MEMORANDUM

State of Alaska

TO: Jon Ferguson
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Alaska Power Authority

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TELEPHONE NO:

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SUBJECT: Draft Technical Memorandum on 1984 Salmon Passage Validation Studies (Task 35)

This draft memorandum presents information to fulfill Task 35 which addresses the Passage Validation Studies (PVS) which were conducted during the 1984 open water field season by the Alaska Department of Fish and Game (ADF&G) Susitna Hydro Aquatic Studies Team. Review comments on the memorandum should be submitted to this office by December 11, 1984. A meeting will be held for interested project participants on December 13, 1984 (1) to discuss comments received and (2) to determine if the revisions in this memorandum warrant a reevaluation of previously established discharges and local flows required for successful and unsuccessful salmon passage at slough and side channel sites. The second topic will be advised in a forthcoming memorandum as it is not programmed in our FY 85 budget.

Draft Technical Memorandum

on 1984 Salmon Passage

Validation Studies

INTRODUCTION AND OBJECTIVES

Preliminary field studies of adult chum salmon (Oncorhynchus keta) passage conditions in slough and side channel spawning habitats of the middle Susitna River were conducted during the 1982 (ADF&G 1983: Appendix B) and 1983 (Sautner et al. 1984) open water field seasons. These studies evaluated the influence of selected channel geometry and hydraulic characteristics on chum salmon passage into and within these habitats. These studies provided the basis for establishing interim salmon passage criteria for estimating the mainstem discharges and related local slough flows required to provide successful and unsuccessful passage conditions for chum salmon migrating into and within these habitats.

A field Passage Validation Study (PVS) was undertaken during the 1984 open water field season to verify or refine interim fish passage criteria and flow requirements established previously as recommended in Sautner et al. (1984). That is, salmon passage criteria curves developed from 1983 data were based on a review of limited field data and observations collected during 1982 combined with the professional judgement of fisheries biologists and hydraulic engineers. The field data available for the initial development of these curves in 1983 were limited. Therefore, it was necessary to obtain additional field data in 1984 to validate the 1983 curves and, if necessary, refine them to more closely represent natural passage conditions for chum salmon.

Accordingly, the 1984 field data were collected to address two main objectives:

1) Verify or refine the 1983 passage criteria curves (Sautner et al 1984) developed from 1982 and 1983 data which describe passage conditions for chum salmon into and within slough and side channel habitats in the middle reach of the Susitna River; and,

2) If necessary, refine the estimates of mainstem discharges and local flows which provide successful and unsuccessful passage conditions for chum salmon into and within all slough and side channel sites previously evaluated.

This memorandum only addresses the first objective as a decision must be made by the Alaska Power Authority (APA) whether to assign resources to address the second objective (memorandum on this topic to follow) in another technical memorandum or, if necessary, a technical report.

SITE SELECTION

Salmon passage conditions were evaluated at 12 slough and side channel sites in the middle reach of the Susitna River during 1984 (Table 1). With the exception of Slough 19, these sites represent the major slough and side channel spawning locations where discharge related passage problems have been previously identified (Sautner et al. 1984). Slough 19 was not previously evaluated but was included as a study site based on previous observations of spawning chum salmon (Barrett et al. 1984) and undocumented passage problems.

FIELD METHODS

The methods presented below focus on the 1984 field methods utilized to characterize the physical conditions influencing passage of adult chum salmon into and/or within slough and side channel habitats. Locations where passage problems are located are referred to as passage reaches. In this study, a passage reach is defined as a portion of the channel at the mouth of or within a study site which is potentially limiting to salmon migration into spawning areas.

In the field, passage reaches were identified by locating areas where water depth was potentially limiting passage of adult chum salmon. A

Table 1. Summary of Passage Validation study sites and corresponding river miles in the middle reach of the Susitna River.

STUDY SITE	RIVER MILE
Whiskers Creek Slough	101.2
Mainstem 2 Side Channel	114.4
Slough 8A	125.9
Slough 9	128.3
Slough 9A	133.6
Slough 11	135.3
Upper Side Channel 11	136.1
Slough 19	140.0
Slough 20	140.1
Side Channel 21	140.6
Slough 21	141.8
Slough 22	144.2

representative transect perpendicular to the flow of water was selected to characterize the depth characteristics for each passage reach and provide a consistent point of measurement. Representative transects were located in the field at the shallowest or most critical point of each passage reach and marked with wood stakes and rebar headpins. To quantitatively describe a specific passage reach, the length, width, and water depth were measured. These variables are defined as follows:

Passage Reach Length: The longitudinal distance of a passage reach along the thalweg channel limited by the upstream and downstream points at which water depth is no longer limiting to salmon passage. The length limits are defined at thalweg water depths of 0.50 feet and 0.67 feet which correspond to threshold passage depths presented in passage Criteria Curves I and II, respectively; (Sautner et al. 1984).[1]

Passage Reach Width: The distance from left water's edge (LWE) to right water's edge (RWE) of a passage reach transect.

Passage Reach Depth: The depth of water within a passage reach which a fish must navigate through in order to proceed upstream. Passage depth is calculated as an average of the mean depth and maximum depth (thalweg depth) at a passage reach transect. The point of maximum depth at a passage reach transect was measured and marked with a flagged spike in the streambed or a staff gage for a consistent point of measurement. Passage depth was calculated later using cross sectional survey data.

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1 Criteria Curve II was eliminated following an analysis of the data and all passage reach lengths previously defined in the field by the 0.67 foot depth were redefined using the 0.5 foot depth (See analytical methods section).

Passage reach length and width were measured with a fiberglass surveyor's tape graduated in one-tenth foot increments. A standard surveying rod or staff gage was used to measure the thalweg depth at each transect.

