,000
8/26	-	7:00 p.m.	partly cloudy	-	-	-	-	-	-	-	-	2.60	13,900
9/8	29.35	4:05 p.m.	overcast-rain	43	47	12	7.6	55	40	110	0	2.63	6,240
9/29	-	2:00 p.m.	clear	39	48	-	-	-	-	-	-	2.70	6,060

Appendix A
Table 10. Water Quality Data Collected from Willow Creek, Little Willow Creek, Kashwitna River and Caswell Creek between July 21 and October 12, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Temperature (°F) Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (μmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Suspended Solids (mg/l) Settlable	Suspended Solids (mg/l) Total
Willow Creek														
7/21		6:50 p.m.	partly cloudy	56	68	10	7.6	20	20	72	-			
9/1	29.10	5:30 p.m.	cloudy rain	49	57	11	7.5	20	20	80	0			
10/12	30.25	10:45 a.m.	clear	-	-	14	7.4	30	30	92	0			
Little Willow Creek														
7/21	-	5:55 p.m.	partly cloudy	57	74	10	7.4	10	10	38	-			
9/1	30.05	5:00 p.m.	mostly cloudy	47	61	11	7.2	10	20	34	0			
10/12	30.20	5:10 p.m.	clear	-	-	13	7.1	30	20	48	0			
Kashwitna River														
7/21	-	4:10 p.m.	mostly sunny	55	74	11	7.7	20	15	44	-			
9/1	30.00	4:05 p.m.	partly cloudy	47	60	11	7.5	20	20	48	10			
10/12	30.15	4:20 p.m.	clear	-	-	14	7.5	25	15	65	0			
Caswell Creek														
7/21	-	4:50 p.m.	partly cloudy	58	77	10	7.5	20	20	55	-			
9/1	30.00	3:25 p.m.	partly cloudy	49	57	11	7.3	15	10	52	0			
10/12	30.15	3:50 p.m.	clear	-	-	13	7.1	20	15	55	0			

Appendix A

Table 11. Water Quality Data Collected from Sheep Creek, Goose Creek, and Montana Creek between July 21 and October 12, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Temperature (°F) Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (µmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Suspended Solids (mg/l) Settlable	Suspended Solids (mg/l) Total
Sheep Creek														
7/21	-	3:15 p.m.	clear	58	75	11	7.4	15	20	32	-			
9/1	30.00	2:30 p.m.	partly cloudy	50	61	12	7.8	15	10	40	5			
10/12	30.15	3:15 p.m.	clear			13	7.2	20	15	55	0			
Goose Creek														
7/21	-	2:15 p.m.	clear	44	72	11	7.3	10	20	36	-			
9/1	30.00	1:40 p.m.	mostly sunny	45	57	11	7.2	10	15	42	0			
10/12	30.10	2:35 p.m.	clear	-	-	13	7.2	20	10	50	0			
Montana Creek														
7/21	-	12:20 p.m.	clear	54	76	10	7.4	10	20	46	0			
9/1	29.95	12:00 p.m.	mostly sunny	47	55	11	7.4	10	10	45	0			
10/12	30.10	2:00 p.m.	clear	-	-	14	7.3	10	5	48	0			

Appendix A
Table 12. Water Quality Data Collected from Slough 3C and Chase Creek between June 26 and October 1, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (umhos/cm)	Turbidity (Ftu)	Gage Height (FT)	Susitna Discharge (CFS)
Whiskers Creek													
6/26	-	1:50 p.m.	clear	58	-	-	-	-	-	-	-	1.10	20,300
7/16	-	1:30 p.m.	partly cloudy	54	66	9	7.4	20	20	46	-	0.70	18,400
7/26	-	4:35 p.m.	partly cloudy	56	60	-	-	-	-	-	-	0.97	19,000
8/10	-	11:30 a.m.	mostly sunny	56	75	9	7.1	20	20	48	5	0.96	18,000
10/1	29.90	10:10 a.m.	clear	37	35	12	7.0	20	10	22	0	(-)0.2	-
Chase Creek													
6/26	-	12:45 a.m.	clear	56	68	-	-	-	-	-	-	5.40	20,300
7/16	-	1:00 p.m.	cloudy-rain	54	64	9	7.3	15	20	48	-	5.39	18,400
7/26	-	7:30 p.m.	partly-cloudy	-	-	-	-	-	-	-	-	5.33	19,000
8/10	-	1:10 p.m.	mostly sunny	58	70	10	7.1	10	20	46	0	5.39	18,000
8/31	-	3:45 p.m.	partly cloudy	50	59	-	-	-	-	-	-	5.28	9,340
9/30	29.75	5:00 p.m.	clear	41	43	12	7.1	15	15	48	0	5.38	5,800

Appendix A
Table 13. Water Quality Data Collected from Fourth of July Creek, Gold Creek, Indian River and Portage Creek between July 17 and September 28, Devils Canyon Project, 1976.

Date	Barometric Pressure	Time	Weather Conditions	Temperature (°F) Water	Air	D.O. (ppm)	pH	Hardness (mg/l)	Total Alkali (mg/l)	Specific Conductance (μmhos/cm)	Turbidity (Ftu)	Suspended Solids (mg/l) Non-Filterable	Settlable	Total
Fourth of July Creek														
7/14	-	11:30 p.m.	partly cloudy	50	63	10	7.2	5	15	68	0			
8/11	-	9:05 a.m.	partly cloudy	53	59	10	7.3	10	10	35	0			
8/27	-	11:00 a.m.	clear	47	57	-	-	-	-	-	-			
9/7	29.80	11:30 a.m.	mostly sunny	45	62	12	7.5	5	10	25	0			
Gold Creek														
8/26	29.35	10:30 a.m.	mostly sunny	43	57	11	8.3	95	80	190	0			
9/8	29.45	6:40 p.m.	overcast drizzle	-	49	12	8.2	105	70	220	0			
Indian River														
7/15	-	5:30 p.m.	partly cloudy	42	67	11	7.6	10	20	42	0			
8/12	29.55	12:00 noon	cloudy rain	48	50	10	7.5	20	20	55	0			
8/26	-	2:00 p.m.	mostly sunny	46	-	-	-	-	-	-	-			
9/28	29.15	5:55 p.m.	cloudy	44	45	12	7.4	15	20	52	0			
Portage Creek														
7/15	-	1:30 p.m.	partly cloudy	44	76	11	7.5	25	20	72	0			
8/13	29.50	11:30 a.m.	mostly sunny	47	68	11	7.5	30	20	70	0			
8/25	-	12:00 noon	mostly sunny	50	-	-	-	-	-	-	-			
9/8	29.30	12:40 p.m.	overcast	43	45	12	7.9	40	10	118	0			

Appendix A

Table 14. Thermograph Set in Susitna River at Parks Highway Bridge; Daily Maximum and Minimum Water Temperatures, Devils Canyon Project 1976.

Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.
June 26	-	54	July 25	52	51	Aug. 23	48	48	Sept. 21	43	43	Oct. 20	34	33
27	56	55	26	-	52	24	48	48	22	44	43	21	35	34
28	55	54	27	53	52	25	48	48	23	44	42	22	35	34
29	55	54	28	52	51	26	48	48	24	42	41	23	34	32
30	56	54	29	51	50	27	-	-	25	41	40	24	30	31
			30	51	50	28	-	-	26	42	41	25	32	30
July 1	54	49	31	52	51	29	-	-	27	42	42	26	32	32
2	49	49				30	-	-	28	42	42			
3	50	49	Aug. 1	54	52	31	-	-	29	42	41			
4	49	46	2	54	53				30	-	-			
5	46	46	3	55	53	Sept. 1	47	46						
6	50	46	4	56	55	2	46	45	Oct. 1	-	35			
7	54	50	5	55	51	3	46	45	2	35	35			
8	55	53	6	51	51	4	45	42	3	36	35			
9	55	54	7	51	51	5	44	42	4	37	36			
10	54	54	8	51	50	6	-	41	5	38	37			
11	56	54	9	50	49	7	-	-	6	34	38			
12	54	52	10	51	49	8	-	-	7	39	38			
13	52	51	11	52	51	9	-	-	8	38	36			
14	53	51	12	50	50	10	-	-	9	36	33			
15	52	51	13	51	49	11	-	-	10	35	32			
16	53	52	14	51	51	12	-	-	11	32	-			
17	52	52	15	51	50	13	-	-	12	32	-			
18	53	52	16	50	49	14	-	-	13	32	31			
19	54	53	17	49	48	15	-	-	14	31	31			
20	54	52	18	48	48	16	-	-	15	31	31			
21	54	52	19	48	47	17	-	-	16	32	31			
22	54	53	20	48	47	18	-	-	17	33	32			
23	53	51	21	48	48	19	-	-	18	33	33			
24	52	51	22	48	48	20	43	42	19	33	33			

Appendix A
Table 15. Thermograph Set in Susitna River above Chase Creek; Daily Maximum and Minimum Water Temperatures, Devils Canyon Project 1976.

Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.
June 21	-	51	July 20	57	55	Aug. 18	51	49	Sept. 16	45	44
22	52	49	21	57	55	19	50	49	17	44	44
23	55	50	22	57	56	20	52	50	18	44	43
24	55	52	23	57	56	21	52	51	19	44	43
25	56	53	24	-	-	22	53	52	20	44	44
26	58	55	25	-	-	23	54	52	21	44	44
27	59	56	26	56	54	24	-	52	22	45	43
28	58	56	27	55	55	25	-	-	23	43	42
29	58	55	28	55	54	26	-	-	24	42	42
30	59	55	29	55	54	27	-	-	25	42	42
			30	59	55	28	-	-	26	43	42
July 1	55	51	31	59	58	29	-	-	27	44	42
2	53	51				30	-	-	28	43	41
3	52	51	Aug. 1	59	58	31	-	48	29	41	
4	51	49	2	58	58						
5	48	47	3	59	57	Sept. 1	49	47			
6	52	48	4	58	56	2	48	47			
7	55	51	5	56	55	3	48	46			
8	58	54	6	55	54	4	46	44			
9	58	56	7	54	54	5	45	44			
10	58	57	8	54	52	6	45	44			
11	58	56	9	52	50	7	44	44			
12	57	56	10	53	50	8	45	44			
13	56	55	11	54	52	9	46	45			
14	57	54	12	54	53	10	46	45			
15	55	54	13	54	53	11	46	45			
16	55	54	14	54	53	12	46	43			
17	56	54	15	53	53	13	45	44			
18	56	55	16	52	52	14	46	45			
19	57	55	17	52	51	15	46	45			

Appendix A

Table 16. Thermograph Set in Susitna River between Devil's Canyon and Portage Creek; Daily Maximum and Minimum Water Temperatures, Devils Canyon Project, 1976.

Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.
June 22	50	50	July 21	53	53	Aug. 19	-	-	Sept. 17	43	43	Oct. 16	33	33
23	50	50	22	53	53	20	-	-	18	42	41	17	34	33
24	51	51	23	53	53	21	-	-	19	42	41	18	35	34
25	52	52	24	53	53	22	-	-	20	42	41	19	35	34
26	54	52	25	53	52	23	-	-	21	43	42	20	35	35
27	54	54	26	52	52	24	-	-	22	43	43	21	35	35
28	55	54	27	52	52	25	52	49	23	43	42	22	35	35
29	55	55	28	52	52	26	49	48	24	42	41	23	35	33
30	55	53	29	53	52	27	48	47	25	41	41	24	33	33
			30	55	53	28	47	46	26	41	41	25	33	33
July 1	52	52	31	56	55	29	46	46	27	-	-	26	33	33
2	52	52				30	47	46	28	-	-	27	33	33
3	51	51	Aug. 1	57	54	31	47	47	29	-	-	28	33	30
4	50	49	2	58	55				39	-	36	29	31	30
5	49	48	3	57	55	Sept. 1	47	47				30	31	31
6	49	48	4	55	53	2	47	46	Oct. 1	36	35			
7	53	49	5	54	54	3	46	45	2	35	34			
8	54	52	6	54	52	4	45	45	3	35	34			
9	55	54	7	53	52	5	43	43	4	36	35			
10	54	54	8	52	52	6	-	-	5	37	36			
11	55	54	9	51	49	7	-	-	6	38	37			
12	55	54	10	48	48	8	45	44	7	38	38			
13	55	54	11	50	48	9	45	44	8	38	34			
14	54	54	12	52	50	10	44	44	9	34	32			
15	53	52	13	52	51	11	44	44	10	32	32			
16	52	52	14	52	50	12	44	43	11	32	32			
17	52	52	15	52	51	13	43	43	12	32	32			
18	53	52	16	51	51	14	43	43	13	32	32			
19	53	53	17	-	-	15	43	43	14	33	32			
20	53	53	18	-	-	16	43	42	15	33	33			

Appendix A
Table 17. Thermograph Set in Birch Creek Below Highway Crossing; Daily Maximum and Minimum Water Temperatures, Devils Canyon Project, 1976.

Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.	Date	Temp. °F Max.	Min.
June 26	67	66	July 25	65	64	Aug. 23	61	59	Sept. 21	50	50	Oct. 20	40	40
27	68	67	26	-	64	24	62	61	22	50	50	21	40	40
28	67	66	27	66	64	25	62	61	23	50	49	22	39	39
29	67	65	28	65	63	26	61	60	24	49	49	23	39	39
30	68	67	29	63	62	27	60	60	25	48	48	24	39	39
			30	63	62	28	-	-	26	48	48	25	39	39
July 1	67	65	31	54	62	29	-	-	27	48	48	26	39	38
2	65	63				30	-	-	28	48	48	27	38	38
3	63	62	Aug. 1	68	65	31	-	-	29	48	48	28	38	38
4	62	60	2	67	66				30	48	47	29	38	38
5	60	57	3	68	66	Sept. 1	58	-				30	38	37
6	62	58	4	67	66	2	58	58	Oct. 1	-	44	31	37	37
7	66	62	5	68	66	3	58	57	2	44	44			
8	64	61	6	66	65	4	57	55	3	44	44	Nov. 1	37	37
9	66	63	7	65	65	5	55	55	4	44	44	2	37	37
10	68	66	8	65	63	6	55	54	5	44	44	3	-	36
11	69	68	9	63	61	7	55	54	6	44	44	4	36	36
12	68	67	10	63	61	8	54	54	7	44	43	Nov. 5-		
13	67	66	11	64	63	9	54	54	8	43	43	25	36	36
14	66	66	12	64	63	10	54	54	9	43	42	26	36	35
15	67	66	13	64	63	11	54	54	10	42	41	27	36	34
16	67	66	14	63	63	12	53	53	11	41	41	28	34	34
17	67	66	15	63	62	13	53	53	12	41	40	29	34	34
18	67	66	16	62	61	14	53	52	13	40	40	30	34	34
19	67	67	17	61	60	15	52	52	14	40	40			
20	67	65	18	60	58	16	52	52	15	40	40	Dec. 1	35	34
21	65	63	19	60	58	17	52	51	16	40	40	2	35	33
22	65	65	20	60	59	18	51	51	17	40	40			
23	65	65	21	60	59	19	51	50	18	40	40			
24	65	64	22	59	59	20	50	50	19	40	40			

Appendix A

Table 18.. Susitna River discharge at Gold Creek; USGS Provisional Data, 1976.

	May		June		July		August		September	
Day	Gage Height	Discharge	Gage Height	Discharge	Gage Height	Discharge	Gage Height	Discharge	Gage Height	Discharge
1			9.43	17,200	10.01	20,600		20,000	7.63	9,200
2			10.28	22,200	10.38	22,800		21,000	7.65	9,280
3			10.99	26,900	10.17	21,500		21,000	7.47	8,640
4			11.31	29,500	9.80	19,300		21,000	7.34	8,220
5			11.30	29,400	9.76	19,100		20,000	7.19	7,770
6			11.29	29,300	9.38	16,900		20,000	7.09	7,470
7			11.07	27,600	9.02	15,100		20,000	6.76	6,480
8			10.98	26,900	9.29	16,400		20,000	6.68	6,240
9			10.61	24,300	9.71	18,800		19,000	6.79	6,570
10			11.36	29,900	9.88	19,800		18,000	6.85	6,750
11			11.79	33,300	9.79	19,200		18,000	6.87	6,810
12	8.72	13,600	11.78	33,300	9.76	19,100		19,000	6.79	6,570
13	9.01	15,000	11.36	29,900	9.91	20,000		20,000	6.64	6,120
14	8.95	14,800	11.16	28,300	10.00	20,500		20,000	6.51	5,780
15	8.65	13,200	11.08	27,600	9.79	19,200		20,000	6.45	5,620
16	8.51	12,600	10.96	26,700	9.65	18,400		20,000	6,60	6,000
17	8.33	11,900	10.86	26,000	9.77	19,100		20,000	6.76	6,480
18	8.52	12,700	10.34	22,500		19,000		20,000	6.57	5,920
19	8.73	13,600	9.81	19,400		20,000	9.79	19,200	6.48	5,700
20	8.53	12,700	9.67	18,500		19,000	9.41	17,000	6.59	5,980
21	8.50	12,600	9.77	19,100		20,000	9.21	16,000	6.89	6,870
22	8.62	13,100	10.08	21,000		20,000	9.09	15,400	7.14	7,620
23	8.91	14,600	10.02	20,600		21,000	8.99	15,000	7.28	8,040
24	9.02	15,100	9.90	19,900		21,000	8.81	14,000	7.19	7,770
25	8.98	14,900	9.85	19,600		20,000	8.81	14,000	6.99	7,170
26	9.02	15,100	9.97	20,300		19,000	8.78	13,900	6.82	6,660
27	9.10	15,500	9.99	20,400		19,000	8.61	13,000	6.76	6,480
28	8.90	14,500	10.09	21,000		20,000	8.33	11,900	6.69	6,270
29	8.68	13,400	10.07	20,900		20,000	8.12	11,100	6.62	6,060
30	8.94	14,700	9.91	20,000		20,000	7.81	9,840	6.52	5,800
31	9.07	15,400				19,000	7.67	9,340		

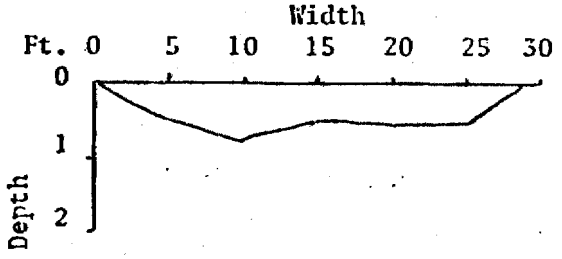
Appendix A

Table 19. Slough 8 Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

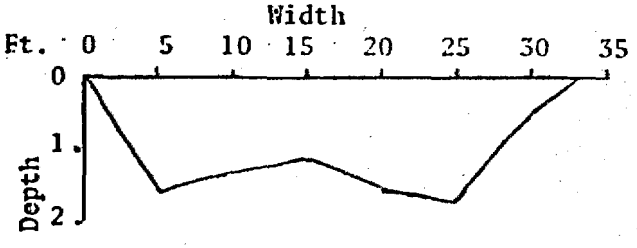
Location of Gauge: Permanent marker is a tree on eastside of slough. Mark is 10.0' above slough bed and gauge is 46' from mark (ribbon).

	June 26, 1976
Elevation	528 ft.
Distance from mouth to gauge	30 yds.
Water surface height at gauge	0.73 ft.
Slough width at gauge	29 ft.
Maximum depth at gauge	0.75 ft.
Change in bed elevation	-
Bed surface composition	sand, gravel
Slough width at mouth	33 ft.
Slough depth at mouth	1.66 ft.
Susitna River mean daily discharge	20,300 CFS

Slough Cross-Section ⊥ to Banks and Adjacent to Gauge (6/26/76).



Cross-Section at Mouth ⊥ to Banks (6/26/76).

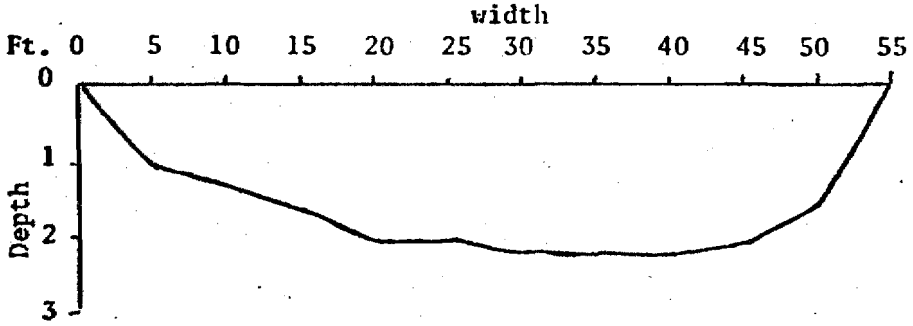


Appendix A
Table 20. Slough 10 Cross-Section and Stage Gauge Information, Devil's Canyon Project, 1976.

Location of Gauge: Permanent marker is tree on east side of slough. Mark is 10.0' above slough bed and gauge is 67' from mark (yellow paint).

	June 25, 1976	September 9, 1976
Elevation	680 ft.	630 ft.
Approximate distance from mouth to gauge	100 ft.	100 ft.
Water surface height at gauge	5.80 ft.	3.71 ft.
Actual water depth at gauge	2.47	0.13 ft.
Slough width at gauge	55 ft.	8 ft.
Maximum depth at cross-section	2.31 ft.	0.47 ft.
Change in bed elevation	-	-0.2 ft.
Bed surface composition	silt, sand	silt, sand
Slough width at mouth	-	-
Slough depth at mouth	-	-
Susitna River mean daily discharge	19,600 CFS	6,570 CFS

Slough Cross-Section⊥ to Banks and Adjacent to Gauge (6/25/760.



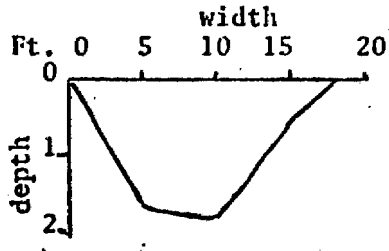
Appendix A
Table 21. Slough 11 Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

Location of Gauge: Permanent marker is tree on east side of slough. Mark is 12.0' above slough bed and gauge is 26.0' from mark (paint and ribbon).

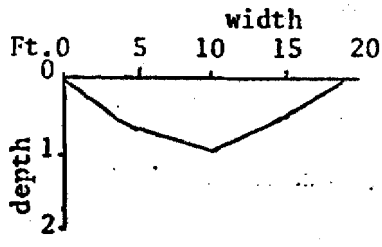
	June 23, 1976	September 9, 1976
Elevation	668 ft.	656 ft.
Approximate distance from mouth to gauge	100 ft.	100 ft.
Water surface height at gauge	4.00 ft.	2.03 ft.
Actual water depth at gauge	-	2.04 ft.
Slough width at gauge	-	18 ft.
Maximum depth at cross-section	-	2.04 ft.
Change in bed elevation	-	-
Bed surface composition	gravel, boulder	sand, gravel, boulder
Slough width at mouth	-	-
Slough depth at mouth	-	-
Susitna River mean daily discharge	20,600 CFS	6,570 CFS

Slough 11 in Three Separate Channels on 9/9/76

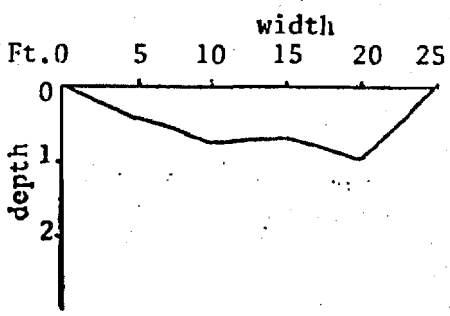
Cross-Section of Channel Farthest from Susitna River to Banks and Adjacent to Gauge 9/9/76.



