The Effect of Gas Supersaturated Water on Juvenile Chinook *(Oncorhynchus tshawytscha)* Held in Cages in the Nechako River, British Columbia

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ABSTRACT

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The Nechako River, a major tributary of the Fraser River in British Columbia, supports a large salmonid population. Elevated levels of total gas pressure (TGP) have been documented in the water below Cheslatta Falls, which is a barrier to upstream migration on the Nechako mainstem. In July and August 1985 and 1986, in situ studies using juvenile chinook (Oncorhynchus tshawytscha), rainbow trout (Salmo gairdneri) and mountain whitefish (Prosopium williamsoni) were conducted to determine if the excess TGP was causing gas bubble trauma (GBT). Gas bubble trauma is a non-pathogenic response of aquatic organisms to gas supersaturation. This report discusses these studies, emphasizing the 1986 results.

In 1986 fish were held at two sites on the river, one near the base of Cheslatta Falls and a second 30 km downstream. There were three treatments at each site; fish held at the surface, at 1 m depth and volitionally, where they were free to move in the upper 1 m of the water column. One fish at the Cheslatta Falls site showed definitive symptoms of GBT after 15 days of exposure. Measurements of TGP ranged from 107.2 to 115.0%, averaging 111.0%. The mortality rate at this site indicated a strong trend associated with gas supersaturation; at 11 to 13 days of exposure, the cumulative mortality rates in the surface and volitional cages were approximately twice that of fish held at depth, where water pressure compensates for excess TGP. However, this trend did not continue as mortality occurred in all treatments. Factors unique to field studies of GBT (versus laboratory or hatchery study) are also discussed.

RÉSUMÉ

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Une population nombreuse de salmonidés fréquente la rivière Nechako, un tributaire important du fleuve Fraser en Colombie-Britannique. On a déjà observé des niveaux élevés de pression gazeuse totale dans les eaux en aval des chutes Cheslatta, qui constituent une barrière pour les saumons qui veulent remonter le cours principal de la rivière Nechako. Au mois de juillet et au mois d'août 1985 et 1986, nous avons fait des études sur le terrain avec des saumons quinnats juvéniles (Oncorhynchus tshawytscha), des truites arc-en-ciel (Salmo gairdneri) et des ménominis de montagnes (Prosopium williamsoni) pour savoir si cette pression gazeuse totale élevée pouvait causer un traumatisme gazeux. Le traumatisme gazeux est une réaction non pathogène des organismes aquatiques à une sursaturation de l'eau en gaz. Ce rapport présente ces études en mettant l'accent sur les résultats de l'année 1986.

En 1986, nous avions deux sites expérimentaux sur la rivière, un près de la base des chutes Cheslatta et l'autre à 30 km en aval. Nous avons pratiqué trois traitements à chacun de ces sites: le premier traitement consistait à maintenir les poissons en surface, le deuxième consistait à les maintenir à une profondeur d'un mètre tandis que dans le troisième traitement, les poissons pouvaient nager librement dans le premier mètre de la colonne d'eau. Au site situé près de la base des chutes, un poisson a montré des symptômes irrémédiables du traumatisme gazeux 15 jours après le début du traitement. La pression totale variait entre 107,2 et 115,0 % et sa moyenne était de 111,0 %. À ce site, le taux de motralité était fortement relié à la sursaturation en gaz: après 11 à 13 jours de traitement, les taux cumulatifs de mortalité dans les cages de surface et dans celles qui couvraient le premier mètre de la colonne d'eau étaient approximativement deux fois plus élevés que celui des poissons maintenus à 1 mètre de profondeur où la pression de l'eau contrebalance la pression excessive des gaz. Cependant, les effects de la sursaturation en gaz sur le taux de mortalité n'ont pas maintenu la même tendance car il y a eu mortalité dans tous les traitements. Les caractéristiques particulières des études sur le terrain portant sur le traumatisme gazeux (par rapport aux études en laboratoire ou réalisées dans des aleviniers) sont aussi examinées.

