HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION Anchorage | DATE December 7, 1984

TO L. Gilbertson | NUMBER 4.3.16/4.3.1.1

FROM J. Bizer | Page 1

SUBJECT Interpretation of ADF&G SuHydro Mainstem and Local Flow Values for Successful Passage Conditions

Sautner et al (1984) presents results of a study to define mainstem and local slough discharge requirements to allow passage of adult chum and sockeye salmon to spawning areas in sloughs and side channels. Estimates of mainstem discharge were calculated assuming a negligible slough discharge and, conversely, estimates of slough discharges were calculated assuming negligible influence of mainstem discharges. For passage reaches near the mouths of the sloughs and side channels, the estimated mainstem flow requirements are extremely conservative since they neglect local flow contribution. In fact, both mainstem discharge and local slough discharge interact to provide water depth in those passage reaches. The analysis presented by Sautner et al (1984) makes no attempt to integrate the two sources of water which present passage conditions. The purpose of this memorandum is to present a first approximation of how local slough discharge and mainstem discharge may interact to provide adequate passage conditions at mainstem discharges considerably less than the independent estimates of mainstem discharge backwater effects.

In the evaluation of the effects of the proposed Susitna Project on aquatic resources downstream of the dams, a principle question centers on the maintenance of salmon populations which utilize habitats which are directly affected by mainstem discharge. The maintenance of these populations depends upon the effects of mainstem discharge on the immigration of adult salmon through the main channel of the Susitna River, the movement of adult salmon into spawning areas, and the use of various habitat types of salmon for spawning, incubation and rearing.

The evaluation of conditions necessary for salmon to gain access to spawning areas is a key step in the overall evaluation of the effects of the proposed project on existing salmon populations and their habitats. Approximately 15-25 percent of the chum salmon (approximately 5000 fish), which enter the Devil Canyon to Talkeetna reach of the Susitna River to spawn, utilize side slough and side channel habitats (Barrett, et al. 1984). Nearly 100 percent of the sockeye salmon (approximately 1500 fish) which enter the Devil Canyon to Talkeetna reach to spawn utilize side slough and side channel for spawning.

Side sloughs are overflow channels of the mainstem which convey turbid mainstem water when mainstem discharge is relatively high. This occurs during the summer open water months. When mainstem discharge is lower, the upstream ends of the sloughs are not overtopped and are similar to small tributaries which convey clear, local surface runoff and groundwater upwelling. These sources of water together are termed local flow or local discharge. During low mainstem discharge conditions, side

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slough discharges range from about 1-2 cfs to more than 10 cfs depending upon whether or not small tributaries enter the sloughs. When the upstream ends of the sloughs are overtopped, slough discharges range upward of several hundred cubic feet of water per second.

Side channels are similar to side sloughs in structure and hydrologic relationships with the mainstem. The principle distinction between these two habitats is that the proportion of time which a side channel conveys mainstem water is considerably greater than that for side sloughs. Klinger and Trihey (1984) distinguish between side sloughs and side channels based on whether the channel is conveying mainstem water. A given channel is considered a side channel when it is conveying mainstem water and is considered a side slough when it is not. For purposes of this discussion, channels will be referred to as sloughs in this sense.

The ability of salmon to gain access to spawning areas within sloughs is dependent upon the depth of water within a given reach of the slough. In general, the shallower the water, the more difficult the passage conditions are for movement of salmon through the reach. The degree of difficulty is dependent not only upon the absolute depth of the water but also upon the length of the reach which must be traversed. Thus, salmon are able to negotiate very shallow water if the reach is short. However, somewhat greater depths are required if the reaches are longer. Reaches of the slough channels in which the water depths are sufficiently shallow to restrict movement of fish are termed passage reaches. Generally, passage reaches are located in riffle areas within the sloughs. For most sloughs, the depth of water through most passage reaches is dependent upon the slough discharge. Slough discharge, in turn, is provided by local surface runoff and groundwater upwelling. (This disregards the influence of mainstem discharge sufficiently great to overtop the upstream end of the channel).