Field observations of fish passage activity were made at passage reaches where salmon were attempting to migrate upstream. Three conditions were defined to classify the relative degree of difficulty encountered by salmon: 1) successful passage, 2) successful passage with difficulty and exposure, or 3) unsuccessful passage. These categories are defined as follows:

Successful Passage: Fish passage into and/or within the spawning area is uninhibited, and would not affect natural production in the area.

Successful Passage With Difficulty and Exposure: Fish passage into and/or within the spawning area is accomplished, but with stress and exposure to predation with the potential of reducing the level of successful spawning in the area. This condition over a long period of time may result in a decline in natural production in the area.

Characteristics of this category are:

1) exposure of the dorsal surface of the fish above water,

2) one or more pauses (eg. stranding, changing directions, or resting) within a passage reach due to shallow water conditions; or

3) repeated attempts to navigate a passage reach before succeeding.

Unsuccessful Passage: Fish passage into and/or within the spawning area may be accomplished by a limited number of fish; however, exposure to excessive stress and increased predation (which are associated with these conditions) may eventually eliminate or greatly reduce the natural production in the area. Characteristics of this category are:

1) absence of fish above a passage reach;

2) excessive exposure of the dorsal surface of the fish above water including partial exposure of eyes, gills, lateral line or caudal fin;

3) one or more pauses within a passage reach resulting in unsuccessful navigation; or,

4) death of a fish while attempting navigation of a passage reach.

Fish passage observations primarily focused on chum salmon due to their more restrictive passage requirements. Observations of other salmon species were noted if present. Fish passage observations were subjectively ranked into one of the three categories of passage based on the characteristics stated above. Passage reach length, width, and maximum depth measurements were collected at the same time observations of fish passage were made.

The substrate conditions at each passage reach were evaluated to characterize channel configuration and the influence of substrate on salmon passage conditions. Substrate data were collected by visually classifying the substrate present at a passage reach into the two dominant size groups. This study utilized the substrate size classification system presented in Table 2.

Table 2. Substrate size classification system used for the 1984 Passage Validation Studies.

Substrate Type	Symbol	Size
SILT	SI	very fines
SAND	SA	fines
SMALL GRAVEL	SG	1/4-1"
LARGE GRAVEL	LG	1-3"
RUBBLE	RU	3-5"
COBBLE	CO	5-10"
BOULDER	BO	10"

In addition, the channel configuration of each passage reach was subjectively ranked as a uniform or non-uniform channel. A uniform passage reach is characterized by a relatively straight, unbraided channel that concentrates the flow of water through one main channel. In contrast, a non-uniform passage reach is characterized by a braided, irregular channel that disperses the flow of water over a wide area.

ANALYTICAL METHODS

The approach for evaluating the physical conditions affecting salmon passage in sloughs and side channels involved two steps:

1. Plotting the salmon passage data (passage depth versus passage reach length) on the appropriate criteria curve distinguishing between successful passage, successful passage with difficulty and exposure, and unsuccessful passage; and,

2. Comparison of the passage data plotted in step number one to the previously developed passage criteria curves presented in Sautner et al. (1984) to determine if revisions to passage criteria are required to more accurately represent natural passage conditions.

Prior to plotting the salmon passage data the thalweg depth and passage length data required adjustments in order to be comparable to the 1982-1983 passage criteria. Thalweg depth values were converted to passage depth which is a more accurate indicator of the water depth affecting salmon passage. This conversion was accomplished using the following equation presented in Sautner et al. (1984):

$d_o = 0.77\ d_t^{\ 0.909}$ where d_o = Passage Depth and
d_t = Thalweg Depth

This equation describes the relationship between thalweg depth and passage depth based on a compilation of slough and side channel cross section profile data.

An adjustment was also required for the passage length data collected using the threshold passage depth of 0.67 feet. Initially, passage reach lengths were measured based on thalweg water depth limits of 0.50 feet and 0.67 feet which correspond to threshold passage depths presented in Criteria Curves I and II, respectively (Sautner et al. 1984). However, during the field season it became apparent that length measurements using the Criteria Curve II thalweg water depth limit of 0.67 feet included areas where salmon appeared to have no passage problems. Field observations suggested that a thalweg water depth limit of 0.50 feet is a more appropriate upper limit. Analysis of the data supported the discontinued use of a thalweg water depth of 0.67 feet and the elimination of Criteria Curve II. Therefore, those lengths measured using a thalweg water depth limit of 0.67 feet were adjusted to represent lengths limited by a thalweg water depth of 0.50 feet. This was accomplished by drawing a scale diagram of selected passage reaches including appropriate streambed and water surface elevations based on thalweg and cross section survey data. A new passage reach length was measured from each diagram using a thalweg water depth limit of 0.50 feet.

Following the appropriate adjustments to the passage reach lengths and depths, the relationship between passage depth and passage reach length was plotted for each of the three categories of fish passage. Several plots of the passage data were completed depicting 1) data collected at uniform passage reaches, 2) data collected at non-uniform passage reaches, and 3) all data combined. Using these passage data plots the original criteria curves were drafted on the appropriate plots to evaluate the accuracy of these curves.

Discrepancies in the data were noted and appropriate revisions were made for the passage criteria to better represent the relationship between passage depth and passage reach length based on the data plots and field observations. Based on these plotted data new fish passage thresholds were developed by visually plotting the lines to obtain a "best fit" in relation to the three categories of fish passage.