Cross-Section of Middle Channel to banks 9/9/76.



Cross-Section of Channel Closest to Susitna River to Banks.

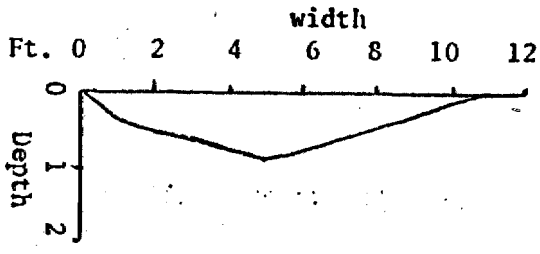


Appendix A
Table 22. Slough 13 Cross-Section and Stage Gauge Information, Devils Canyon Project, 1976.

Location of Gauge: Permanent marker is tree on east side of slough. Mark is 11.0 feet above slough bed and gauge is 10 feet from mark (paint and ribbon).

	June 25, 1976	September 9, 1976
Elevation	688 ft.	664 ft.
Approximate distance from mouth to gauge	40 ft.	40 ft.
Water surface height at gauge	4.18 ft.	3.63 ft.
Actual water depth at gauge	0.85 ft.	0.37 ft.
Slough width at gauge	11 ft.	6 ft.
Maximum depth at cross-section	0.85 ft.	0.37 ft.
Change in bed elevation	-	-0.31 ft.
Bed surface composition	silt, sand, gravel	silt, sand, gravel
Slouth width at mouth	9 ft.	0 ft.
Slough depth at mouth	0.55 ft.	0.00 ft.
Susitna River mean daily discharge	19,600 CFS	6,570 CFS

Slough Cross-Section ⊥ to Banks and Adjacent to Gauge (6/25/76).



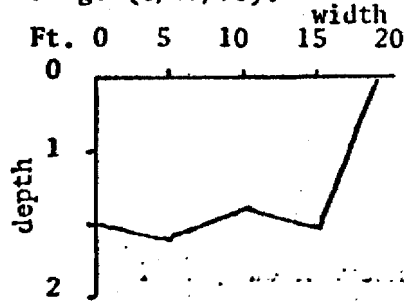
Appendix A

Table 23. Slough 14 Cross-Sections and Stage Gauge Information, Devil Canyon Project, 1976.

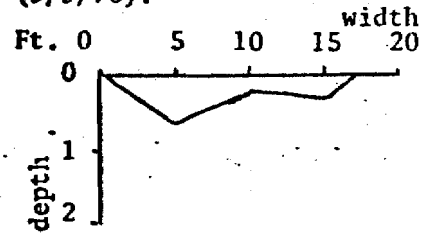
Location of Gauge: Permanent marker is tree on east side of slough. Mark is 9.0' above slough bed and gauge is 26' from mark.

	June 25, 1976	September 9, 1976
Elevation	685 ft.	660 ft.
Approximate distance from mouth to gauge	100 ft.	100 ft.
Water surface height at gauge	1.82 ft.	0.29 ft.
Actual water depth at gauge	1.82 ft.	0.22 ft.
Slough width at gauge	19 ft.	17 ft.
Maximum depth at cross-section	2.15 ft.	0.60 ft.
Change in bed elevation	-	0.0 ft.
Bed surface composition	gravel, silt	gravel, sand, silt
Slough width at mouth	15 ft.	1 ft.
Slough depth at mouth	1.41 ft.	0.3 ft.
Susitna River mean daily discharge	19,600 CFS	6,570 CFS

Slough Cross-Section ⊥ to Banks and Adjacent to Gauge (6/25/76).



Slough Cross-Section ⊥ to Banks and Adjacent to Gauge (9/9/76).



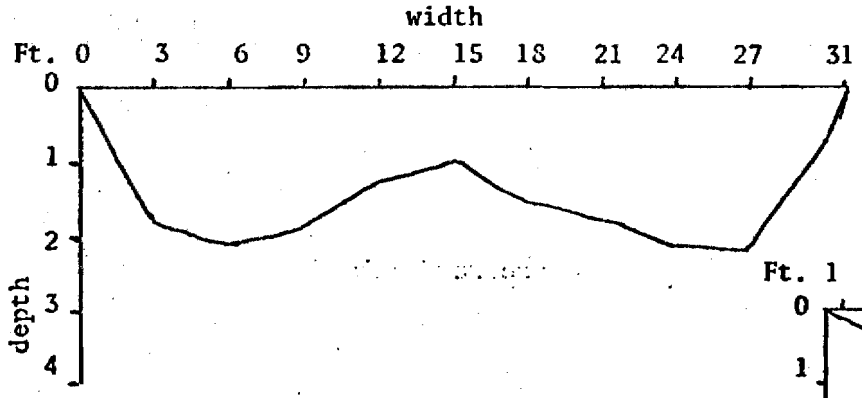
Appendix A

Table 24. Slough 15 Cross-Sections and Stage Gauge Information, Devil s Canyon Project, 1976.

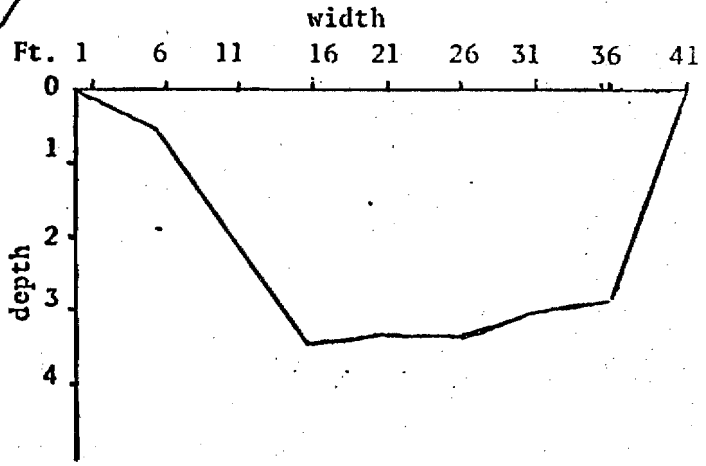
Location of Gauge: Permanent marker is tree on west side of slough. Mark is 10.0' from slough bed and gauge is located 13.0' feet from mark (ribbon).

	June 24, 1976	September 7, 1976
Elevation	703 ft.	691 ft.
Approximate distance from mouth to gauge	150 yds.	150 yds.
Water surface height at gauge	2.23 ft.	0.76 ft.
Actual water depth at gauge	-	0.54 ft.
Slough width at gauge	31 ft.	7.2 ft.
Maximum depth at cross-section	2.15 ft.	0.64 ft.
Change in bed elevation	-	+0.2 ft.
Bed surface composition	silt	silt, sand, gravel
Slough width at mouth	41 ft.	~1 ft.
Slough depth at mouth	3.44 ft.	0.4 ft.
Susitna River mean daily discharge	19,900 CFS	6,480 CFS

Susitna River Mean Daily Discharge
Slough Cross-Section⊥ to Banks
at Staff Gauge (6/24/76).



Slough Cross-Section⊥ to Banks
at Mouth (6/24/76).



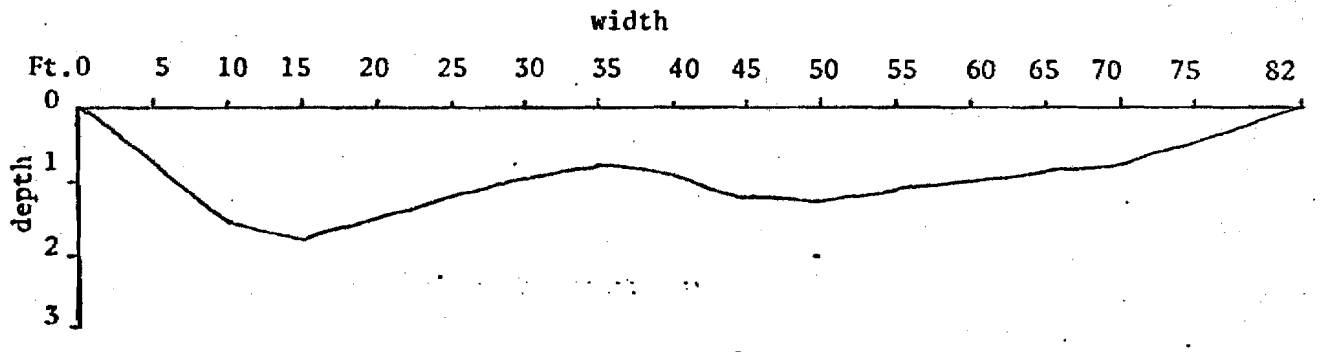
Appendix A

Table 25. Slough 16 Cross-Section and Stage Gauge Information, Devil's Canyon Project, 1976.

Location of Gauge: Permanent marker is tree or north side of slough. Mark is 13.0' above slough bed and gauge is 44' from mark.

	June 24, 1976	September 7, 1976
Elevation	708 ft.	694 ft.
Approximate distance from mouth to gauge	50 yds.	50 yds.
Water surface height at gauge	5.50 ft.	3.78 ft.
Actual water depth at gauge	2.24 ft.	0.28 ft.
Slough width at gauge	65 ft.	11 ft.
Maximum depth at gauge section	1.74 ft.	0.36 ft.
Change in bed elevation	-	-0.3 ft.
Bed surface composition	silt, sand, gravel	silt, sand, gravel
Slough width at mouth	-	-
Slough depth at mouth	-	-
Susitna River mean daily discharge	19,900 CFS	6,480 CFS

Slough Cross-Section ⊥ to Banks and Adjacent to Gauge, Beginning from the North Bank (6/24/76).



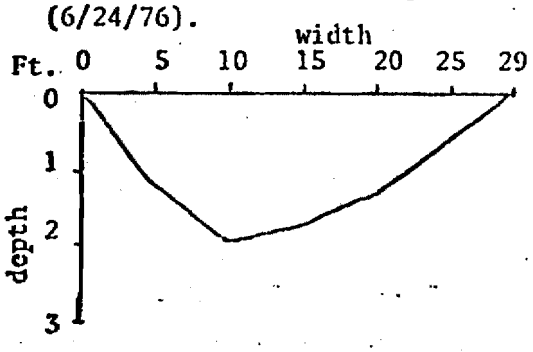
Appendix A

Table 26. Slough 17 Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

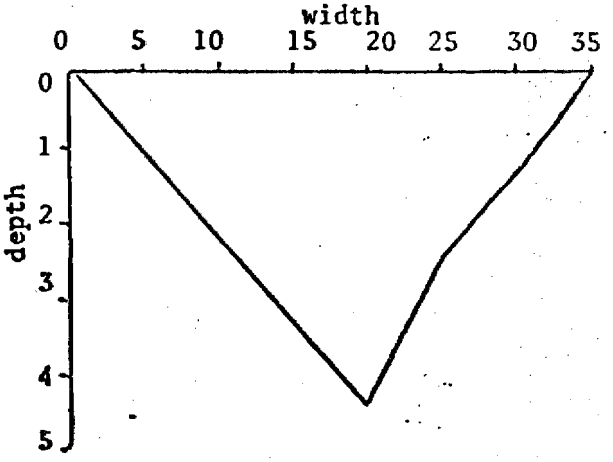
Location of Gauge: Permanent marker is tree on west side of slough. Mark is 12.0' above slough bed and gauge is 24.0' from mark.

	June 24, 1976	September 29, 1976
Elevation	715 ft.	-
Approximate distance from mouth to gauge	50 yds	50 yds.
Water surface height at gauge	5.30 ft.	3.78 ft.
Actual water depth at gauge	1.76 ft.	.60 ft.
Slough width at gauge	29 ft.	.60 ft.
Maximum depth at gauge	1.76 ft.	.40 ft.
Change in bed elevation	-	-
Bed surface composition	very soft silt	very soft silt
Slough width at mouth	35 ft.	0
Slough depth at mouth	4.40 ft.	0
	19,900 CFS	6,060 CFS

Cross-Section of Slough ⊥ to Banks & Adjacent to Gauge (6/24/76).