INTRODUCTION

Chinook salmon, sockeye salmon (O. nerka), rainbow trout (Salmo gairdneri), and other fish species utilize the Nechako River, a large northern tributary of the Fraser River, British Columbia.

In December 1950, the Province of British Columbia issued a water licence to the Aluminum Company of Canada (Alcan) to develop storage capacity in the Nechako River watershed upstream of Cheslatta River and in the Nanika River watershed upstream of Glacier Creek. Development of the Nechako system, labelled Kemano I, involved construction of the 91.5 m (300 ft) rock filled Kenney Dam at Grand Canyon on the upper Nechako River. There is no discharge of water at the dam and the old riverbed carries only seepage between the dam and Cheslatta Falls. At the western end of the reservoir a 17 km (10 mi) diversion tunnel supplies water to hydro-electric generating facilities on the Kemano River, about 16 km (10 mi) upstream from Gardner Canal on the British Columbia coast (Fig. 1). Release of surface water from the 907 sq km (350 sq mi) Nechako Reservoir behind the dam occurs at Skins Lake spillway, flows through a chain of lakes and plunges over Cheslatta Falls, entering the Nechako riverbed at Cheslatta Flats.

A wide range of studies have been undertaken by government agencies and Alcan to determine the impacts of existing and further proposed developments on fish. One area of study has involved assessing the origin and impact of elevated levels of dissolved atmospheric gases in the Nechako River. During some periods of the year, Nechako River water contains substantially more dissolved atmospheric gas than would water at equilibrium with the atmosphere. This supersaturation occurs primarily as a result of air entrainment at Cheslatta Falls. Aquatic organisms in such an environment can develop gas bubbles or emboli in their organs, tissues and vascular systems. In fish, the problem is commonly termed "gas bubble disease" or more appropriately "gas bubble trauma" as the cause is physical rather than pathogenic. Symptoms of GBT vary according to the level of supersaturation, duration of exposure and species and age (life cycle stage) of fish. Salmonids are among the least tolerant fish species. Acute and chronic toxicity result in net reduced yield (Weitkamp and Katz 1980).

Prior to 1985, measured and modelled dissolved total gas pressure (TGP) values suggested that Nechako River supersaturation levels were sufficient to cause chronic or acute toxicity (Alderdice and Jensen 1985). Therefore in situ GBT studies were conducted on the Nechako River in the summers of 1985 and 1986. The object of these field studies was to determine the biological effects of supersaturated Nechako River water on fish. Chinook, rainbow trout and mountain whitefish fry were used in the preliminary 1985 studies which were accompanied by TGP studies.

The key results of the 1985 studies were first, the appearance of external symptoms of GBT in one fish and second, a high incidence of haemorrhaging in the fins and eyes of fish, which can be symptomatic of GBT. In retrospect, the 1985 study periods were too short (12 days of exposure or

