Exxon Valdez Oil Spill
Restoration Project Annual Report

Tributary Restoration and Development Project:
Port Dick Creek, Lower Cook Inlet, Alaska

Restoration Project 98139A2
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: The Port Dick Creek Tributary Spawning Habitat Restoration Project was initiated under the restoration surveys (Restoration Study Number 105) in FY/91 and FY/92 which resulted in the selection of Port Dick Creek for further instream restoration work. A tributary restoration feasibility analysis was initiated at this site in 1991 and was continued through the spring of 1993. The restoration project was initially approved for continued funding in FY/94 and FY/95, however, spending was placed on hold pending further review and discussion at the supplemental workshop held in Anchorage January, 1995. A Detailed Project Description " Proposed Spawning Channel Construction Project Port Dick Creek, Lower Cook Inlet" (Restoration Project 95139), was written, and the project was subsequently approved by the Exxon Valdez Oil Spill Trustee Council (EVOSTC) in May, 1995. In June 1996, two tributaries to Port Dick Creek were excavated to produce stable surface flow which created an estimated 2,500 m^2 of additional spawning habitat. A three-year evaluation project was initiated in FY97 to determine project success by determining fry production and streambed stability. This is the third annual report to be submitted.

Abstract: Port Dick Creek, located 25 miles southeast of Homer on the outer coast of the Kenai Peninsula, is an important pink and chum salmon producer in Lower Cook Inlet (LCI). Because the stream experienced declines in total returns since 1987, the Alaska Department of Fish and Game (ADF&G) conducted a five-year feasibility analysis and initiated EVOS-funded efforts to restore spawning habitat in two former tributaries taken out of production by the 1964 Alaska earthquake. Approximately 3,000 m^3 of material was excavated from both tributaries and since 1996, over 3,300 pink and chum salmon have colonized and spawned in the new habitat. To date, spawning adults of both species potentially deposited over 5,000,000 eggs with over 458,000 fry estimated emerging from the tributaries.

Key Words: Alluvial, chum salmon, *Exxon Valdez* oil spill, groundwater, habitat, instream, *Oncorhynchus gorbuscha*, *Oncorhynchus keta*, pink salmon, Port Dick, restoration, sedimentation, spawning channel.

Project Data: *Description of data* - Data collected to support the spawning tributary design includes water level and temperature data. *Format* - text files. *Custodian* - Mark Dickson, 3298 Douglas Place, Homer, Alaska 99603-8027, e-mail: mark_dickson@fishgame.state.ak.us. *Availability* – upon request.

Citation:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In 1991, the Alaska Department of Fish and Game, (ADF&G) Commercial Fisheries Management and Development Division (CFM&D), conducted restoration surveys (R105) on the outer coast of the Kenai Peninsula to identify pink salmon *Onchorynchus gorbusca* and chum salmon *Onchorynchus keta* spawning systems that would benefit from instream habitat restoration. Port Dick Creek, located within Kachemak Bay State Wilderness Park approximately 25 miles southeast of Homer (Figure 1) was chosen because 1) it is considered one of the more important wild pink and chum salmon production streams in the Lower Cook Inlet area; 2) the 1964 earthquake caused an uplift of material within two tributaries of Port Dick Creek that virtually eliminated the available spawning habitat that was in existence prior to the earthquake (Val McLay, Homer fisherman, Personal communication); and 3) the total return of chum salmon to Port Dick Creek has declined in recent years.

The total return (catch & escapement) of Port Dick Creek Chum salmon has averaged only 4,600 fish for the ten year period, 1989-1998, compared to the previous 15 year period (1974-1988) of 31,000 fish (Figure 2). A compete closure on directed commercial fishing for Port Dick Creek chum salmon has been in effect since 1994 and the biological escapement goal, established at 4,000 fish, has been met only twice since 1988 ADF&G (*in press*). The primary species targeted is the native chum salmon of Port Dick Creek; however, pink salmon will also benefit from the instream restoration project.

The goal of the restoration project is to reverse the decline in chum and pink salmon stock abundance and provide for a harvestable surplus as a mitigative measure to address the results of the *Exxon Valdez* Oil Spill (EVOS). If stable surface water can be restored within the two Port Dick Creek tributaries, then annual fry production of 500 and 297 fry/m^2 can be expected at a spawning density of 1.0 female/m^2 for pink and chum salmon respectively (McNeil, 1969; Heard, 1978; Lister et. al, 1980; Bonnel, 1991).

The two intermittent but largely subterranean tributaries of the Port Dick Creek watershed were selected for restoration as shown in Figure 3, and designated as the primary and secondary Tributaries. The larger primary tributary intersects Port Dick Creek near the high tide line and receives its surface water flow from a small lake of less than 4 ha. at an elevation of 300 m. Prior to the 1964 earthquake, the primary tributary had a stable surface water system that successfully produced pink and chum salmon (Val McLay, Homer fisherman, personal communications). The lower 150 m of the primary tributary was affected by uplift from the earthquake, causing a dry streambed of rock and cobble during times of average to low discharge. The nearby secondary tributary (Figure 3) had an intermittent surface water flow due to fluctuations in its groundwater source. Previous to restoration there was no evidence of salmon spawning within the secondary tributary; however, it provided an opportunity to create additional spawning habitat within the Port Dick Creek drainage. Feasibility studies conducted from 1991 through 1995 were designed to determine the suitability of excavating the tributaries to increase spawning habitat. The studies revealed that during the winter months surface water withdrew 10-80 cm below streambed level in the primary tributary and 10-30 cm in the secondary tributary (Dudiak et al., 1996). The tributaries were carefully designed from the collected data to withstand two extremes, low and high water events with a goal of sustaining long term salmon habitat.

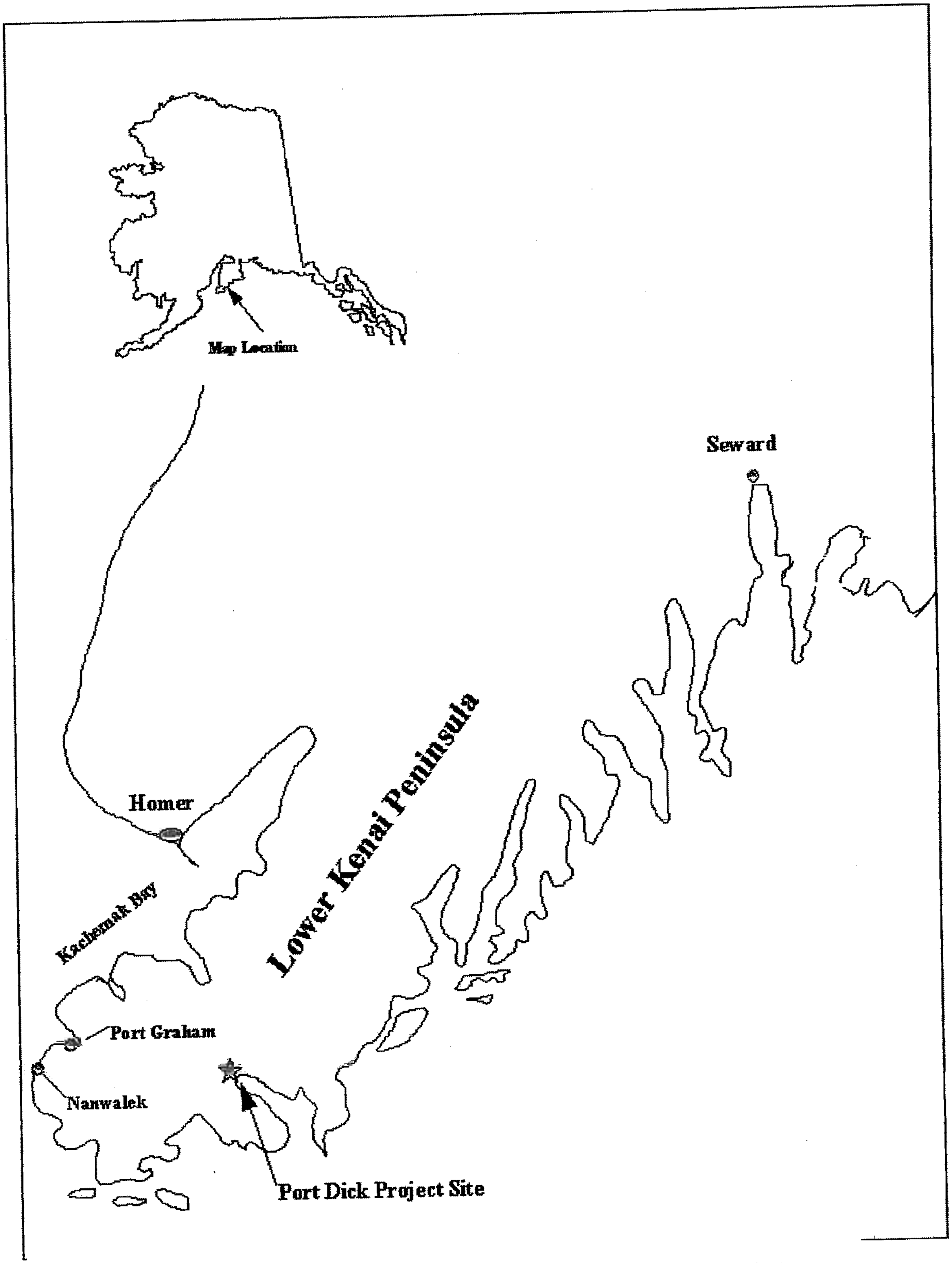

Figure 1. Map of Lower Cook Inlet showing the location of the Port Dick Creek Project.

In June of 1996, approximately 3,000 m^3 of deposited material was excavated from both tributaries creating up to 2,500 m^2 of stable spawning habitat. In July and August 1996, an estimated 1,229 pink and 466 chum salmon colonized and spawned in both tributaries depositing an estimated 1,517,935 pink and chum salmon eggs. The following spring ADF&G field staff enumerated 146,936 pink and 131,519 chum fry from the primary and 34,405 pink fry from the secondary tributary for a total of 312,860 fry. Colonization and spawner abundance for subsequent years, 1997 and 1998 were estimated at 938 and 3,361 fish for pink and chum respectively; both tributaries (Table 1). Mean length at emergence for chum (39.2 mm) and pink fry (33.9 mm) falls within the size range expected for emergent chum and pink fry throughout their Pacific range as discussed in Groot & Margolis (1991).

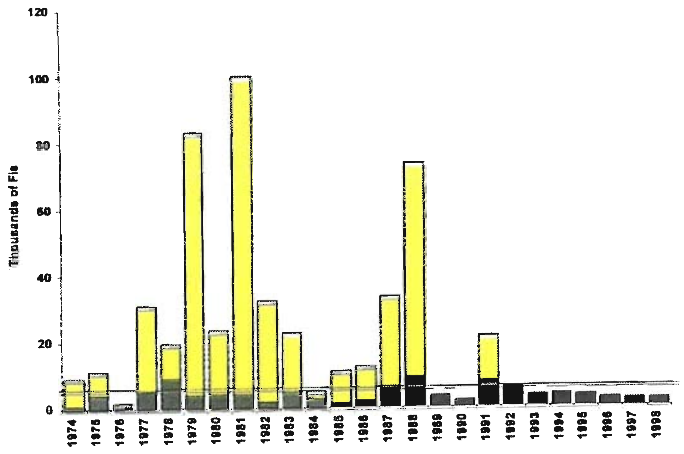

Figure 2. Total return (catch & escapement) of Port Dick Creek Chum Salmon, 1974-1998.

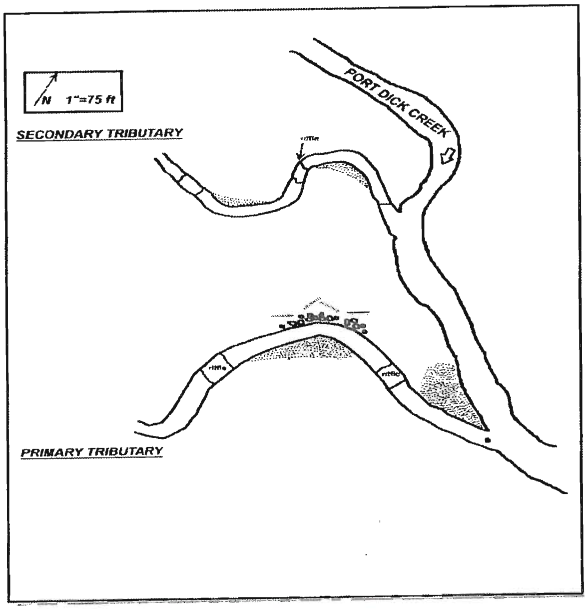

Figure 3. Diagram of the Primary and Secondary Tributaries entering Port Dick Creek.