Slough Cross-Section ⊥ to Banks at Mouth (6/24/76).

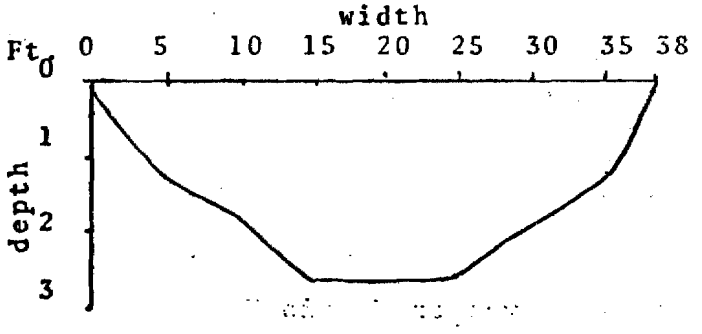


Appendix A
Table 27. Slough 18 Cross-Section and Stage Gauge Information, Devils Canyon Project, 1976.

Location of Gauge: Permanent marker is tree on north side of slough. Mark is 6.0' above slough bed and gauge is 24' from mark.

	June 24, 1976	Sept. 29, 1976
Elevation	714 ft.	-
Approximate distance from mouth to gauge	40 yds.	40 yds.
Water surface height at gauge	1.80 ft.	.98 ft.
Actual water depth at gauge	1.80 ft.	.98 ft.
Slough width at gauge	38 ft.	-
Maximum depth at cross-section	2.54 ft.	-
Change in bed elevation	-	-
Bed surface composition	silt	silt
Slough width at mouth	3 ft.	0 ft.
Slough depth at mouth	0.3 ft.	0 ft.
Susitna River mean daily discharge	19,900 CFS	6,060 CFS

Slough Cross-Section ⊥ to Banks and Adjacent to Guage (6/24/76)



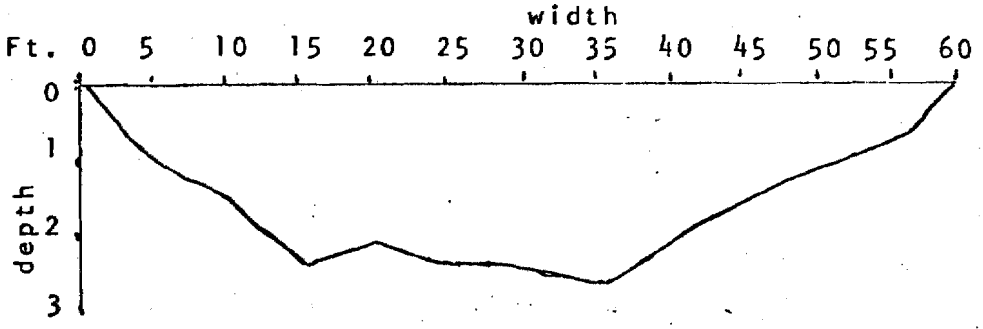
Appendix A

Table 28. Slough 19 Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

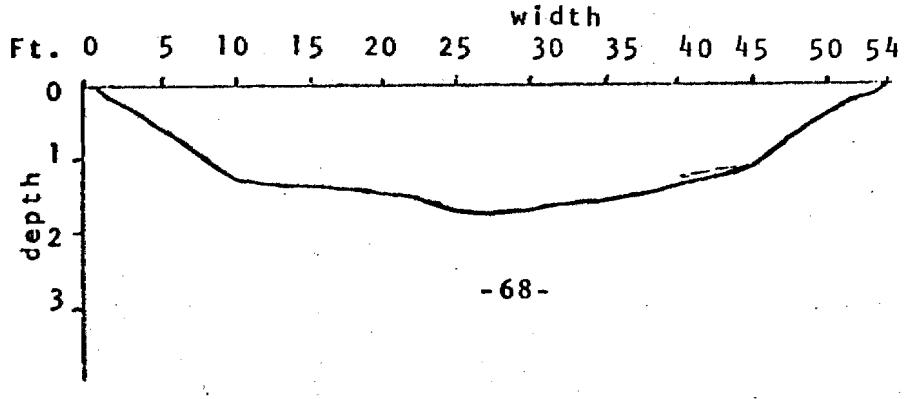
Location of Gauge: Permanent marker is tree on south side of slough. Mark is 9.0' from slough bed and gauge is 53' from mark.

	June 25, 1976	Sept. 8, 1976
Elevation	724 ft.	718 ft.
Approximate distance from mouth to gauge	50 ft.	50 ft.
Water surface height at gauge	5.82 ft.	5.13 ft.
Actual water depth at gauge	2.43 ft.	1.59 ft.
Slough width at gauge	60 ft.	54 ft.
Maximum depth at cross-section	2.53 ft.	1.72 ft.
Change in bed elevation	-	+0.1 ft.
Bed surface composition	soft silt	soft silt
Slough width at mouth	11 ft.	0
Slough depth at mouth	1.95 ft.	0
Susitna River mean daily discharge	19,600 CFS	6,240 CFS

Slough Cross-Section to Banks & Adjacent to Gauge (6/25/76)



Slough Cross-Section to Banks & Adjacent to Gauge (9/8/76)

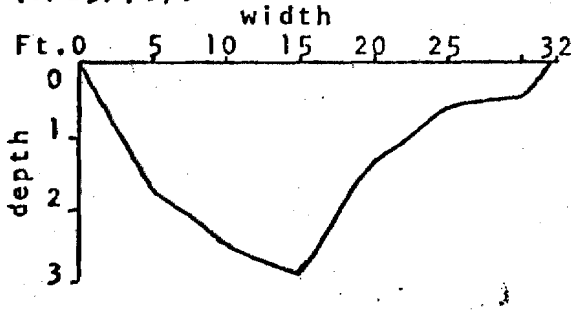


Appendix A
Table 29. Slough 20 Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

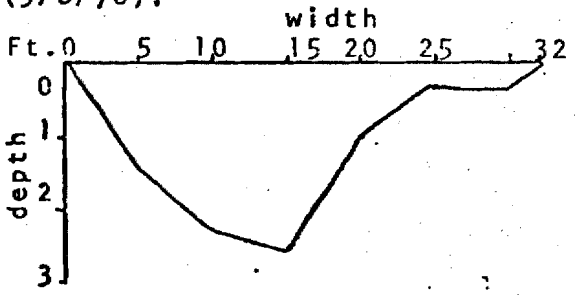
Location of Gauge: Permanent mark is tree on south side of slough. Mark is 10.0' above slough bed and gauge is 47' from tree.

	June 25, 1976	September 8, 1976
Elevation	709 ft.	724 ft.
Approximate distance from mouth to gauge	150 yds.	150 yds.
Water surface height at gauge	2.78 ft.	2.63 ft.
Actual water depth at gauge	2.50 ft.	2.50 ft.
Slough width at gauge	32 ft.	32 ft.
Maximum depth at cross-section	2.83 ft.	2.60 ft.
Change in bed elevation	-	-
Bed surface composition	silt, sand	silt, sand
Slough width at mouth	35 ft.	4 ft.
Slouth depth at mouth	1.84 ft.	0.5 ft.
Susitna River mean daily discharge	19,600 CFS	6,240 CFS

Slough Cross-Section 1 to Banks & Adjacent to Gauge (6/25/76).



Slough Cross-Section 1 to Banks & Adjacent to Gauge (9/8/76).



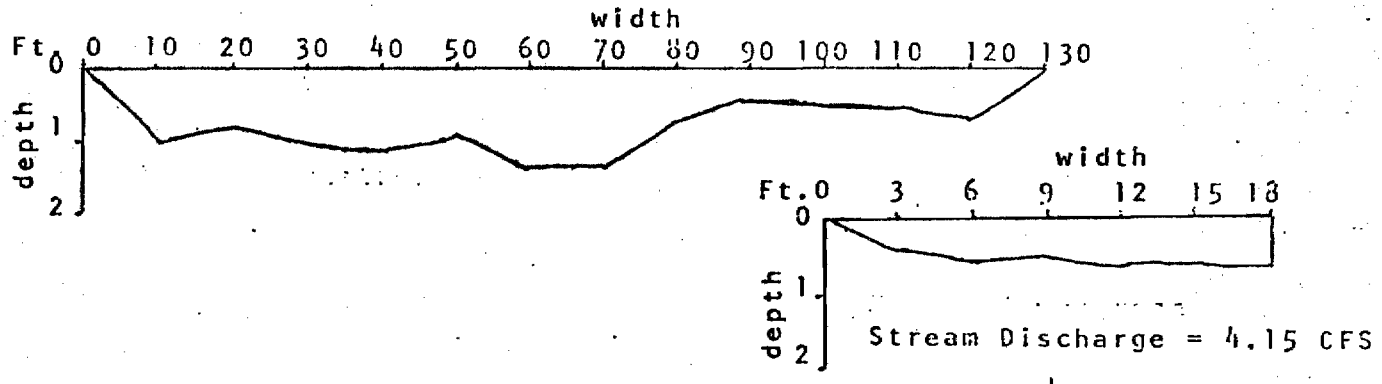
Appendix A

Table 30. Slough 3C Slough Cross Sections and Stage Gauge Information, Devils Canyon Project, 1976.

Location of Gauge: Permanent marker is tree on north side of slough. Mark is 11.0' above slough bed and gauge is 50.0' from mark.

	June 26, 1976	October 1, 1976
Elevation	426 ft.	-
Approximate distance from mouth to gauge	1,000 ft.	1,000 ft.
Water surface height at gauge	1.10 ft.	Below Gauge
Slough width at gauge	130 ft.	8 ft.
Maximum depth at cross-section	1.30 ft.	0.4 ft.
Change in bed elevation	-	-0.25 ft.
Bed surface composition	silt, sand	silt, sand, grvl.
Width	-	-
Depth	-	-
Actual water depth at gauge	1.10 ft.	0.3 ft.
Susitna River mean daily discharge	20,300 CFS	<5,800 CFS

Tributary Cross-Section ⊥ to Banks and Adjacent to Gauge (6/26/76).



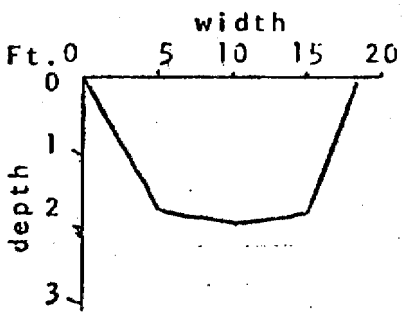
Tributary Cross-Section ⊥ to Banks
Appox. 0.25 Mi. Above Gauge (7/26/76).
Chinook Salmon Spawn at this Site.

Appendix A
Table 31. Chase Creek Cross-Sections and Stage Gauge Information, Devils Canyon Project, 1976.

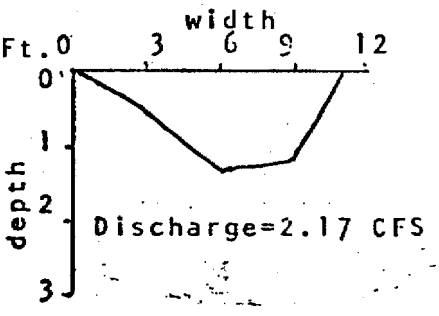
Location of Gauge: Permanent mark is rock on west side of creek. Mark is 1.0' above creek bed and gauge is 5.0' from mark.