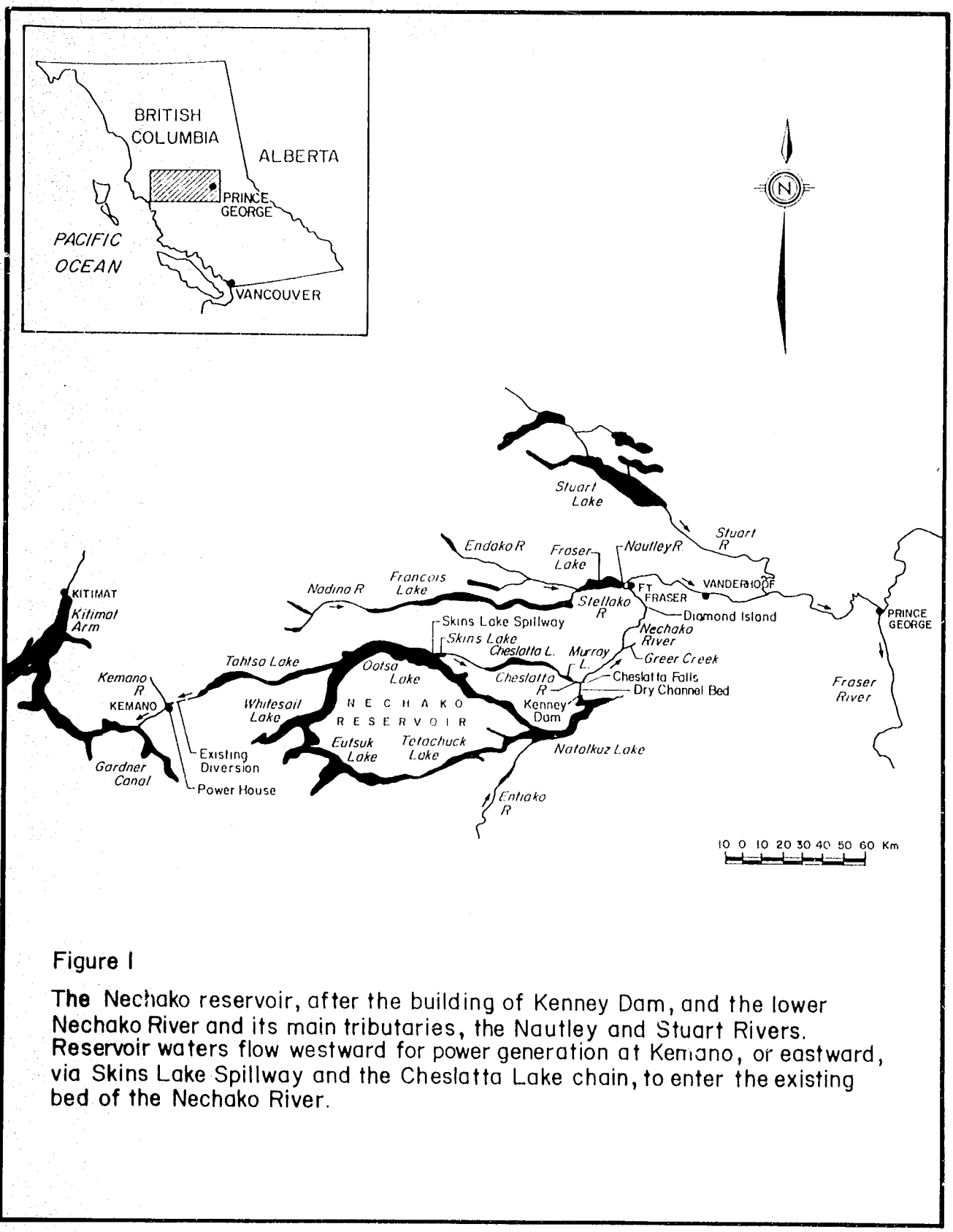

Figure I

The Nechako reservoir, after the building of Kenney Dam, and the lower Nechako River and its main tributaries, the Nautley and Stuart Rivers. Reservoir waters flow westward for power generation at Kemano, or eastward, via Skins Lake Spillway and the Cheslatta Lake chain, to enter the existing bed of the Nechako River.

less) and the TGP levels too low (107.6 to 112.6%) for significant mortality or extensive external symptoms of GBT to appear. The experimental design was dependent on stable flows and the tests were concluded after 9 to 12 days when flows changed. Further modelling work by Jensen et al. (1986) suggested that at least 20 to 30 days exposure would be required for GBT symptoms to appear at those TGP levels.

The main objective of the 1986 field study was to expose resident (Nechako River) juvenile chinook to typical TGP levels that occur during periods of high discharges in summer. In addition, continuous monitoring of TGP was conducted near the base of Cheslatta Falls. This paper presents the study results.

