APPENDIX D

Models of Hydraulic Conditions and Chum Salmon Spawning Habitat in Selected Susitna River Sloughs.

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CONTRIBUTORS

| | |
|---|---|
| Aquatic Habitat and Instream Flow Studies (AH) Project Leader and Principal Contact | Christopher Estes |
| AH Fish Habitat Utilization Subproject Leader and Appendix Report Coordinator | Andrew Hoffmann |
| Hydraulic Engineer | E. Woody Trihey |
| Data Processing Project Leader | Allen Bingham |
| Graphics | Sally Donovan<br>Anne Reilly |
| Typing Staff | Peggy Skeers<br>Loretta Channell |
| Editors | Christopher Estes<br>Andrew Hoffmann<br>Doug Vincent-Lang |
| Data Collection | Andrew Hoffmann<br>Kim Sylvester<br>Len Vining<br>Sheryl Salasky<br>Jeff Blakely<br>Don Volk<br>Dean Beers<br>E. Woody Trihey<br>Christopher Estes |
| Data Entry and Calibration | Kim Sylvester<br>Rick Sinnott<br>Chris Kent<br>Tommy Withrow<br>E. Woody Trihey |
| Data Analysis | Rick Sinnott<br>Kim Sylvester<br>Sheryl Salasky<br>Kathy Sheehan<br>Allen Bingham |
| Text | Rick Sinnot<br>Andrew Hoffmann<br>Christoper Estes<br>Kim Sylvester |

ACKNOWLEDGEMENTS

The authors express their appreciation to the other ADF&G Su Hydro Aquatic Studies Program staff who provided their support to this appendix. Appreciation is also extended to Harza-Ebasco Susitna Joint Venture subcontractors who provided editorial review of an earlier draft of this report.

Special appreciation is extended to Nikki Newcome, ADF&G, who provided technical consultation with the data entry and calibration of the hydraulic model.

## INTRODUCTION

This appendix presents three models: 1) a model of available hydraulic conditions in sloughs as determined by slough discharge; 2) a model of chum salmon selection of redd sites in sloughs as determined by slough hydraulic conditions; and 3) a model of the wetted surface area of available hydraulic habitat categories in sloughs versus their suitability* for spawning by chum salmon at different slough flows. It represents the final step in a narrowing focus of investigation. Appendix B analyzes adult salmon migration up the Susitna River and access conditions into the mouths of nine selected sloughs between Talkeetna and Devil Canyon. Appendix C describes the distribution and abundance of adult salmon in 34 sloughs and 20 tributaries in the Talkeetna to Devil Canyon reach of the Susitna River. In Appendix C spawning areas in sloughs are also compared with substrate composition and areas of upwelling ground water.

Spawning is a critical period in the life cycle of any fish, particularly salmon. In the Susitna River basin, salmon often spawn in sloughs. Reduction in Susitna River discharges that occur as a result of filling and operation of the proposed hydroelectric facility is expected to affect hydraulic conditions in sloughs. Chum salmon were the most abundant salmon spawning in sloughs in 1981 and 1982. Consequently their spawning requirements were selected for this initial phase of analysis.

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* Habitat suitability is the relationship between fish habitat preference and habitat availability (Baldridge and Amos 1983).

In the first model, two hydraulic variables, water depth and velocity, were analyzed in four sloughs over a wide range of predicted slough discharges. The second model is a frequency distribution of chum salmon redds among available water depths, velocities and substrate types in three sloughs at low slough flows (4-8 cfs). The quantity and quality of chum salmon spawning habitat in sloughs is dependent upon environmental factors, some of which are flow dependent. Significant differences in the hydraulic variables of water depth and velocity, substrate composition and upwelling ground water* are expected to affect habitat suitability for spawning salmon in sloughs. The third model, a habitat suitability model developed for three sloughs, combined available water depths, velocities and substrate types at a predicted slough flow of 5 cfs with the frequency distributions of chum salmon redds.

## METHODS

### Hydraulic Model

Hydraulic data were collected and analyzed to predict the hydraulic conditions that would be available in a slough for a range of slough

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* Substrate composition was assumed to remain static for the range of predicted slough flows. Upwelling ground water is not evaluated in this appendix because of an inability to accurately identify point-specific sources in gravel, rubble, cobble, or boulder substrates. These variables are addressed qualitatively in Appendix C and a quantitative evaluation is planned in future studies.

flows. Supplemental information which supports this analysis is tabulated and summarized in the Basic Data Report (ADF&G 1983: Volume 4) as follows: location maps of sloughs, study reaches and transects (Appendix 4-F), survey data for each cross section (Appendix 4-E), cross sectional profiles of each transect (Appendix 4-A) and thalweg profiles (Volume 4).

### Site selection and data collection

Five sloughs (8A, 9, 21, Rabideux and Chum Channel) were initially selected for a model of hydraulic and habitat conditions in sloughs of the Susitna River (RM 76.0 to 141.0). These sloughs were selected because they included a wide variety of slough characteristics and were assumed to represent hydraulic conditions present in most Susitna River sloughs (ADF&G 1981a, 1982, 1983: Volume 4). Rabideux Slough was not modeled because at high mainstem stages the right bank was overtopped by the mainstem and at low mainstem stages water ceased flowing through the slough.

Each slough study area consisted of a representative reach with transects. Study reach and transect locations were selected based on criteria described in Bovee and Milhous (1978) and Trihey and Wegner (1981) and represented proportions of each lotic habitat type present within a slough. They were also selected to encompass areas known to support chum salmon spawning during 1981. A study team consisting of a fishery biologist and a hydraulic engineer familiar with the U.S. Fish and Wildlife Service Instream Flow Group (IFG) methodology (Bovee 1982) directed the site selection, transect location, data reduction, and hydraulic model calibration.

Representative reaches included a minimum of 10 percent of the total length of the slough (ADF&G 1983: Volume 4). The length of wetted surface area in each slough decreased as the upper portion of the slough became dewatered (ADF&G 1983: Volume 4). Thus, the relative proportion of each representative reach to total slough length increased in sloughs 8A, 9 and 21 during periods of low flow when chum salmon were observed spawning (August - September).

Selecting a representative reach in each slough presented a problem generally limited to the mainstem confluence area. A backwater zone extended up into the sloughs from the confluence of the slough mouth with the mainstem river.* The size of the backwater zone varied with mainstem discharge. A discussion of the influence of mainstem flows on backwater zones in sloughs is included in several ADF&G reports (ADF&G 1981a, 1982, 1983: Appendix 4-F). Accordingly, the representative reach for each slough was located in a portion of the sloughs which would be upstream of the backwater zone for all mainstem flow conditions less than those required to breach the head of the slough.

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* The hydraulic model used for this study cannot be applied to lentic conditions.

Techniques for collecting hydraulic data at points (verticals) along transects are described by Trihey and Wegner (1981) and Bovee and Milhous (1978).

### Data analysis

The hydraulic conditions in the sloughs were simulated using the IFG-4 computer program (Milhous et al. 1981). The program was designed for use by resource specialists to model hydraulic conditions for a wide range of discharges.

Field data were reduced and coded according to the procedures described by Trihey (1980). Procedures for entering the data into the IFG-4 computer program and for model calibration are described in Milhous et al. (1981).

The IFG-4 hydraulic model, is intended for use where hydraulic variables are assumed to be one of the major determinants affecting fish distribution and abundance. It is based on the assumption of steady flow conditions within a rigid channel. Observed shifts in slough bottom profiles across transects in study sloughs varied at the most 0.1 - 0.2 ft between discharges. These variations were probably attributable to acceptable errors in measurement. In these cases the different values were averaged. Also, discharge can increase or decrease during measurement of a series of transects within a study area. Transect discharges measured during and immediately following the highest measured flow event at Slough 9 were averaged for use in the computer simulation.

Observed water depths, velocities, water surface elevations and slough flows were used to calibrate the hydraulic models. Calibrating the IFG-4 model, as described by Milhous et al. (1981), involved slight adjustments to observed depths, velocities and water surface elevations within the range of accuracy of the field measurements (0.1 ft in depth, 0.1 ft/sec in velocity, or 0.01 ft in water surface elevation). Predicted depth and velocity values were compared with actual field measurements at known flows. Computer generated roughness coefficients ("Manning's n" values) were adjusted when necessary to better approximate observed velocities. Values for roughness coefficients were assigned within an acceptable range of potential values (Trihey 1980). Observed water surface elevations and discharges were compared with predicted water surface elevations and discharges. To determine whether the calibration process was completed, the velocity adjustment factors (VAF) were evaluated. The VAF is the ratio between the calibration and predicted discharge which is used to calculate predicted point velocities and is rated as either good, fair, marginal, poor, or very poor. A VAF for a calibrated model which is between 0.9 and 1.1 is considered good. A VAF less than 0.70 or greater than 1.30 is considered very poor.

After it is calibrated, the IFG-4 program can predict hydraulic conditions for individual slough cells* at any discharge within the calibration range. Depending on how accurately the model fits observed values, hydraulic conditins can only be modeled for given flows which range from 40 percent of the lowest measured flow to 250 percent of the highest measured flow (Bovee and Milhous 1978).

Direct comparison of observed hydraulic conditions in the four study sloughs is not feasible because the specific flow values and the range of flows measured at each slough varied. Thus, four predicted slough discharges (5, 50, 150, and 300 cfs) were chosen to standardize hydraulic conditions so that comparisons between the sloughs could be made. Sloughs 9 and 21 were evaluated for all four flow ranges; Chum Channel for three of the flows (5, 50, and 150 cfs); and Slough 8A for two of the flows (5 and 50 cfs). The lowest predicted discharge for the four sloughs, 5 cfs, was selected because low flow discharges ranging between 4 and 8 cfs were measured at sloughs 8A, 9, and 21 during the period of salmon spawning. A low intermediate flow for the four sloughs, 50 cfs, was selected because it was the maximum predictable flow within the calibration range of the model for Slough 8A. A high intermediate flow of 150 cfs was selected for sloughs 9, 21, and Chum Channel because it was a high predictable flow for Chum Channel. The high flow for sloughs 9 and 21, 300 cfs, was selected because the highest predictable flow for Slough 21 was in this range.

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* A slough cell encompasses the surface area surrounding each vertical between adjacent verticals and transects which is assumed to have the same habitat characteristics as the vertical at the center of the cell.

## Spawning Habitat Model

The spawning habitat model presents the relationships of chum salmon selection of redd sites in sloughs to slough hydraulic conditions. Water depth, velocity and substrate composition are considered important physical variables which determine acceptable spawning habitat for Pacific salmon (Reiser and Bjornn 1979). Significant amounts of variation in spawning location can be explained by distributions in water depths, velocity and substrate (Gorman and Karr 1978). Evaluation of these characteristics to develop a slough spawning habitat model were initiated in 1982.

### Site selection and data collection

Five sloughs (8A, 9, 21, Rabideux and Chum Channel) were initially selected for a study to model salmon spawning habitat. These sloughs were selected because of their relative importance to the fishery, based on observed numbers of spawning salmon in previous years (ADF&G 1981a, b, 1982, 1983: Volume 4).

Low flows in the Susitna River during 1982 apparently prevented access of adult salmon to some 1981 spawning areas (Appendix B); thus, anticipated salmon redds were not observed in Chum Channel or Rabideux Slough in 1982. Consequently, these two sloughs were deleted from the spawning habitat model study.

Slough spawning habitat study areas encompassed the entire slough (with the exception of the backwater zone). Water depth, velocity and substrate composition were examined at all active salmon spawning redds in the sloughs between August 25 and September 6, 1982. Specific techniques for locating spawning salmon and sampling redd sites are described in other publications (ADF&G 1981b, c, 1983: Volume 4; Estes et al. 1981; Wilson et al. 1981). Spawning salmon were observed directly from the slough banks. During observations the sloughs were clear, shallow, and slow-moving. Therefore, salmon were easily seen and identified.

Sufficient numbers of chum, pink, and sockeye salmon redds must be sampled to determine a multivariant suitability function based on probability (see suitability model section below); Bovee and Cochnauer (1977) recommend a minimum of 200. Although observations of redds for the three species were insufficient to meet this criterion, chum salmon were the most abundant salmon observed spawning in the sloughs (37 redds measured in Slough 8A, 48 in Slough 9, and 33 in Slough 21). Consequently, their spawning requirements were selected for detailed analysis.