	June 26, 1976	Sept. 30, 1976
Elevation	462 ft.	-
Approximate distance from mouth to gauge	50 ft.	50 ft.
Water surface height at gauge	5.40 ft.	5.38 ft.
Actual water depth at gauge	2.07 ft.	2.05 ft.
Tributary width at gauge	18 ft.	18 ft.
Maximum depth at cross-Section	2.07 ft.	2.05 ft.
Change in bed elevation	3	0
Bed surface composition	sand, gravel	sand, gravel
Tributary width at mouth	17 ft.	-
Tributary depth at mouth	1.16 ft.	-
Susitna River mean daily flow	20,300 CFS	5,800 CFS

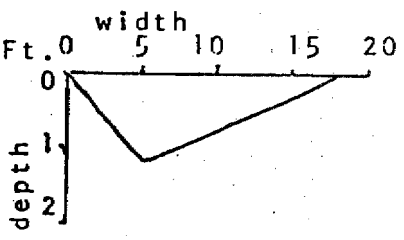
Tributary Cross-Section ⊥ to Banks and Adjacent to Gauge (6/26/76).



Tributary Cross-Section ⊥ to Banks and Adjacent to Gauge (7/26/76).



Tributary Cross-Section at Mouth (6/26/76)



Appendix A
Table 32. Tributary Flow Data, Devils Canyon Project, 1976.

Tributary	Date	Flow (CFS)
Portage Creek	9/8/76	500 (Est.)
Gold Creek	9/8/76	17
Fourth of July Creek	7/27/76	12
	9/9/76	37
Whiskers Creek	8/26/76	4

APPENDIX B

SELECTED BIBLIOGRAPHY OF DAM IMPACTS

Adams, James R. 1969. Thermal power, aquatic life and kilowatts on the Pacific Coast. Presented at American Power Conference annual meeting, Chicago, Illinois, April 22-25, 1969. In: Proceedings of the American Power Conference. Vol. 31. Dept. of Engineering Research. Pacific Gas and Electric Company, Emeryville, California. pp. 2-12.

Andrew, F.J. and G.H. Geen. 1958. Sockeye and pink salmon investigations at the Seton Creek hydroelectric installation. Inter. Pacific Salmon Fis. Comm. Progress report. New Westminster, B.C., Canada, 113 pp.

_____. 1960. Sockeye and pink salmon production in relation to proposed dams in the Fraser River system. Inter. Pacific Salmon Fish. Comm. Bull. XI. New Westminster, B.C., Canada. 259 pp.

Andrew, F.J., L.R. Kersey, and P.C. Johnson. 1955. An investigation of the problem of guiding downstream migrant salmon at dams. Inter. Pacific Salmon Fish. Comm., Bull. VIII. New Westminster, B.C., Canada. 65 pp.

Anonymous. No date. Facilities to pass downstream migrants and reservoir rearing data. [Forwarded by National Oceanographic and Atmospheric Administration. National Marine Fisheries Service. Columbia Fisheries Program Office, P.O. Box 4332, Portland, Oregon]. 17 pp.

Antonikov, A.F. 1964. Hydroelectric construction and the problem of fish passage facilities. Hydroelectric Construction, No. 3, pp. 26-29. Translated by Ole A. Mathisen, Fisheries Research Institute, Univ. of Washington, College of Fisheries. Circular No. 225. Seattle, December, 1964.

Atton, F.M. 1975. Impact analysis: Hindsight and foresight in Saskatchewan. J. Fish. Res. Board, Canada, Vol. 32(1). January. pp. 101-105.

Austin, R.W. 1973. Turbidity: Some definitions, methods of measurement and problems. 7 pp. + Fig. [Memorandum, March 9, 1973].

Beiningen, K.T. and W.J. Ebel. 1970. Effect of John Day Dam on dissolved nitrogen concentration and salmon in the Columbia River, 1968. Trans. Am. Fish. Soc., Vol. 99(4), Oct. pp. 664-671.

Bell, M.C. 1952. Streams, dams and salmon movements. Western Fisheries, Vol. 44(4): July. pp. 32-40.

_____. 1953. Fisheries research at high dams in Washington State. British Columbia Natural Resources Conference, Transactions, 6th: Victoria, B.C. pp. 102-106.

_____. 1954. Salmon fisheries versus power development. World Fishing. pp. 392-396+.

_____. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries engineering research program. U.S. Army Corps of Engineers. North Pacific Division, Portland, Oregon. Loose leaf, 34 charts.

Bell, Milo C., A.C. Delacy, and H.D. copp. 1972. A compendium on the survival of fish passing through spillways and conduits. For the Fisheries Engineering Research program. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon. January. 121 pp. + figures.

Bell, Milo C., et al. 1967. A compendium on the success of passage of small fish through turbines. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon. May. 268 pp.

Bell, R. 1959. Time, size, and estimated numbers of seaward migration of chinook salmon and steelhead trout in the Brownlee-Oxbow section of the Middle Snake Rivers. Idaho Dept. Fish and Game, Boise, Idaho. March 1, 36 pp.

Bentley, W.W. and H.L. Raymond. 1967. Collection of juvenile salmonids from turbine intake gatewells of major dams in the Columbia River system, Bureau of Commercial Fisheries, Biological Laboratory, Seattle, Washington, 12 pp.

Bishop, D. 1974. A hydrologic reconnaissance of the Susitna River below Devils Canyon. Environaid. Juneau, Oct. 55 pp.

Bouck, Gerald R., et al. 1976. Observations on gas-bubble disease among wild adult Columbia River fishes. Trans. Am. Fish. Soc., Vol. 105(1), Jan. pp. 114-115.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. Progress report No. 2. Intern. Pac. Salmon Fish. Comm., New Westminster, B.C., Canada. 26 pp.

_____. 1972. Mechanisms controlling migration of sockeye salmon fry. Bull. XXI. Intern. Pac. Sal. Fish. Comm., New Westminster, B.C., Canada. 86 pp.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon. J. Fish. Res. Board Can. Vol. 9(6), Nov. pp. 265-323.

_____. 1953. Research in salmon migration over high dams: The nature of the biological problems. British Columbia Natural Resources: Conferences, 6th Transactions. pp. 96-102.

_____. 1956. Some principals in the thermal requirements of fishes. Quart. Rev. Biol. Vol. 31(2), June. pp. 75-87.

_____. 1957. Salmon research and hydropower development. J. Fish. Res. Board Can. Nanaino, B.C. July 15.

_____. 1957. Salmon research and hydroelectric power. J. Fish. Res. Board Can. Bull. No. 114. Ottawa, Canada. 26 pp.

_____. 1958. Implications and assessment of environmental stress. H.R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, Univ. of British Columbia, Vancouver. pg. 69-83.

Bush, Robert D. 1974. Flows in rivers in the Susitna system. Xerox copy of a personal communication (unpublished). 5 pp.

Calderwood, W.J. 1928. Hydroelectricity and salmon fisheries. Trans. Am. Fish. Soc. Vol. 58, pp. 154-160.

Calkins, Thomas P. 1959. The effect of fin removal on the swimming ability of young silver salmon. Fisheries Research Institute, Circular 109. College of Fisheries, Univ. of Washington, Seattle. Nov.

Canada Dept. of the Environment. 1973. Water requirements for the fisheries resource. Fisheries and Marine Service, Pacific Region, Vancouver, B.C. Prepared by A.F. Lill and R. E. Hamilton. Environmental Quality Unit, Southern Operations Branch. April 24. 21 pp. + Figs.

Canada Dept. of Fisheries. 1957. A report on the fisheries problems related to the power development of the Cheakamus River system. Vancouver, B.C. March., 39 pp + Figs.

Canada Dept. of Recreation and Conservation. 1976. Method for determining minimum acceptable flows in British Columbia's salmon, char, and trout streams. Draft copy. Fish and Wildlife Branch, Victoria, British Columbia. March. 67 pp.

Canada Fisheries and Marine Service. 1975. Additional aquatic resource studies in the Aisminik system relative to hydroelectric development. Environment Canada. Fisheries and Marine Service, NBCY Division, PAC/T-75-4. Northern Operations Branch, Pacific Region. 7 charts.

Canfield, W. 1968. Method for counting coho fry in small streams. J. of Fish. Res. Board of Can. Vol. 25(3). March. pg. 823.

Chambers, John. 1963. McNary spawning channel: Resume of the five years study, 1957-1962, first draft. State of Washington, Dept. of Fisheries, Research Div. May. 66 pp.

Chambers, John S., T.K. Meekins, and J.H. Harris. 1964. Research relating to McNary supplemental spawning channel. Annual report. (July 1, 1963 through June 10, 1964). State of Washington, Dept. of Fisheries, Research Div. 38 pp + appendix.

Clay, C.H. 1955. Downstream fish migration over dams. B. C. Prof. Engr. Vol. 6(10). Oct. pp. 15-18.

Clemens, W.A. 1958. The Fraser River salmon in relation to potential power development. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin, Institute of Fisheries, University of British Columbia, Vancouver. pp. 3-10.

Cobb, J.N. 1925. An experiment in lifting salmon over high dams. Journal of Electricity, Vol. 54(1). Jan. pp. 50-53.

Collings, M.R. 1974. Generalizations of spawning and rearing discharges for several Pacific salmon species in western Washington. USGS in cooperation with the State of Washington. Dept. of Fisheries. Open file report. Tacoma, Washington. 39 pp.

Collings, M.R., R.W. Smith and G.T. Higgins. 1972. Hydrology of four streams in western Washington as related to several Pacific salmon species: Humptulis, Elochoman, Green and Wynochee rivers. U.S. Dept. of the Interior, Geological Survey. Prepared in cooperation with the State of Washington, Dept. of Fisheries, Tacoma, Washington. 128 pp.

Collins, Gerald B. 1952. Factors influencing the orientation of migrating anadromous fishes. U.S. Fish and Wildlife Fishery Bull. Vol. 52(73) No. 585. Woodshole Oceanographic Contribution Institution. U.S. Gov't. Printing Office. Washington, D.C. pp. 374-396.

_____. 1954. Research on anadromous fish passage at dams. U.S. Fish and Wildlife Service, Seattle, Washington. Reprinted from Transactions of the Nineteenth North American Wildlife Conference, March 8, 9, 10, 1954. Wildlife Management Institute, Washington, D.C. March. pp 418-423.

_____. 1956. Research on fishway problems. U.S. Fish and Wildlife Service. Nov. pp. 118-125. [xerox copy of a section of U.S. Army Corps of Engineers report].

_____. 1958. The measurement of performance of salmon in fishways. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, Univ. of British Columbia, Vancouver. pp. 85-91.

_____. 1963. Fish passage research. Reprinted from American Zoologist. Vol. 3(3). August. 1 pp.

_____. No date. New methods for study of fishery problems. U.S. Fish and Wildlife Service. Seattlen, Washington. 7 pp. [personal copy, original].

_____. No date. The measurement of performance of salmon in fishways. U.S. Fish & Wildlife Service, Seattle, Wn. pp. 85-91.

Collins, Gerald B. and C.H. Elling. 1960. Fishway research at the fisheries-engineering research laboratory. U.S. Dept. of the Interior, Fish & Wildlife Service, Bur. of Commercial Fisheries. Circular 98, Nov. 17 pp.

Collins, Gerald B., J.R. Gauley, and C.H. Elling. 1962. Ability of salmonids to ascend high fishways. Trans. Am. Fish. Soc. Vol. 91(1) Jan. pp 1-7.

Collins, Gerald B., et al. 1975. The Snake River salmon and steelhead crisis, its relation to dams and the national energy crisis. Northwest Fisheries Center. National Marine Fisheries Service, Seattle, WA. Feb. 30 pp.

Collins, Gerald B., P.S. Trefethen, and C.D. Volz. 1975. Factors affecting electrotaxis in salmon fingerlings. Processed Report. Prepared by Northwest Fisheries Center, Natl. Marine Fisheries Service, Seattle, WA. June. 45 pp.

Conroy, Fay. 1976. Desirable stream flows for salmon spawning and rearing. Personal communication. Washington Dept. of Fisheries, Olympia, WA. Feb. 10. 2 pp.

Cooper, A.C. 1973. Temperature control during sockeye spawning period in McKinley Creek in 1969. Part I. Progress Report No. 27. International Pacific Salmon Fisheries Commission, New Westminster, B.C., Canada, 34 pp.