RESULTS

Passage reach dimension measurements, substrate type, and observations of chum salmon passage were collected at individual passage reaches at each study site (Table 3). A total of 145 adult chum salmon were observed at 33 passage reaches representing all 12 study sites in the middle reach of the Susitna River. Classifying the channel configuration of all these passage reaches into uniform or non-uniform categories shows that 70% of them fall into the non-uniform category while only 30% are uniform.

Salmon passage data collected during this study are plotted on the original criteria curves in Figures 1 and 2. Figure 1 corresponds to Criteria Curve I and shows data collected at passage reaches characterized by a uniform, unobstructed channel. Figure 2 corresponds to Criteria Curve II and depicts data collected at passage reaches with a non-uniform, obstructed channel.

Table 3. A summary of chum salmon passage data collected at passage reaches within slough and side channel study sites in the middle reach of the Susitna River.

Passage Depth (Feet)	Passage Reach Length (Feet)	# of Fish Observations for each Category of Salmon Passage: Successful Passage	Difficult Passage	Unsuccessful Passage	Channel Configuration	Substrate Type
0.11	103			1	Uniform	SA/LG
0.16	62			6	Uniform	LG/SG
0.16	113			1	Non-uniform	RU/CO
0.17	62			1	Uniform	LG/SG
0.17	253			1	Non-uniform	LG/SG
0.18	38			1	Non-uniform	RU/LG
0.18	109			6	Non-uniform	RU/LG
0.19	88			1	Non-uniform	LG/RU
0.19	281			1	Non-uniform	CO/RU
0.22	263			1	Non-uniform	LG/RU
0.23	121			1	Non-uniform	BO/SI
0.23	121			1	Non-uniform	LG/SG
0.24	54		8	1	Non-uniform	LG/SG
0.25	59			1	Non-uniform	LG/SG
0.25	73			1	Non-uniform	BO/SI
0.25	95		1	1	Non-uniform	LG/SG
0.26	80		3	9	Uniform	LG/RU
0.26	85		2	2	Uniform	LG/RU
0.26	165			1	Non-uniform	SI/SA
0.27	79		5	1	Uniform	LG/RU
0.27	148			4	Non-uniform	LG/RU
0.27	526			1	Non-uniform	CO/RU
0.28	421			1	Uniform	LG/SA
0.29	38	1			Uniform	SA/LG
0.30	35	1			Uniform	SA/SI
0.30	40		2		Uniform	LG/RU
0.30	75		6	4	Non-uniform	CO/LG
0.31	58		1		Non-uniform	RU/LG
0.32	27		3		Uniform	LG/RU
0.32	156			1	Non-uniform	RU/CO
0.33	25			1	Non-uniform	RU/CO
0.33	75		2		Non-uniform	RU/LG
0.34	23		3	1	Non-uniform	RU/CO
0.34	65	1	2		Non-uniform	RU/LG
0.35	25			1	Non-uniform	RU/CO
0.37	35	1	3		Uniform	LG/RU
0.37	38		1		Uniform	LG/RU
0.37	45		5	10	Non-uniform	SI/SA
0.40	7	2			Uniform	RU/LG
0.41	19	2			Uniform	LG/SG
0.43	137		2		Non-uniform	CO/RU
0.44	33	5	1		Non-uniform	LG/SG
0.48	146		8		Non-uniform	CO/LG
0.50	0	1			Non-uniform	RU/CO
0.54	0	2			Non-uniform	CO/RU
0.55	0	1			Non-uniform	LG/SG
0.56	0	1			Non-uniform	CO/RU
0.59	0	3			Non-uniform	LG/SG
0.60	0	1			Non-uniform	CO/RU
0.64	0	2			Non-uniform	LG/CO
	Totals	24	58	63		

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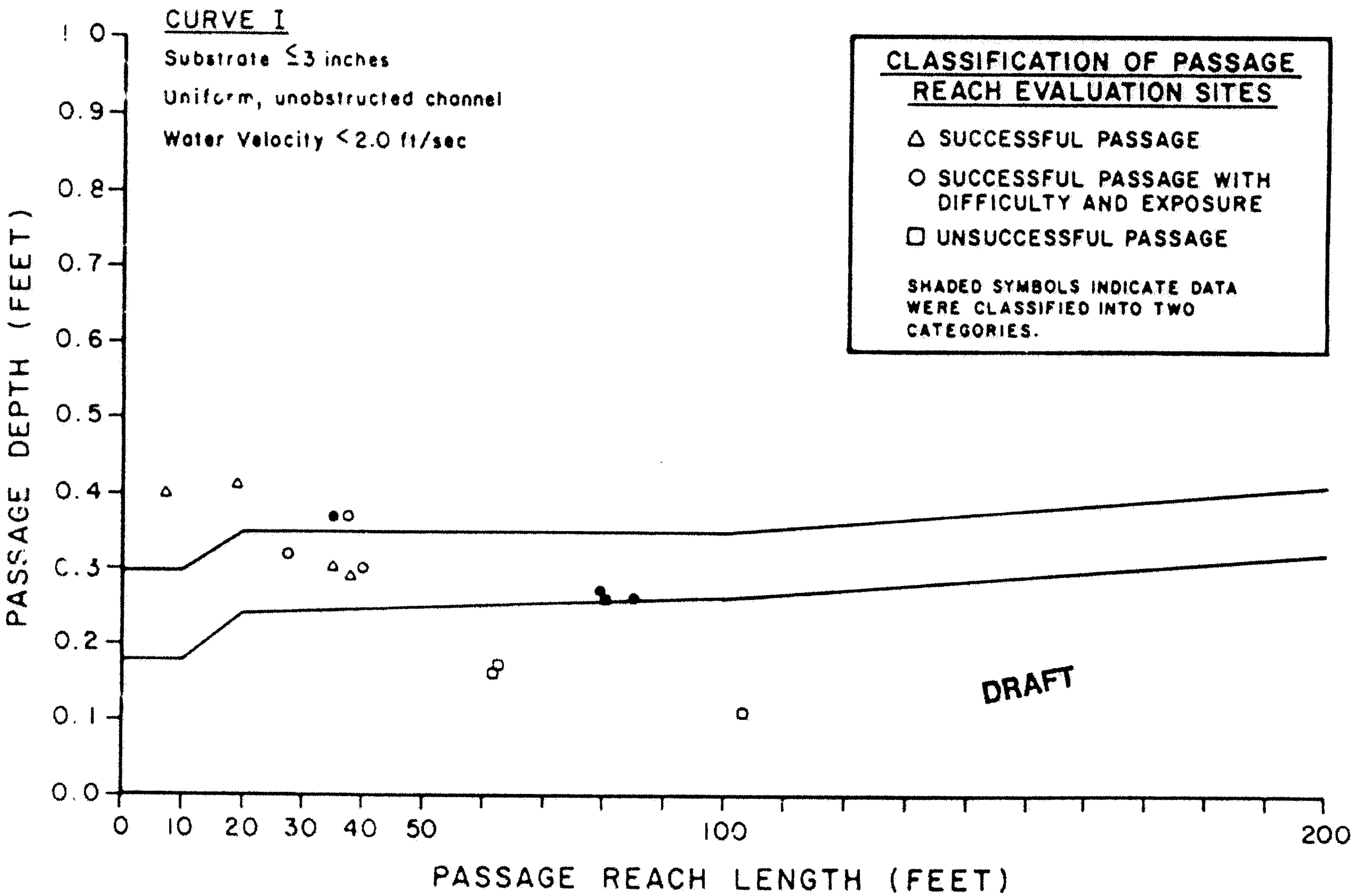