METHODS AND MATERIALS

In 1986, fish were held in the Nechako River in cylindrical cages supported in a floating holding pen framework (Fig. 2). Cages were held at surface and 1 m (3.2 ft) depth regardless of stage. The fish in cages at 1 m depth functioned as control fish. They were exposed to the same water quality as surface fish with the exception that they were hydrostatically compensated and experienced TGP levels 10% less than fish at surface. 'Volitional' cages, which allowed fish to move freely in the upper metre of the water column, were also installed. Two holding pen sites were chosen, one located 0.5 km (0.3 mi) downstream of Cheslatta Falls, with a second site 30 km (19 mi) downstream of the falls adjacent to Frank Schumans' property (Fig. 3).

The period of study extended from July 18 to August 16, 1986. Discharge as measured at Water Survey of Canada (WSC) Station 08JA017, Nechako River below Cheslatta Falls, ranged from 150 CMS (5300 cfs) to 278 CMS (9800 cfs).

The holding pens were constructed of 2 x 4 and 2 x 6 stock with plywood gusset reinforced corners. The sections were bolted together and vinyl garden fencing 1.21 m (4 ft) wide was stapled to the bow and side panels. Plywood enclosed 2.44 m x 0.30 m x 0.30 m (8 ft x 1 ft x 1 ft) styrofoam floats were attached to vertical rails on the sides of the pen. Nine vertical dowels, used to support the cages (described below) within the pen, were supported using horizontal cross members attached to the bottom of the pen and the top of the float rails.

The cages, rented from Coastline Environmental Services Ltd., were constructed of 6.35 mm (0.25 in) opening vexar (plastic) mesh formed into a cylinder 30 cm (12 in) in diameter and 75 cm (30 in) in length providing a cage volume of approximately 53 l (14 gal) (Fig. 4). Access was through a zippered opening running the length of the cage. An aluminum framework supported the mesh cylinder.