Cooper, A.1. 1965. The effect of transported stream sediments on the survival of sockeye and pink salmon eggs and alevin. Inter. Pac. Salmon Fish. Comm., Bull. XVIII. New Westminster, B.C., Canada. 71 pp.

Cooper, Edwin L.)Ed.). 1967. A symposium on water quality criteria to protect aquatic life. Presented at the 96th annual meeting, Kansas City, Missouri, Sept. 1966. Am. Fish. Soc. Special Publication No. 4. Supplement to Vol. 96(1). Trans. Am. Fish. Soc. 37 pp.

Curtis, Brian. 1959. Changes in a river's physical characteristics under substantial reduction in flow due to hydroelectric diversion. Calif. Fish and Game. Vol. 45(3). pp. 181-188.

Davidson, Robert C., et. al. 1959. Experiments on the dissolved oxygen requirements of cold-water fishes. Sewage and Industrial Wastes. Vol. 31(8). Aug. pp. 950-966.

Dawley, Earl and W.J. Ebel. 1975. Effects of various concentrations of dissolved atmospheric gas of juvenile chinook salmon and steelhead trout. NOAA, National Marine Fisheries Service, Northwest Fisheries Center, Seattle, WA. Jan. 18 pp.

Dawley, Earl, et al. 1975. Salmon bioassay of supersaturation of dissolved gas in water. NOAA. Natl. Marine Fisheries Service, Northwest Fisheries Center, Seattle, WA. March. 37 pp.

Dawley, Earl, et al. 1975. Studies on effects of supersaturation of dissolved gases on fish. NOAA. Natl. Marine Fisheries Service, Northwest Fisheries Center, Seattle, WA. Sept. 85 pp.

Day, Duane, E. 1966. Population stratification and homing behavior in juvenile coho salmon. Washington Dept. of Fisheries. Fisheries Research Papers. Vol. 2(4). Dec. pp. 75-79.

Dean, E.L. 1975. Churchill River Study (Missinipe Probe); aquatic ecology and fisheries in Reindeer Lake. Final report No. 10. Saskatchewan Fisheries Laboratory. Dept. of Tourism and Renewable Resources. Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson, 181 pp.

Dickson, I.W. 1975. Hydroelectric development of the Nelson River system in northern Manitoba. J. Fish. Res. Board Can. Vol. 32(1) Jan. pp 106-116.

Dill and Northcote. 1970. Effects of gravel size, egg depth, and egg density on intragravel movement and emergence of coho salmon (oncorhynchus kisutch) alevins. J. Fish. Res. Board Can. Vol. 27(7) July. pp. 1191-1199.

Dominy, C.L. 1973. Recent changes in Atlantic salmon runs in the light of environmental changes in the Saint John River. Biol. Conserv., New Brunswick, Can. Vol. 5(2). pp. 105-113.

Dooley, John M. 1975. Application of U.S. Bureau of Reclamation water surface profile program (WSP) Proceedings of the Fort UnionCoal Symposium. Vol. 2. Aquatic ecosystems section. Sponsored by the Montana Academy of Sciences at Eastern Montana College, Billings, Montana. April. pp. 138-154.

Doyle, Paul F. and J.M. Childers. 1975. Channel erosion surveys along the TAPS route, Alaska, 1975. U.S. Dept. of the Interior. Geological Survey, Open-file report (Basic data), Anchorage, Alaska. 95 pp.

Duncan, Richard N. and I.J. Donaldson. 1968. Tatoo-marking of fingerling salmonids with fluorescent pigments. J. Fish. Res. Board Can. Vol. 25(10). Oct. pp. 2233-2236.

Dutmie, H.C. and M.L. Ostrofsky, J.L. 1975. Environmental impact of the Churchill Falls (Labrador) hydroelectric project. A preliminary assessment. J. Fish. Res. Board Can. Vol. 32(1). Jan. pp. 117-125.

Ebel, Wesley J. 1969. Supersaturation of nitrogen in the Columbia River and its effect on salmon and steelhead trout. U.S. Fish & Wildlife Service. Fish Bull. 68. pp. 1-11.

_____. 1970. Effect of release location on survival of juvenile fall chinook salmon, Onchorynchus tshawytscha. Reprinted from Trans. Am. Fish. Soc., Vol. 99(4). Oct. pp. 672-676.

_____. 1971. Dissolved nitrogen concentrations in the Columbia and Snake rivers in 1970 and their effect on chinook salmon and steelhead trout. NOAA Technical Report. NMFS SSRF-646. National Marine Fisheries Service, Seattle, WA. August. 7 pp.

_____. 1974. Marking fishes and invertebrates III. Coded wire tags useful in automatic recovery of chinook salmon and steelhead trout. MFR Paper 1069. Marine Fisheries Review. Vol. 36(7). pp. 10-13.

_____. No date. Relations between fish behavior, bioassay information and dissolved gas concentrations on survival of juvenile salmon and steelhead trout in Snake River. (Source unknown). pp. 516-527.

_____. No date. Standards for total dissolved gases (nitrogen). Northwest Fisheries Center, Seattle, WA. 8 pp.

Ebel, Wesley J., E.M. Dawley, and B.M. Monk. 1971. Thermal tolerance of juvenile Pacific salmon and steelhead trout in relation to supersaturation of nitrogen gas. U. S. Fish and Wildlife Service Fishery Bull., Vol. 69(4). June. pp. 833-843.

Ebel, Wesley J. and C.H. Koski. 1968. Physical and chemical limnology of Brownlee Reservoir, 1962-64. U. U. Fish and Wildlife Fishery Bull. Vol. 67(2). Dec. pp. 295-335.

Ebel, Wesley, R.W. Kroma, and H.L. Raymond. 1973. Evaluation of fish protective facilities at Little Goose Dam and review of other studies relating to protection of juvenile salmonids in the Columbia and Snake rivers, 1973. NOAA. National Marine Fisheries Service, Northwest Fisheries Center, Division of Coastal Zone and Estuarine Studies, Seattle, WA. 53 pp.

Ebel, Wesley J., S.L. Park, and R.C. Johnsen. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. U. S. Fish and Wildlife Fishery Bull. Vol. 71(2). pp. 549-563.

Ebel, Wesley J., et al. 1971. Progress report on fish protective facilities at Little Goose Dam and summaries of other studies relating to the various measures taken by the Corps of Engineers to reduce losses of salmon and steelhead in the Columbia and Snake rivers. NOAA. Nat'l. Marine Fisheries Service, North Pacific Fisheries Research Center, Seattle, WA. Sept. 58 pp.

Ebel, Wesley J., et al. 1975. Effect of atmospheric gas supersaturation caused by dams on salmon and steelhead trout of the Snake and Columbia rivers. NOAA. National Marine Fisheries Service, Northwest Fisheries Center (processed). Jan. 111 pp.

Efford, I.E. 1975. Assessment of the impact of hydrodams. J. Fish. Res. Board Can. Vol. 32(1). Jan. pp. 196-209.

Falconer, Derek D. 1964. Practical trout transport techniques. The Progressive Fish-Culturist. Vol. 26(2). April. pp. 51-58.

Farr, Winston E. 1974. Traveling screens for turbine intakes of hydroelectric dams. Reprinted from Proceedings of the SecondEntrainment and Intake Screening Workshop. L.D. Jensen (Ed.). The Johns Hopkins University Cooling Water Research Project. Report No. 15. pp. 199-203.

Farr, Winston E. and E.F. Prentice. 1974. Mechanical operation of horizontal traveling screen model VII. Reprinted from Proceedings of the Second Entrainment and Intake Screening Workshop. L.D. Jensen (Ed.) The John Hopkins University Cooling Water Research Project. Report No. 15. pp. 215-222.

Food and Agriculture Organization of the United Nations. 1976. Indices for measuring responses of aquatic ecological systems to various human influences. FAO. Fisheries Technical Paper No. 15. A report of the ACNMR/LABO working party on ecological indices of stress to fishery resources. Rome. 66 pp.

Franklin, Donald R. and L.L. Smith, Jr. 1960. A unitized system of water level and fish population control structures for spawning sloughs. The Progressive Fish-Culturist. Vol. 22(3). July. pp. 138-190.

Fraser, J.C. No date. Regulated stream discharge for fish and other aquatic resources. FIRI/T112. Senato Research Information Section, Fishery Resources Division, FAO, 00100, Rome, Italy.

Friese, Nancy Y., et al. 1976. Southcentral railbelt area-Susitna River Basin. Fish and Wildlife studies related to the Corps of Engineers Devil Canyon-Watana Reservoir hydroelectric project. Alaska Dept. of Fish and Game. Feb. 168 pp.

Fry, F.E.S. 1958. Approaches to the measurement of performance in fish. H.R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, University of British Columbia, Vancouver. pp. 93-97.

Geen, G.H. 1975. Ecological consequences of the proposed Moran Dam on the Fraser River. J. Fish. Res. Board Can. Vol. 32(1). Jan. pp. 126-135.

Geen, G.H. and F.J. Andrew. 1961. Limnological changes in Seton Lake resulting from hydroelectric diversions. Inter. Pac. Salmon Fish Comm. Progress Report No. 8. New Westminster, B.C. 75 pp.

Gershon, Kulin and P.R. Compton. 1975. A guide to methods and standards for the measurement of water flow. U.S. Dept. of Commerce. Institute for Basic Standards, Natl. Bur. of Standards, Washington, D.C. May. 90 pp.

Giger, Richard D. 1973. Stream flow requirements of salmonids. Federal Aid job final report, Oregon Wildlife Commission. AFS-62. 120 pp.

Gordon, R.N. 1965. Fisheries problems associated with hydroelectric development. The Canadian Fish Culturist. Vol. 35. Oct. pp. 17-36.

Groves, Alan B. and A.J. Novotny. 1965. A thermal marking technique for juvenile salmonids. Trans. Am. Fish. Soc. Vol. 94(4). Oct. pp. 386-389.

Gunsolus, Robert T. and G.J. Eicher. 1970. Evaluation of fish passage facilities at the North Fork project on the Clackamus River in Oregon. A research project of the Fish Commission of Oregon, Oregon Game Commission, U. S. Bur. of Comm. Fisheries, U.S. Bureau of Sport Fisheries and Wildlife, and Portland General Electric Company. Sept. 104 pp.

Haas, James B. 1965. Fishery problems associated with Brownlee, Oxbow, and Hells Canyon Dams on the Middle Snake River. Fish Commission of Oregon. Portland Investigational Report No. 4. pp. 84-95.

Haddix, M.H. and C.C. Estes. 1976. Lower Yellowstone River Study Final Report. Research conducted by the Montana Dept. of Fish and Game - Environment and Information Division. Sponsored by the U. S. Dept. of the Interior - Bureau of Reclamation. Oct. 86 pp.

Hamilton, J.A.R. and F.J. Andrew. 1954. An investigation of the effect of Baker Dam on downstream migrant salmon. Intern. Pac. SalmonFish. Comm., Bull. VI. New Westminster, B.C. 73 pp.

Hamilton, Roy. 1974. Water requirements for the fisheries resource of the Deadman River. Internal Report Series No. PAC/1-74-1. Habitat-Protection Unit. Southern Operations Branch, Dept. of the Environment, Fisheries and Marine Service, Pacific Region, Vancouver, B.C., Can. Feb. 14 pp. + Figs.

Harry, A. 1917. The fishways in the dams and waterworks in Switzerland. Swiss Wasserwirtschafts-Verhandes No. 5 Verlag Rascher V. Co., Zurich and Leipzig (translated from the German by W.M. Chapman). 79 pp.

Harvey, H.H. and A.C. Cooper. 1962. Origin and treatment of a super saturated river water. Intern. Pac. Salmon Fish. Comm. Progress Report No. 9. New Westminster, B.C., Can. 19 pp.

Hecky, R.E. 1975. Churchill River study (Missinipe Probe): sediments in Sokatisewin and Reindeer lakes. Final Report No. 12. Saskatchewan Fisheries Laboratory. Dept. of Tourism and Renewable Resources. Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 56 pp.