Figure 1. Original Criteria Curve I plotted with chum salmon passage data collected at passage reaches characterized by a uniform, unobstructed channel within sloughs and side channels.

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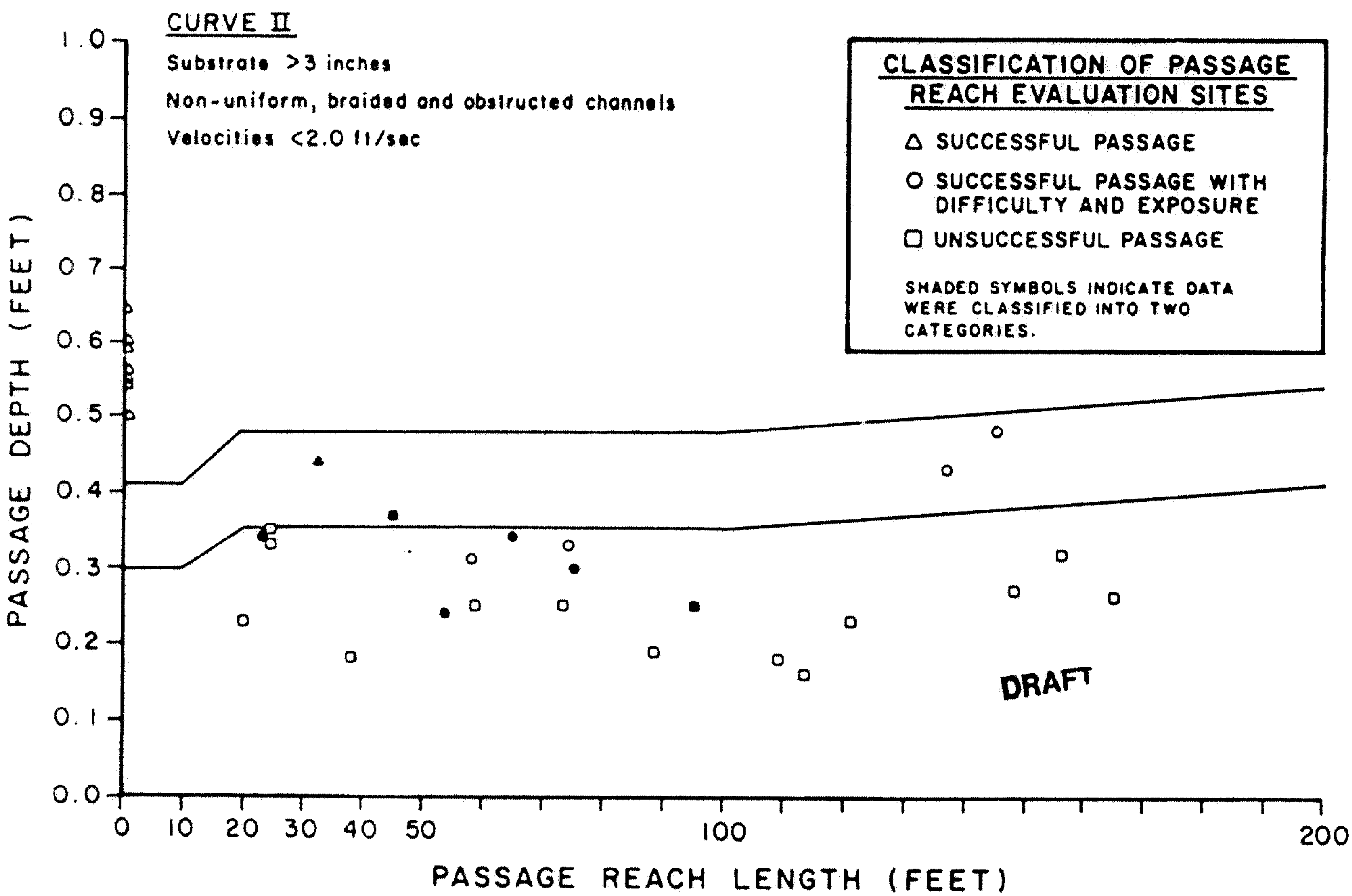

Figure 2. Original Criteria Curve II plotted with chum salmon passage data collected at passage reaches characterized by a non-uniform, obstructed channel within sloughs and side channels.