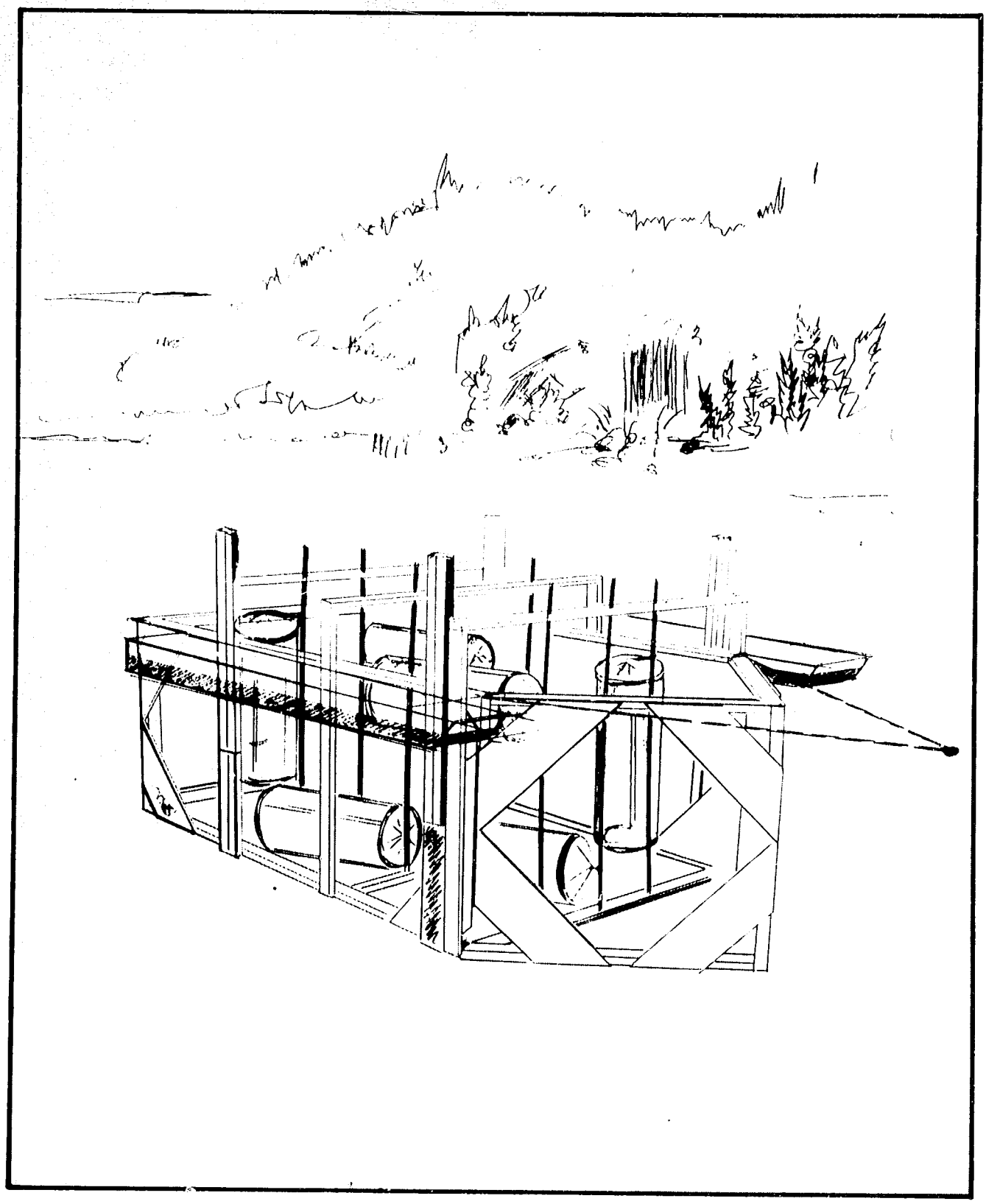

Figure 2 **Artist's Rendering of Holding Pen and Cages at Cheslatta Falls Site**