For passage reaches located near the downstream ends of the sloughs, water depth is influenced not only by discharge from the slough, but also by backwater effects of the mainstem. The backwater effect on the depth of water in a given passage reach is evident when the water surface elevation of the mainstem at that passage reach is greater than that which can be solely attributed to local slough discharge.

Studies conducted by ADF&G SuHydro during 1982 (ADF&G 1983a,b) resulted in estimates of the access conditions corresponding to various mainstem discharges and water surface elevations at a limited number of sloughs.

Results presented for the 1983 studies (Sautner et al. 1984) expand the number of sloughs and side channels studied and provide independent estimates of local flow and mainstem discharges corresponding to threshold values for successful and unsuccessful passage conditions. These results have raised several questions regarding the local and mainstem discharges necessary to provide successful passage conditions for chum and sockeye salmon.

The results presented by ADF&G SuHydro (Sautner et al. 1984) are the first attempts to show the relationship between mainstem and local flows in providing adequate access conditions to the sloughs and side channels for chum and sockeye salmon. Previous reports (ADF&G 1983a, b and Trihey 1982) evaluated passage conditions only on the basis of mainstem flow. In some cases, this led to a relatively low mainstem discharge requirement since it did not account for local flow contribution to passage depths for salmon access into the sloughs. In other cases, the analyses resulted in high estimates of mainstem discharges required to provide adequate passage conditions for adult salmon. The latest report presents results of independent calculations of flows, either mainstem or local, which provide successful or unsuccessful passage conditions.

In understanding these values, it must be kept clearly in mind that mainstem flows and local flows required to provide successful passage conditions were calculated independently of each other. In the report (Sautner et al. 1984), the mainstem flow determined to provide successful passage conditions was calculated under the assumption of negligible local flow, likewise, the local flow required to provide the same passage conditions was calculated assuming no direct mainstem backwater influence. A similar rationale was used to calculate mainstem and local flows to meet the unsuccessful/successful-with-difficulty threshold criterion. By integrating the mainstem and local flow calculations, a somewhat better appraisal of passage conditions relative to mainstem flow becomes apparent.

To provide a basis for comparing conditions for a passage reach at various mainstem discharges, ADF&G (Sautner et al. 1984) established three passage conditions: unsuccessful, successful with difficulty, and successful. These correspond to the terms acute, restricted and unrestricted, respectively, as previously used by ADF&G (1983a, b). The three passage conditions are distinguished by threshold depths within the passage reaches. The specific threshold passage depths for the three passage conditions are also dependent upon the length of the passage reach; that is, the threshold depths are greater for long passage reaches than for short passage reaches. Two sets of criteria curves were developed by ADF&G and are presented in the latest report as Figures 6-4 and 6-5 (Sautner, et al. 1984). Two curves were developed to account for two different types of passage reaches: uniform channel and non-uniform channel.

An explanation of the results obtained for Passage Reaches (PR) I and II at Slough 11 is provided below to demonstrate how these results can be integrated into an analysis of access conditions.

In the 1983 ADF&G Reports (1983 a, b), it is estimated that a mainstem discharge of 6,700 cfs is sufficient to provide successful (unrestricted) access conditions into Slough 11. Results of the 1984 analysis indicate that mainstem discharges of 16,200 cfs and 33,200 cfs are required to provide successful passage conditions at Passage Reaches I and II respectively. These results were obtained by determining the streambed elevations at the highest points of the thalweg profile 1/ in the passage reaches, determining the water depths and water surface elevations required to meet the passage criteria, and then determining what mainstem discharge is necessary to provide those water surface elevations (depths). This portion of the analysis was based upon the assumption of a negligible local flow from the slough itself.

For PR I, the critical point in the passage reach (that is, the highest point along the thalweg) is at an elevation of 667.75 ft, mean sea level, (MSL). This is shown on Figure 6-E-7 of the ADF&G report (reprinted here as Figure 1) at approximately Station 3+50. By adding the passage depths which distinguish unsuccessful from successful-with-difficulty and successful-with-difficulty from successful, (0.32 and 0.41 ft, respectively) the water surface elevations for unsuccessful and successful conditions are less than El. 668.09 and greater than El. 668.16, respectively. (The passage depth requirements are from Curve I, Figure 6-4 and assume a passage reach length of 250 ft). The water surface elevations and thalweg elevation are depicted in Figure 2 as constants over the range of mainstem discharges.