Data analysis

Frequency distributions of water depths, velocities and substrate composition at chum salmon redds, measured at slough flows of 4-8 cfs, were plotted. To reduce variability of the continuous variables (depth and velocity) associated with small sample sizes of redds, adjacent values were grouped (Bovee and Cochnauer 1977). A difference of ± 0.1

ft or ft/sec was considered to be within the range of potential field measurement error. Therefore, 0.2 ft was chosen as the depth increment and 0.2 ft/sec was chosen as the velocity increment. The same increments were used for water surface area of available depths and velocities so that frequency distributions of depth and velocity at redds would be comparable. A previous habitat suitability study in Alaska used depth increments of 0.3 and 0.4 ft and velocity increments of 0.5 ft/sec (Wilson et al. 1981, Baldrige and Amos 1983).

### Suitability Model

In order to determine whether a particular type of habitat is important for a particular fish species/life stage (e.g., spawning chum salmon), the utilized habitat must be compared to the total amount and types of available habitat.

Habitat suitability is defined by the percent occurrence of a fish observed within increments of an environmental variable weighted against the corresponding percent occurrence of available area within increments of the same variable (Baldrige and Amos 1983). The IFG provides a computer program, the Physical Habitat Simulation System (PHABSIM), which merges the IFG-4 model with habitat preferences of fish (Milhous et al. 1981).

There are four methods which quantify the combined habitat preference of a fish species/life stage for water depth, velocity and substrate composition. These techniques are: multivariate suitability functions, preference curves, binary criteria, and multivariate functions in association with preference curves. Each technique has certain strengths, weaknesses and limiting assumptions (Bovee 1982).

Our intention to use a multivariate suitability function was precluded. A multivariate suitability function cannot be derived without sufficient data and it is difficult, if not impossible, to supplement the function with professional judgment (Bovee 1982). Insufficient redds were available for measurement during 1982 to determine the probability of finding a certain combination of environmental conditions given the presence of a fish (Bovee and Cochnauer 1977, Voos 1981).

The preference curve method (Bovee and Cochnauer 1977, Baldrige and Amos 1983) was a possibility but preference curves are environmentally dependent (Bovee 1982). That is, individual stocks of a species/life stage have adapted to the environmental conditions of the stream system they are found in. Habitat criteria for a species that are collected in one system should not be applied to another unless their applicability to one another is validated (Estes et al. 1981, Wilson et al. 1981, Bovee 1982). Thus, it cannot be assumed that preferences of salmon in Susitna River sloughs are similar to those in other watersheds. Differences in preference curves from other watersheds may represent real differences in microhabitat preference, availability, or sampling bias. Given that equivalent sampling procedures were used, another bias that must be considered is one that would be present if the range of available habitat values is less than the range that would otherwise be utilized by the fish species/life stage.

The binary criteria method was too simplistic. Dealing only with presence or absence of a fish in a habitat, it makes no distinction between varying degrees of habitat suitability. However, analysis of criteria has an advantage over the use of statistical functions which describe species behavior. That is, criteria need no statistical justification and do not "require more than professional judgment as to sufficiency of conditions" (Bovee 1982).

Our analysis borrowed concepts from both the binary criteria and preference curve methods. The compromise was to increase the number of categories of fish preference. Rather than considering simple presence or absence, predictions of habitat availability were used to categorize habitat as optimal, preferred, utilized, or unacceptable. These hierarchical categories are based on an ordinal scale of measurement (i.e., no value is placed on the interval between each category). In contrast, preference curves, used to determine weighted usable areas, are necessarily based on the ratio scale of measurement, where values between 0 (unacceptable habitat) and 1 (optimal habitat) are specified by a probability-of-use curve (Bovee 1982).

Because a distinction was made between those conditions that were optimal, preferred or utilized, our method approximates the utility of a weighted usable area analysis without the use of probability functions, which require a minimum sample size. Because the preference criteria were determined from field observations, rather than hypothesized or adapted from a literature review of chum salmon spawning in other streams, they are relevant to conditions observed in Susitna River sloughs during 1982.

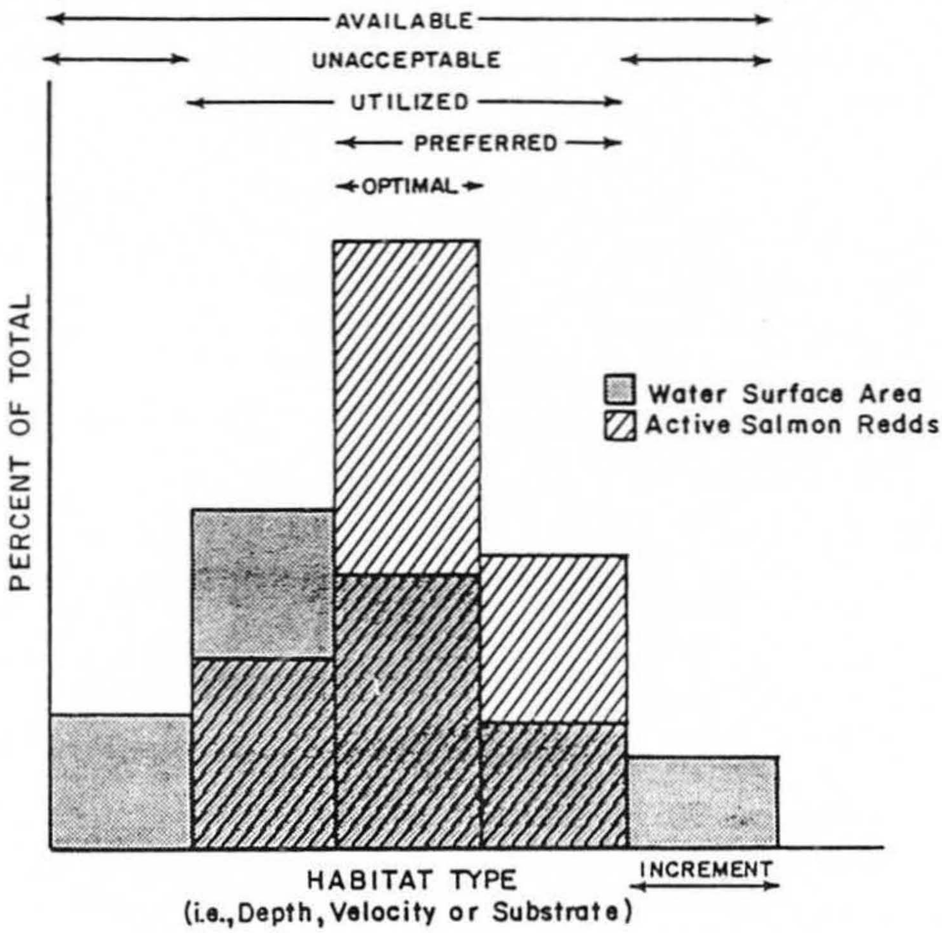
In developing a suitability model for the evaluation of fish habitats, the following assumptions (Baldridge and Amos 1983) adapted from Bovee and Cochnauer (1977) were applied:

1) individual fish tend to select the most favorable habitat from within the total range of available habitat. They use less favorable habitat with lesser frequency and eventually leave the area, if possible, before microhabitat conditions become lethal;

2) individual fish are most frequently observed in their most preferred habitat conditions; therefore, frequency of observation can be accepted as an indication of habitat utilization and frequency of observation weighted by habitat availability can be accepted as an indication of suitability; and

3) individual fish select values of one habitat variable independently of the other habitat variables as long as all these other variables are within the tolerable range of the species/life stage.

Habitat suitability was determined in six steps. First, the frequency distribution of active redds and corresponding frequency distributions of available habitat variables predicted by the hydraulic model were superimposed. Second, spawning habitat was categorized (unacceptable, utilized, preferred, or optimal) based upon a combination of the percent




Appendix Figure D-1. Illustration of habitat categories based on fish preference.

occurrences of redds and each available habitat variable (Appendix Figure D-1). Criteria for each habitat preference category were:

- Unacceptable spawning habitat in a slough included those available increments of a particular habitat variable (i.e., water depth, velocity or substrate composition) where active redds were not observed.

- Utilized spawning habitat in a slough included those available increments of a particular habitat variable where active redds were observed. Utilized spawning habitats included those that were also preferred and optimal.

- Preferred spawning habitat in a slough included those available increments of a particular habitat variable where the proportion of active redds exceeded the proportion of water surface area. Preferred spawning habitats included optimal habitat.

- Optimal spawning habitat in a slough included those available increments of a particular habitat variable in which the largest proportion (mode) of redds occurred.

Third, the cumulative frequencies of utilized water depths, velocities and substrate types were compared with those that were available and tested for significant differences in distribution with a Kolmogorov-Smirnov two-sample test (Conover 1971). This test allows for comparisons between two distributions and can distinguish differences associated with both central tendency (e.g., median) and variability (e.g., variance). If there is no statistically significant difference between what was available and what the fish selected, then no preference could be inferred with the existing data base.* Fourth, the habitat preference categories of each significant habitat variable representing a slough cell were compared. If all habitat variables within a cell were in the same category, the surface area of that cell was assigned to that category. If different categories were assigned to the habitat variables within a cell, the least selective category was assigned to the surface area of the cell (e.g. if depth were classified as optimal and substrate classified as utilized in a cell, that cell would be classified as utilized). Fifth, the surface area of all cells were summed to determine the water surface area of the study reach.* Sixth, the surface area of each habitat preference category was divided by the total water surface area of the study reach to determine the percentage of total water surface area for each category within the study reach.

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* Regardless of the outcome of the statistical test, available and utilized data will continue to be collected for all three habitat variables because of the low sample sizes used in this test and the biological significance of these variables. Another Kolmogorov-Smirnov two-sample or similar test will be performed after the 1983 field season, when sample size and observed range of available depths, velocities or substrate types are considered to be sufficient.

Appendix Table D-1. Calibration of water surface elevations and discharges at two flows (6.7 and 90 cfs) for transects in Chum Channel: 1982.

| Transect | Water Surface Elevation (ft) | | Discharge (cfs) | | | Velocity Adjustment Factor |
|---|---|---|---|---|---|---|
| | Observed | Predicted | $\bar{X}$ Observed | Predicted | % Diff | |
| 1 | 172.10 | 172.10 | 6.7 | 6.5 | -3 | 1.0000 |
| 2 | 172.28 | 172.28 | 6.7 | 6.8 | +1 | 1.0000 |
| 3 | 172.32 | 172.32 | 6.7 | 6.8 | +1 | .9995 |
| 4 | 172.32 | 172.32 | 6.7 | 6.7 | 0 | .9862 |
| 5 | 172.35 | 172.35 | 6.7 | 7.1 | +6 | .9746 |
| 6 | 172.35 | 172.35 | 6.7 | 6.5 | +3 | .9977 |
| 7 | 172.50 | 172.50 | 6.7 | 6.8 | +1 | 1.0000 |
| 8 | 172.66 | 172.66 | 6.7 | 6.5 | -3 | .9484 |
| 1 | 172.45 | 172.45 | 90.0 | 88.3 | -2 | .9879 |
| 2 | 172.72 | 172.72 | 90.0 | 90.8 | +1 | .9968 |
| 3 | 172.79 | 172.79 | 90.0 | 90.9 | +1 | .9960 |
| 4 | 172.81 | 172.81 | 90.0 | 89.0 | -1 | .9873 |
| 5 | 172.93 | 172.93 | 90.0 | 93.9 | +4 | 1.0035 |
| 6 | 173.02 | 173.02 | 90.0 | 91.4 | +2 | .9992 |
| 7 | 173.10 | 173.10 | 90.0 | 92.1 | +2 | .9658 |
| 8 | 173.13 | 173.13 | 90.0 | 89.6 | -1 | .9971 |

Appendix Table D-2. Calibration of water surface elevations and discharges at three flows (4, 7 and 20 cfs) for transects in Slough 8A: 1982.