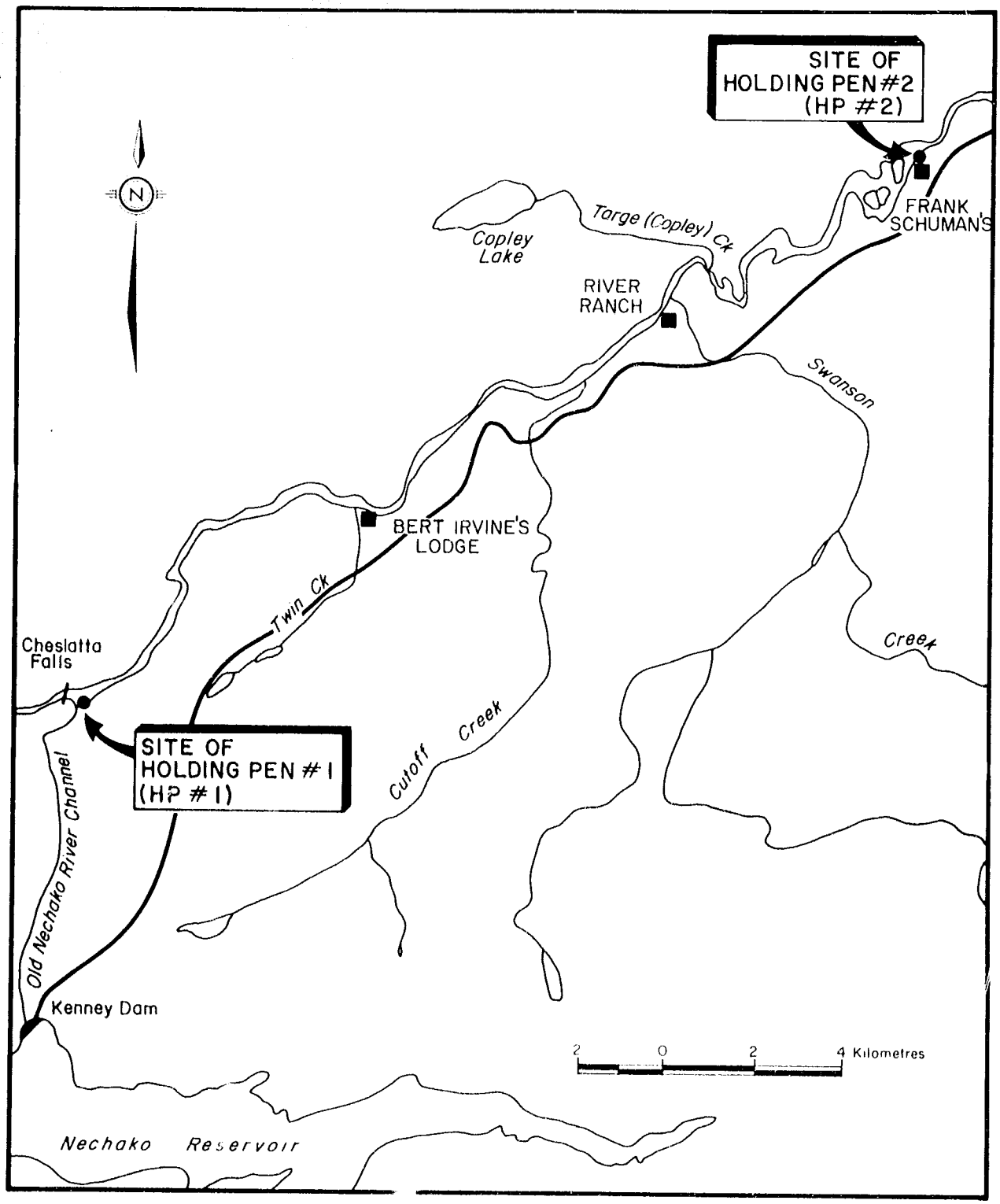

Figure 3 **1986 Nechako River Gas Bubble Trauma Study Area Showing Test Sites HP#1 and HP#2**