Figure 3 shows the combined data plotted on Criteria Curve I. A review of the plotted data in Figure 3 indicated that further revisions of the curve were necessary. Data were not available to support the sharp downward inflections in the 0-20 foot range of the curve. General field observations of chum salmon passage also did not support the original passage criteria presented in this area of the curve (Jeff Blakely, personal communication). Therefore, the criteria curves for both successful and unsuccessful passage were revised based on these plotted data points. The final result was the development of two straight lines referred to as "threshold limits". These lines represent the threshold criteria for successful and unsuccessful passage of chum salmon in the middle reach of the Susitna River.

Figure 4 illustrates the revised passage criteria thresholds which best represent the combined salmon passage depth. Figure 5 presents a comparison of the new criteria thresholds and Criteria Curve I. The distribution of fish observations for each category of fish passage in relation to the revised passage criteria thresholds is presented in Figure 6.

DISCUSSION

Salmon passage data collected during 1984 indicate that the criteria curves developed from 1982 and 1983 data (Sautner et al. 1984) should be revised. Passage data plotted on Criteria Curve I (corresponding to uniform, unobstructed channels; substrates less than 3 inches in diameter) fall within the general range of the passage category to which the data correspond. The data also appear to be equally distributed around the threshold levels for successful and unsuccessful passage indicating that this curve accurately

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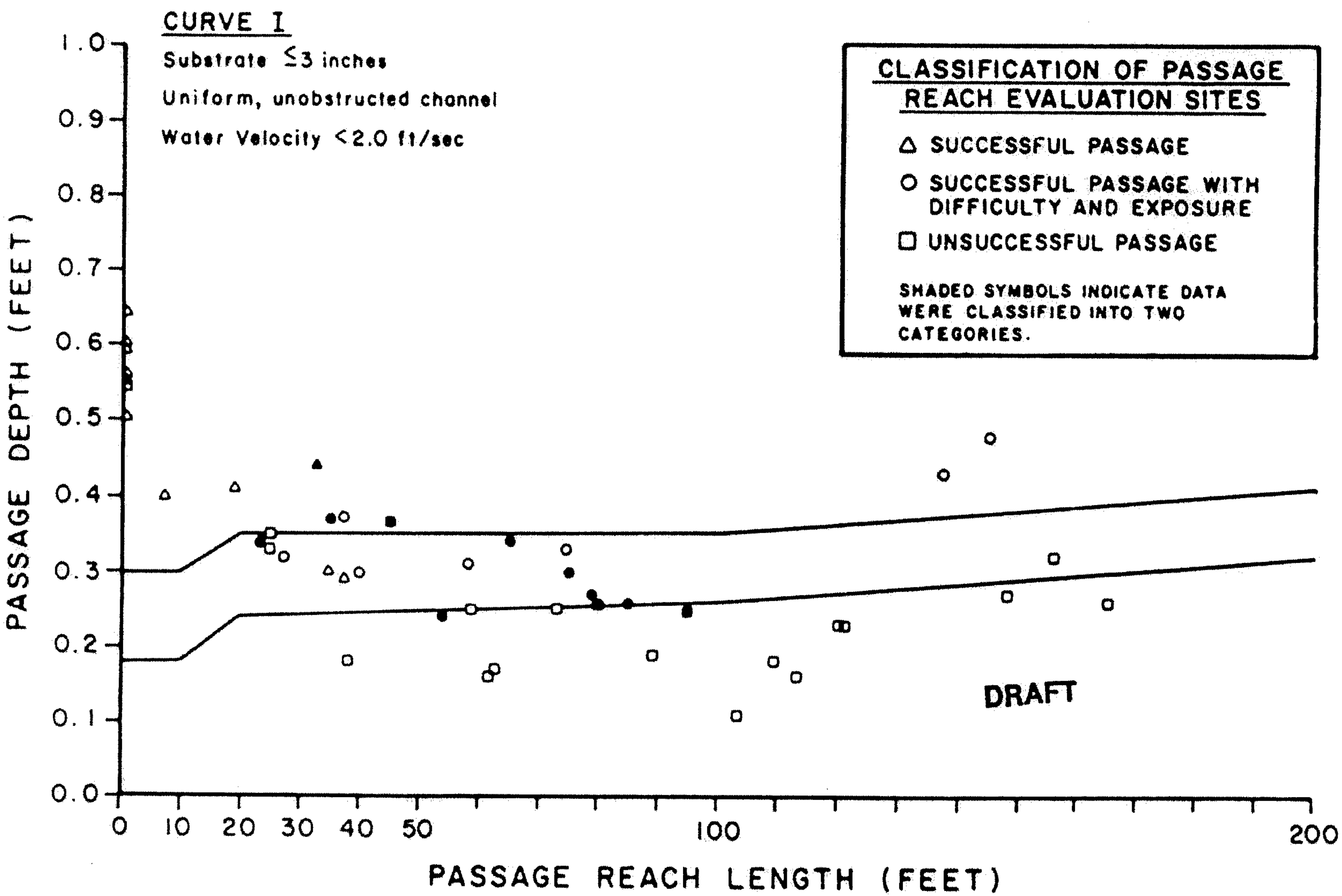

Figure 3. Original Criteria Curve I plotted with chum salmon passage data collected at all passage reaches within sloughs and side channels.