Hem, John D. 1970. Study and interpretation of the chemical characteristics of natural water. Second Ed. Geological survey water supply paper 1473. U. S. Govt. Printing Office, WA. 363 pp.

Hoar, William S. 1951. The behavior of chum, pink, and coho salmon in relation to their seaward migration. J. Fish. Res. Board of Can. Vol. 8(4). Oct. pp. 241-243.

_____. 1958. The analysis of behavior of fish. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, Univ. of British Columbia, Vancouver. pp. 99-111.

Holmes, Harlon B. and M.C. Bell. 1960. A study of the upstream passage of anadromous fish at Willamette Falls, with recommendations for improvements in fish-passage facilities. Final Report (unpublished) to Oregon Fish Commission, Portland. Jan. 126 pp. + Figs.

Hooper, Douglas R. 1973. Evaluation of the effects of flows on trout stream ecology. Dept. of Engineering Research, Pacific Gas and Electric Company. Emeryville, CA. Jan. 97 pp.

Hourston, W.R. 1958. Power development and anadromous fish in British Columbia. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, Univ. of British Columbia, Vancouver. pp. 15-24.

Huang, P.M. and W.K. Liaw. 1975. Churchill River Study (Missinipe probe) sediments in Drinking Lake. Final report No. 15. Saskatchewan Fisheries Laboratory. Dept. of Tourism and Renewable Resources. Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 20 pp.

Huber, E.E. Fish protection at intake structures and dams: Guidance screens and collection devices. ORNL EIS-74-67. Bibliography. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 37830. Microfiche copy.

Huston, Joe E. 1974. Revision of 1965 fishery analysis, Libby Dam project, Kootenai River, Montana. Montana Dept. of Fish & Game. April 4. 34 pp.

Institution of Civil Engineers. Institution Research Committee, 1942. Report of the committee on fish-passes. William Clowes and Sons, Ltd., London. 59 pp.

Irving, R.B. and P. Cuplin. 1956. The effect of hydroelectric developments on the fishery resources of the Snake River. Idaho Dept. of Fish and Game. Final report on project F-8-R, p. 29. 167 pp.

Issac, Dennis L. 1973. Rearing juvenile spring chinook salmon in large reservoirs. Fish Commission of Oregon. Annual Report. July 1, 1972-June 30, 1973. NOAA. Natl. Marine Fisheries Service. July. 8 pp.

_____. 1974. Rearing juvenile spring chinook salmon in large reservoirs. Fish Comm. of Oregon. Annual Report. July 1, 1973-June 30, 1974. NOAA. Natl. Marine Fisheries Service. July. 5 pp.

_____. 1975. Rearing juvenile spring chinook salmon in large reservoirs. Fish Commission of Oregon. Annual Report, July 1, 1974-June 30, 1975. NOAA. Natl. Marine Fisheries Service. July. 4 pp.

Janke, P. 1976. Notes-survey of sloughs and tributaries to Susitna River made June 23-26 with Jim Riis, research biologist, Sport Fish Division, Alaska Dept. of Fish & Game. Engineering Section, Anchorage. June 29. 14 pp. (unpublished).

Jeltes, R. 1974. Prompt detection and tracing of oils and other detrimental chemicals in the environment. Water Research. Vol. 8. pp. 977-987.

Johnsen, Richard C. and E.M. Dawley. 1974. The effect of spillway flow deflectors at Bonneville DAm on total gas supersaturation and survival of juvenile salmon. Final Report. NOAA. Natl. Marine Fisheries Service. Northwest Fisheries Center. Coastal Zone and Estuarine Studies Division, Seattle, WA. Dec. 18 pp.

Junge, Charles O. No date. The effect of superimposed mortalities on reproduction curves. No other references available. Probably research briefs. Oregon Fish Commission. 8 pp.

_____ and J. Haas. 1968. Fish passage problems at Columbia River dams. Memorandum. Fish Comm. of Oregon. Portland. Nov. 18.

_____ and A.L. Oakley. 1966. Trends in production rates for Upper Columbia River runs of salmon and steelhead and possible effects of changes in turbidity. Oregon Fish Comm. Research Briefs. Vol. 12(1). April. pp. 22-43.

Kaill, Michael W. 1976. Trip report instream flow needs AFS/ASCE. May 3-6. Boise, Idaho (unpublished).

Katz, Max, et al. 1968. Effects of pollution on fish life. Water Pollution Control Federation Journal. Vol. 40(6). June. pp. 1007-1033.

Kipper, Z.M. and I. Mileiko. 1967. Fishways in hydro-developments of the USSR. Rybnae Khozijaistno. Moscow. pp. 24-37, 46-53. Translated by A. Wald Israel. Program for scientific translations, Ltd. U.S. Dept. of Commerce. Clearinhouse for federal scientific and technical information. Springfield, VA.

Korn, Lawrence. 1972. The feasibility of rearing sockeye salmon in reservoirs. Fish Commission of Oregon. Management and Research Div. Summary Report. Sept. 5 pp.

Langbein, Walter B. and L.B. Leopold. 1964. Quasi-equilibrium states in channel morphology. Am. J. Sc. Vol. 262(6). June. pp. 782-794.

Lawrence, J.R. 1975. Churchill River study (Missinipe probe): primary production in Churchill and Reindeer River lakes. Final Report No. 13. Saskatchewan Fisheries Laboratory. Dept. of Tourism and Renewable Resources. Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 20 pp.

Leopold, Luna B. and T. Maddock, Jr. 1959. The hydraulic geometry of stream channels and some physiographic implications. U.S. Geological Survey. Professional Paper 252. Washington, D.C. 1953. Reprinted 1959. 57 pp.

Liaw, W.K. and O'Connor, J.F. 1975. Churchill River study (Missinipe probe): impact on five Churchill River lakes. Final Report 8. Saskatchewan Fisheries Laboratory. Dept. of Tourism and Renewable Resources. Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 198 pp.

Liscom, Kenneth L. 1971. Orifice placement in gatewells of turbine intakes for bypassing juvenile fish around dams. Reprinted from Trans. Am. Fish. Soc., Vol. 100(2). April. pp. 319-324.

_____. 1973. Sonic tags in sockeye salmon, Onchorynchus nerka, give travel time through metropolitan waters. MFR Paper 1007. Marine Fisheries Review. Vol. 35(9). pp. 38-41.

Lister and Walker. 1966. The effect of flow control on freshwater survival of chum, coho, and chinook salmon in the Big Qualicum River. Can. Fish Culturist No. 37. August. pp. 3-25.

Logging and Fish Habitat. 1976. USDA Forest Service, Alaska Dept. of Fish and Game, Alaska Dept. of Natural Resources. GPO 699-882. 21 pp.

MacKinnon, Dixon and W.S. Hoar. 1953. Responses of coho and chum salmon fry to current. J. Fish. Res. Board, Can. Vol. 10(8). pp. 523-538.

Major, Richard L. and J.L. Mighell. 1969. Egg-to-migrant survival of spring chinook salmon, Oncorhynchus tshawytscha, in the Yakima River, Washington, U.S. Fish and Wildlife Service. Fishery Bull. Vol. 67(2). pp. 347-359.

_____. 1967. Influence of Rock-Reach Dam and the tempeature of the Okanogan River on the upstream migration of sockeye salmon. U.S. Fish and Wildlife Service. Fishery Bull. Vol. 66(1). Jan. pp. 131-147.

Major, Richard L. and G.J. Paulik. 1972. Effect of encroachment of Wanapum Dam Reservoir on fish passage over Rock Island Dam, Columbia River. U.S. Fish and Wildlife Service. Fishery Bull. Vol. 70(1). pp. 125-140.

Marcuson, Pat. 1968. Stream sediment investigation. Montana Fish and Fame Dept., Fisheries Division. South Central Montana Fishery. F20-R-13. Job No. III. Helena, MT. Unpublished. Oct. 1 through Sept. 30. 10 pp.

May, Bruce. 1975. The mitigation myth-the real impact of Libby Dam on Fisheries has finally surfaced. Montana Outdoors. Nov./Dec. pp. 7-10.

_____. 1975. Temperature data from Kootenai River. Office memorandum. State of Montana. Dept. of Fish and Game. Helena, Mt. Dec. 3. 2 pp.

McCluney, W.R. 1975. Radiometry of water turbidity measurements. J. Wat. Poll. Cont. Fed. Vol. 47(2). Feb. pp. 252-265.

McCoy, George A. 1974. Preconstruction assessment of biological quality of the Chena and Little Chena Lakes flood control project near Fairbanks, AK. USGS Water Resources Investigations 29-74. 84 pp.

McGrath, C.J. 1956. Inland fisheries and the engineer. Trans. Inst. Ireland. Vol. 82. pp. 51-79.

Merriman, Daniel and L.M. Thorpe. 1976. The Connecticut River ecological study: the impact of a nuclear power plant. Am. Fish. Soc. Mono. No. 1. Washington, D.C. 252 pp.

Monan, Gerald E. and J.H. Johnson. 1974. Distribution of 1965 fall chinook salmon between the Dalles and McNary Dams, as determined by sonic tagging. Final report. Financed by U.S. Army Corps of Engineers. Walla Walla District and Northwest Fisheries Center. National Marine Fisheries Service, Division of Coastal Zone and Estuarine studies. Seattle, WA. Sept. 11 pp.

Monan, Gerald E., J.H. Johnson, and G.F. Esterberg. 1975. Electronic tags and related tracking techniques aid in study of migrating salmon and steelhead trout in the Columbia River Basin. MFR Paper 1121. Marine Fisheries Review. Vol. 37(2). Feb. pp. 9-15.

Monan, Gerald E. and K.L. Liscom. 1973. Radio tracking of adult spring chinook salmon below Bonneville and the Dalles dams, 1972. Final report. Financed by U.S. Army Corps of Engineers, Portaldn District and NOAA, National Marine Fisheries Service, Northwest Fisheries Center, Division of Coastal Zone and Estuarine Studies, Seattle, WA. Feb. 37 pp.

_____. 1974. Radio tracking of spring chinook salmon to determine effect of spillway deflectors on passage at Lower Monumental Dam, 1973. Final report. Financed by U.S. Army Corps of Engineers, Portland District and Northwest Fisheries Center. Natl. Marine Fisheries Service. Division of Coastal Zone and Esturine Studies, Seattle, WA. Jan. 20 pp.

_____. 1974. Radio tracking studies of fall chinook salmon to determine effect of peaking on passage at Bonneville Dam, 1973. Final report. Financed by U.S. Army Corps of Engineers, Portland District and Northwest Fisheries Center. Natl. Marine Fisheries Service. Division of Coastal Zone and Estuarine Studies, Seattle, WA. June. 28 pp.

_____. 1975. Radio tracking studies to determine the effect of spillway deflectors and fallback on adult chinook salmon and steelhead trout at Bonneville Dam, 1974. Final report. Financed by U.S. Army Corps of Engineers, Portland District and Northwest Fisheries Center. Natl. Marine Fisheries Service. Coastal Zone and Estuarine Studies Division, Seattle, WA. Feb. 38 pp.

Monan, Gerald E., K.L. Liscom, and J.R. Smith. 1970. Sonic tracking of adult steelhead in Ice Harbor Reservoir, 1969. Final report. Bureau of Commercial Fisheries, Biological Laboratory. Seattle, WA. Feb. 13 pp.

Monk, Bruce H., E. Dawley, and K. Beiningen. 1975. Concentration of dissolved gases in the Willamette, Cowlitz and Boise rivers, 1970-72. National Marine Fisheries Data Report 102. Natl. Marine Fisheries Service. Seattle, WA. June. 19 pp.

Neave, F. 1958. Stream ecology and production of anadromous fish. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin, Institute of Fisheries, Univ. of British Columbia, Vancouver. pp. 43-48.

Needham, P.R. 1949. Dam construction in relation to fishery protection problems in the Pacific Northwest. North American Wildlife Conference. 4th Transaction. pp. 276-282.