1/ The thalweg elevation is defined as the lowest elevation or the deepest point of a cross-section through a water channel. A thalweg profile is constructed by connecting the deepest points of several cross-sections along the length of the channel.

By superimposing the stage-discharge relationship from the data obtained from a staff gage located at the mouth of Slough 11 (ADF&G Gage 135.3W1) (Quane, et. al 1984), it is possible to determine the mainstem discharges corresponding to unsuccessful and successful passage threshold conditions. The staff gage data are plotted on Figure 2. Based upon this curve along, and assuming no influence of local flow, mainstem discharges less than 15,200 cfs result in unsuccessful (acute) access conditions at PR I and mainstem discharges greater than 16,200 cfs result in successful (unrestricted) passage conditions.

A second superimposition of local flow vs water surface elevation within PR I onto Figure 2 requires the definition of the relationship between local flow and mainstem flow for values of mainstem discharge less than that which will overtop of the upstream berm. This relationship is highly variable since the local slough flow is a composite of local surface runoff and groundwater upwelling.

A relationship between mainstem discharge and groundwater upwelling has been defined for Slough 11 (Beaver 1984). The relationship is based on discharge data recorded at the R&M recording station in Slough 11 near PR III (Figure 1). Since there is little local runoff into Slough 11 (it has a small drainage basin), it was assumed that all local flow was due to groundwater upwelling. The relationship between slough groundwater flow (S) and mainstem discharge measured at Gold Creek (G) is:

$$S = 1.51 + 0.000102G \qquad (1)$$

For various mainstem dischrges, this equation defines the corresponding groundwater discharge at the recordig station in Slough 11. At points further downstream from the recording station, e.g. within PR I, additional local flow is acquired from further groundwater upwelling. Woodward-Clyde (1984) estimated that the local flow at PR I is approximately 145 percent of the flow calculated at the Recording Station. (This assumes a linear increase in slough reach and also assumes the discharge at the recording station is 100 percent). Therefore, local slough flow at PR I can be scaled to mainstem discharge by the following equation:

$$S(PR\ I) = 1.45\ (1.51 + 0.000102G) \qquad (2)$$

Use of Equation 2 allows scaling of slough flow to the corresponding mainstem discharge. The scaling for PR I in Slough 11 is shown as the bottom x-axis scale in Figure 2.

Based upon field observations and estimates (Sautner et al. 1984), the local flows which present unsuccessful and successful passage conditions at PR I in Slough 11 (assuming no mainstem backwater effects) are less than 3 cfs and greater than 4 cfs, respectively. By converting these to mainstem discharges using equation 2, 3 cfs corresponds to a mainstem discharge of 5,480 cfs and 4 cfs corresponds to a mainstem discharge of 12,240 cfs.

By plotting these values on Figure 2, where 3 cfs is the unsuccessful threshold criterion (at WSEL 668.07) and 4 cfs is the successful threshold criterion (at WSEL 668.16), a relationship between local flows and mainstem discharges which provide various access conditions is described. Successful access conditions are provided through the groundwater mechanism when mainstem discharge is greater than 12,200 cfs. In contrast mainstem discharge provides successful passage conditions through backwater effects alone at PR I only when mainstem discharge exceeds 16,000 cfs.

A similar analysis for PR II within Slough 11 is presented in Figure 3. In this case the thalweg reference elevation is at El. 670.0 ft MSL and the passage depths corresponding to the unsuccessful and successful threshold criteria are 0.32 and 0.41 from Figure 6-4 (ADF&G 1984) for a passage reach length of 745 ft. The corresponding water surface elevations are 670.32 ft. MSL and 670.41 ft MSL, respectively. The mainstem stage discharge relationship used in Figure 3 is the same as for Figure 2, at Staff Gage 135.3W1. A staff gage is located within PR II. However, the stage-discharge relationship at the gage is highly influenced by slough discharge and does not define a representative relationship between mainstem discharge and water surface elevation assuming negligible slough flow. For this reason, the stage discharge relationship for staff gage 135.3W1 is used.