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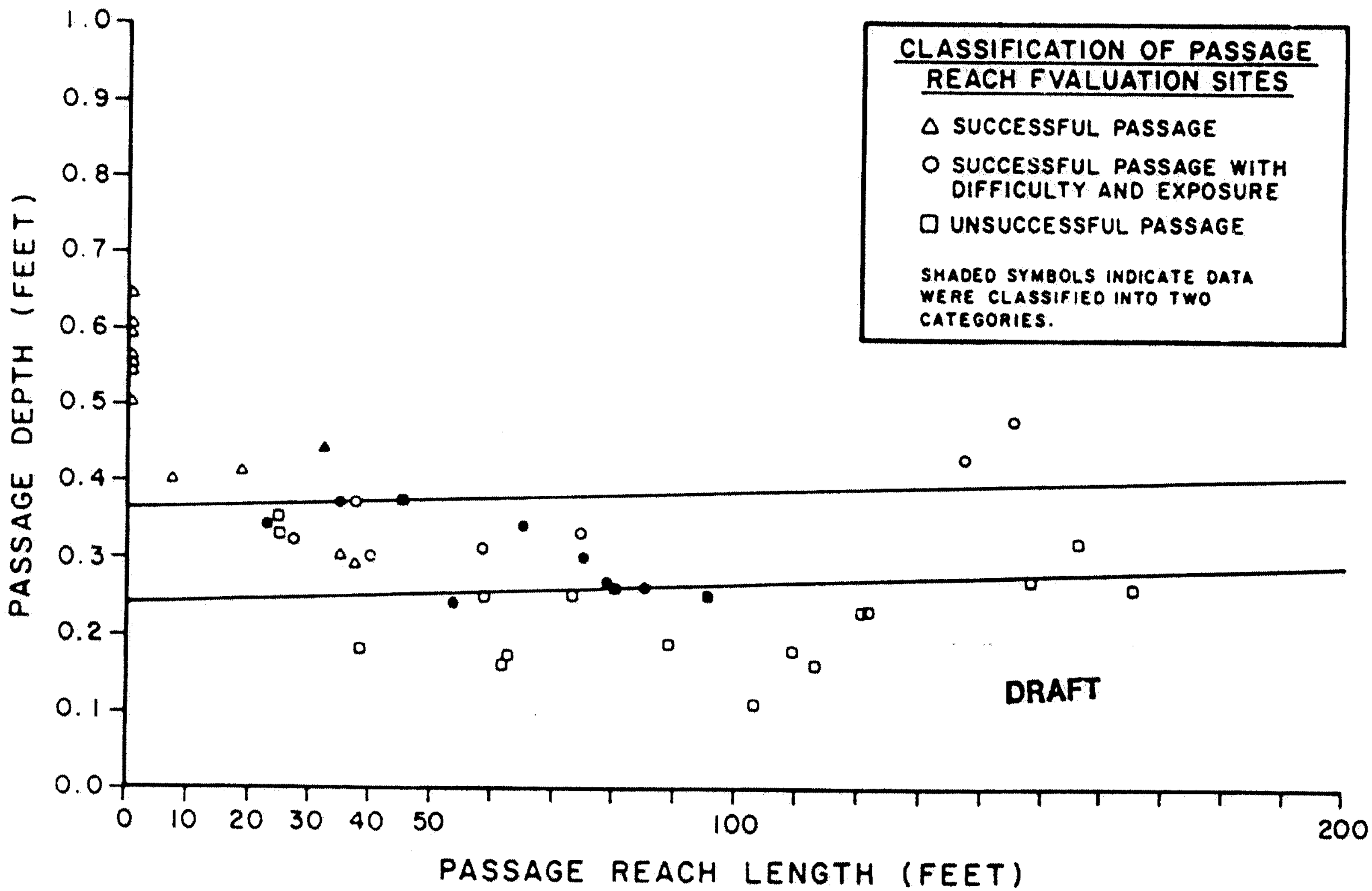

Figure 4. Revised passage criteria thresholds for successful and unsuccessful passage of chum salmon within sloughs and side channels in the middle reach of the Susitna River.