| Transect | Water Surface Elevation (ft) | | Discharge (cfs) | | | Velocity Adjustment Factor |
|---|---|---|---|---|---|---|
| | Observed | Predicted | $\overline{X}$ Observed | Predicted | % Diff | |
| 1 | 565.47 | 565.50 | 4.0 | 4.1 | +3 | .9539 |
| 2 | 565.48 | 565.51 | 4.0 | 4.0 | 0 | .9288 |
| 3 | 565.52 | 565.55 | 4.0 | 4.0 | 0 | .9344 |
| 4 | 565.84 | 565.87 | 4.0 | 4.0 | 0 | 1.0043 |
| 5 | 566.01 | 566.02 | 4.0 | 4.0 | 0 | .9124 |
| 6 | 566.05 | 566.06 | 4.0 | 4.1 | +3 | 1.0036 |
| 7 | 566.31 | 566.32 | 4.0 | 4.0 | 0 | 1.0108 |
| 8 | 566.62 | 566.63 | 4.0 | 4.0 | 0 | 1.0060 |
| 9 | 567.20 | 567.21 | 4.0 | 4.0 | 0 | .9866 |
| 10 | 567.20 | 567.21 | 4.0 | 4.0 | 0 | .9851 |
| 11 | 567.20 | 567.21 | 4.0 | 4.0 | 0 | .9884 |
| 1 | 565.65 | 565.60 | 7.0 | 7.1 | +1 | .9895 |
| 2 | 565.66 | 565.61 | 7.0 | 7.1 | +1 | .9746 |
| 3 | 565.69 | 565.64 | 7.0 | 7.1 | +1 | .9617 |
| 4 | 566.05 | 566.03 | 7.0 | 7.0 | 0 | 1.0076 |
| 5 | 566.13 | 566.13 | 7.0 | 7.0 | 0 | .9740 |
| 6 | 566.15 | 566.15 | 7.0 | 7.1 | +1 | 1.0146 |
| 7 | 566.37 | 566.37 | 7.0 | 7.0 | 0 | .9833 |
| 8 | 566.68 | 566.68 | 7.0 | 7.0 | 0 | 1.0350 |
| 9 | 567.28 | 567.28 | 7.0 | 7.0 | 0 | .9991 |
| 10 | 567.29 | 567.29 | 7.0 | 7.0 | 0 | .9955 |
| 11 | 567.29 | 567.29 | 7.0 | 7.0 | 0 | 1.0107 |
| 1 | 565.76 | 565.80 | 20.05 | 20.1 | +1 | 1.0206 |
| 2 | 565.77 | 565.81 | 20.05 | 20.1 | +1 | 1.0082 |
| 3 | 565.80 | 565.84 | 20.05 | 20.1 | +1 | 1.0086 |
| 4 | 566.37 | 566.38 | 20.05 | 20.2 | +1 | .9898 |
| 5 | 566.36 | 566.36 | 20.05 | 19.9 | -1 | 1.0198 |
| 6 | 566.37 | 566.37 | 20.05 | 20.1 | +1 | .9367 |
| 7 | 566.48 | 566.48 | 20.05 | 20.0 | 0 | 1.0103 |
| 8 | 566.79 | 566.79 | 20.05 | 19.9 | -1 | 1.0009 |
| 9 | 567.44 | 567.44 | 20.05 | 20.0 | 0 | 1.0048 |
| 10 | 567.46 | 567.46 | 20.05 | 20.0 | 0 | 1.0052 |
| 11 | 567.45 | 567.45 | 20.05 | 20.1 | +1 | .9920 |

Appendix Table D-3. Calibration of water surface elevations and discharges at three flows (8, 145 and 232 cfs) for transects in Slough 9: 1982.

| Transect | Water Surface Elevation (ft) | | Discharge (cfs) | | | Velocity Adjustment Factor |
|---|---|---|---|---|---|---|
| | Observed | Predicted | $\bar{X}$ Observed | Predicted | % Diff | |
| 1 | 592.40 | 592.40 | 8.0 | 8.0 | 0 | .9908 |
| 2 | 592.60 | 592.60 | 8.0 | 8.1 | +1 | 1.0026 |
| 4 | 592.75 | 592.75 | 8.0 | 8.0 | 0 | .9961 |
| 6 | 593.40 | 593.36 | 8.0 | 8.1 | +1 | 1.0212 |
| 7 | 593.45 | 593.44 | 8.0 | 8.0 | 0 | 1.0117 |
| 8 | 593.40 | 593.39 | 8.0 | 7.9 | -1 | 1.0054 |
| 9 | 593.50 | 593.50 | 8.0 | 8.2 | +3 | .9930 |
| 10 | 593.60 | 593.59 | 8.0 | 8.0 | 0 | .9945 |
| 1 | 593.43 | 593.42 | 145.0 | 146.4 | +1 | 1.0073 |
| 2 | 593.60 | 593.57 | 145.0 | 144.7 | 0 | 1.0148 |
| 4 | 593.60 | 593.65 | 145.0 | 145.3 | 0 | 1.0450 |
| 6 | 594.00 | 594.18 | 145.0 | 144.9 | 0 | .9973 |
| 7 | 594.20 | 594.25 | 145.0 | 147.0 | +1 | 1.0028 |
| 8 | 594.20 | 594.29 | 145.0 | 143.3 | -1 | 1.0182 |
| 9 | 594.30 | 594.35 | 145.0 | 145.4 | 0 | 1.0221 |
| 10 | 594.30 | 594.37 | 145.0 | 144.7 | 0 | 1.0118 |
| 1 | 593.70 | 593.71 | 232.0 | 234.6 | +1 | .9903 |
| 2 | 593.80 | 593.83 | 232.0 | 231.0 | 0 | .9987 |
| 4 | 594.00 | 593.94 | 232.0 | 232.6 | 0 | .9848 |
| 6 | 594.50 | 594.36 | 232.0 | 231.4 | 0 | .9621 |
| 7 | 594.50 | 594.45 | 323.0 | 235.9 | +2 | .9814 |
| 8 | 594.20 | 594.52 | 232.0 | 229.5 | -1 | .9798 |
| 9 | 594.60 | 594.56 | 232.0 | 231.8 | 0 | .9920 |
| 10 | 594.60 | 594.54 | 232.0 | 231.4 | 0 | .9893 |

Appendix Table D-4. Calibration of water surface elevations and discharges at three flows (5, 10 and 157 cfs) for transects in Slough 21: 1982.

| Transect | Water Surface Elevation (ft) | | Discharge (cfs) | | | Velocity Adjustment Factor |
|---|---|---|---|---|---|---|
| | Observed | Predicted | $\bar{X}$ Observed | Predicted | % Diff | |
| 3 | 744.23 | 744.28 | 5.0 | 5.0 | 0 | 1.0067 |
| 4 | 744.25 | 744.29 | 5.0 | 5.0 | 0 | .9726 |
| 5 | 744.27 | 744.31 | 5.0 | 4.8 | -4 | 1.0295 |
| 6 | 744.55 | 744.57 | 5.0 | 4.8 | -4 | .9952 |
| 7 | 744.74 | 744.77 | 5.0 | 5.0 | 0 | .9655 |
| 3 | 744.60 | 744.50 | 10.0 | 10.0 | 0 | .9951 |
| 4 | 744.59 | 744.51 | 10.0 | 10.0 | 0 | .9990 |
| 5 | 744.61 | 744.51 | 10.0 | 9.7 | -3 | .9968 |
| 6 | 744.78 | 744.72 | 10.0 | 9.8 | +2 | 1.1046 |
| 7 | 744.99 | 744.93 | 10.0 | 10.0 | 0 | 1.0641 |
| 3 | 745.84 | 745.90 | 157.0 | 156.8 | 0 | .9906 |
| 4 | 745.85 | 745.90 | 157.0 | 156.2 | -1 | .9882 |
| 5 | 745.87 | 745.96 | 157.0 | 158.3 | +1 | .9562 |
| 6 | 745.89 | 745.94 | 157.0 | 157.8 | +1 | .9970 |
| 7 | 745.98 | 746.02 | 157.0 | 157.7 | 0 | .9558 |

## RESULTS

### Hydraulic Model

#### Accuracy and precision

The IFG-4 model must be calibrated to meet required standards of precision (Milhous et al. 1981). The IFG-4 models for hydraulic simulation in sloughs 8A, 9, 21, and Chum Channel predicted the water surface elevation and discharge at each transect. Seventy-three percent of the predicted water surface elevations were within 0.05 foot of observed water surface elevations (Appendix Tables D-1 to D-4). Overall, predicted water surface elevations were highly correlated with observed values (r = 0.999). Eighty-two percent of the predicted discharges at each transect differed from mean observed discharges for each slough by no more than 1 percent. Only one predicted transect discharge deviated by more than 5 percent from its observed mean discharge (Chum Channel Transect 5). Overall, predicted discharges at each

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* If a backwater zone within a slough were to exist for any of the predicted discharge values, that area would have been subtracted from the total surface area of the slough before the model was applied. Backwater areas within sloughs are also used by spawning salmon. Therefore, plans for the 1983 field season include sampling these areas and, if possible, developing a suitability model.

Appendix Table D-5. Comparison of observed and predicted water depths and velocities along Slough 8A Transect 1 in 1982 at two slough flows: 4 and 20 cfs.

| | 4 cfs | | | | 20 cfs | | | |
|---|---|---|---|---|---|---|---|---|
| | Depth (ft) | | Velocity (ft/sec) | | Depth (ft) | | Velocity (ft/sec) | |
| Segment[a] | obs. | pred. | obs. | pred. | obs. | pred. | obs. | pred. |
| LWE 12 | .40 | .60 | .00 | .00 | .70 | .90 | .05 | .05 |
| 14 | .80 | .85 | .00 | .00 | 1.05 | 1.15 | .05 | .05 |
| 16 | .90 | .90 | .10 | .00 | 1.20 | 1.20 | .10 | .05 |
| 18 | 1.00 | .95 | .00 | .00 | 1.20 | 1.25 | .10 | .05 |
| 20 | 1.00 | 1.00 | .00 | .00 | 1.30 | 1.30 | .10 | .05 |
| 22 | 1.00 | 1.00 | .00 | .02 | 1.30 | 1.30 | .10 | .11 |
| 24 | 1.05 | 1.10 | .05 | .02 | 1.40 | 1.40 | .10 | .11 |
| 26 | 1.20 | 1.25 | .05 | .04 | 1.40 | 1.55 | .10 | .12 |
| 28 | 1.30 | 1.35 | .05 | .04 | 1.50 | 1.65 | .10 | .12 |
| 30 | 1.45 | 1.40 | .03 | .04 | 1.70 | 1.70 | .10 | .12 |
| 32 | 1.40 | 1.40 | .10 | .03 | 1.70 | 1.70 | .10 | .11 |
| 34 | 1.50 | 1.45 | .10 | .04 | 1.65 | 1.75 | .10 | .13 |
| 36 | 1.60 | 1.50 | .05 | .04 | 1.80 | 1.80 | .10 | .12 |
| 38 | 1.55 | 1.55 | .05 | .04 | 1.80 | 1.85 | .10 | .12 |
| 40 | 1.60 | 1.60 | .00 | .06 | 1.90 | 1.90 | .20 | .18 |
| 42 | 1.65 | 1.60 | .05 | .06 | 1.80 | 1.90 | .20 | .18 |
| 44 | 1.60 | 1.60 | .05 | .06 | 1.85 | 1.90 | .30 | .30 |
| 46 | 1.60 | 1.60 | .05 | .06 | 1.90 | 1.90 | .20 | .25 |
| 48 | 1.60 | 1.55 | .10 | .08 | 1.90 | 1.85 | .35 | .32 |
| 50 | 1.55 | 1.50 | .05 | .07 | 1.80 | 1.80 | .30 | .32 |
| 52 | 1.50 | 1.50 | .05 | .10 | 1.80 | 1.80 | .40 | .32 |
| 54 | 1.50 | 1.50 | .05 | .10 | 1.70 | 1.80 | .45 | .37 |
| 56 | 1.50 | 1.45 | .05 | .07 | 1.75 | 1.75 | .30 | .32 |
| 58 | 1.40 | 1.35 | .05 | .06 | 1.65 | 1.65 | .30 | .30 |
| 60 | 1.25 | 1.20 | .05 | .06 | 1.50 | 1.50 | .35 | .35 |
| 62 | 1.10 | 1.05 | .00 | .06 | 1.35 | 1.35 | .30 | .30 |
| 64 | 1.00 | .95 | .00 | .06 | 1.30 | 1.25 | .25 | .26 |
| 66 | .95 | .90 | .05 | .06 | 1.30 | 1.20 | .20 | .20 |
| 68 | .95 | .90 | .00 | .06 | 1.30 | 1.20 | .20 | .20 |
| 70 | .95 | .85 | .00 | .09 | 1.30 | 1.15 | .20 | .20 |
| 72 | .85 | .80 | .00 | .07 | 1.10 | 1.10 | .20 | .13 |
| 74 | .90 | .80 | .00 | .03 | 1.10 | 1.10 | .20 | .12 |
| 76 | .80 | .80 | .00 | .03 | 1.10 | 1.10 | .15 | .12 |
| 78 | .85 | .75 | .00 | .01 | 1.00 | 1.05 | .15 | .07 |
| 80 | .80 | .65 | .00 | .01 | 1.00 | .95 | .10 | .07 |
| 82 | .60 | .60 | .00 | .01 | .90 | .90 | .10 | .07 |
| 84 | .65 | .55 | .00 | .01 | 1.00 | .85 | .10 | .07 |
| 86 | .50 | .45 | .00 | .01 | .80 | .75 | .10 | .07 |
| 88 | .45 | .35 | .00 | .00 | .65 | .65 | .05 | .05 |
| 90 | .30 | .20 | .00 | .00 | .60 | .50 | .00 | .05 |
| RWE 92 | .10 | .05 | .00 | .00 | .40 | .30 | .00 | .05 |
| 94 | | | | | .20 | .15 | .00 | .11 |
| RWE 96 | | | | | .00 | .05 | .00 | .00 |
| | r = .99 | | r = .44[b] | | r = .99 | | r = .93[b] | |