As derived in the ADF&G Report (Sautner et al. 1984) mainstem discharges of 31,900 and 33,200 cfs are required to meet the WSELs corresponding to the unsuccessful and successful passage criteria thresholds, assuming no influence of local flow.

The mainstem discharges required for the respective passage depths via the groundwater mechanism are less than those which are required to provide passage depth via the backwater mechanism. Scaling of slough discharge to mainstem discharge assumes that slough discharge at PR II is 127 percent of the discharge at the recording station (Woodward-Clyde 1984). Therefore, the following equation was used to scale slough discharge (S) to mainstem discharge (G):

$$S\ (PR\ II) = 1.27\ (1.51 = 0.000102G) \qquad (3)$$

Local flows at the unsuccessful and successful passage condition thresholds are estimated to be 3 and 4 cfs, respectively (Sautner et al. 1984). These local groundwater flows correspond to mainstem discharges of 8,350 and 16,075 cfs, respectively.

A somewhat different relationship between groundwater upwelling in slough discharge and mainstem discharge is presented by Woodward Clyde (1984). The equation presented by Woodward-Clyde for Slough 11 is more conservative and includes data collected during the summer of 1984. The equations used by Woodward-Clyde for PR I and PR 11 in Slough II are:

$$S = 1.45\ (1.43 + .000087G) \quad \text{for PR I} \qquad (4)$$

$$S = 1.27\ (1.43 + .000087G) \quad \text{for PR II} \qquad (5)$$

The corresponding mainstem flows for 3 and 4 cfs flows through PR I and PR II are:

		Passage Conditions	
		Unsuccesful	Successful
PR I	Local Discharge	< 3 cfs	> 4 cfs
	Mainstem Discharge	< 7340 cfs	> 15270 cfs
PR II	Local Discharge	< 3 cfs	> 4 cfs
	Mainstem Discharge	< 10715 cfs	> 19765

The above analyses and comparisons for PRs I and II in Slough 11 are summarized in Table 1. It is evident that passage conditions are dependent on mainstem discharge in one of two ways: directly as a function of the backwater effect and indirectly as a function of mainstem discharge influence on the rate of groundwater upwelling. From the information presented in Table 1, it is concluded that successful passage conditions are present at PR I when mainstem discharge is 12,240 cfs or greater. Similarly, it is concluded that successful passage conditions

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are present at PR II when mainstem discharge is 16,075 cfs. In both cases presented above, the influence of mainstem discharge in providing successful conditions is via the groundwater mechanism. In other passage reaches in other sloughs, the influence of the mainstem via the backwater mechanism may be predominant. This determination of mainstem discharges required for each passage reach would provide a more comprehensive evaluation of effects of the project on adult salmon passage into spawning areas.

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cc: E. Marchegiani, APA
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Table 1

Susitna Hydroelectric Project
Summary of Mainstem Discharge Relationships
to Slough 11 Passage Conditions

Passage Reach	Threshold	Passage Depth Criteria	Thalweg Elevation	Threshold Water Surface Elevation	Threshold Mainstem Discharge Corresponding to WSEL via Backwater	Threshold Local Flow Corresponding to WSEL	Threshold Mainstem Discharge Corresponding to WSEL via Local flow (Equations 2 and 3)
		(ft)	(ft MSL)	(ft MSL)	(cfs)	(cfs)	(cfs)
I	Unsuccessful	0.32	667.75	668.07	15,200	3	5,480
I	Successful	0.41	667.75	668.16	16,200	4	12,240
II	Unsuccessful	0.32	670.00	670.32	31,900	3	8,350
II	Successful	0.41	670.00	670.41	33,200	4	16,075