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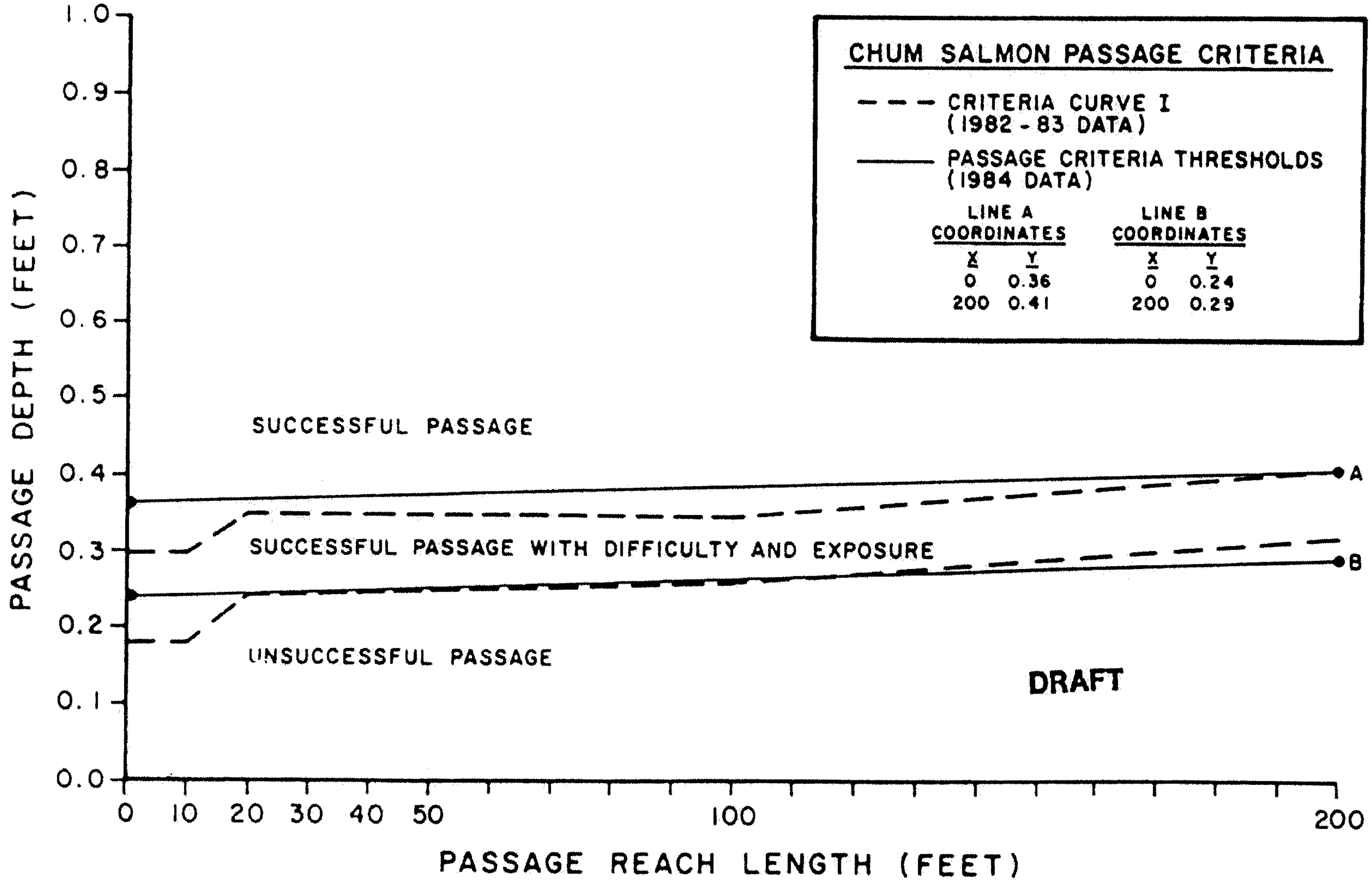

Figure 5. Comparison of original Criteria Curve I with revised passage criteria thresholds for successful and unsuccessful passage of chum salmon.

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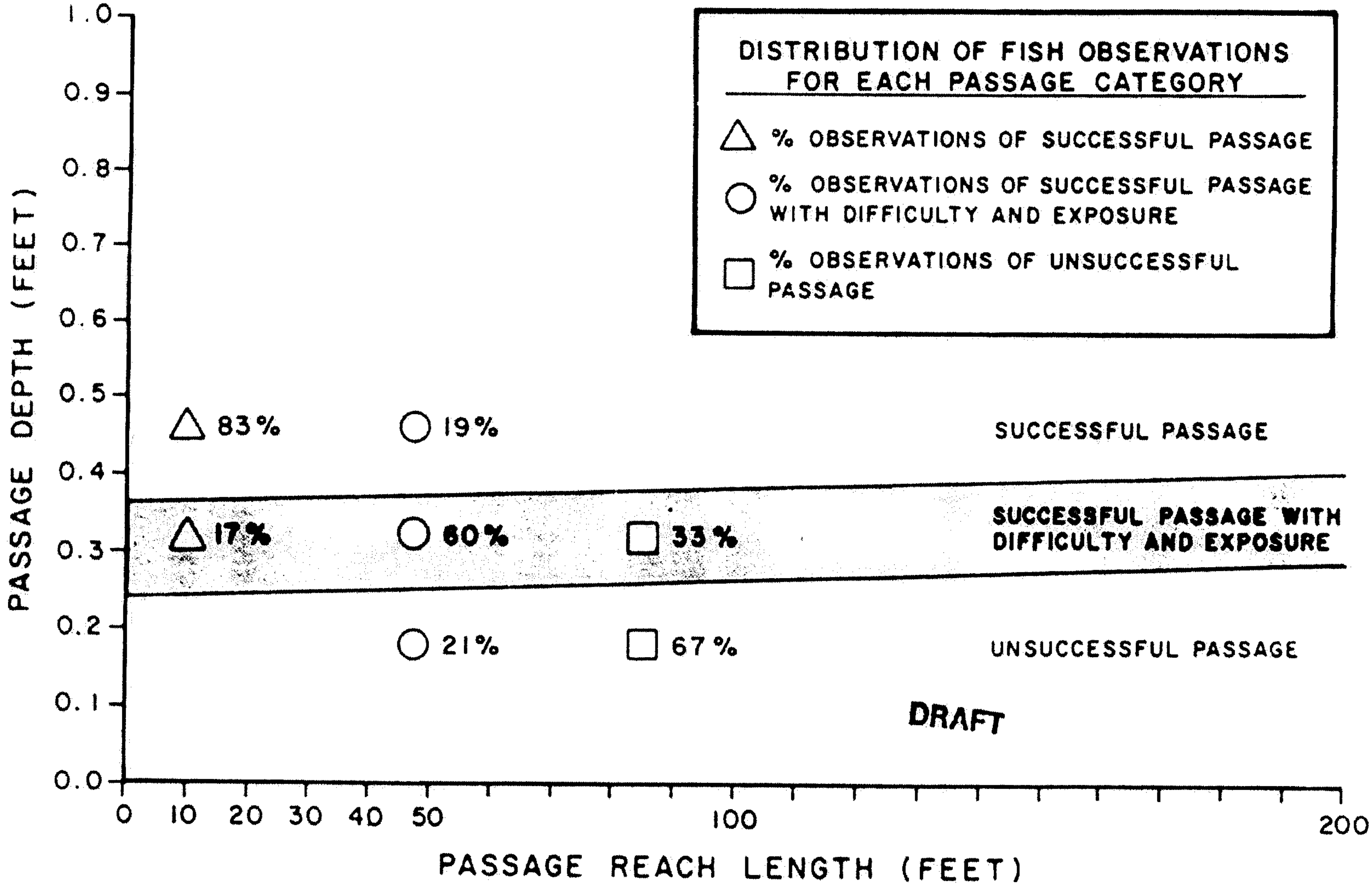