The tributaries were designed from data collected from the feasibility analysis to withstand two extremes, low and high water events, with a goal to sustain spawning channel stability. Project evaluation is limited to overall survivability, i.e. spawning success as measured by fry production. Additional project success is evaluated through long term monitoring and evaluation of the physical stability of the tributaries by evaluating sediment and bedload transport as well as the stability of riffles and streambanks in the project site area.

This is the fifth year of the project funded by the EVOS Trustee Council. The feasibility study, 1991-1995, was jointly funded by ADF&G and the EVOS Trustee council.

OBJECTIVES

The initial objectives of restoring spawning habitat within the primary and secondary tributary was accomplished in June 1996. Current objectives include a program to determine overall survivability through fry production (fry produced/m^2) as well as sedimentologic stability as related to the restored tributaries. Work performed during FY99 is intended to accomplish the following:

1. Continue to estimate spawning success in the restored tributaries through egg to fry survivals and fry production, and estimate adult production as a result of the increased spawning habitat.
2. Continue to evaluate the success of the restored tributaries through sediment transport analysis.
3. Prepare annual Port Dick Detailed Project Descriptions and annual reports. Prepare long term monitoring results for peer review and evaluation in preparation for publication.
4. Monitor and evaluate water/tributary parameters including sediment transport parameters approximately six times per year.

METHODS

Study Area

Port Dick Creek is located on the Outer Gulf Coast of the Kenai Peninsula on the exposed coastline of the Gulf of Alaska (Figure 1). The area is characterized and influenced by the warming effect of the maritime currents of the North Gulf Coast, and annual rainfall can exceed 60 inches ADNR (1994). The predominate vegetation type is Sitka Spruce and Western Hemlock forest and is considered climax. Sitka Spruce commonly reach a diameter of 24 inches. The Port Dick Creek corridor is narrow (less than 250 m) with adjacent slopes in excess of 30%.

Project Evaluation

Successful instream habitat restoration and research requires cautious planning and competent scientific evaluation. It remains essential that restoration projects be thoroughly documented and objectively evaluated so that we can learn from project performance to improve future efforts (Kondorf et al., 1996). Two components exist with this project to measure success, the overall fishery survival and the physical stability evaluation component. For the fishery component, fry production and size at emergence (length), as well as hydrologic parameter monitoring (temperature, salinity and water velocity, stream stage and discharge), address the suitability of the restored spawning habitat to produce salmon fry. Bonnel (1991), found that fry production (fry produced per unit area), rather than egg to fry survival, may be a more suitable method to measure project success and longevity because of complicating factors influencing variability in estimating egg to fry survival. These factors include uncertainty in spawner counts, degree of egg retention, variations in fecundity, predation and problems associated with fry trapping.

One of the principal factors to consider with respect to fry production at this site, however, is the long-term stability of the spawning habitat. This is being evaluated using several techniques including tracer gravel, scour chains and surveyed streambed transects. These studies use the physical parameter data also needed for the biological evaluation, in particular hourly stream stage records of flood events.

Spawner Abundance and Fry Production

Colonization and spawner abundance was estimated. The spawning escapement for each tributary was determined from periodic ground (foot) surveys by a 2-person CFM&D ground survey crew as part of the annual program to enumerate spawning escapements in 11 Lower Cook Inlet (LCI) index streams. To standardize the escapement, ground survey data from both tributaries were generated into daily escapement estimates using stream life data (number of days) live and dead count, the number of surveys and the time between surveys Yuen (1993). Accumulated pink and chum salmon escapements are then estimated from:

$$\frac{\sum_{i=1}^{n} \frac{(x_i + x_{i-1})}{2} (d_i - d_{i-1})}{10.8}$$

where n = number of surveys, d_i = Julian calendar date of survey i, and x_i = number of live pink or chum salmon observed in the study stream during the survey i. To estimate spawner abundance we took periodic stream survey data and generated accumulated escapement estimates using a stream life value of 10.8 days. The stream life value was derived by averaging stream life values from streams in Prince William Sound that had similar characteristics as Port Dick Creek, Bue et al.1998; Brian Bue, Personal communication, ADF&G, Anchorage). Because stream life is variable and that the value can change from one system to another depending on size, timing of return as well as other factors, we present in Table 1, a range of spawner abundance estimates based on stream life values of 8.5 days (Perrin et al.1990; Bue et al.1998) and 17.5 days (Helle, 1964). The higher end of the range (17.5 days) is the value that ADF&G has used for over 30 years to develop the pink and chum spawning abundance data base.

To estimate fry production (fry produced/m^2) we simply divided the number of fry by the area of habitat available for spawning within each tributary. The area of each tributary was determined by averaging the widths measured with hand held tapes at several points and multiplying by the length. The spawning area was defined as habitat with water > 6" which is preferred by pink and chum salmon (Groot and Margolis, 1991).

To enumerate seaward migrating fry, intertidal fry traps were installed at the mouth of each tributary (Figures 4 and 5). At the primary tributary, migrating fry entered the trap through a 1.5 m square tunnel entrance that funnels to a cylindrical entrance at the trap. Meshed wings extended from each side of the tunnel entrance to the north and south shores of the tributary and effectively fished 100% of the tributary width (Figure 4). The trap is rectangular in shape, 1.0 m x 0.85 m x 0.80 m (L x W x H), with the up-stream fashioned into a funnel shaped entrance. Baffles were installed to divert current and provide resting areas for captured fry.

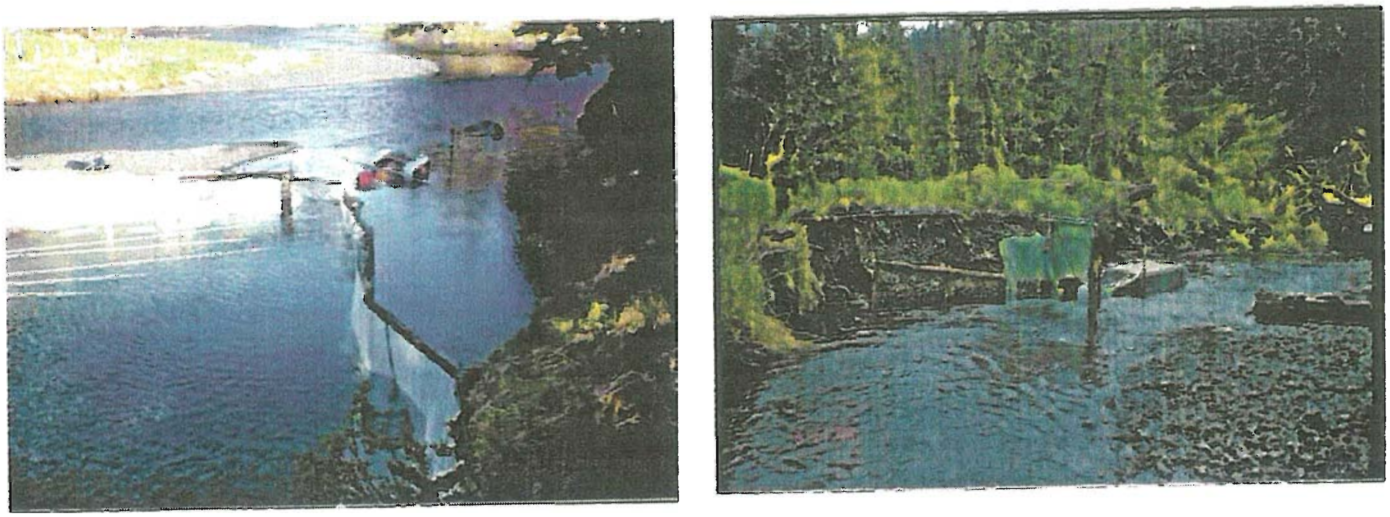

Figure 4. Picture of the fry trap used to capture pink and chum salmon fry that emigrated the primary (left) and secondary tributary, Port Dick Creek, Alaska.

The primary tributary is located within the intertidal zone and is affected by tides greater than 10.5' as recorded in the Cordova, Alaska District Tide Table. At tide elevations less than 10.5’ the tributary is unaffected and measures approximately 11.0 m wide and 1.0 m deep at the trap location (Figure 4 and 5). At elevations of 10.5’ and above, the maximum width increases to more than 20 m and the depth increases to over 2.0 m. The trap was designed to float during tidal intrusions. To maintain trapping effectiveness the fyke wing on the north side of the fry trap

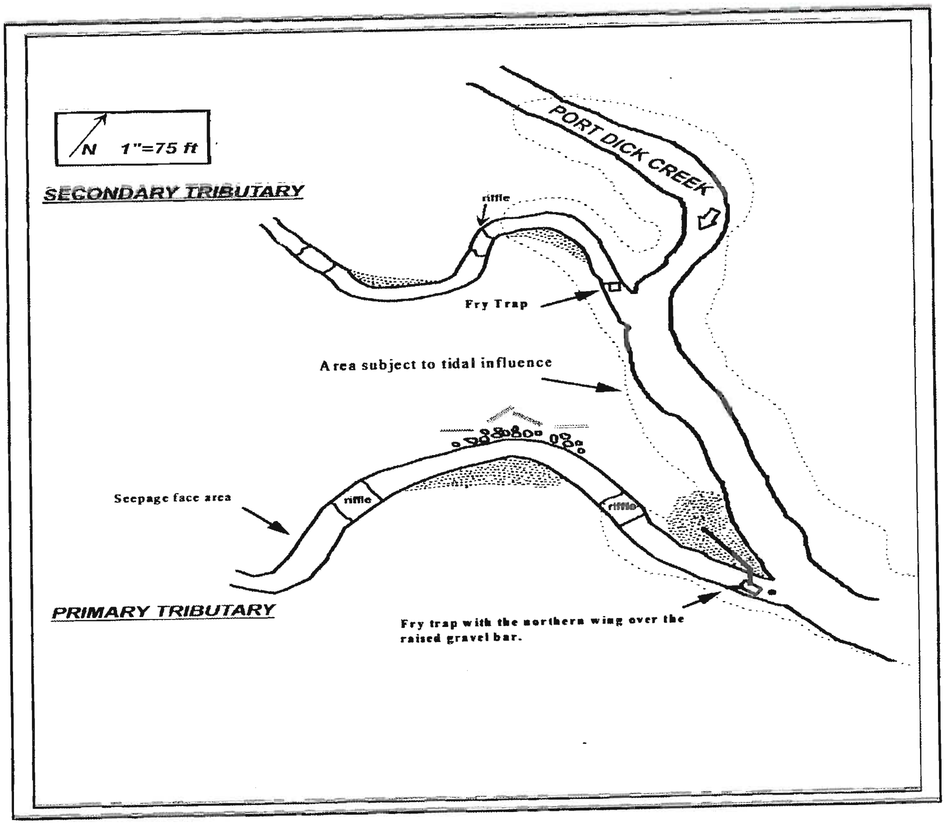

Figure 5. Diagram of the Primary and Secondary tributaries with the location of the fry traps and the area subject to tidal influence.

was extended over an adjacent raised gravel bar that is submerged by tides greater than 12.0' (Figure 5).

A fry trap similar in size and shape (Figure 4) was used in the secondary tributary. Meshed fyke panels attached to the trap from each side of the funnel entrance extended to the east and west streambanks and so that the fyke trap effectively fished 100% of the tributary (Figures 4 and 5). Tidal influence is minimal at this location and does not require that the fry trap float. The trap was checked several times per day and trapped fry were identified to species, enumerated, and recorded in the fyke net log.

All fry that entered the traps were enumerated. When the numbers of fry were manageable (e.g. < 4,000), they were identified to species, counted with hand held tally counters, and recorded in the fyke net log. When numbers of emigrating fry were too great to be counted by hand a subsampling and bio-massing procedure was used. Then, all fry entering the trap were weighed to the nearest 0.1 kg using a hanging scale. Twenty fish per day were subsampled to determine average weight (to the nearest 1.0 g in a tared container using an Ohaus CT 600 portable electronic scale) To maintain accurate species composition during peak emigration, several hundred additional fish were sampled for specie composition throughout the 24 hour period. To calculate the total number of fish for a given 24 hour period, the total weight of the catch was multiplied by the ratio of pink to chum fry and divided by the average weight of each specie.