[a]Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

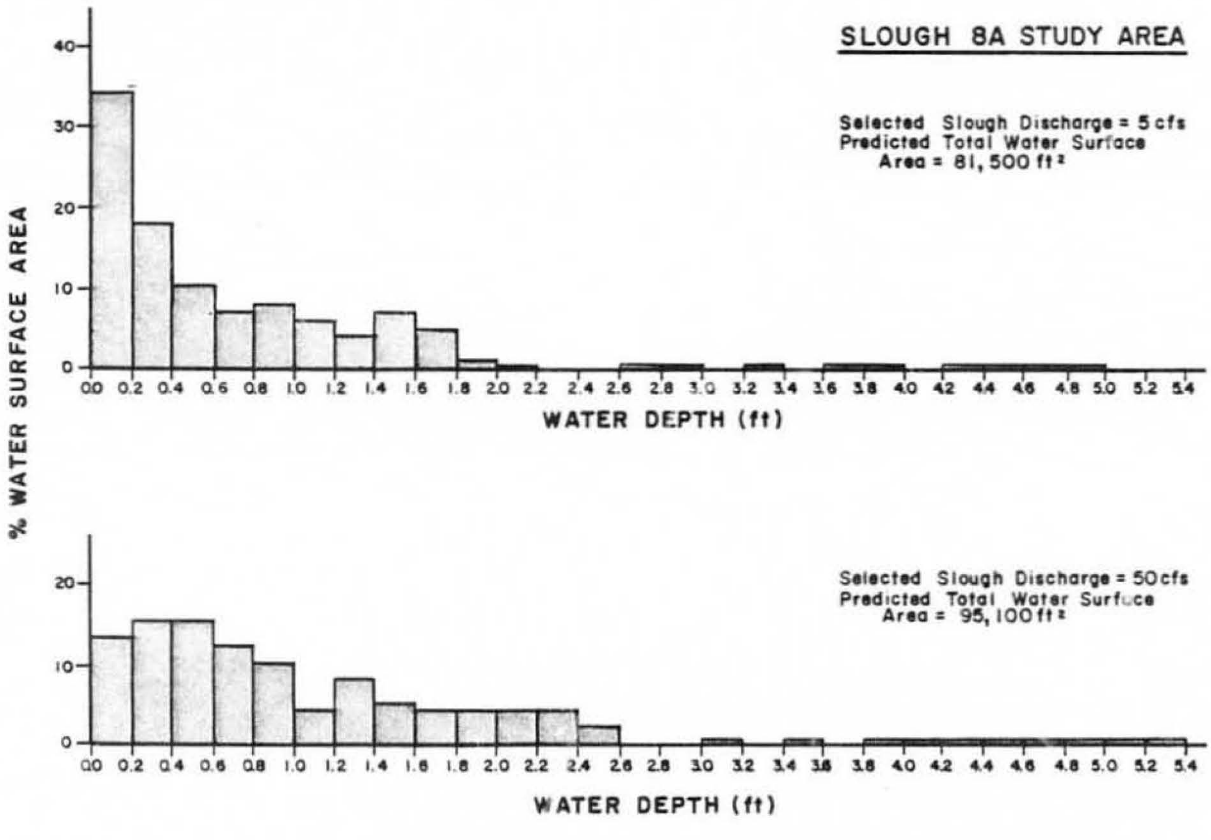
[b]Predicted velocities in each segment rounded to nearest 0.05 ft/sec before determining correlation coefficient to compensate for rounding of observed velocity measurements in the field.

Appendix Table D-6. Comparison of observed and predicted water depths and velocities along Chum Channel Transect 5 in 1982 at two slough flows: 6.7 and 90 cfs.

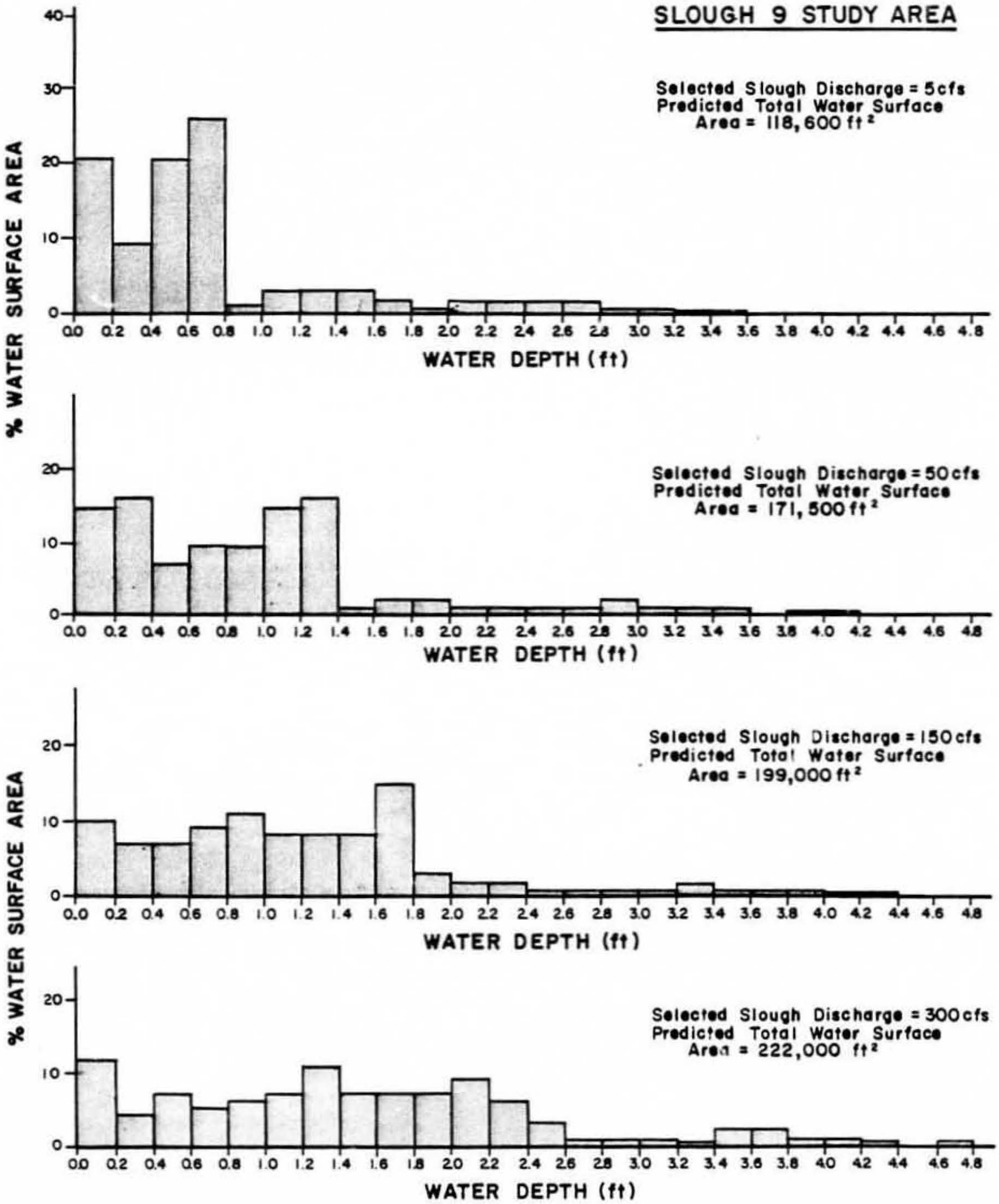
| | 6.7 cfs | | | | 90 cfs | | | |
|---|---|---|---|---|---|---|---|---|
| | Depth (ft) | | Velocity (ft/sec) | | Depth (ft) | | Velocity (ft/sec) | |
| Segment[a] | obs. | pred. | obs. | pred. | obs. | pred. | obs. | pred. |
| LWE 24 | | | | | .00 | .08 | .00 | .04 |
| 26 | | | | | .10 | .18 | .10 | .10 |
| 28 | | | | | .20 | .28 | .60 | .61 |
| 30 | | | | | .30 | .38 | .80 | .81 |
| 32 | | | | | .40 | .48 | 1.30 | 1.29 |
| 34 | | | | | .50 | .53 | 1.30 | 1.32 |
| LWE 35.2 | .00 | | .00 | | | | | |
| 36 | | .08 | | .00 | .60 | .63 | 1.90 | 1.40 |
| 37 | .10 | | .00 | | | | | |
| 38 | | .15 | | .58 | .60 | .73 | 1.90 | 1.73 |
| 39 | .20 | | .20 | | | | | |
| 40 | | .25 | | .24 | .80 | .83 | 1.80 | 1.81 |
| 41 | .30 | | .30 | | | | | |
| 42 | | .45 | | .29 | 1.00 | 1.03 | 2.10 | 2.11 |
| 43 | .50 | | .30 | | | | | |
| 44 | | .60 | | .29 | 1.20 | 1.18 | 2.20 | 2.21 |
| 45 | .50 | | .30 | | | | | |
| 46 | | .65 | | .39 | 1.30 | 1.23 | 2.20 | 2.21 |
| 47 | .70 | | .50 | | | | | |
| 48 | | .75 | | .49 | 1.30 | 1.33 | 2.40 | 2.41 |
| 49 | .70 | | .50 | | | | | |
| 50 | | .85 | | .44 | 1.40 | 1.43 | 2.50 | 2.51 |
| 51 | .70 | | .40 | | | | | |
| 52 | | .85 | | .39 | 1.50 | 1.43 | 2.30 | 2.31 |
| 53 | .70 | | .40 | | | | | |
| 54 | | .85 | | .39 | 1.50 | 1.43 | 2.30 | 2.31 |
| 55 | .70 | | .40 | | | | | |
| 56 | | .80 | | .44 | 1.50 | 1.38 | 2.20 | 2.21 |
| 57 | .70 | | .50 | | | | | |
| 58 | | .75 | | .44 | 1.40 | 1.33 | 2.20 | 2.21 |
| 59 | .60 | | .40 | | | | | |
| 60 | | .70 | | .39 | 1.40 | 1.28 | 2.10 | 2.11 |
| 61 | .50 | | .40 | | | | | |
| 62 | | .60 | | .34 | 1.20 | 1.18 | 2.20 | 2.21 |
| 63 | .50 | | .30 | | | | | |
| 64 | | .50 | | .39 | 1.20 | 1.18 | 2.00 | 2.01 |
| 65 | .40 | | .30 | | | | | |
| 66 | | .40 | | .24 | 1.10 | .98 | 2.00 | 2.01 |
| 67 | .30 | | .20 | | | | | |
| 68 | | .20 | | .24 | 1.00 | .78 | 1.80 | 1.81 |
| 69 | .10 | | .00 | | | | | |
| 70 | | .03 | | .28 | .70 | .58 | 1.30 | 1.57 |
| RWE 71 | .00 | | .00 | | | | | |
| 72 | | .00 | | .00 | .50 | .53 | 1.30 | 1.40 |
| 74 | | | | | .50 | .48 | 1.30 | 1.32 |
| 76 | | | | | .40 | .48 | 1.10 | 1.12 |
| 78 | | | | | .50 | .48 | .90 | .90 |
| 80 | | | | | .40 | .38 | .70 | .71 |
| 82 | | | | | .30 | .28 | .50 | .50 |
| 84 | | | | | .20 | .23 | .40 | .39 |
| 86 | | | | | .20 | .23 | .50 | .50 |
| 88 | | | | | .20 | .18 | .40 | .40 |
| 90 | | | | | .10 | .13 | .20 | .20 |
| 92 | | | | | .10 | .08 | .20 | .20 |
| RWE 94 | | | | | .00 | .02 | .00 | .08 |
| | r = .98 | | r = .56[b] | | r = .99[b] | | r = .99[b] | |

[a]Distance (ft) along transect from left bank head pin. LWE and RWE are left and right water's edge at the two discharges.