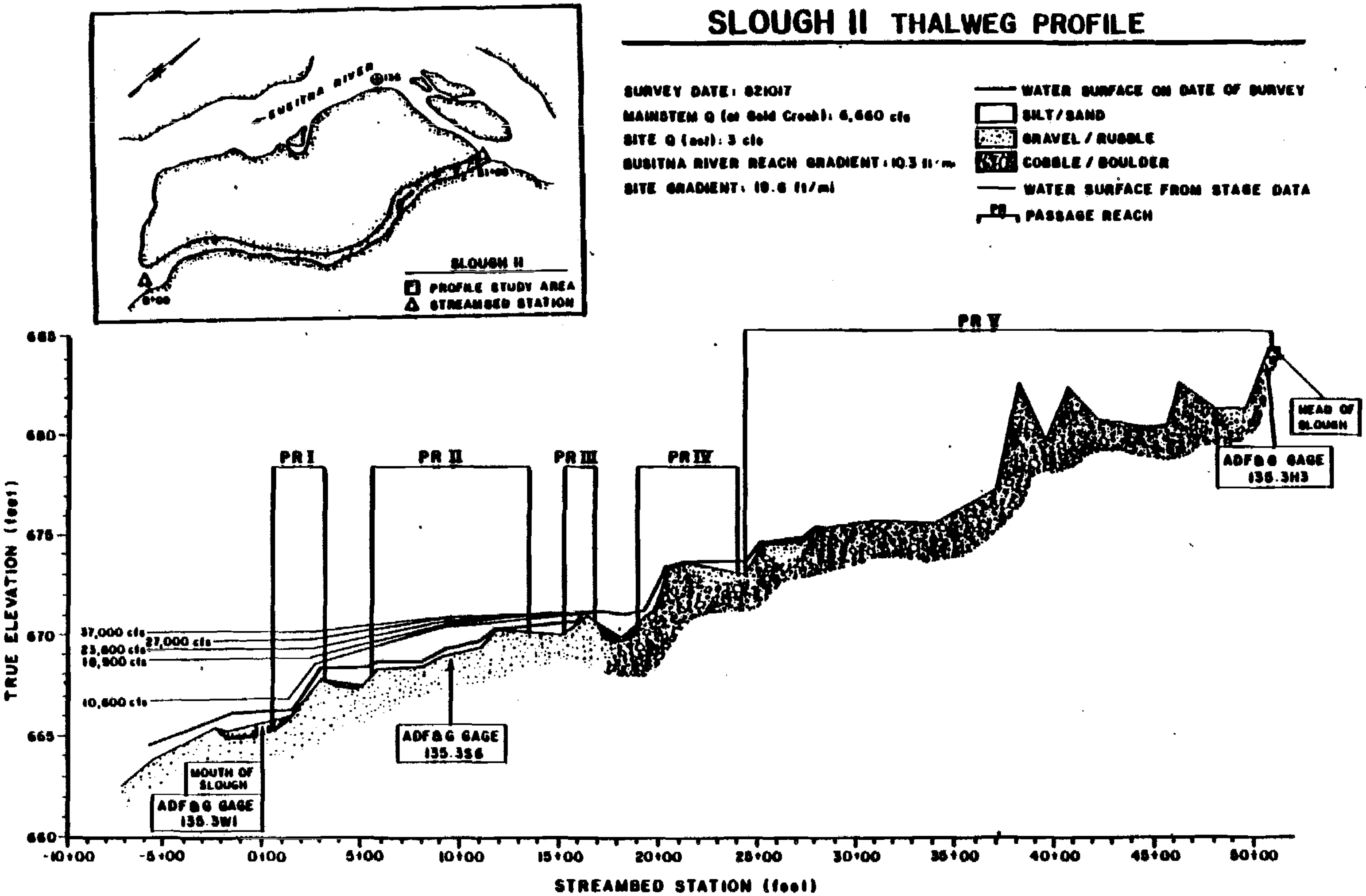

Figure 6-E-7. Thalweg profile of Slough 11.