Figure 6. Percent distribution of fish passage observations for each category of passage in relation to the revised passage criteria thresholds.

represents the range of lengths and depths corresponding to the various categories of salmon passage. Criteria Curve II, however, does not appear to adequately represent salmon passage data collected at applicable sites. The majority of these data fall well below the threshold limit for successful and unsuccessful passage indicating that this curve is not an accurate representation of natural passage conditions.

Based on field observations of fish passage conducted during the 1984 field season, one of the important assumptions regarding passage criteria appears to be inaccurate. This assumption is:

1. All passage reaches can be described as either uniform, straight channels with small substrate (less than or equal to 3 inches in diameter), or non-uniform, braided channels with large substrate (greater than 3 inches in diameter).

Exceptions to this assumption were encountered at several study site passage reaches (e.g. Sloughs 20 and 21) during the past field season. Non-uniform channels were observed in passage reaches with predominantly small substrate (See Table 3). Passage reaches with predominantly large substrate and uniform channels were also encountered. In these situations it was often very difficult to classify certain passage reaches under one particular criteria curve. The relative importance of the passage reach characteristics, channel configuration or substrate size, was evaluated. Based on field observations, differences in channel configuration appeared to have a greater overall effect on flow and therefore, on salmon passage conditions.

If substrate is disregarded in the salmon passage criteria analysis, the above assumption can be rewritten as follows:

1. All passage reaches can be described as either uniform, straight channels, or as non-uniform, braided channels.

This assumption indicates that passage reaches can still be classified into two categories. Classifying established passage reaches into one of these two categories reveals that 71% of the passage reaches are characterized by non-uniform channels. Based on this information, passage reaches in the middle reach of the Susitna River are predominantly characterized by non-uniform channels.

When length and depth data for both uniform and non-uniform passage reaches are plotted separately (Figures 1 and 2) and together (Figure 3) there are no significant differences in the plotted data that would require the need for two sets of curves. The combined data closely fit Criteria Curve I for uniform channels. Criteria Curve II, for non-uniform channels, appears to overestimate water depths needed for successful passage. This was verified in the field when measuring lengths of passage reaches using the Criteria Curve II thalweg water depth of 0.67 feet. Passage reaches for which this depth value was used for establishing the upstream and downstream limits included depths where fish did not appear to have any passage problems. A thalweg water depth of approximately 0.50 feet appeared to be a more accurate indicator of the depth of water at which fish would first encounter passage difficulty.

It appears that Criteria Curve I more closely fits the salmon passage data collected during the PVS regardless of the channel configuration and substrate size. For this reason, supported with field observations, it was determined that only one set of passage criteria are necessary. These salmon passage criteria thresholds are similar to Criteria Curve I with some adjustments to the successful and unsuccessful curves.

Due to revisions of the salmon passage criteria, a reevaluation of passage reaches should be conducted to more accurately estimate mainstem discharges and local flows required for successful and unsuccessful passage conditions. In some cases these new criteria may also result in the reevaluation of passage reaches established during 1984. However, it should be noted that since Criteria Curve II overestimated depths, the required flow regimes for successful and unsuccessful passage are conservative and would still be valid for providing fish passage. A reevaluation of these flows using the new criteria can only result in lower values of previously established discharge or local flow estimates. The present data may be adequate for the purposes of this study as the revised estimates would most likely be minimal.

CONCLUSIONS

1. All passage reaches can be described as either uniform, straight channels or as non-uniform, braided channels. Passage reaches in the middle reach of the Susitna River are predominantly non-uniform.

2. The passage data indicate that two separate sets of criteria curves are not required to describe passage requirements for chum salmon.

3. The thalweg depth threshold of 0.67 feet from Criteria Curve II is an overestimate of the water depth required for successful passage for chum salmon. A thalweg depth of 0.5 feet is a more accurate indicator of the depth at which salmon would first encounter passage difficulty.

4. The revised salmon passage criteria are represented by two straight lines, referred to as threshold limits, which best fit the passage data collected during 1984. The threshold limits represent the criteria for successful and unsuccessful passage of chum salmon in the middle reach of the Susitna River.

5. The distribution of fish passage field observations in relation to the threshold limits for successful and unsuccessful passage of chum salmon support the revision of the original criteria curves.

6. Field observations and passage data collected during 1984 do not verify the downward inflection represented by the first 20 feet of the original criteria curves. Straight lines were extrapolated through this area to the passage depth scale in the revised passage criteria threshold limits.

7. Passage depth appears to be the critical physical factor affecting salmon passage. Based on the threshold limits for successful and unsuccessful passage of chum salmon, passage depth increases only slightly over passage reach lengths up to 200 feet.

8. Passage reaches should be reevaluated utilizing revised threshold limits to more accurately estimate mainstem discharges and local flows required

for successful and unsuccessful passage conditions. Because passage criteria were revised downward, earlier flow projections would be acceptable but may be too conservative.

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