Physical Parameter Evaluation

Four types of sensors were installed following excavation of the tributaries in June 1996: water temperature, level, velocity and conductivity. Figure 6 shows the general measurement locations and field arrangement of the equipment. Project methods are to continue measuring spawning channel bed-load sediment transport to address the long-term stability of the spawning habitat created through the restoration project.

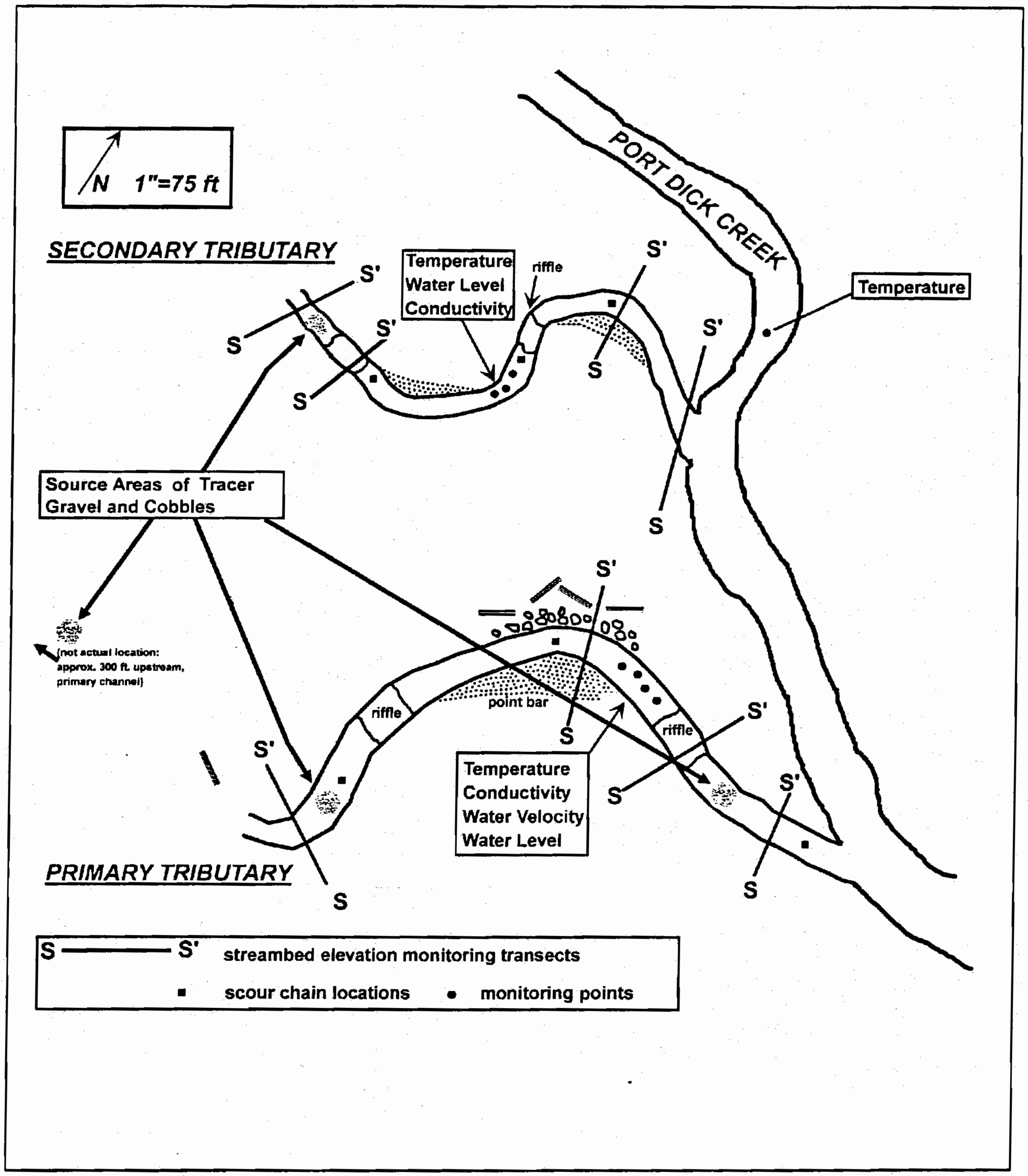

Figure 6. Physical parameter monitoring locations at the Primary and Secondary Tributary, Port Dick Creek.

The changing channel geometry after construction and sensitivity of salmon eggs to stream stage necessitated monitoring of water levels after the spawning channel was constructed. Stream stage is also used to determine the timing of flood events and their discharge, which is critical for interpreting the sediment transport data. Stream stage is measured using water level pressure transducers with a precision of 0.01 ft of water within the pressure range expected at the site. The transducers measure pressure relative to atmospheric pressure in standpipes mounted into the streambank and connected to the streambed (one for each tributary).

Surface water temperature is measured to an accuracy < 0.4 C at least every hour, in both tributaries. In 1997 identical thermistors were added within the spawning gravel as well to better determine temperature effects directly on salmon eggs during incubation.

When comparing results of the present study to previous studies it is useful to have similar accuracy. Temperature effects on salmon cited in the literature (e.g. Pauley, 1988; Wangaard, 1983) correlate egg to fry survival rates to temperature using similar accuracy. The temperature probes are secured within the top 10 cm of substrate to facilitate comparisons of temperature to fry production rates and to protect the sensors. An additional temperature monitoring point in Port Dick Creek is used to provide a comparison to the known chum and wild pink salmon runs in that reach as shown in Figure 6.

Water velocity measurements are taken to estimate discharge in both tributaries, as well as estimate the near-bed water velocity for sediment transport purposes. The water velocity measurement station is now intended for use in obtaining near-bed water velocities in flooding conditions.

The effects of tides on the tributaries are partly gauged by one conductivity sensor in each of the tributaries. Seawater has a conductivity of approximately 40 to 50 msiemens, which requires an electrode spacing much greater than conductivity sensors for fresh water. The conductivity meter used is calibrated from fresh water to full strength sea water, however the electrode spacing is designed for discerning salinity changes in the spawning channel. Both conductivity sensors are temperature compensated.

The physical parameter data is collected using datalogging equipment that easily retains measurements every hour for 2 months. A solar panel was added in 1997 to increase the battery life due to additional sensors and a projected more intensive monitoring schedule in FY98. That is, several rapid sampling intervals will be monitored in FY98 to obtain more information on tidal and flood events, which will help augment the data collected for more detailed sediment transport analyses.

Streambed Stability

Stream stability is affected by channel morphology and channel material (Myers et al., 1992), both factors of which were changed during spawning channel excavation. Four methods typically used in detailed sediment transport studies of gravel-bedded streams are being used to monitor long-term stream stability for this project. The methods include measurement and comparison of changes in surveyed stream transects, use of tracer cobbles and gravel, measurement of changes in scour chain positions and measurements of surface water energy slope.

The eight stream transects shown in Figure 6 are surveyed periodically for both streambed elevation change and water discharge measurements. The streambed elevations are made using a Total Station surveying instrument and prism rod. Each measured point is recorded in both

The eight stream transects shown in Figure 6 are surveyed periodically for both streambed elevation change and water discharge measurements. The streambed elevations are made using a Total Station surveying instrument and prism rod. Each measured point is recorded in both position and elevation with a vertical precision of approximately 0.01 feet. The elevations of the cross sections are made in reference to seven surveyed monuments, all of which are referenced to bedrock. The transects are taken along a surveyors tape stretched above the streambed to aid in the surveying. The number of measurements for each cross section generally ranges from 20 to 40 measurements.

The elevation and position of each point along a cross section is compared to previous cross sections to determine a sediment budget and to monitor the spawning bed surface area.

Near-bed water velocity is a parameter that is periodically monitored using an on-line water velocity probe. The bed shear velocity, a parameter important in gravel-bedded stream sediment transport models, may be estimated using near bed velocity (Wilcock, 1996).

Bedload sampling has the advantage of directly sampling the rate of bedload transport along the streambed for a given measured discharge, however the Helley-Smith method is not easily implemented given the timing of flood events that coincide with inclement weather at this remote site. Sufficient discharge must be available for transport, particularly a problem for gravel transport which has longer residence times than finer sediment. Therefore a third water level monitoring station was added to help determine when gravel transport events would be occurring, and to monitor their duration. This station will be online in April, 1998, and will help in the implementation of bedload sampling 'traps' to replace the Helley-Smith method.

Finally, tracer gravel and cobbles are being used to determine rates of gravel transport, which is of particular concern for the post excavation phase of the spawning channels. Port Dick Creek Tributary gravel and cobbles were constructed into tracer material. Some of the gravel used is in the range useful for salmon spawning. The cobbles and gravel were marked using holes drilled in the material and each filled with a unique numbered copper disc and epoxy (the tracers must be unobtrusive, yet easy to find). The shape of the tracer material was as rounded as possible in order to reduce shape-induced uncertainties in the course of their movement (Cavazza, 1981).

The weight and orthogonal axes of each tracer were measured. The tracers were then carefully replaced with other gravel into the streambed at different tracer strip source locations. In addition to the effects of any resulting bed armor disturbance on transport, it is also known that gravel sized bedload at a one location may not be entrained in the same flood event where bedload is entrained at an adjacent location.

Therefore it is typically important that a lot of tracers be used to lessen these effects. There are four tracer strip locations, and each tracer source area originally contained 170 tracers. The tracers are being relocated periodically with a metal detector to determine the amount of movement from the source area for the specific tracer material during periods of high discharge. Significant movement of the tracers seem to occur only during significant flood events. Each tracer will be re-weighed periodically throughout the long-term monitoring, and re-deployed to the source area if found near the mouth of either tributary.

Use of scour chains is the final method for addressing streambed stability. Scour chains are an inexpensive method for determining the thickness of bed mobility (depth of scour and depth of fill) following high discharge events. The scour chains consist of vertically oriented and weighted stainless steel link chain (1 inch links). The length of horizontal chain and depth to the chain were recorded, and chains reoriented for measurements of subsequent high discharge events. This allows the evaluation of scour (flood) events such as the depth of bedload scour and/or depth of subsequent sediment burial. Such maximum-event data helps determine the mobility of sediment during high discharge (Gordon et al., 1992).

Sediment Transport Analyses

The measured sediment transport parameters will then be used in surface water models to help answer questions concerning the long term streambed stability, the short term ability for the channel to maintain its water depth and to determine what changes in the channel geometry could be made to improve the streambed stability. In addition, comparison studies are being made with other gravel-bedded stream studies in the literature.

One parameter that is becoming better defined at the Port Dick site is the 'flushing flow' or critical discharge necessary for significant bedload transport in these gravel-bedded streams (e.g. Kondolf, 1996). Other basic parameters that are useful in surface water modeling and that can be derived from the onsite data are shear stress, sedimentologic characteristics, stream width, stream depth profile and variations in discharge.

Models that use these parameters for gravel-bedded streams are continually being refined, researched and published. For example, Bridge et al. (1992) recently published a basic sediment transport model for gravel-bedded streams that includes the critical discharge parameter, Hassan and Church proposed a model for gravel movement using tracer data (1991) and a model for the mixing of bedload downgradient from a source area (1994). Whiting and Dietrich (1993) and Dietrich and Whiting (1989) have worked with models that include meanders in gravel bedded rivers, an important component at this site. In addition there are valuable published data sets for comparison studies available for gravel bedded flow, for example from laboratory flume studies (e.g. Pizzuto, 1990).

A final subject that is of interest to the site is studying the influence of small and large drop structures and their effect on gravel sediment transport. These topics often appear in the context of bridge construction, since bridges frequently must be founded on erodible material. The scour of a gravel-bedded river is different at the location of a drop structure, so a variety of studies (e.g. Laursen et al., 1984) indicate the stable sediment size at sloping sills and erosion depth directly below drop structures.

Elements of more specific papers on drop structures will also be useful in deriving models that describe sediment transport at drop structures (e.g. Humpherys, 1986; Fiuzat, 1987;

Christodoulou, 1985). A related topic is streambank stability analyses (e.g. Chang, 1990). These topics are useful to keep in mind should future channel changes be undertaken.