FIGURE 2: Discharge and Passage Conditions at Passage Reach I in Slough 11

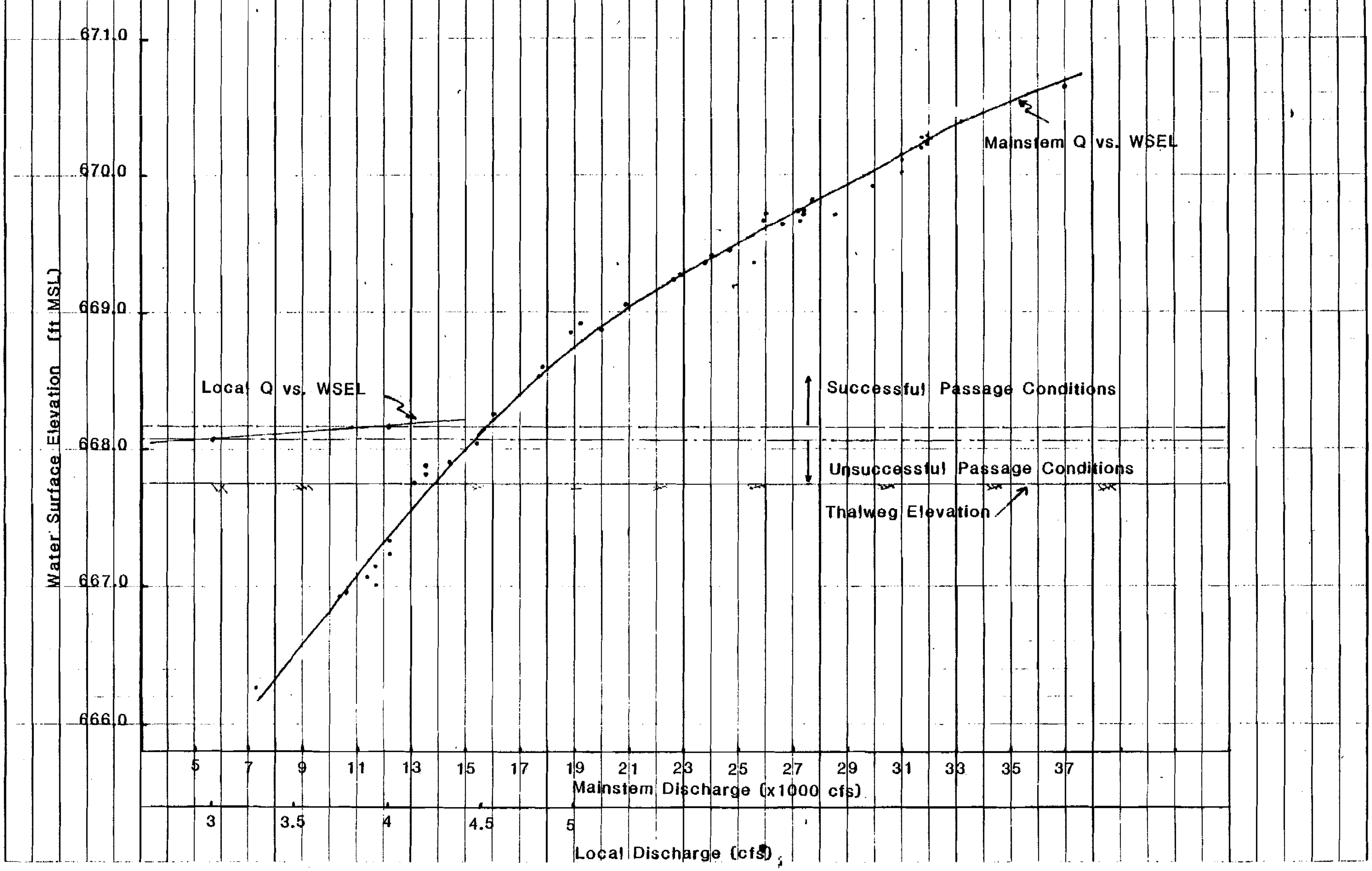

FIGURE 3: Discharge and Passage Conditions at Passage Reach II in Slough 11