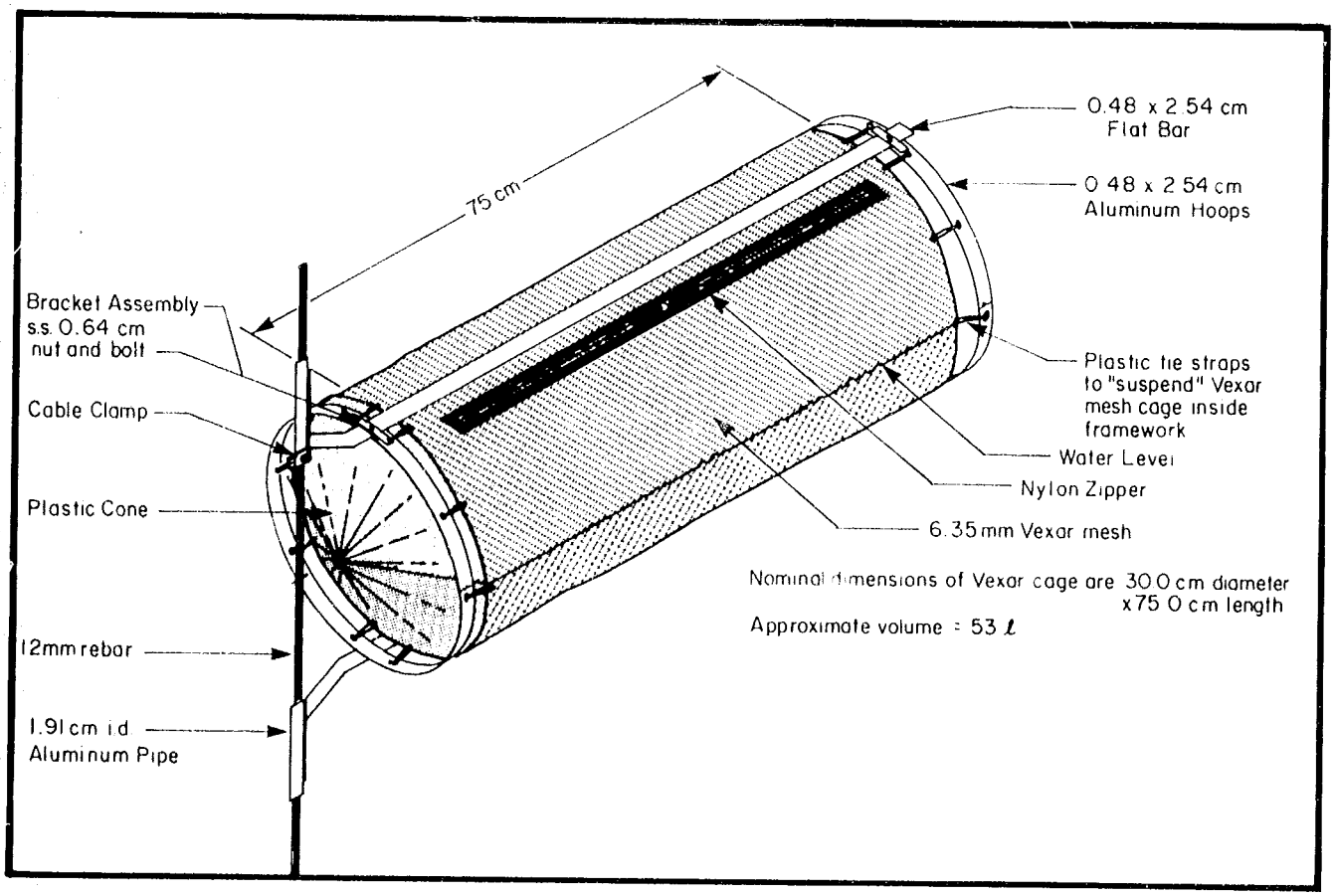

Figure 4 **Cages for Gas Bubble Trauma Studies**

Six cages were installed vertically (three at surface and three at depth) and three were installed horizontally as volitional cages. A plastic cone at the front of the vertical cages enabled the longitudinal axis of the cage to orient itself in the direction of the current flow, thereby providing in-cage water speeds less than those considered the maximum allowable (3 fish lengths/second) to avoid swimming fatigue (D. Alderdice, pers. comm.) Similarly, the upstream face of the volitional cages was covered with plastic material to provide shelter for fish. Surface cages were held with the longitudinal axis at the surface, with the bottom of the cage 10 cm (4 in.) below the water surface. Cages at depth rested on the pen framework such that the centerline of the longitudinal axis was at 1 m (3.2 ft) depth. The nine cages were positioned in a staggered fashion so that there was no possibility of a position effect. The pen was then placed in the water and attached by bow painter to a concrete block anchor. Finally, the floats were adjusted on the rails to place the pen at the proper position in the water column.

Chinook fry were captured July 12 by beach seining along the shore in front of Bert Irvines' Lodge where they were held in a net pen until being transferred to the study sites.

Prior to placing the fish in the cages, they were anesthetized in a 0.3 ml/l (0.033% by volume) solution of 2-phenoxyethanol, promptly weighed to ± 0.2 gram with an Ohaus electronic balance, measured (fork length) to ± 1 mm, and placed in a recovery bucket. Upon recovery, twenty chinook were gently introduced into each cage. Fish were placed in the nine cages (20 fish/cage) at the Cheslatta Falls holding pen (HP#1) midday, July 18. There were insufficient fish to fill all nine cages at the holding pen adjacent to Frank Schumans' property (HP#2), hence only six cages (two of each type) were filled midday, July 20. The other remaining cages with the exception of the third volitional cage were filled over a period to August 4.