RESULTS

Project Evaluation

Colonization and Spawning: 1998

Chum Salmon escapement into Port Dick Creek, estimated at 1,840 fish in 1998, continued to decline for the fifth consecutive year while the minimum biological escapement goal (established at 4,000 fish) has not been achieved since 1993 ADF&G (*in press*). In contrast, the pink salmon escapement (estimated at 57,100 fish in 1998. has steadily increased from a 6,600 fish escapement in 1995. The biological escapement goal for pink salmon at Port Dick Creek is set at 20,000 to 100,000 fish.

Colonization and spawning by chum salmon into the primary tributary decreased from 525 fish in 1997 to 133 in 1998 while 19 chums were estimated to have spawned in the secondary tributary, down from 105 in 1997. Colonization and spawning by pink salmon into both tributaries in 1998 increased by an order of magnitude (308 in 1997 to 3,209 in 1998; Table 1).

Table 1. Summary of pink and chum salmon spawner abundance estimates to the primary and secondary tributaries since 1996 (first year spawning habitat was restored). A stream life of 10.8 was chosen to provide a point estimate for abundance based on stream characteristics similar to previous work in Prince William Sound, Bue et al. (1998). A range of estimates (stream life 17.5 & 8.5 days) is presented to illustrate the variability associated with stream life and spawner abundance estimation.

Habitat Available[a]	**Primary Tributary ($1{,}200 m^2$)**						**Secondary Tributary ($800\ m^2$)**					
Species	**Pink**			**Chum**			**Pink**			**Chum**		
Stream life (days)	17.5	**10.8**	8.5	17.5	**10.8**	8.5	17.5	**10.8**	8.5	17.5	**10.8**	8.5
Spawner abundance (thousands of fish)												
1996	.422	**.936**	1.19	.282	**.458**	.582	.149	**.293**	.373	.008[a]	**.008**[a]	.008[a]
1997	.146	**.237**	.301	.324	**.525**	.667	.044	.071	.090	.065	**.105**	.133
1998	1.34	**2.18**	2.77	.082	**.133**	.169	.638	**1.03**	1.31	.012	**.019**	.024

a *Inadequate spawner survey data; number is peak survey value.*

Assessment of spatial spawning activity within the tributaries was limited to observations by an ADF&G ground survey crew while conducting spawner abundance surveys. Seven observations 1,7,15,27 July and 7,26 August, indicated that the majority of the spawning activity in the primary tributary, by both species, occurred between Port Dick Creek and the first riffle. Spawning in the secondary tributary was concentrated in the lower 2/3 of the tributary (Figure 3). Exceptions were noted in both tributaries during increased surface water flow. Then, fish were observed spawning above the second riffle in the primary tributary and throughout the secondary tributary.

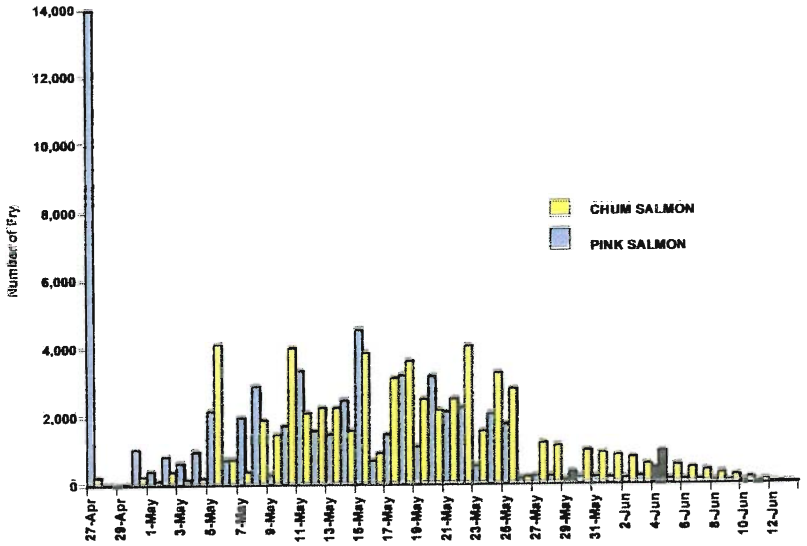

Figure 7. Pink and chum fry emergence from the primary tributary, Port Dick Creek, 1998. The trap was removed from the tributary 12 of 18 days due to high water events 28 May through 13 June. Values for 28 May – 11 June were interpolated except for June 3 & 4 where actual values were used. A river otter was found in the trap on 26 May.

Spawning densities (females/m^2) were calculated for each tributary and expressed in relation to area actually available for spawning. In the primary tributary, the upper 30 m is developed into a seepage face (i.e. an area where instream structures are incorporated to diffuse flood energy and prevent streambed movement; Figure 5). As a result, approximately 300 m^2 is unavailable for spawning. Major flooding and transport events recorded during May 1998, resulted in streambank scouring and subsequent sediment deposition downstream of the first riffle within the primary tributary. Consequently, approximately 25% of the useable spawning habitat (as determined by qualitative observations) may have been unavailable for the 1998 spawning return. A thorough analysis of the "sediment wave" is continued in Stream Stability Evaluation. In the secondary tributary, the entire 150 m length (or 800 m^2) was available for spawning resulting in a combined total spawning area of 1,700 m^2. Spawning densities for pink salmon were recorded at 1.2 and 0.6 females/m^2 for the primary and secondary tributaries respectively. Spawning densities for chum salmon were considerably lower at 0.07 and 0.01 females/m^2 for the primary and secondary tributaries respectively (Table 2).

Spawning success, Primary Tributary (1997 Broodyear, 1998 Fry Emigration)

Adverse weather postponed travel to the project site and deployment of the fry traps was delayed until 26 April. Debris carried by rising water clogged the wings to the trap and forced the crew to lower the wings during the evening hours of 27-28 April. The emigration period was beset with flood events caused by high precipitation that forced the removal of the trap on 28 May and 30 May through 2 June and 5 June through 11 June. We were able to fish the trap for limited time on 29 May, 3 & 4 June.

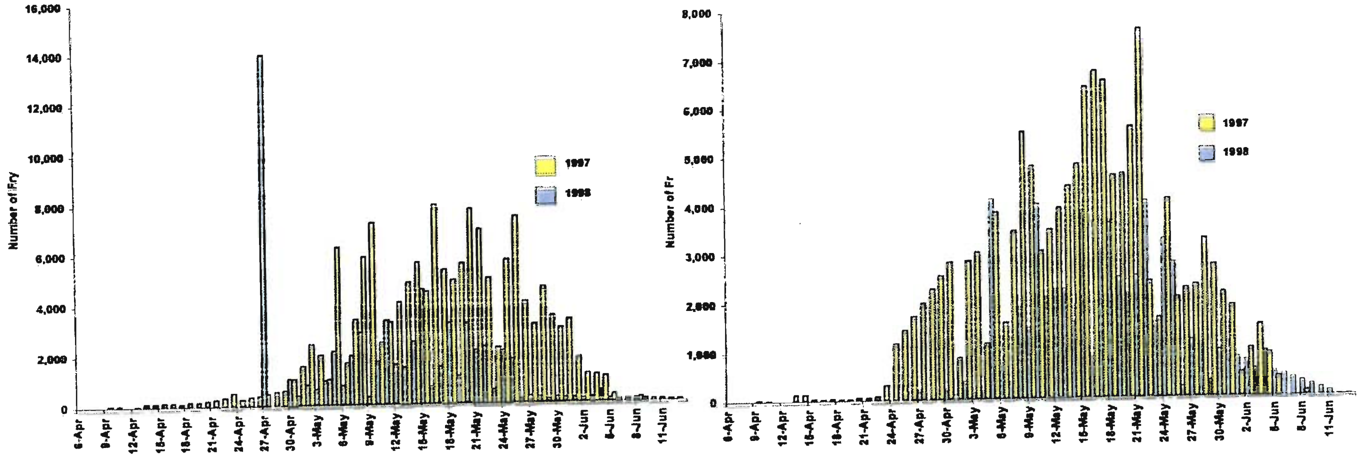

Figure 8. Emergent timing of pink (left) and chum salmon fry from the Primary tributary, 1997 and 1998. The 1998 data is interpolated 28 May – 11June except for 29 May and June 3 & 4 (dark bars) where actual data is used.

Table 2. Number of spawners and spawning densities for 1997 produced using a low and high value for stream life with the 1998 fry emergence and production, primary and secondary tributaries, Port Dick Creek. A stream life of 10.8 was chosen to provide a point estimate for abundance based on stream characteristics similar to previous work in Prince William Sound, Bue et al. (1998).

Habitat Available^a	**Primary Tributary (1,200m^2)**						**Secondary Tributary (800 m^2)**					
Species	**Pink**			**Chum**			**Pink**			**Chum**		
Streamlife (days)	17.5	10.8	8.5	17.5	10.8	8.5	17.5	10.8	8.5	17.5	10.8	8.5
No. of females^b	73	119	151	162	263	334	22	36	45	33	53	67
Spawning Density(f/m^2)	0.06	0.1	0.13	0.14	0.22	0.28	0.02	0.05	0.06	0.04	0.07	0.08
Fry Emergence	61,877			62,003			13,197			8,009		
Fry Production (fry/m)	51.6			52.0			16.6			10.2		

An estimated 61,877 pink and 62,003 chum fry (123,880 total) were enumerated through the primary tributary fry trap for the period ending 13 June (Figure 7). The peak daily emergence occurred on 27 April with 13,958 pink fry while peak chum output occurred on 5 May at 4,104 fry. A delay deploying the fry traps prevented monitoring of the initial emergence, however, the subsequent emergence trend developed similar to 1997 Figure 8. The high initial emergence of pink fry recorded on the first trapping day is shown to be associated with the first tidally-influenced surface water temperature spike of the spring shown in Figure 10.

The fry trap system in the primary tributary was placed as far downstream as possible without the stronger current of Port Dick Creek interfering. However, this left an estimated 132 m^2 of habitat uncounted downstream of the fyke net. (Figures 4 and 5). Spawning activity was noted within this area by the field staff. Given a production of 51.6 fry/m^2 for pink and 52.0 fry/m^2 for chum

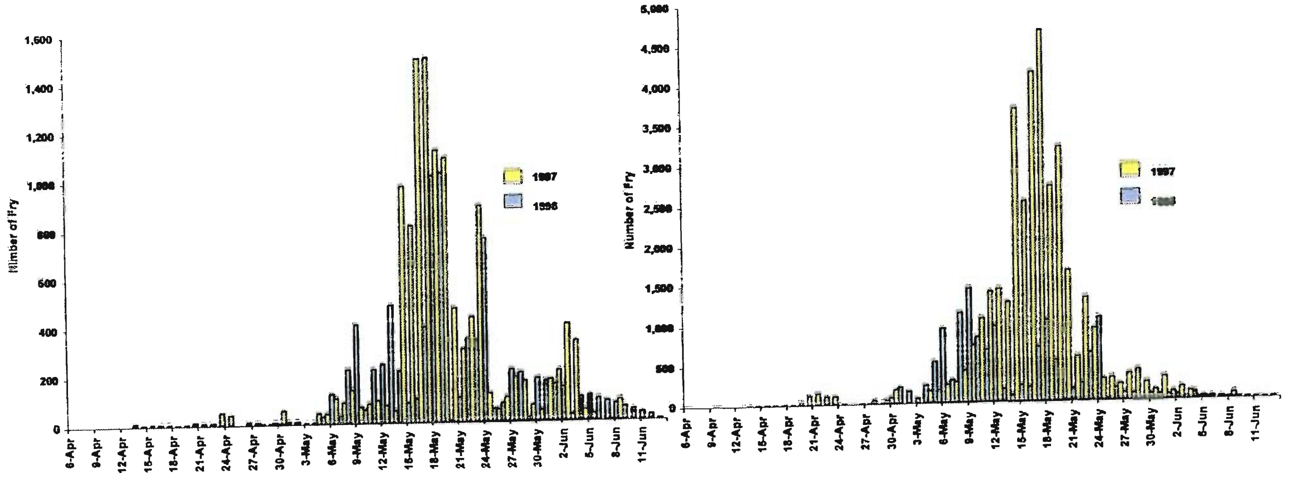

Figure 9. The 1997 and 1998 chum (left) and pink fry emigration from the secondary tributary, Port Dick Creek. A delay in the deployment of fry traps for 1998 prevented monitoring during early emergence. The 1998 data is interpolated 28 May – 11June except for 29 May and June 3 & 4 (dark bars) where actual data is used.

fry, as measured for the primary tributary, an additional 13,675 additional pink and chum fry may have emerged downstream of the fry trap.