Nemenyi, Paul. 1941. An annotated bibliography of fishways: covering also related aspects of fish migration, fish protection, and water utilization. Prepared in cooperation with the Iowa State Conservation Comm., No. 389. Studies in Engineering, Bull. 23. The State Univ. of Iowa, Iowa City. 64 pp.

Newcomb, T.W. 1974. Changes in blood chemistry of juvenile steelhead trout, Salmo gairdneri, following sublethal exposure to nitrogen supersaturation. J. Fish. Res. Board Can. Vol. 31(12). pp. 1953-1957.

Pacific Northwest River Basins Commission. 1974. Anatomy of a river: An evaluation of water requirements for the Hell's Canyon reach of the Middle Snake River; conducted March, 1973. Vancouver, July. 202 pp.

Park, Donn L. and Ebel, W.J. 1974. Marking fishes and invertebrates. II. Brand size and configuration in relation to long term retention on steelhead trout and chinook salmon. MFR Paper 1068. From Marine Fisheries Review. Vol. 36(7). July. pp. 7-9.

Patalas, K. and A. Salki. 1975. Churchill River study (Missinpe probe), crustacean plankton in Reindeer Lake. Final report 11. Saskatchewan Fisheries Laboratory, Dept. of Tourism and Renewable Resources, Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 76 pp.

Phinney, Lloyd A. 1973. Western Washington power dam review. State of Washington. Dept. of Fisheries, Management and Research Div. Jan. 55 pp. (1971 Progress Report).

_____. 1974. Report on the 1972 study of the effect of river flow fluctuations below Merwin Dam on downstream migrant salmon. State of Washington, Dept. of Fisheries, Management and Research Div. FPC Report, Project No. 935, Feb. 23 pp (Supplemental Progress Report-Power Dam Studies).

Prentice, Earl F. and F.J. Ossiander. 1974. Fish diversion systems and biological investigation of horizontal traveling screen Model VII. Proceedings ofthe SecondEntrainment and Intake Screening Workshop. L.D. Jensen (Ed.). The Johns Hopkins Univ., Cooling Water Research Project, Report No. 15. pp. 205-219.

Pretious, E.S., L.R. Kersey, and G.P. Contractor. 1957. Fish protection and power development of the Fraser River. The Fraser River Hydro and Fisheries Research Project, Univ. of British Columbia, Vancouver, Can. Feb. 65 pp, + appendices.

Raleigh, Robert F. and W.J. Ebel. No date. Effect of Brownlee Reservoir on migrations of anadromous salmonids. Reprint from Reservoir Fishery Resources Symposium. pp. 415-443.

Raymond, Howard L. 1968. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake rivers. Trans. Am. Fish. Soc. Vol. 97(4). Oct. pp. 356-359.

_____. 1974. Snake River runs of salmon and steelhead trout trends in abundance of adults and downstream survival of juveniles. Processed Report. Northwest Fisheries Center, Natl. Marine Fisheries Service, Seattle, WA. Nov. 6 pp. & Figs.

Rawson, D.S. 1958. Indices to lake productivity and their significance in predicting conditions of reservoirs and lakes with disturbed water levels. H. R. MacMillan Lectures in Fisheries: The Investigation of Fish-Power Problems. Edited by P.A. Larkin. Institute of Fisheries, Univ. of British Columbia, Vancouver, Can. pp. 27-42.

Reed, Edward B. 1962. Limnology and fisheries of the Saskatchewan River in Saskatchewan. Fisheries Report No. 6. Fisheries Branch, Dept. of Nat. Resources, Province of Saskatchewan. 48 pp.

Rucker, Robert R. No date. Gas-bubble disease: Mortalities of coho salmon, Oncorhynchus kisutch, in water with constant total gas pressure and different oxygen-nitrogen ratios. U. S. Fish and Wildlife Service Fishery Bulletin. Vol. 73(4). pp. 915-918.

Ruggles, C.P. and W.D. Watt. 1975. Ecological changes due to hydroelectric development on the Saint John River. J. Fish. Res. Board of Can. Vol. 32(1),. Jan. pp. 161-170.

Sawchyn, W.W. 1975. Churchill River study (Missinipe probe); impact on the Reindeer River and four Churchill River lakes. Final Report No. 9. Saskatchewan Fisheries Laboratory, Dept. of Tourism and Renewable Resources, Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 260 pp.

Schiewe, Michael H. 1974. Influence of dissolved atmospheric gas on swimming performance of juvenile chinook salmon. Reprinted from Trans. Am. Fish. Soc. Vol. 103(4). Oct. pp. 717-721.

Schoneman, Dale E. and C.O. Junge, Jr. 1954. Investigations of mortalities to downstream migrant salmon at two dams on the Elwha River. Washington State, Dept. of Fisheries. Research Bull. No. 3. April. 51 pp.

Sheridan, William L. 1962. Relation of stream temperatures to timing of pink salmon escapements in southeast Alaska. H. R. MacMillan Lectures in Fisheries - Symposium on Pink Salmon. Univ. of British Columbia, Vancouver. pp. 87-102.

Siebert, J. and T.J. Brown. 1975. Characteristics and potential significance of heterotrophic activity in a polluted fjord estuary. J. Exper. Mar. Bio. Ecology. Vol. 19. pp. 97-104.

Sims, Carl W. 1970. Emigration of juvenile salmon and trout from Brownlee Reservoir, 1963-65. U.S. Fish and Wildlife Service Fishery Bull. Vol. 68(2). U.S. Govt. Printing Office. April. pp. 245-259.

Slaney, F.F. and Co., Ltd. 1973. Minimum flow requirements Alouette River. For Fisheries and Marine Services, Southern Operations Branch, Dept. of the Environment, Vancouver, British Columbia. August. 38 pp.

Smith, Jim Ross. 1974. Distribution of seaward migrating chinook salmon and steelhead trout in the Snake River above Lower Monumental Dam. MFR Paper 1081. Marine Fisheries Review. Vol. 36(8). August. pp. 42-45.

Smith, Jim R. and W.J. Ebel. 1973. Aircraft refueling trailer modified to haul salmon and trout. MFR Paper 1000. Marine Fisheries Review. Vol. 35(8). pp. 37-40.

Smith, Jim Ross and W.E. Farr. 1975. Bypass and collection system for protection of juvenile salmon and trout at Little Goose Dam. MFR Paper 1125. Marine Fisheries Review. Vol. 37(2). Feb. pp. 31-35.

Stanford Ichthyological Bulletin. 1940. Dams and the problem of migratory fishes. Special symposium issue. Natural History Museum, Stanford Univ., CA. Vol. 1(6). May 3. pp. 173-215.

Stalnaker, C.B. and J.L. Arnett. 1976. Methodologies for the determination of stream resource flow requirements: an assessment. U.S. Fish and Wildlife Service. Office of Bio. Services, Western Water Allocation, Utah State Univ., Logan, UT. 199 pp.

Thompson, K.E. 1972. Determining stream flows for fish life. Flow Requirement Workshop: Proceedings, Instream Flow Requirement Workshop. Pacific Northwest River Basins Commission, Portland, OR. pp. 31-50.

_____. 1974. Methodology for determining instream flow requirements of salmonids in Hells Canyon, Snake River. In: Anatomy of A River. Hells Canyon Controlled Flow Task Force, Pacific Northwest River Basins Commission, Vancouver, WA. pp. 91-103.

Townsend, G.H. 1975. Impact of the Bennett Dam on the Peace-Athabasca Delta. J. Fish. Res. Board of Can. Vol. 32(1). Jan. pp. 171-176.

Trefethen, Parker S. 1968. Passage of migrant fish at dams. In: Fish Passage Research, Review of Progress, 1961-1966. U.S. Bureau of Commercial Fisheries, Circular No. 254. Seattle, WA. Oct. pp. 3-5, 10-14.

Trefethen, Parker S. and W.J. Ebel. 1973. Collection and transportation system of juvenile salmonids evaluated at Little Goose Dam. MFR Paper No. 999. Marine FisheriesReview. Vol. 35(8). pp. 33-36.

Tsvetkov, V.I., D.S. Pavlov, and V.K. Nezdoliy. 1972. Changes of hydrostatic pressure lethal to the young of some freshwater fish. Am. Fish. Soc. in cooperation with Scripta Publishing Co., J. Icthy. Vol. 12(2). pp. 307-318.

U.S. Army Corps of Engineers. 1960. Research on fishway problems. Bur. of Commercial Fisheries, U.S. Fish and Wildlife Service. July. pp. 76-90.

_____. Alaska District. 1975. Southcentral railbelt area, Alaska. Upper Susitna River Basin, draft environmental impact statement. Anchorage, AK. Sept. 96 pp.

_____. 1975. Southcentral Railbelt area, Alaska. Draft. Interim Feasibility Report. Hydroelectric power and related purpose for the Upper Susitna River Basin. Sept.

_____. 1975. Hydroelectric power and related purposes. Southcentral Railbelt area, Alaska. Upper Susitna River Basin Interim Feasibility report, the study and report. Dec. 12. 114 pp.

_____. 1975. Hydroelectric Power and Related Purposes. South-central railbelt area, Alaska. Upper Susitna River Basin Interim Feasibility Report, Appendix I, Part 1. Dec. 12, 6 Sect. N.P.

_____, 1975. Hydroelectric Power and Related Purposes. South-central railbelt area, Alaska. Upper Susitna River Basin Interim Feasibility Report, Appendix II. Dec. 12. 65 pp.

_____. North Pacific Division. 1960. Progress report on fisheries - Engineering Research Program, Portland, OR. July. 152 pp.

_____. 1966. Third progress report on fisheries engineering research program. Portland, OR. March. 124 pp.

_____. 1972. Annual Fish-Passage Report, Columbia River Projects. Bonneville, John Day, the Dalles, McNary: Snake River projects; Ice Harbor, Lower Monumental, Little Goose. Portland, OR. and Walla Walla, WA. 16 pp. (115 tables and 27 plates).

_____. 1976. Fourth Progress report on fisheries engineering research program, 1966-1972. May. 48 reports by contributing authors.

U.S. Dept. of the Interior. 1969. Effects of placer mining on water quality in Alaska. Federal Water Pollution Control Admin. Northwest Region - Alaska Water Laboratory, College, AK. Feb. 79 pp.

Van Loocke, R., et al. 1975. Soil and groundwater contamination by oil spills; problems and remedies. Intern. J. Environ. Study. Vol. 8. pp. 99-111.

Vernon, E.H. 1958. An examination of factors affecting the abundance of pink salmon in the Fraser River. Progress Report. Intern. Pac. Salmon Fish. Comm., New Westminster, B.C., Can. 49 pp.

Walters, C. 1975. An inter-disciplinary approach to development of watershed simulation models. J. Fish. Res. Board, Can. Vol. 32(1). Jan. pp. 177-195.

Westley, Ronald E. 1966. Limnological study of Merwin, Upper Baker, and Lower Baker reservoirs. Summary report. State of Washington, Dept. of Fisheries, Research Div. June. 206 pp.

Wickett, W.P. 1959. Effects of siltation on success of fish spawning. Pacific Northwest Symposium on Water Pollution Research - Proceedings. 5th - pp. 16-22. U.S. Public Health Service, Water Supply and Water Pollution Control Program. Portland, OR. March 23-24.

Willard, J.R. 1975. Churchill River study (Missinipe probe); benthic fauna in Sokatisewin Lake. Final Report 14. Saskatchewan Fisheries Laboratory, Dept. of Tourism and Renewable Resources, Saskatoon, Saskatchewan. Edited by Judith Mitchell. Produced by J.S. Wilson. 54 pp.

Williams, I.V. 1969. Implication of water quality and salinity in the survival of Fraser River sockeye smolts. Progress Report No. 22. Intern. Pac. Salmon Fish Comm., New Westminster, B.C., Can. 46 pp.

_____. 1973. Investigation of the prespawning mortality of sockeye in Horsefly River and McKinley Creek in 1969. Progress Report No. 27., Part II. Inter. Pac. Salmon Fish Comm., New Westminster, B.C., Can. 42 pp.