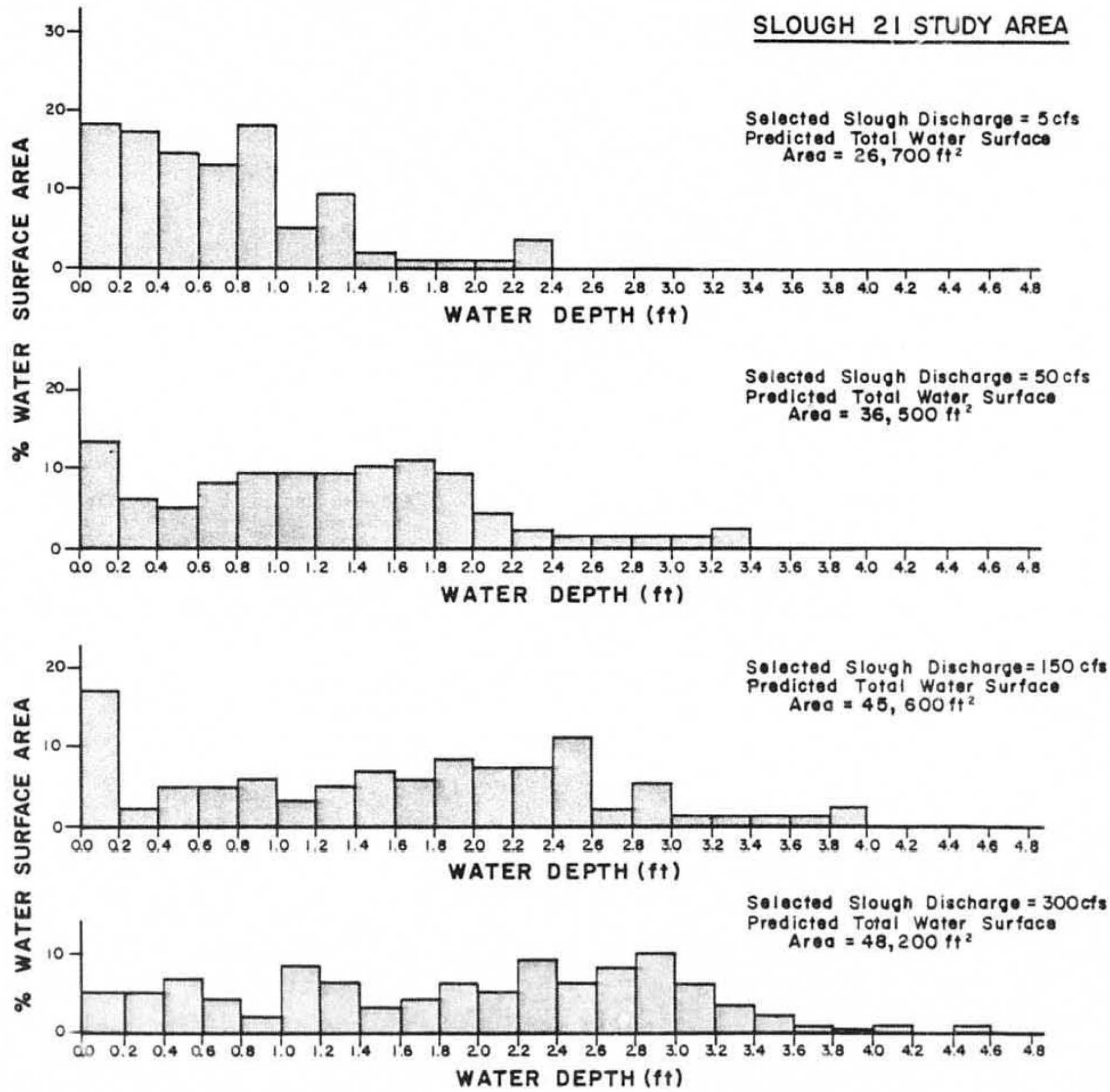
[b]Predicted water depths and velocities in each segment rounded to nearest 0.05 ft and 0.05 ft/sec, respectively, before determining correlation coefficent to compensate for rounding of observed velocity.



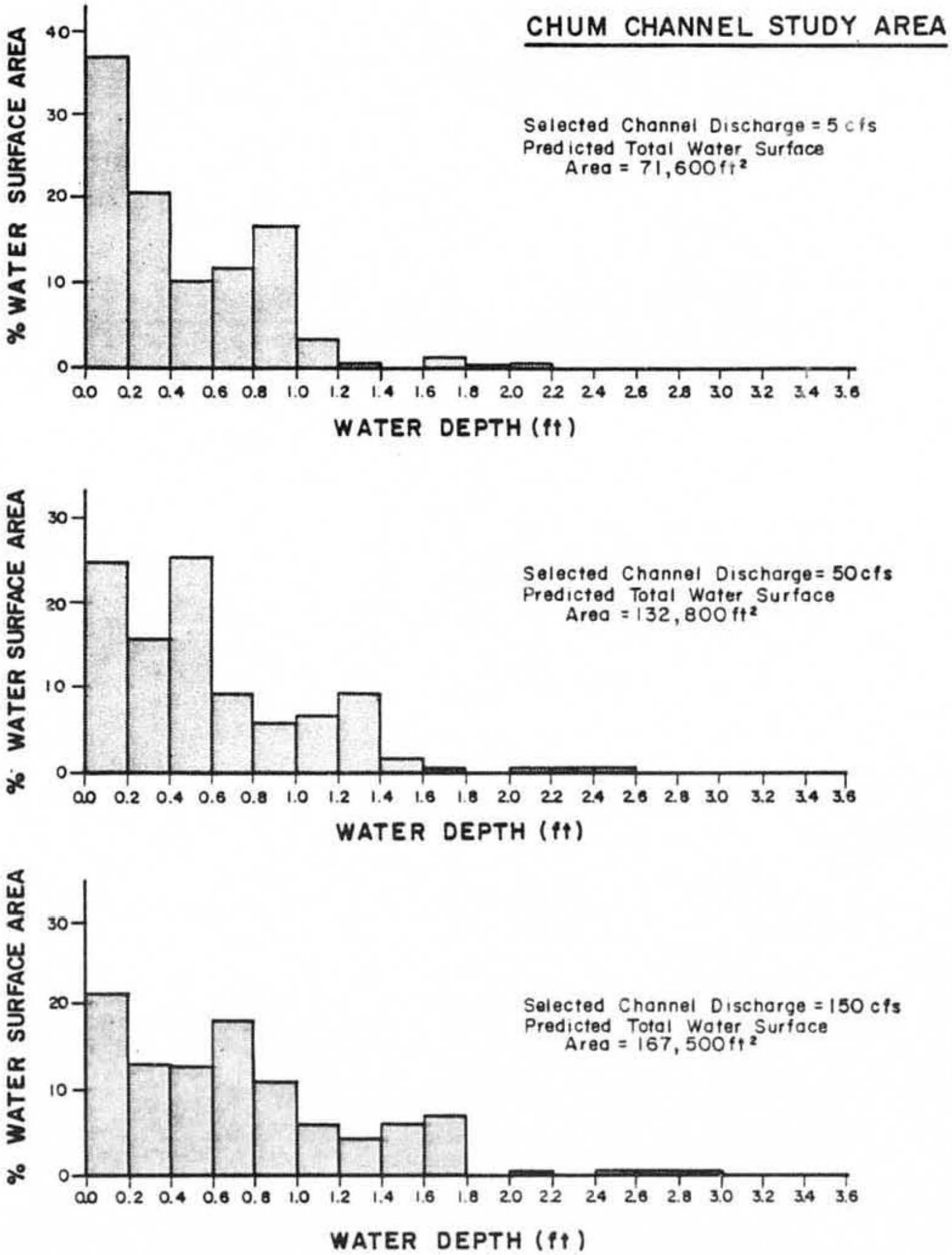

Appendix Figure D-2. Frequency distribution of the predicted water depths available for two selected discharges (5 and 50 cfs) in the Slough 8A study area.



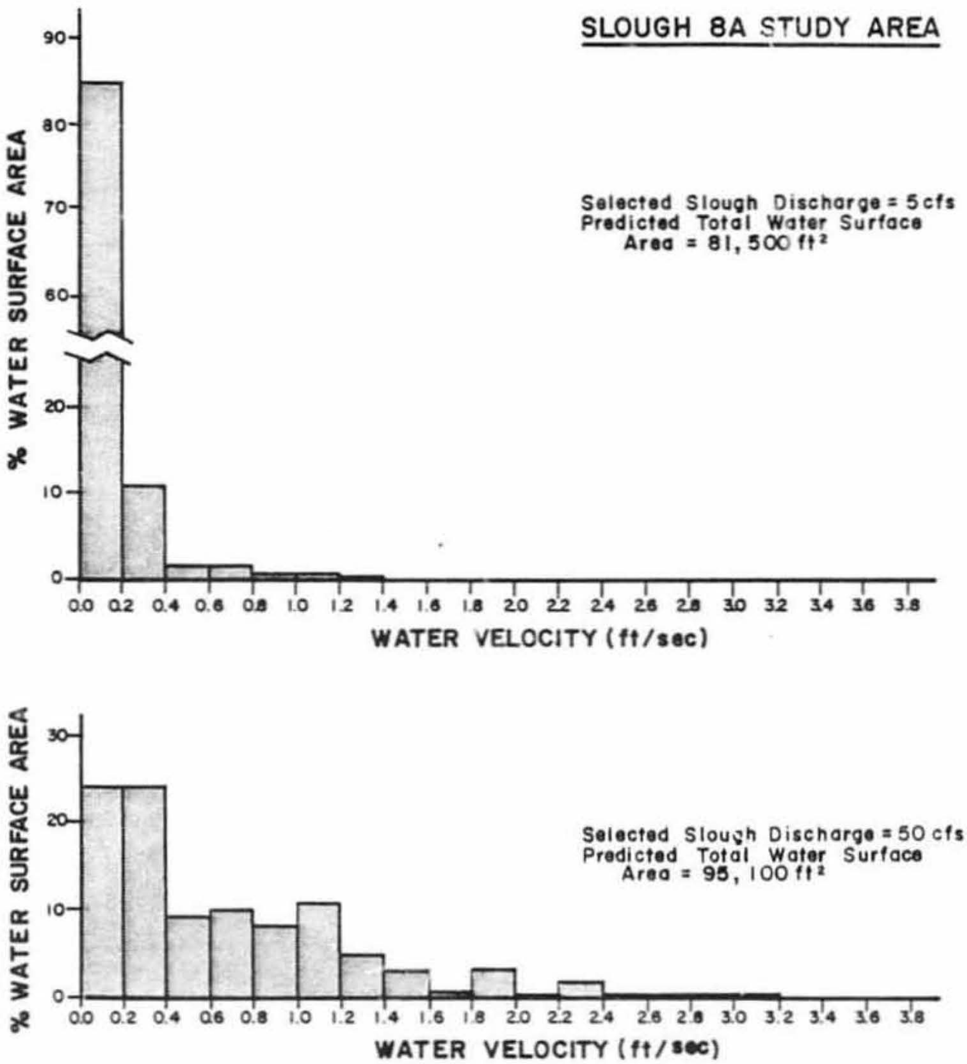

Appendix Figure D-3. Frequency distribution of the predicted water depths available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 9 study area.