Length at emergence (1997 data) was measured from 218 chum and 196 pink fry captured from the primary tributary. Mean lengths were calculated at 39.5 mm and 33.7 mm for pink and chum fry respectively. Length at emergence was not measured in 1998.

Spawning Success, Secondary Tributary: 1997 Broodyear, 1998 Fry Emigration

Fry trapping began on 27 April, with a daily output of 38 pink and 3 chum fry. The peak daily count occurred on 9 May for pink and 19 May for chum fry at 1,422 and 1,022 fry respectively (Figure 9). An estimated 13,197 pink and 8,009 chum fry, 21,206 total, were counted out of the secondary tributary (Table 2). The seasonal emigration pattern developed comparable to the primary tributary with respect to the seasonal temperature trend and peak fry output. Fry production was measured at 16.6 and 10.2 fry/m^2 for pink and chum respectively.

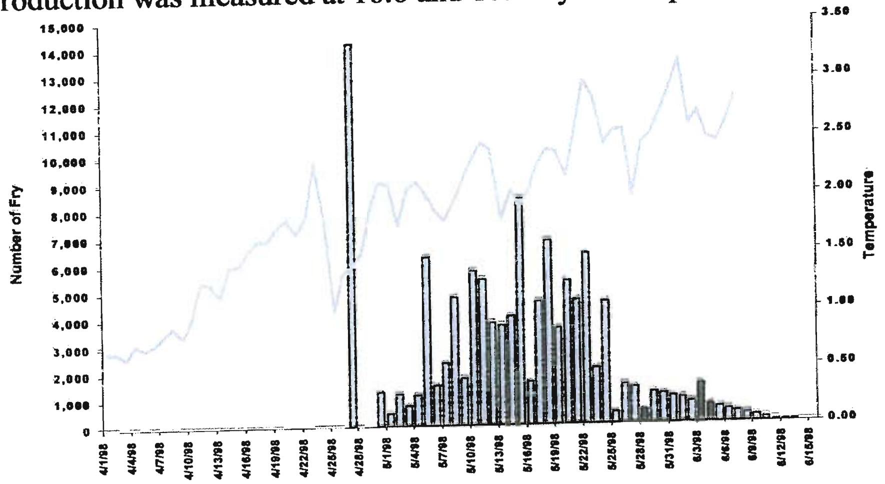

Figure 10. Pink and chum salmon fry emigration from the primary tributary with the seasonal trend of increasing surface water temperatures. Temperature data were 24 hour averages with the spikes a result of tidal intrusions of 10.5' or greater. The data is interpolated 28 May – 11June except for 29 May and June 3 & 4 (dark bars) where actual data is used

Stream Stability Evaluation

In evaluating the stream stability data it is important to keep in mind that constraints exist as to when the data can be collected in the field. For example, there is only a limited amount of time in the summer each year when the tracers can be recovered between spawning activity and the

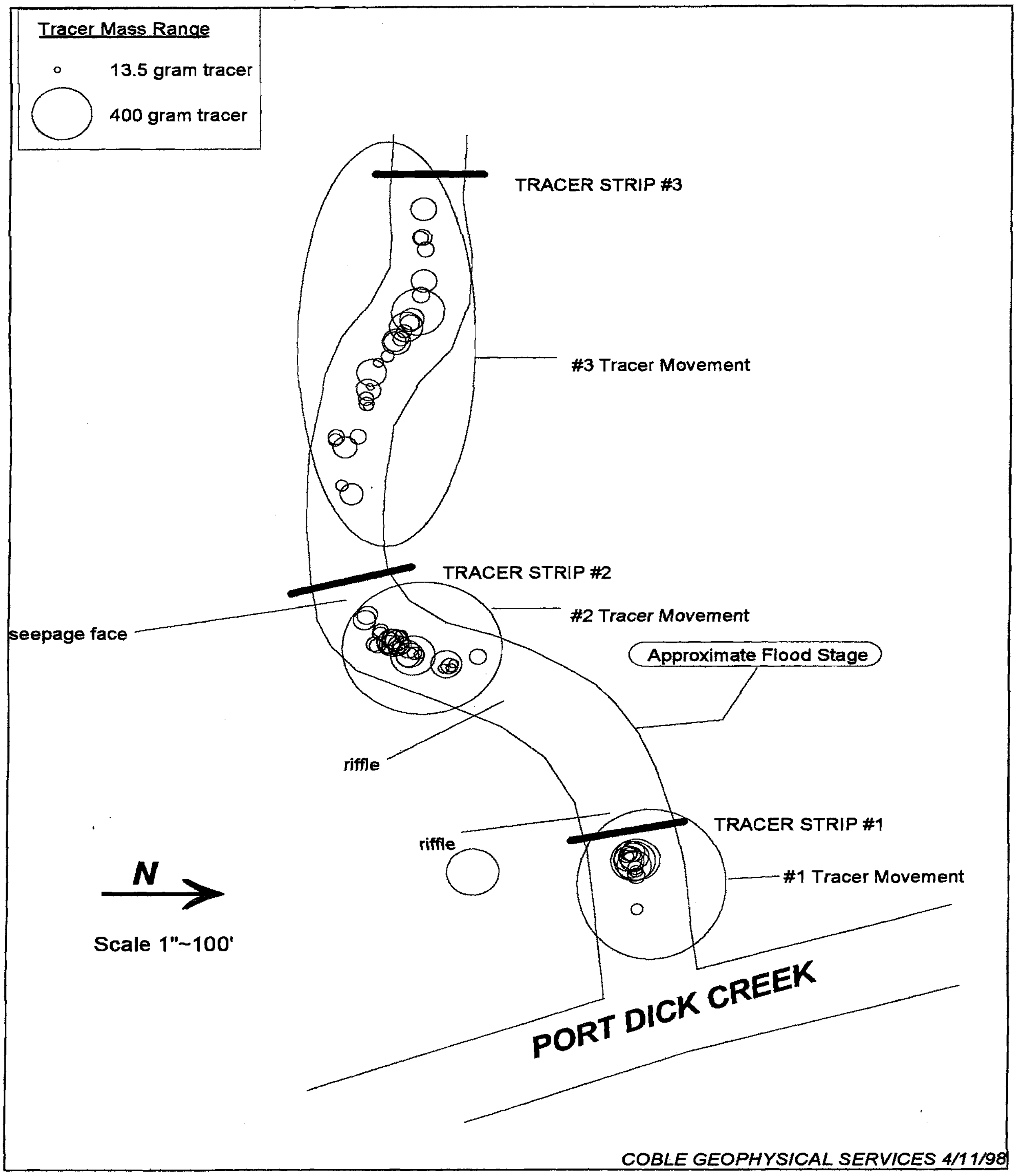

Figure 11. Tracer Gravel Movement in the Primary Tributary up to 7/27/97.

presence of developing salmon eggs. Figure 11 shows the tracer movement in the primary tributary detected up to 7/5/97. The bedload transport of tracer gravel was found to be along the deepest part of each tributary (the thalweg) as would be expected, despite the channel-wide tracer locations within the source areas. Figure 11 shows that there is significant gravel transport above the site compared to the mouth of the primary tributary. Figure 11 also shows a rough trend in downstream fining of the tracers as might be expected. The tracers from source area #3 clearly moved further than tracers from the other source areas which may indicate a greater overall upgradient sediment transport rate, though it is important to be cautious when interpreting tracer results for the reasons mentioned previously. In 1998 some tracers in group #3 had merged with group #2. Significant tracer movement probably occurs only during the peaks of selected flood events in this watershed, one of which is shown in Figure 12.

A single significant flood event in 1998 caused significant movement in the secondary channel tracers of up to 30 meters. The flood stage is shown in Figure 12, where the peak discharge was approximately 300 cfs. The secondary channel tracer positions (of tracers that moved significantly) caused by this flood is shown in Figure 13. There is great potential for such work to calibrate sediment transport rate estimates, since the transport occurred during a known flow regime.

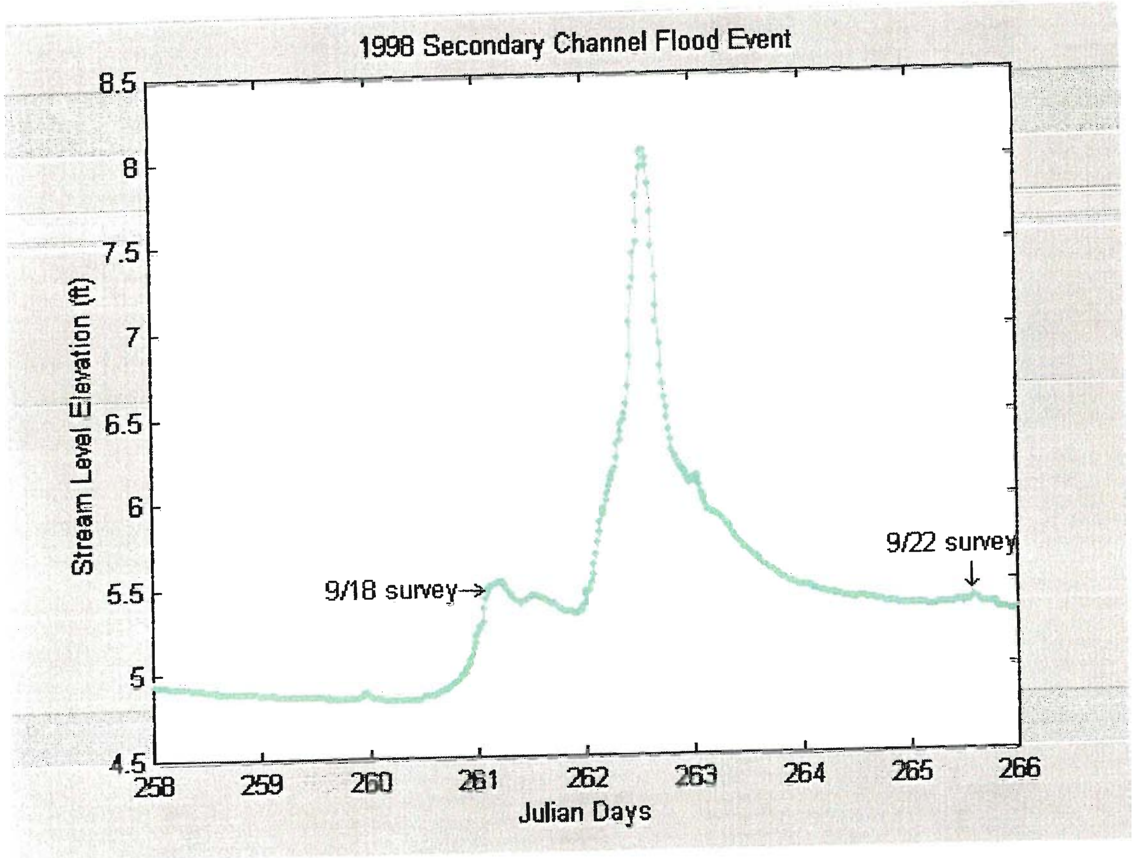

Figure 12. Stream stage during a significant sediment transport event; surveys of stream cross section elevations were taken both before and after this event.

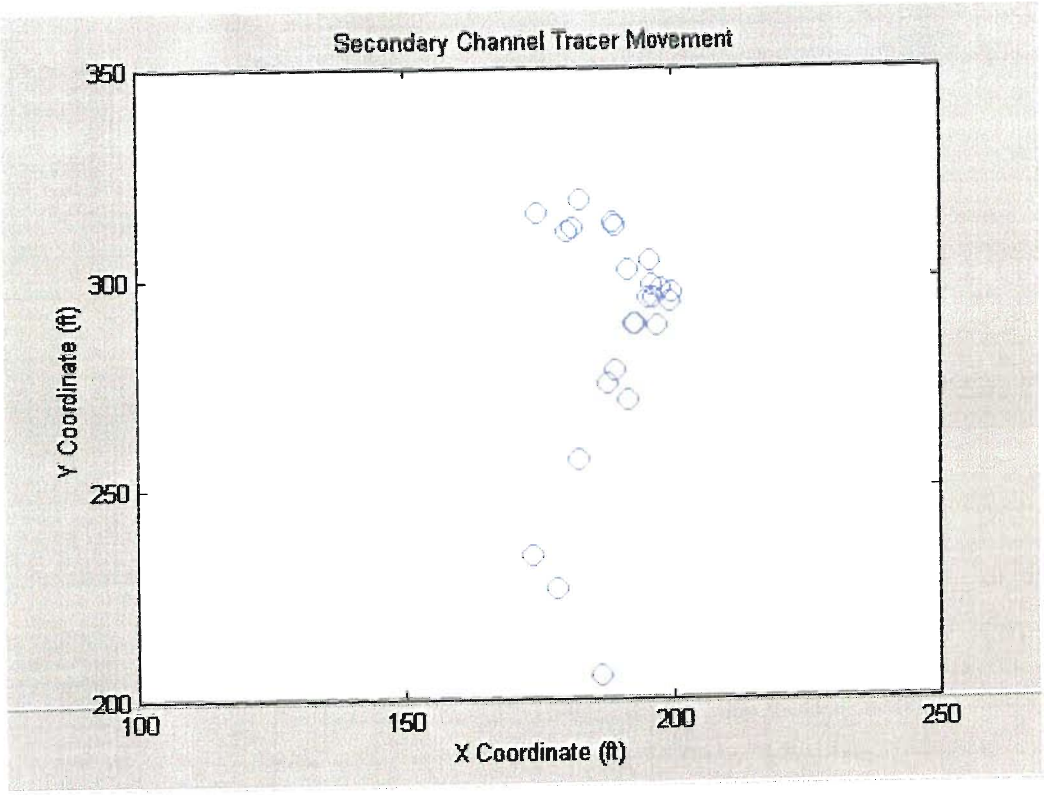

Figure 13. Tracer movement in the secondary channel caused by the flood event shown in the previous figure.

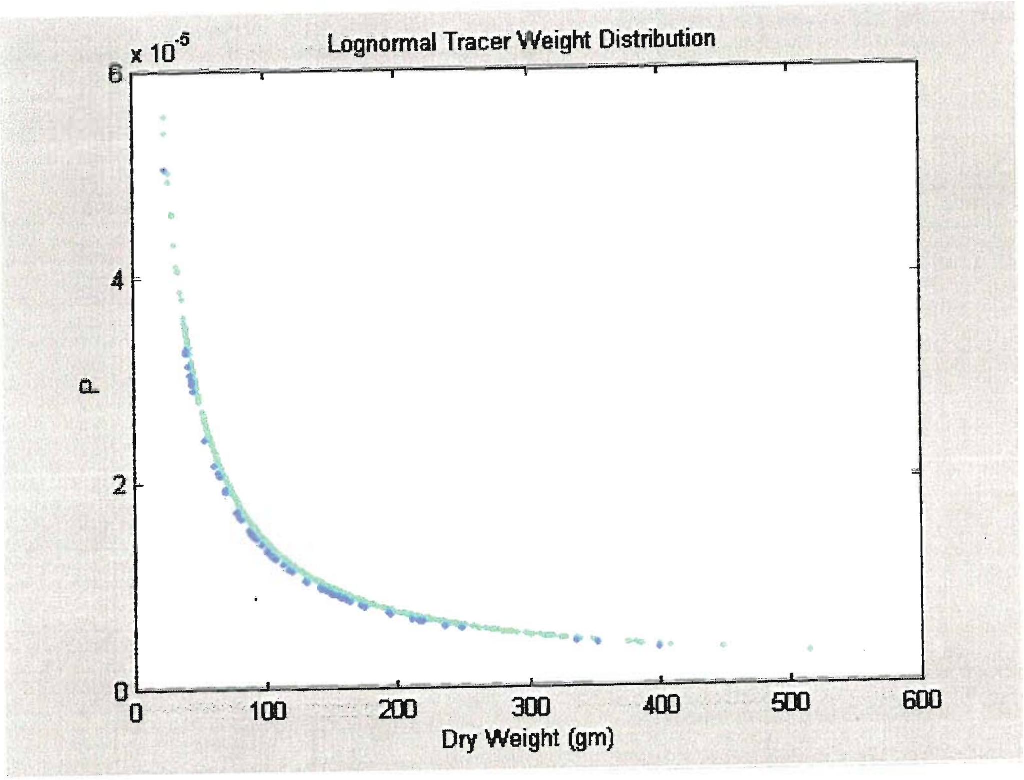

Figure 14. Slight preferential movement of the lighter tracers caused the distribution shift of the darker symbols, which represent all tracers that exhibited significant movement from their source areas.

It is also important to note before using tracer information whether or not differences in gravel specific gravity; weight and/or dimensions are causing preferential transport. The different sized gravel are used for comparisons to size-selective tracer studies such as Ashworth et al. (1989). Bridge et al. (1992) show why tracer densities and tracer dimensions are important for studying the results of tracer transport, so the lengths of the orthogonal gravel axes were measured for completeness, which could turn out to be a useful parameter in the long term.

All these parameters were investigated, and so far there is only a slight preference shown for the lighter tracers to be selectively transported as shown in Figure 14. Figure 15 shows the effects of gravel morphology on tracer movement, where the circled tracers represent tracers found to have moved significantly. So far these results indicate that there is surprisingly little preference of movement correlated to tracer parameters, perhaps due in part to the extreme flood conditions required to initiate significant gravel transport. More tracers and tracer data is being collected for FY99, and proposed for FY00.

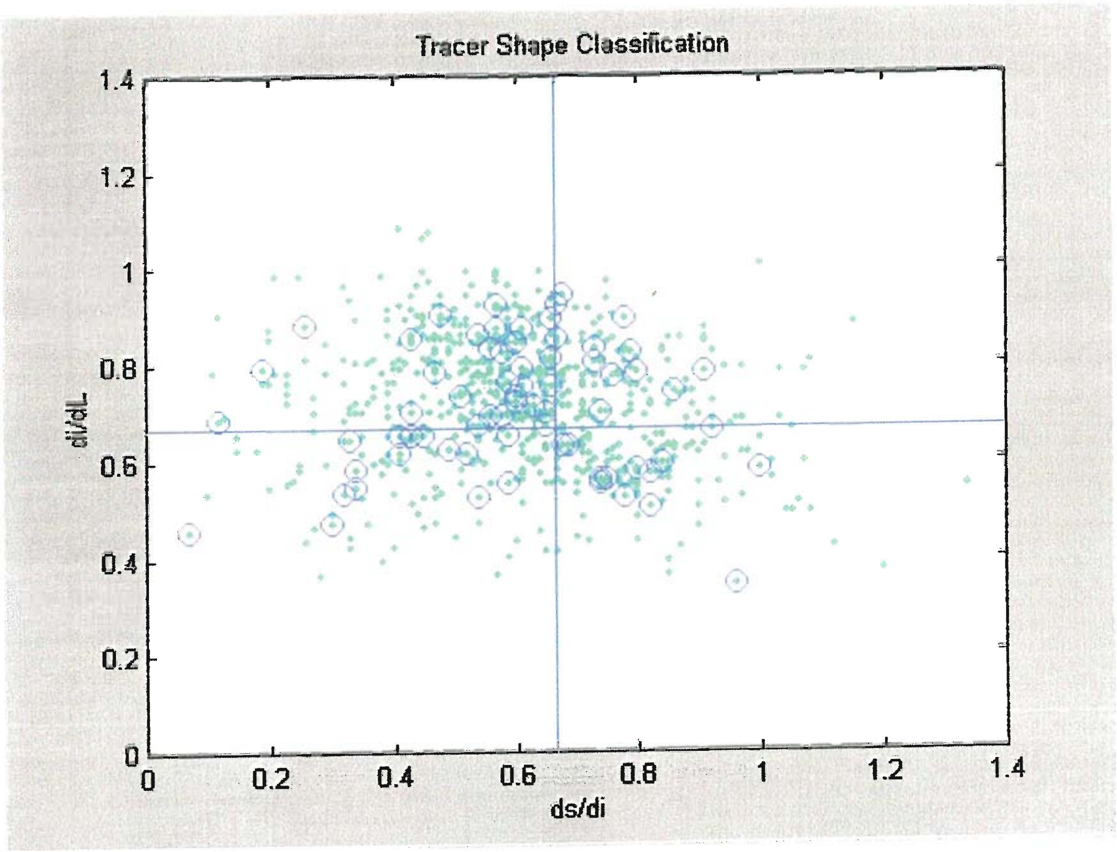

Figure 15. Tracers classified according to the lengths of their orthogonal axes: circled tracers moved significantly.

It is important to evaluate the energy slope of such floods when interpreting both the tracer gravel data and other sediment transport parameters. Figure 16 shows the effects of a flood event on the stream energy slope. Note that tidal influences tend to decrease the energy slope, whereas the influence of Port Dick Creek on the spawning channels is to either reduce or increase the erosive power of a flood event, depending on its flood stage hydrograph.

These monitored parameters combine to show that the movement of spawning gravel as bed load is complex, intermittent and yet very important to understanding of the stability problems this project poses. Hassan et al. (1991) have also had success using tracer gravel in gravel-bedded streams to calculate gravel transport rates which will be useful in the discussion of construction techniques for future spawning channel projects in gravel-bedded streams.

Measuring the variation of parameters across a section of a stream channel can also be a very useful way to monitor streambed stability. Numerous studies have used this technique successfully, e.g. Jacobsen, 1995 in AGU Monograph 89. Dietrich and Whiting (1989) concluded in their work with gravel-bedded rivers that monitored stream cross sections were very useful for the study of gravel transport. One such cross section is shown for the primary channel in Figure 17.

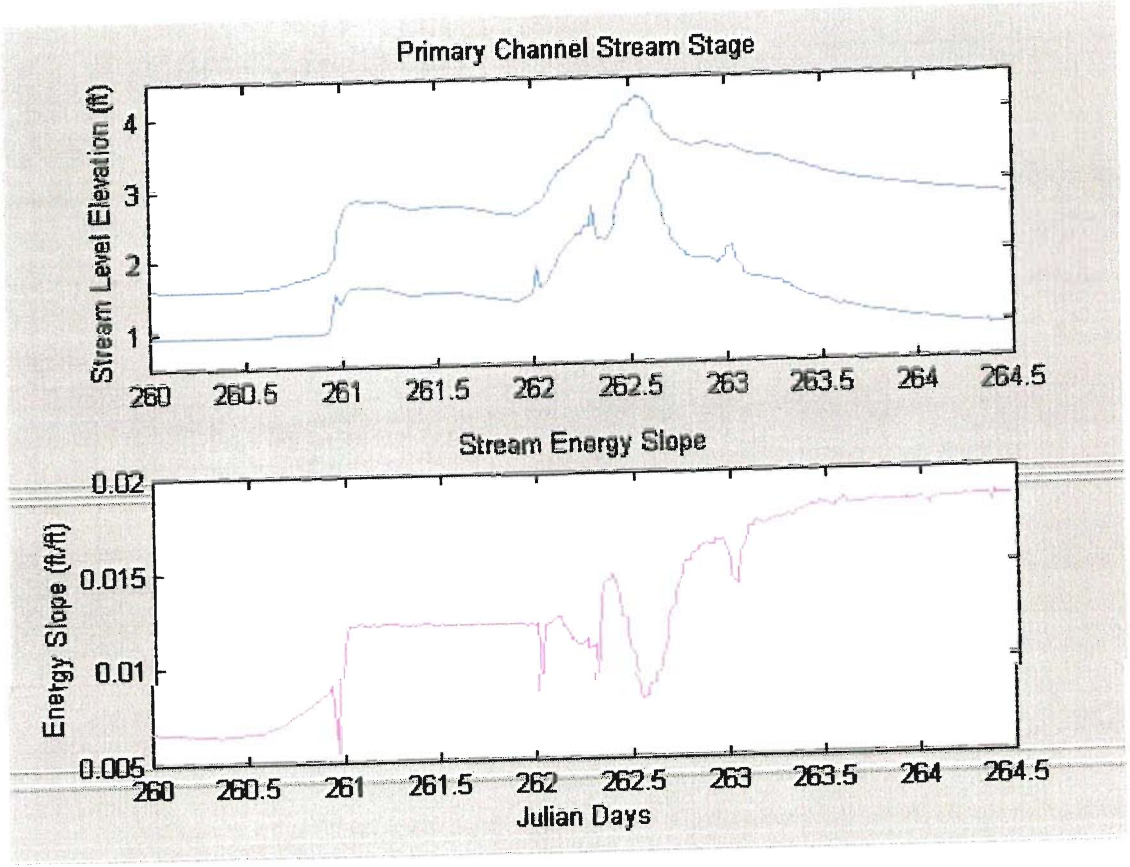

Figure 16. Stream energy slope and stream stage from the primary channel stilling wells.