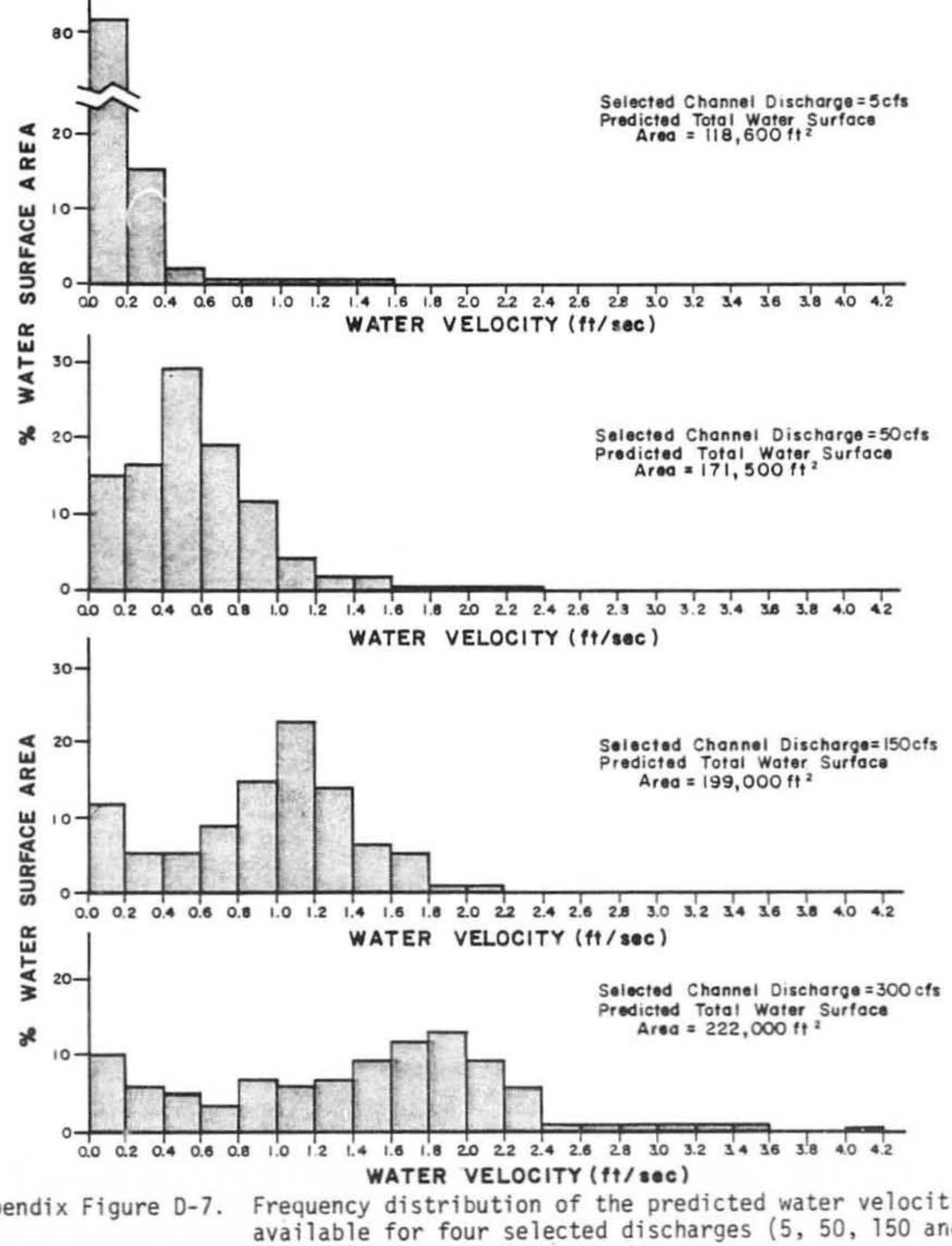

Appendix Figure D-4. Frequency distribution of the predicted water depths available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 21 study area.



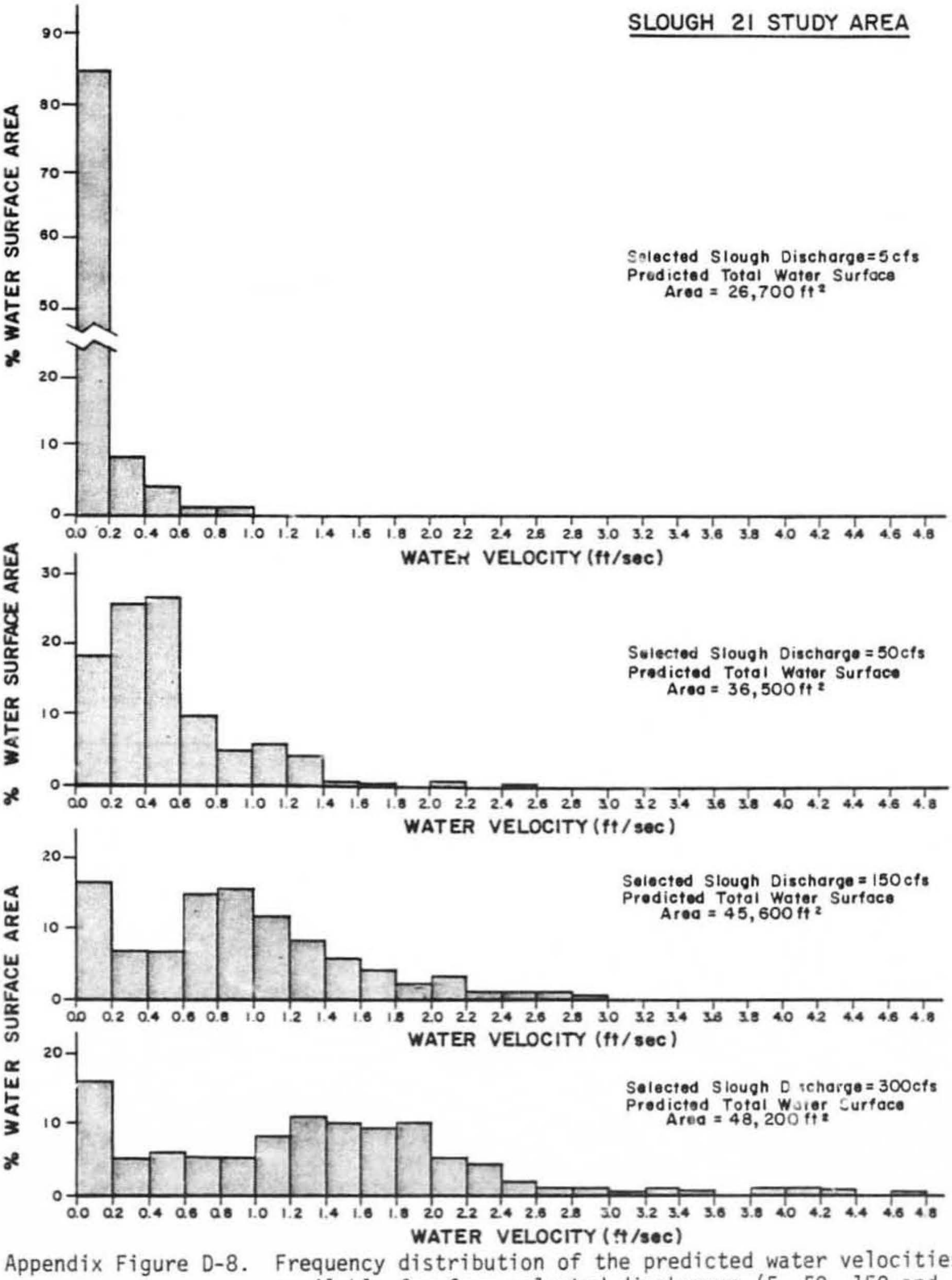

Appendix Figure D-5. Frequency distribution of the predicted water depths available for three selected discharges (5, 50 and 150 cfs) in the Chum Channel study area.



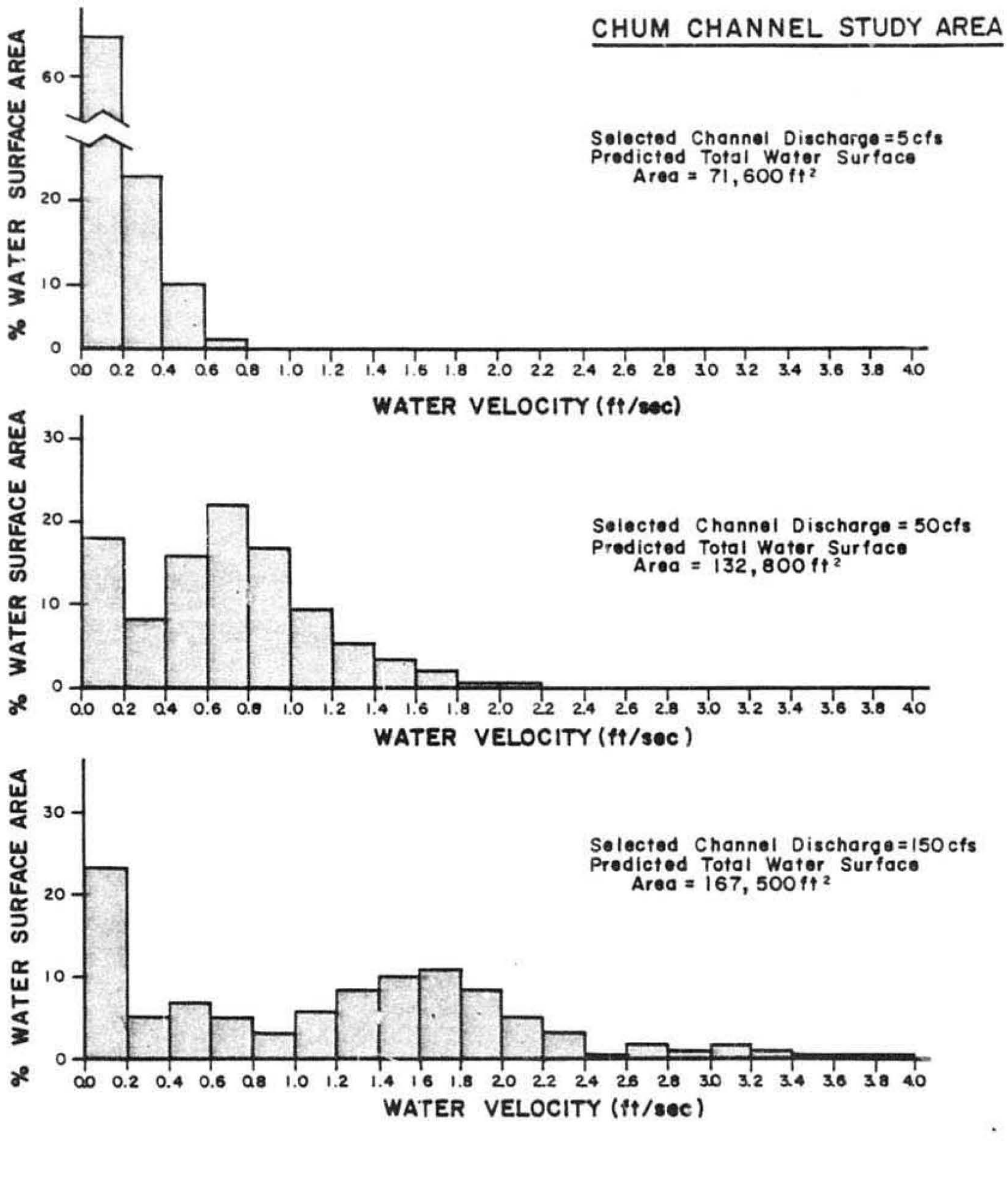

Appendix Figure D-6. Frequency distribution of the predicted water velocities available for two selected discharges (5 and 50 cfs) in the Slough 8A study area.




Appendix Figure D-7. Frequency distribution of the predicted water velocities available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 9 study area.




Appendix Figure D-8. Frequency distribution of the predicted water velocities available for four selected discharges (5, 50, 150 and 300 cfs) in the Slough 21 study area.




Appendix Figure D-9. Frequency distribution of the predicted water velocities available for three selected discharges (5, 50 and 150 cfs) in the Chum Channel study area.