The streambed elevation changes from the surveyed cross sections are continually changing, although generally within a few centimeters of their post-excavation levels. There have been some exceptions as recently discussed by Coble et al., 1998, however these data are preliminary and may primarily be due to localized bank erosion. Such deposition is of interest to the project, even if it is localized, since it forms part of the bedload sediment transport. The surveyed cross sections help monitor the 'sediment waves' as they migrate through the system. The monitored cross sections are primarily useful for the long term objectives of this project.

The scour chains were relocated and unburied on 7/4/97 using both the total station and a submersed metal detector. The scour chain positions are shown in Figure 6. The primary tributary scour chain 'B' as shown in Figure 6 showed no indication of scour or deposition as of 7/4/97. This scour chain would be mostly affected by any movement in the boulder and log riffles of the seepage face area. Scour chain 'A' was found oriented downstream and covered by a lobe of sediment approximately 23 cm. in depth. It is suspected that this sediment also came primarily from localized bank slough, however in this case there was also a significant amount of scouring as the scour chain was found oriented downstream. The re-buried chain 'A' will be evaluated again in July, 1998 to help determine the sediment budget in that reach of the primary tributary.

Both scour chains 'C' and 'D' in the secondary channel showed no signs of re-alignment as of 7/4/97, however both were covered with a small amount of bedload sediment. The scour chain at the head of the secondary tributary was covered with less than 3 cm of fine sediment and leaf litter, while the scour chain closer to the mouth of the secondary tributary was covered with approximately 10 cm. of gravel bedload. The burial near the mouth was probably due to local stream bank erosion and bank sloughing. The fall floods in 1997 and 1998 seem to have carried significant bedload, however, so some changes in the scour chain data will be of interest when the biologists allow their exposing again in July, 1998.

Finally, riffle elevations are being monitored to determine riffle stability. Figure 18 shows the small relative elevation shift in the upper primary boulder riffle for two years of measurement, close to the error in measurement. This monitoring is important since elevation changes in the riffles could cause differences in sediment transport. The data is in three dimensions, so in tilting the plots 90 degrees it is also known that there has been no significant creep in the riffles.

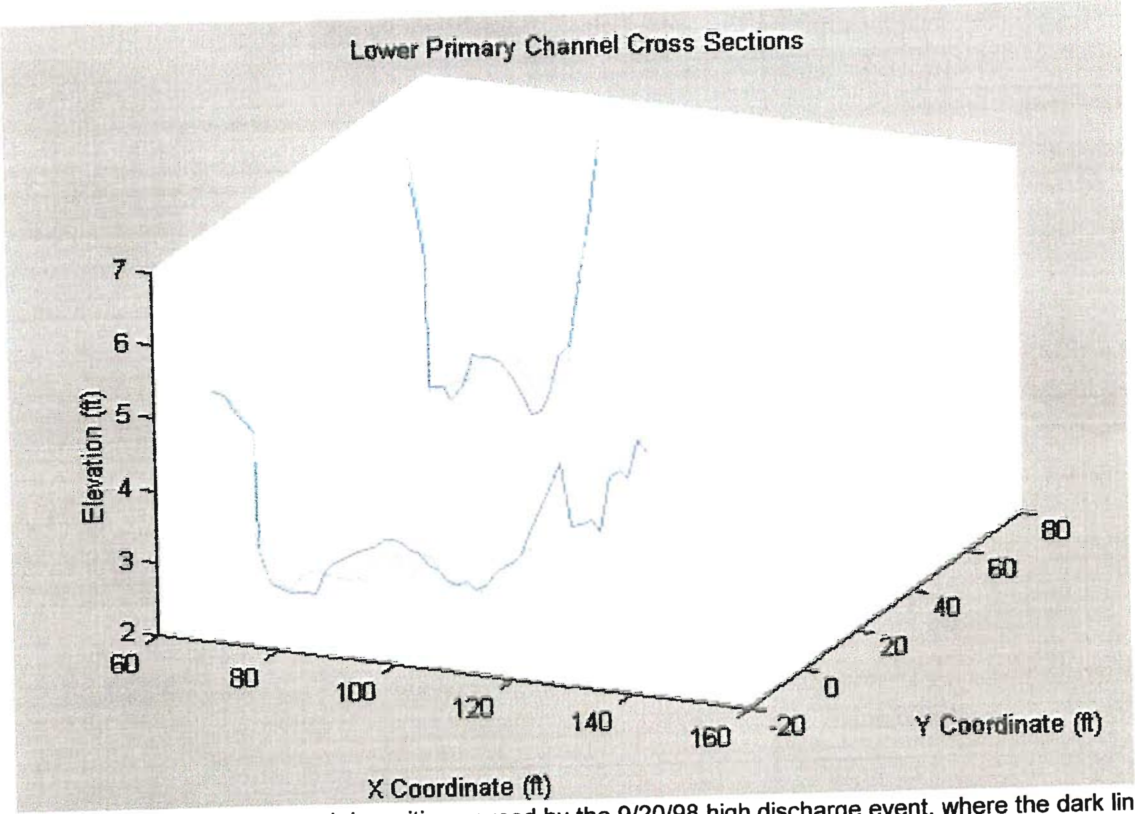

Figure 17. Flood erosion and deposition caused by the 9/20/98 high discharge event, where the dark lines represent stream cross section elevations one day following the flood.

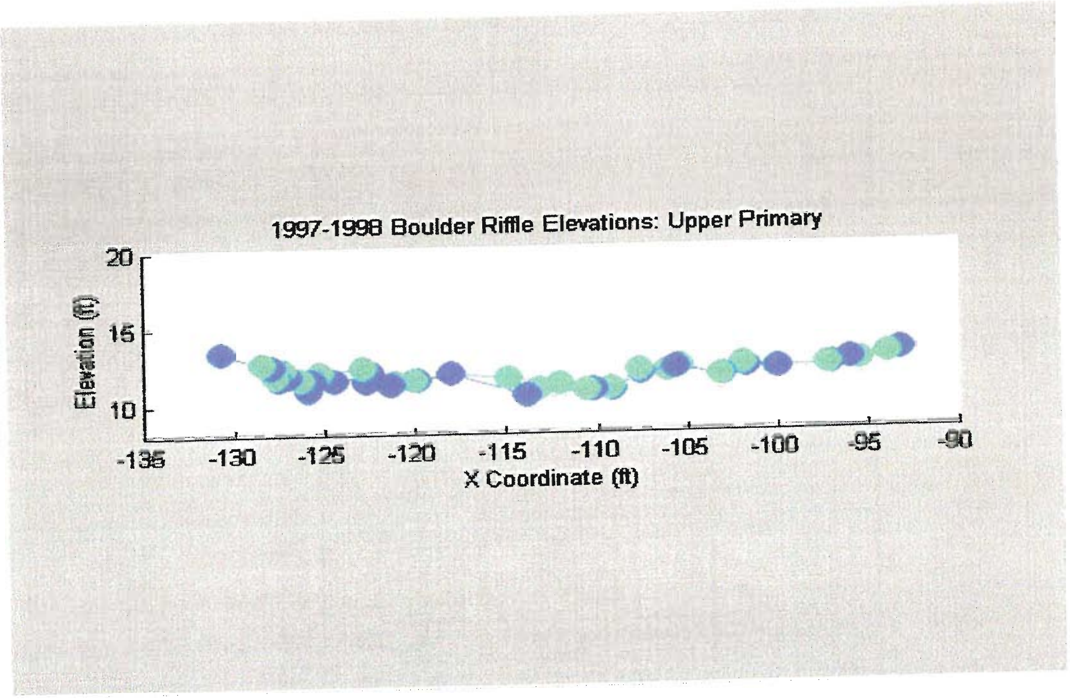

Figure 18. Upper primary channel boulder riffle. Boulder riffle positions and elevations in 1997 (light symbols) and 1998.

Discussion

This is the second reporting period which salmon production (emergent fry) and the third period that adult colonization and spawning is estimated from the restored spawning habitat. The two primary objectives to evaluate project success include the overall survivability of salmon to the restored habitat (i.e. colonization/spawning and fry production), and the determination of the long term spawning habitat stability. Both objectives require relatively long term data sets. From the biological perspective, a complete life cycle of chum salmon is 3-4 years, a minimum period for determining salmon production from the tributaries. A relatively long data set is also required from the standpoint of gravel transport in gravel-bedded stream systems. The data in this report has been discussed with these considerations in mind.

Evaluation of colonization/spawning and fry production is limited to overall survivability. In-depth research into individual variables that can effect egg to fry survivability, i.e., gravel size, intra-gravel water flow and oxygen levels are outside the original objectives of this project. Accordingly, evaluation and results of spawning success is intended to illustrate that the results achieved at Port Dick Creek fall within the parameters expected in natural salmon streams or similar instream spawning habitat projects.

Tributary Colonization, 1998

To estimate spawner abundance we took periodic stream survey data and generated accumulated escapement estimates using a stream life value of 10.8 days. The stream life value was derived by averaging stream life values from streams in Prince William Sound that had similar characteristics as Port Dick Creek, Bue et al.1998; Brian Bue, Personal communication, ADF&G, Anchorage). A range of spawner abundance estimates is generated using stream life values of 8.5-17.5 days (Helle, 1964; Perrin et al.1990; Bue et al.1998) and presented in Table 2. The higher end of the range (17.5 days) is the value that ADF&G has used for over 30 years to estimate and develop the pink and chum spawning abundance data base.

Total colonization and spawning abundance (pink and chum salmon) for 1998 was estimated at 3,361 fish, an increase of 938 fish from 1997 (Table 1). Pink salmon comprised the majority of the increase with 2,176 and 1,033 fish in the primary and secondary tributary respectively. The increase in colonization abundance for pink salmon is consistent with the increase in spawning escapement for Port Dick Creek, where the 1998 escapement was estimated at 57,100 fish, an increase of over 54% from 1997 (Table 1). Potentially, a component of the 54% increase of the 1998 adult pink salmon return to the Port Dick Creek system is a result of first year (brood year 1996; BY96) production from the new habitat. Measurement of the potential contribution to the total spawning return is difficult at best due to a lack of a marked salmon recovery program. In addition, increases in pink salmon spawner abundance were estimated at two other nearby LCI index streams. Island Creek and Rocky River (7 miles SE and 5 miles SW of Port Dick Creek respectively) had 108% and 150% increases respectively when compared to the previous even-year return (ADF&G, *in press*).

Table 3. Summary of spawning densities (females/m^2) and subsequent fry production (Fry/m^2) 1996-1998. The number of females is assumed at 50% of the total estimated spawner abundance. Spawner abundance is estimated with 10.8 days stream life.

Species	Primary Tributary Spawner density (females/m^2) Pink	Chum	Secondary Tributary Spawner density (females/m^2) Pink	Chum
Stream life (days)	**10.8**	**10.8**	**10.8**	**10.8**
1996	**0.4**	**0.2**	**0.2**	**0.01**
(Fry/m^2)	**(122)**	**(109)**	**(43)**	**(15)**
1997	**0.1**	**0.2**	**0.04**	**0.06**
(Fry/m^2)	**(52)**	**(52)**	**(17)**	**(10)**
1998	**1.2**	**0.07**	**0.6**	**0.01**

In contrast to the increase in pink salmon abundance, the estimated chum salmon spawning abundance for Port Dick Creek continued to decline for the fifth consecutive year. The 1998 spawning escapement was estimated at 1,840 fish (an all time low) and more than 50% less than the biological escapement goal set at 4,000 fish (ADF&G *in press*). Likewise, the colonization and spawning abundance for chum salmon for both tributaries was only 24% of the previous year, 630 in 1997 compared to 152 salmon for 1998. The first year chum salmon will return to Port Dick Creek system from the additional habitat production will be 2000 (39.5% aged 0-3; 58.6% aged 0-4).

Spawning densities for each tributary were estimated resulting with a high of 1.2 females/m^2 (pink salmon in the primary tributary) to a low of 0.01 females/m^2 for chum salmon in the secondary tributary (Table 3). Clearly optimal spawning densities for chum salmon have yet to be reached. Chum fry production as a result of density of spawning was found to increase to 2.5 females/m^2 at several groundwater-fed side sloughs (Lister et al.; 1980), however, spawning success (fry production) was found to slow appreciably after 0.5 females/m^2. Pink salmon production from Sashin Creek, a surface-fed creek in Southeast Alaska, was maximized at 1.0 females/m^2 and declined rapidly at 2.2 females/m^2 (McNeil, 1969; Heard, 1978).

We believe optimal spawning densities, particularly chum salmon, within the tributaries will be dependent partly on the increased production that the restored spawning habitat itself will gradually produce. Particularly if our original hypothesis (FY96 Detailed Project Description, *EVOS* T.C.) is correct in assuming that unstable spawning habitat within the main stem of Port Dick Creek is periodically taken out of production because of flooding and freeze-out events. Accordingly, spawning densities may not increase within the tributaries until spawner abundance increases and overflow from the main stem of Port Dick Creek is created. Merrell (1962) noted that in years when the number of spawners was high in Sashin Creek, all of the available habitat was utilized and when few were present, they spawned mostly in the lower portion of the stream.

We anticipate increased adult chum salmon production in 2000 when the first age component (aged 0.3) fish return from the 1997 fry emigration (BY96).

Fry Emergence Patterns

Daily and seasonal timing of fry output occurred within parameters expected for pink and chum salmon in southcentral Alaska. Divergence (output spikes) from the seasonal emigration trend is shown to be associated with water temperature spikes (associated with tides > 10.5' or greater), increased turbidity, and stream flows (Figure 10).

Water temperature spikes associated with tidal intrusions of 10.5' or higher in the primary tributary is suspected of increasing daily fry emergence (Figure 10). This emergence pattern fits with work completed by Coburn and McCart (1967). They could manipulate fry output from incubator trays by increasing or decreasing water temperatures; few fry left when temperatures were low, and large numbers left when the temperature was increased. Long term work by ADF&G staff at a pink and chum salmon hatchery near Homer, Alaska, have shown that fry output from incubator trays is influenced by increased water temperatures from the saltwater intrusion. There, the high tides would infiltrate instream intake-pipes and raise water temperatures in the hatchery by 4.0°C-9.0°C, elevating fry output (Dave Waite, ADF&G, Tutka Hatchery, personal communications.) Increased turbidity associated with increased water velocity caused by rain or snowmelt is also shown to correlate with increased daily fry output. Further work by Coburn and McCart (1967), has shown that increased turbidity associated with increasing stream discharge at Kleanza Creek, British Columbia, caused large numbers of pink salmon fry to leave even when water temperatures were falling.

Length at emergence was determined from 218 chum and 196 pink fry ,1997 data, captured from the primary tributary. Mean lengths were found at 39.5 mm for chum and 33.7 mm for pink fry. These lengths fall within the size expected for pink and chum fry within their pacific range (Groot & Margolis, 1991).

Fry Production

Fry produced per unit area, rather than egg to fry survival, may be a more suitable method to measure project success and longevity because of complicating factors influencing variability in estimating egg to fry survival (Bonnel, 1991). These factors include uncertainty in spawner counts, degree of egg retention, variations in fecundity, predation and problems associated with fry trapping.

Fry production (fry/m^2) fell in 1998 in both tributaries. The sharpest decline was measured for pink fry in the primary tributary where 51.6 fry/m^2 (spawning density 0.1 females/m^2) were counted versus 122 fry/m^2 @ 0.4 females/m^2 the year before. Chum production in the primary tributary was only 48% of the previous year when 109 fry/m^2 @ 0.2 females/m^2) were counted versus only 52 fry/m^2) @ 0.2 females/m^2 (Table 3). Consequently, the overall number of pink and chum fry emigrating the tributaries was only 45% of the previous year; 145,627 fry in 1998 versus 324,889 fry from 1997 (BY96). In the primary tributary pink fry emigration fell to 61,966 fry down from 146,936 fry the previous year and chum fry emigration in the secondary tributary declined to 8,009, down from 12,029 fry. The decline in fry production for 1998 (BY97) is assumed linked with lower 1997 adult colonization and spawning density levels. Pink salmon spawner abundance for 1997 was only 25% of the previous year (Table 1), although overall chum salmon abundance for 1997 was estimated at 630 fish, slightly higher than 1996.

A review of 1998 fry production from both tributaries (BY97), indicates that additional fry production may be realized when increased spawner abundance occurs. Lister et al. (1980) found as many as 517 chum fry/m^2 produced @ 2.5 females/m^2 at seven chum salmon spawning areas studied. Production (of fry) however, did not increase appreciable after 0.5 females/m^2. Work by McNeil (1969), at Sashin Creek a stable surface-fed stream in southeast Alaska found similar results. Fry production (pink and chum) was found at 500 fry/m^2 at 1.0 female per m^2, however production declined to approximately 100 fry/m^2 when densities increased to 2.2 females/m^2.

Physical Factors Affecting Survival

Several physical factors can affect development and/or emergence (survival) of pink and chum salmon fry including, but not limited to temperature, stream flow, turbidity, and salinity. Physical differences exist between the tributaries which may have produced or contributed to differences in survivals. Fry production was higher in the primary tributary for the second year; 52.0 fry/m^2 for both pink and chum fry compared to 16.5 and 10.0 fry/m^2 for pink and chum in the secondary tributary.

The first and most obvious difference is the source water which in the secondary tributary is groundwater fed consequently, water in that tributary is shallower and velocity slower. Water velocity in the primary tributary is frequently twice that of the secondary tributary. For example, on 29 September 1997, the water velocity in the Primary Tributary measured 0.34 m/s versus 0.16 m/s in the secondary tributary. Water velocity was measured at mid channel in both tributaries. Groot and Margolis (1991) have shown that chum salmon prefer between 0.2 and 0.8 m/s for spawning (80%), although spawning has been observed in water velocities between 0 and 1.67 m/s. The preferred spawning velocities for pink salmon range from 0.30 to 1.4 m/s, with an average water velocity over the redds of 0.70 m/s (Groot and Margolis, 1991). Pink salmon prefer more intragravel oxygen than Chum salmon, which is consistent with a higher velocity preference, whereas Chum salmon prefer spawning grounds with upwelling water, i.e. gaining streams.

Water temperatures in the secondary tributary fell to below freezing at the streambed level on 30 December through 15 February (1997), likely the result of the slower, shallower water. Although temperature thermistors were not installed at egg burial depth, redd freeze-out may have occurred and affected survivals. By contrast, in the primary tributary temperatures at the streambed level fell to 0^0 C only once at the monitored location. The 1998 data for surface water temperature and discharge as well as temperatures at egg burial depth as they relate to fry production will be analyzed further for the final report.

Physical Factors Affecting Streambed Stability

Sediment and bedload transport in gravel-bedded rivers has received far less attention in the published literature compared to stream channels of finer grained sediments, probably due in part to the long term data collection required to establish and verify models of such systems. The sediment transport objectives for this project range from determining the effect of high discharge events on the sediment transport and bed armor of natural gravel-bedded streams and rivers (e.g. Ikeda et al., 1990) to numerical modeling of long term spawning channel stability. Discerning the effects of altering a gravel-bedded stream channel on sediment transport and deposition is a side benefit of this study useful for future spawning habitat rehabilitation projects.

In addition to the long term data being collected already, the streambed stability aspect of the project has identified the need for more data directly pertaining to the onset of sediment transport. The sediment transport analysis will benefit from the addition of online measurements of surface water energy slope in the primary tributary as mentioned previously. This data will be calibrated to surface water slope measurements at other locations in the tributaries for a more comprehensive data set concerning surface water dynamics. In addition, more near-bed velocity measurements during peak flow events will be monitored, such as the data shown in Figure 19 for a small flood event in the primary channel. These data will be used to support the sediment transport modeling and stream stability analyses.

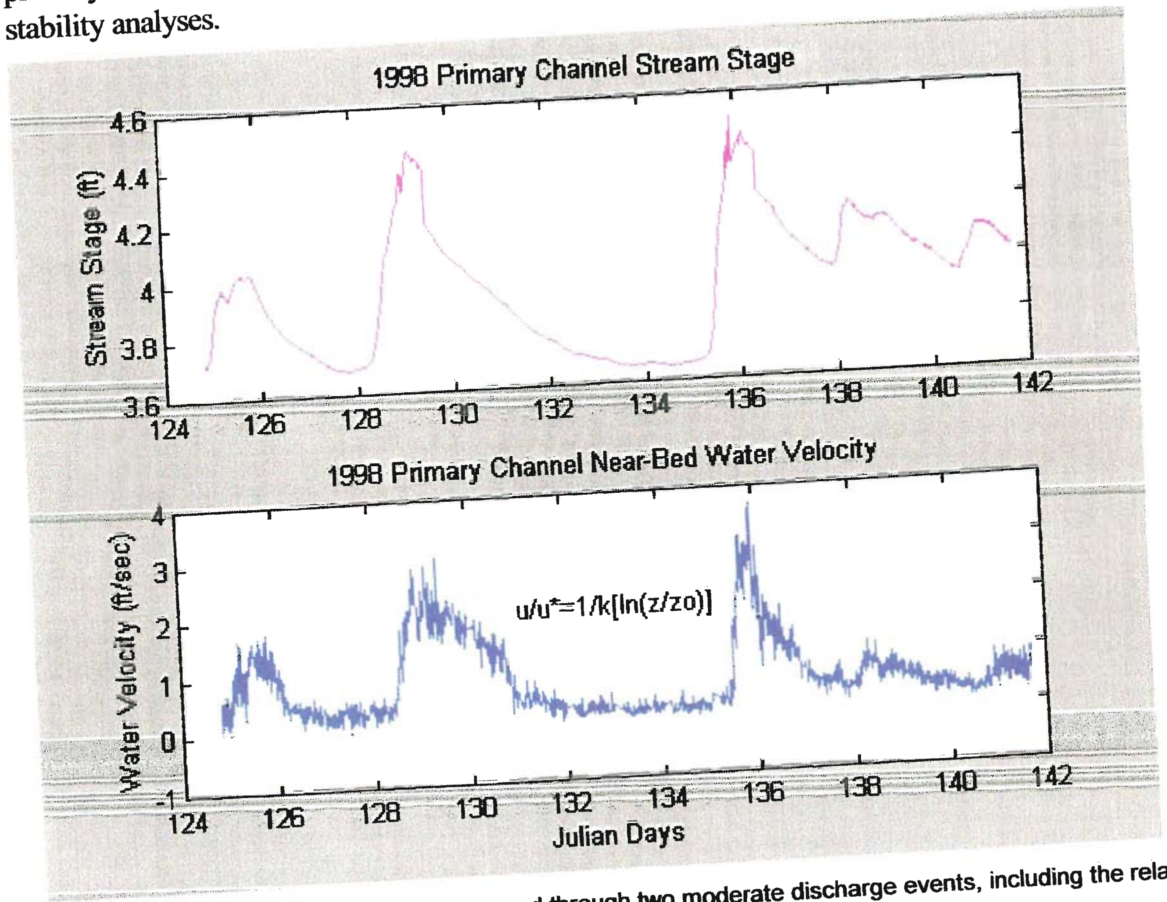

Figure 19. Near-bed water velocity measured through two moderate discharge events, including the relationship of shear stress to near-bed water velocity.

CONCLUSIONS

Enough data has been collected to date such that a relationship between fry production and the hydrologic and sedimentologic data is beginning to be made as shown in this report. The sediment transport data continues to be collected with some adjustments to the data collected as detailed in the report. As a result, this project has proceeded towards a workable data set for the sediment transport modeling and research priorities, such as determining an effective discharge for both tributaries and addressing long term streambed stability. Assuming optimal spawning densities of 1.0 female/m^2 and 1,605 m^2 of spawning habitat, primary and secondary tributaries, with a production of 500 fry/m^2, an estimated 802,500 pink and chum fry could be produced annually.

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