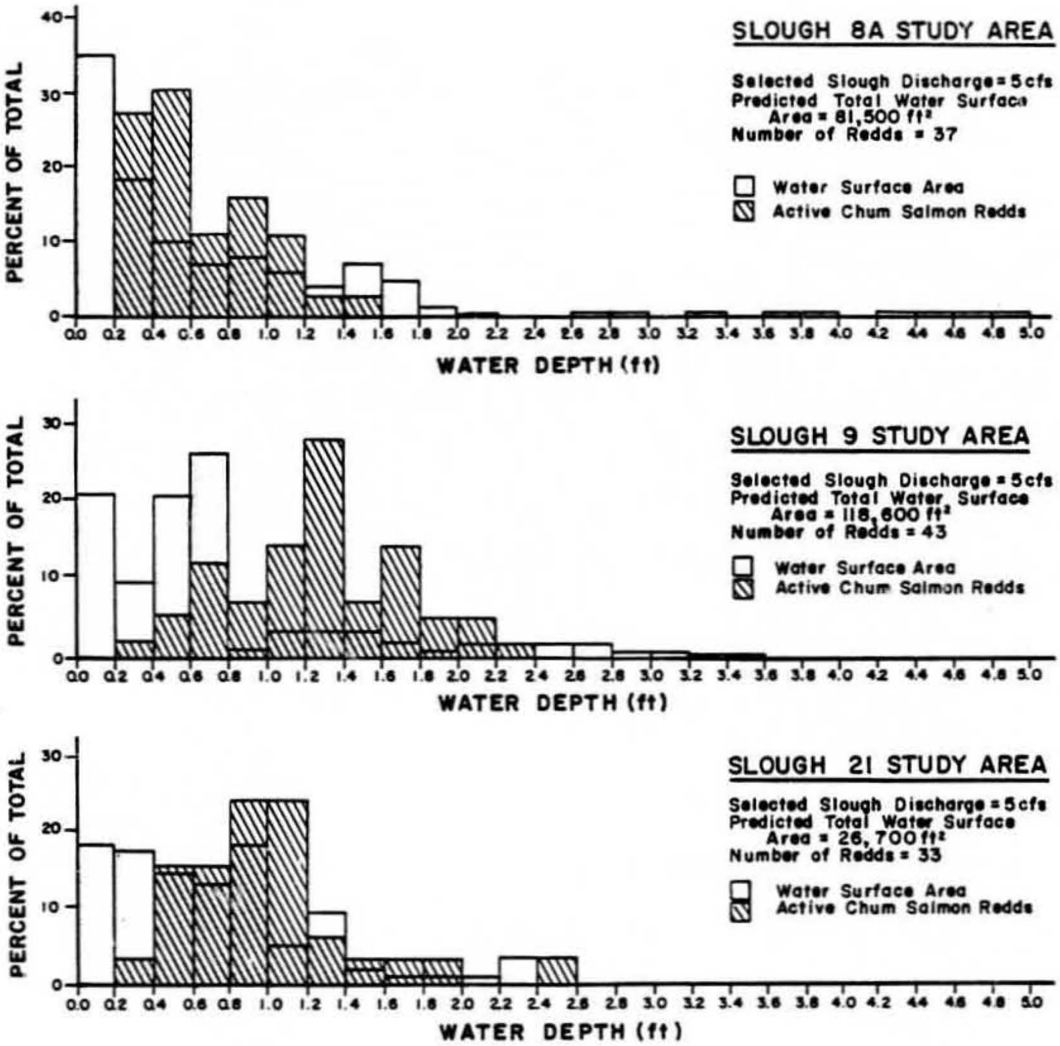
transect were highly correlated with mean slough discharges (r = 0.999). All but one vaf were considered good (0.9 < VAF < 1.1). Forty-seven percent of the VAF values were 1.00 ± 0.01. The single exception was the velocity adjustment factor for Slough 21 Transect 6 (at 10 cfs) which was considered fair (VAF is 0.85-0.9 or 1.1-1.15).

Precision standards also recommend keeping predicted water depths and velocities in each cell within 0.1 ft and 0.2 ft/sec of the observed depths and velocities (Milhous et al. 1981). A comparison of observed and predicted depths and velocities along two transects at two discharges with some of the lowest correlation coefficients (Appendix Tables D-5 and D-6) are provided. Correlation coefficients may be somewhat misleading at the discharge level at which the models were calibrated. At shallow depths and low velocities, differences of 0.1 ft or ft/sec can appear disproportionally large.

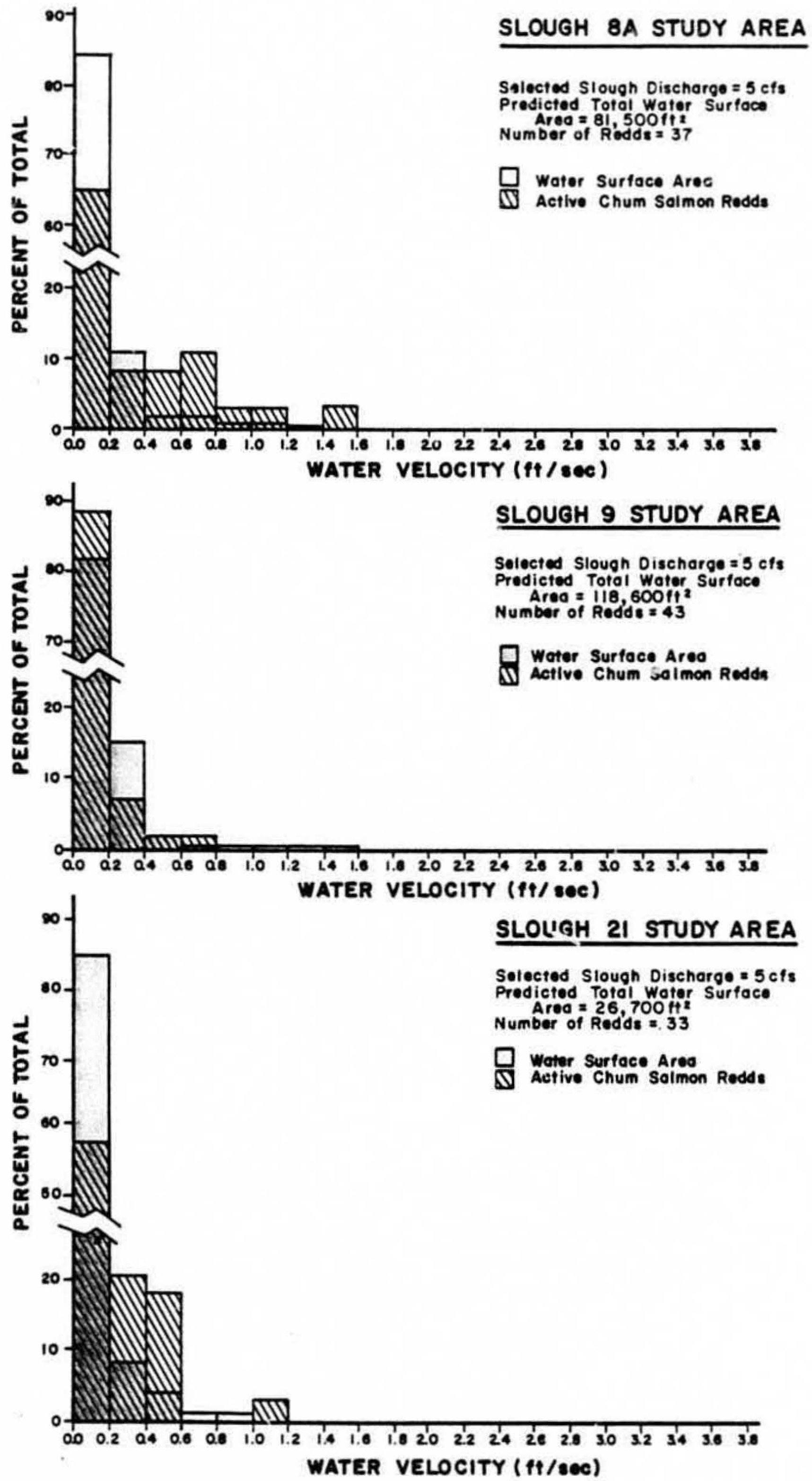
### Predicted hydraulic conditions

The predicted proportions of available depths and velocities are presented for slough flows of 5 and 50 cfs for all four sloughs; 150 cfs for sloughs 9, 21, and Chum Channel; and 300 cfs for sloughs 9 and 21 (Appendix Figures D-2 to D-9) for comparative purposes.

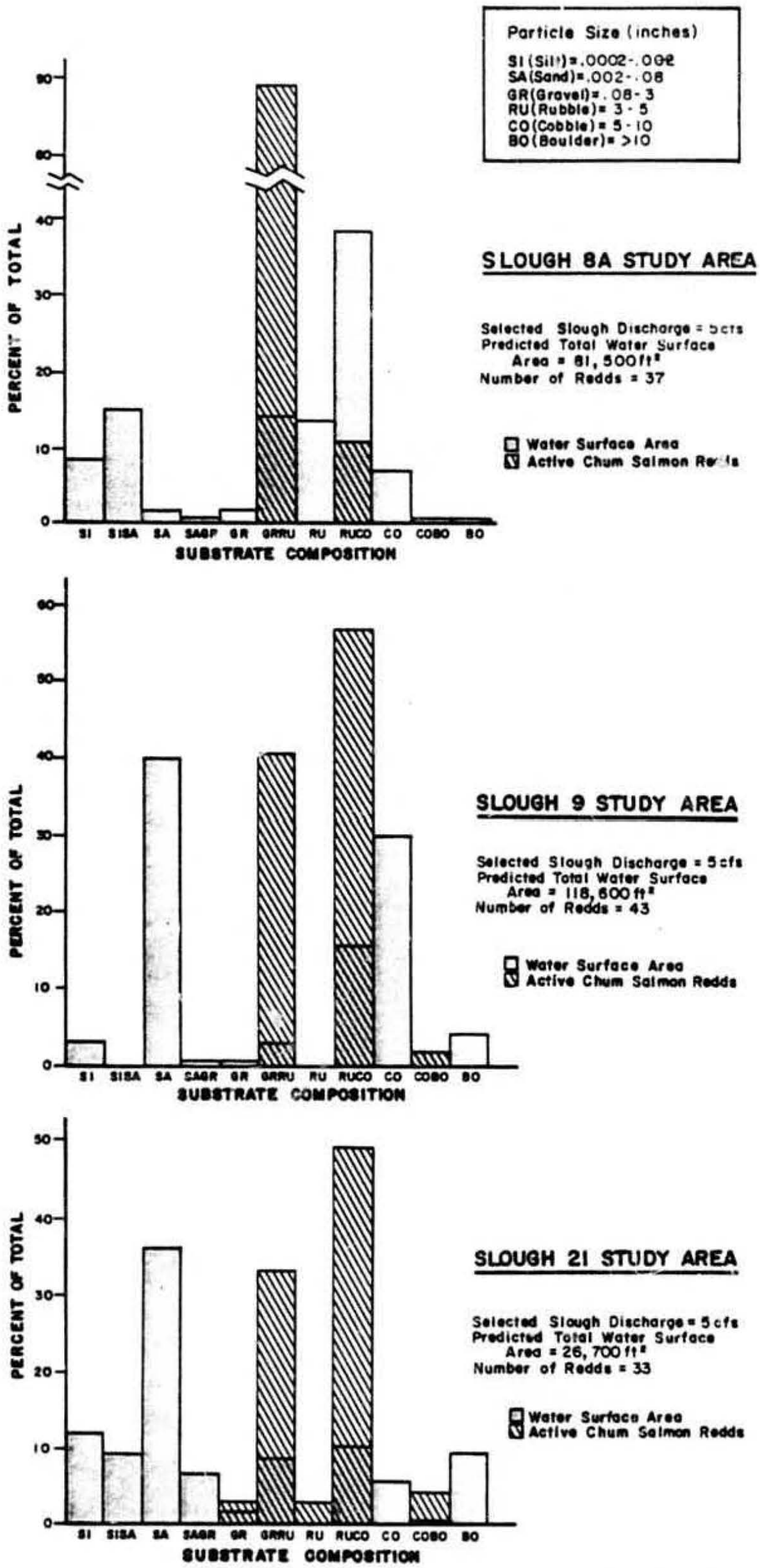
Water depths, velocities and discharge in a slough increase substantially when the slough head is breached by water from the mainstem. Sloughs 8A, 9, 21 and Chum Channel were breached at mainstem flows of 33,000 cfs, 19,500 cfs, 25,000 cfs and 53,000 cfs, respectively. When sloughs




Appendix Figure D-10. Comparisons of the frequency distributions of observed water depths at chum salmon redds (August-September 1982) with predicted water depths available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.




Appendix Figure D-11. Comparisons of the frequency distributions of observed water velocities at chum salmon redds (August-September 1982) with predicted water velocities available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.




Appendix Figure D-12. Comparisons of the frequency distributions of observed substrate composition at chum salmon redds (August-September 1982) with predicted substrate composition available in sloughs 8A, 9 and 21 for slough flows of 5 cfs.

8A, 9 and 21 were not breached, their discharges were generally less than 30 cfs (ADF&G 1983: Volume 4).

As breaching occurred, slough flows increased rapidly. On July 21, 1981, the discharge in Slough 8A was 551 cfs at a mainstem flow of 40,000 cfs at Gold Creek (ADF&G 1981b). Conversely, slough flows decreased rapidly when mainstem stage fell below breaching stage. Therefore, in these three sloughs, discharges greater than 30 cfs were of short duration in late summer and winter months, as recorded during the past two years.

Suitability of Available Habitat for Chum Salmon Spawning

Data from the hydraulic and spawning habitat models were combined in the suitability model (Appendix Figures D-10 to D-12). Available water depths, velocities and substrate types were compared with those found at chum salmon redds. Distributions of each hydraulic variable differed significantly ($p < 0.05$) between sloughs 8A, 9 and 21 at 5 cfs. Depths and substrate types at chum salmon redds in all three sloughs (4-8 cfs) differed significantly ($p < 0.05$) from those available (5 cfs). The importance of velocity at low slough flows was difficult to determine. Velocities measured at active redds (Appendix Figure D-11) did not differ significantly ($p > 0.05$) from available velocities in sloughs 8A and 9 at predicted slough flows of 5 cfs. However, available and utilized velocities were significantly different in Slough 21 at 5 cfs. Therefore, at slough flows of 5 cfs, water depth and substrate composition were considered the most important of these habitat variables evaluated for determining salmon habitat preference.

Preferences of spawning chum salmon for specific ranges of water depth and substrate composition in sloughs 8A, 9 and 21 are summarized in the following paragraphs. Gaps in the ranges of utilized water depths and substrate types can probably be attributed to the low sample size of redds rather than actual avoidance of those depths and substrate types by the spawning salmon. In addition, the proportion of total water surface area that was utilized, preferred and optimal for spawning is estimated.

In Slough 8A, at 5 cfs, the water depths used by spawning chum salmon were 0.2-1.6 and 1.8-2.0 ft. Gravel-rubble and rubble-cobble substrates were used. Preferred water depths were 0.2-1.2 ft and the preferred substrate was gravel-rubble. Optimal water depths were 0.4-0.6 ft and the optimal substrate was gravel-rubble. The Slough 8A study area was comprised of 30.5 percent usable spawning area. Only 6.0 percent of the total water surface area was preferred and 1.0 percent was optimal for spawning.

In Slough 9, at 5 cfs, the water depths used by spawning chum salmon were 0.2-2.4 ft. Gravel-rubble, rubble-cobble and cobble-boulder substrates were used. Preferred water depths were 0.8-2.2 ft and the preferred substrates were gravel-rubble and rubble-cobble. Optimal water depths were 1.2-1.4 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 9 study area was comprised of 24.4 percent usable spawning area. Only 0.8 percent of the total water surface area was preferred and 0.3 percent was optimal for spawning.

In Slough 21, at 5 cfs, the water depths used by spawning chum salmon were 0.2-2.0 and 2.4-2.6 ft. Substrate types used for spawning ranged from gravel to cobble-boulder. Preferred water depths were 0.4-1.2 and 1.4-2.0 ft. The preferred substrates ranged from gravel to rubble-cobble and cobble-boulder. Optimal water depths were 1.0-1.2 ft and optimal substrates were gravel-rubble and rubble-cobble. The Slough 21 study area was comprised of 21.4 percent usable spawning area. Only 8.2 percent of the total water surface area was preferred and 1.5 percent was optimal for spawning.

## DISCUSSION

Chum salmon did not spawn in sloughs at water depths less than 0.2 ft. The upper limit of depths used for spawning was probably not reached because of low flows in August and September 1982. Water depths used for spawning in all three sloughs were within the range of depths (0.16-3.9 ft) reported for chum salmon redds in the Chena River (Kogl 1965). Similarly, water depths in the sloughs were within the range of depths (0.25-3.5 ft) reported for chum salmon redds in the Terror and Kizhuyak Rivers on Kodiak Island (Wilson et al. 1981).

The frequency distributions of water velocities at redds in the three sloughs were not significantly different ($p > 0.05$) at a predicted flow of 5 cfs. As with depths, the upper limit of velocities used for spawning was probably not observed because of low flows in August and September 1982. Water velocities used for spawning in all three sloughs were within the range of velocities (0.0-2.0 ft/sec) reported at chum salmon redds in the Chena River (Kogl 1965). Velocities reported at chum salmon redds in the Terror and Kizhuyak rivers (0.0-3.9 ft/sec) were even higher (Wilson et al. 1981).

Adequate aeration of chum salmon eggs, like those of other salmonids, requires moving water (Wesche and Rechard 1980, Hale 1981). When redds were located in velocities of 0.0-0.2 ft/sec, upwelling ground water was frequently observed. Chum salmon were found to prefer areas of upwelling ground water in the Alaskan interior (Kogl 1965, Francisco 1977) and on Kodiak Island (Wilson et al. 1981). Upwelling ground water, which is warmer in winter than surface water, also prevents substrate freezing in shallow water and in slow currents (Levanidov 1954, Kogl 1965, Sano 1966, Francisco 1977). Upwelling ground water may be the principal variable influencing the suitability of habitat for spawning by chum salmon, and water depth, velocity and substrate composition the secondary factors, within the limits of tolerance.

The specific relationships between base slough flows and Susitna River mainstem discharges, when mainstem flows are lower than breaching stage, is presently unknown. Intuitively, it would seem that increases in local surface runoff or ground water seepage (due to rainfall or accelerated snow melt, for example) would increase base slough flows. However, rainfall or accelerated snow melt events that are likely to cause increases in local runoff would also likely be coincident with increases in basin runoff that would stimulate an increase in mainstem discharge and overtop the sloughs. Thus, it is difficult to identify the specific relationship between local runoff and slough flow under natural flow conditions.

An increase in slough flow may not result in a proportional increase in spawning habitat or production. That is, not all added water surface area may be of sufficient depth, have suitable substrate composition or upwelling conditions. Under these circumstances, a reduction in the proportion of habitat acceptable for spawning could result. Secondly, salmon eggs and alevin remain in the gravel of redds for months and require a long term supply of water. Peaks in the Susitna River flow that are large enough to breach sloughs are generally short term. Spawning in this ephemeral habitat would result in unsuccessful incubation if it became dewatered and ground water were absent.

Although incubation and rearing can be successful during low water conditions, this in no way reduces the necessity for seasonally timed high discharges in the mainstem. Medium to high mainstem water levels are important to slough access and subsequent movement into upper reaches of the slough (where upwelling ground water may then be sufficient to prevent complete dewatering at low flows) often depends on breaching at the slough heads (Appendices B and C). High flows also flush accumulations of silt and sand from spawning substrate.

Substrate composition at redds in these three Susitna River sloughs differed from that found in other Alaskan chum salmon spawning areas. Redds in the three sloughs were not observed in substrate smaller than gravel, including the combination of sand-gravel. Rubble mixed with either gravel or cobble was the optimal spawning substrate. Most other studies found gravel (0.08-3 inches) substrate to be most commonly used (Francisco 1976, Morrow 1980, Wilson et al. 1981). Rubble substrates, with particles as large as 5 inches, were utilized on the Delta River (Francisco 1976).

Water depths, velocities and substrate types at chum salmon redds in sloughs are comparable with spawning sites in the Susitna River, where a much wider range of environmental conditions prevail. Chum salmon spawn infrequently in side channels of the Susitna River. However, at 15 mainstem chum salmon redds observed between September 4-14, 1982, water depths ranged from 0.5-2.5 ft (ADF&G 1983: Volume 4). Water velocities measured at the same 15 redds ranged from 0-0.2 ft/sec. These water depths and velocities were within the ranges measured at chum salmon redds in sloughs and more closely resembled side channel habitat conditions than those of the mainstem. Substrate composition at 13 of the 15 redds was 60-90 percent gravel, rubble and/or cobble.

No attempt was made to calculate utilized proportions of water surface area at predicted flows other than 5 cfs (i.e., 50, 150, or 300 cfs). Therefore, at present, the proportion of water surface area used by spawning chum salmon can only be predicted at this slough flow. Because breaching events are of short duration in late summer and water conditions were unusually low during the spawning period in 1982, we were unable to establish an upper limit of water depth and velocity tolerated by spawning chum salmon in the Susitna River sloughs. It would be misleading to try to predict salmon habitat preferences at slough discharges where water depths and velocities exceeded those available at measured low flows of 4-8 cfs. However, as discussed previously, this does not seriously hamper our analysis because base slough flows during the spawning season generally are low.

The analysis of water depth and substrate composition with our spawning habitat suitability model, should not be the sole decision-making factor for evaluating salmon spawning habitat conditions in sloughs. Ground water upwelling and seepage, water velocity, water quality, intragravel and surface water temperatures, backwater zones, and access into sloughs must also be considered. A better understanding of the relationships of mainstem flows to slough flows and the relative contributions of various water sources (e.g., ground water upwelling and seepage, and surface waters) to slough flows is also required in order to link the suitability model to changes in mainstem flow.

Plans for data collection during the 1983 field season are based on the observations in this and other ADF&G reports. Additional data from chum salmon redds in sloughs are required if we are to develop multivariate suitability curves for a habitat model. It may be possible to combine samples collected within study areas during different years if they are not found to be significantly different. Additional hydraulic data must also be collected at intermediate and high flows in order to calibrate the hydraulic models over a wider range of discharges. Other plans for 1983 include collecting hydraulic and habitat data from transects and redds in slough backwater zones, side channels, and tributaries of the Susitna River between Talkeetna and Devil Canyon. An attempt will also be made to collect data from pink, sockeye, coho, and chinook salmon redds to include these species in the spawning habitat model. Intragravel and surface water temperatures are planned for collection at transects while the salmon are spawning to compare available temperatures with those observed at redds. Methods for accurately detecting presence of upwelling ground water, in an early stage of development, will be used to quantify upwelling conditions in sloughs if proven feasible.

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Appendix D: Models of Hydraulic Conditions and Chum Salmon Spawning Habitat in Selected Susitna River Sloughs.

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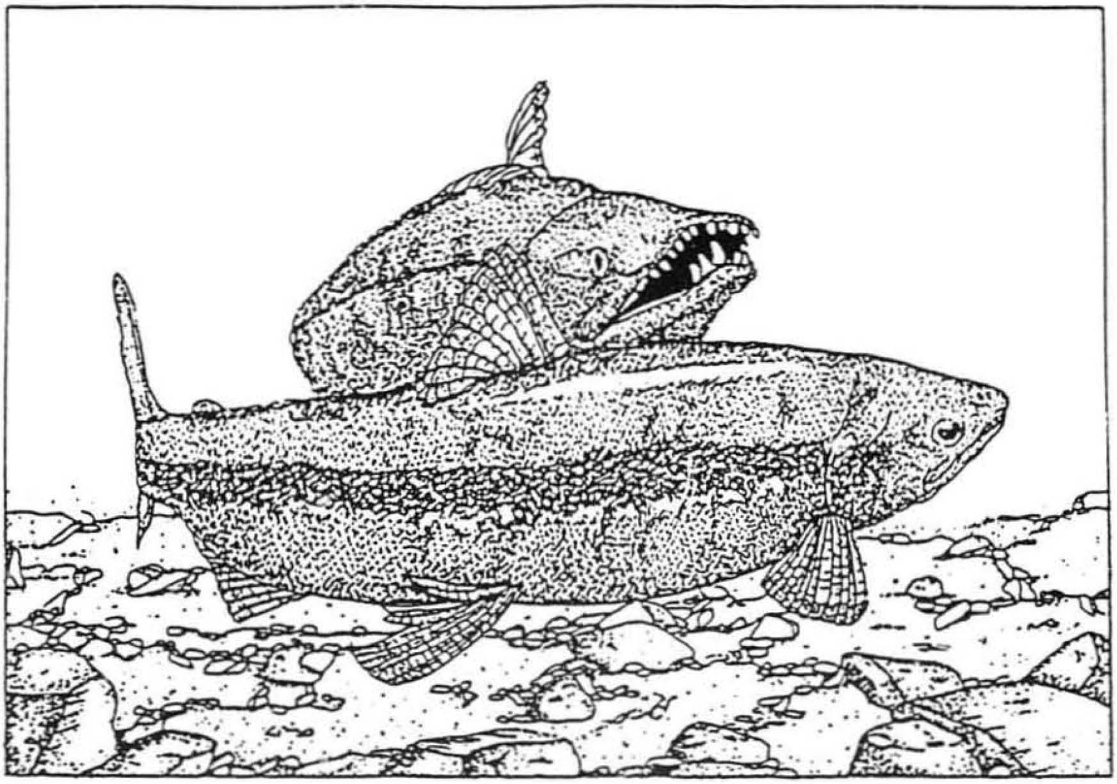
# 185



# SUSITNA HYDRO AQUATIC STUDIES
## PHASE II REPORT

Synopsis of the 1982
Aquatic Studies and Analysis of
Fish and Habitat Relationships

— APPENDICES —

by

ALASKA DEPARTMENT OF FISH AND GAME
Susitna Hydro Aquatic Studies
2207 Spenard Road
Anchorage, Alaska 99503

1983