The condition of the fish was checked daily. Mortalities were removed and promptly examined microscopically at x15 to x60 for external symptoms of GBT. Symptoms looked for included bubbles in the fins, skin tissue (integument), roof of the mouth and in large numbers of scale pockets on the lateral line; haemorrhaging in the eye area or at the base of the fins; difficulty in swimming and loss of equilibrium; flattening of the dorsal fin; and exophthalmia. Weight and fork length were recorded. Debris that collected on the cages was removed with gentle scrubbing. Fish were not fed and were dependant on drift that entered the cage as a source of food.

On July 24 the stage dropped rapidly grounding HP#2 in the shallows, leaving the middle surface cage suspended in the air and killing the fish in that cage. Modifications were made to prevent recurrence of this problem and nine fish, captured by electroshocking in Twin Creek, (Fig. 3) were placed in the cage July 31 and August 1. On August 4, additional fish were electroshocked at Twin Creek. Twenty were placed in the surface stern cage and 20 in the depth stern cage, neither of these cages having been previously filled.

The experiment at HP#1 concluded abruptly midday, August 7 when the pen broke free of its anchorage while being moved to quiet water and was destroyed downstream. Some of the fish were promptly recovered from cages but all were dead. The mortalities which had been recovered from surface and volitional cages were processed as usual and preserved; those recovered from depth cages were only preserved. The holding cages and a portion of the pen were removed from the river.

The experiment at HP#2 was concluded August 15 and 16. All remaining fish were processed and preserved. The holding pen was removed from the water and the cages cleaned and dismantled.

TOTAL GAS PRESSURE MEASUREMENTS

Continuous monitoring of TGP and related air and water quality parameters was conducted near the base of Cheslatta Falls from mid July to late September, and spot air and water quality measurements were taken at HP#1 and HP#2 during the GBT study (Fig. 3).

A Terrascience Ltd. Terra 8 data logger was installed at the site July 15. An Instrumentation Northwest Ltd. atmospheric barometric pressure (BP) probe, Terrascience Ltd. air and water temperature probes and a modified Novatech 300c were connected directly to the Terra 8. The data logger, BP and air temperature probes, and Novatech instrument and battery pack were installed in a Stevenson screen. The screen and the car battery which provided primary power to the Terra 8 were held in an open shed. The water temperature and tensionometer probes were submerged 0.5 to 1 m (1.6 to 3.3 feet) water depth in well mixed mainstem flow. The Terra 8 was programmed to record data from all probes hourly after initial calibration.

System maintenance included monitoring the Terra 8 to obtain real time probe values, confirming probe values (i.e. calibration), and changing batteries and silastic tubing in the tensionometer probe. Calibration involved checking BP, temperature, and tensionometer readings against spot measurements with a Pauline aneroid barometer, a thermometer accurate to ± 0.1 deg. C, and an additional Novatech 300B tensionometer, respectively. In addition, dissolved oxygen was measured using the Winkler titration method. The positions of the immersed probes were adjusted on several occasions as water stage changed.

The data in memory were downloaded via cassette tape recorder approximately once a week. The memory was then erased and the Terra 8 reset to begin another automatic data acquisition cycle. Two data gaps occurred. The first, July 18 to 21, was a result of incorrect programming. The second, September 8 to 10, was a result of the memory being full due to a delay in downloading and erasing.

The data on cassette tapes were transferred to floppy disk and imported to a spreadsheet format using Terrascience Ltd. software, an IBM PC and/or Compaq 286, and Lotus 123 Version 2.0.

Air and water quality spot measurements were made at HP#2 as well during the GBT experimental period. Water temperature was recorded on a thermograph installed as part of a tem erature monitoring program. Intermittent barometric pressure, tensionometer, and D.O. measurements were made.

RESULTS

PHYSICAL-CHEMICAL RESULTS

Continuous automatic recording of water and air quality conditions at Cheslatta Falls using the Terra 8 data logger spanned the period July 12 to Sept. 23 in 1986. All TGP values were supersaturated. From the data logger records (N=1581), moist TGP ranged from 101.9% (2000 hrs Sept. 4) to 115.0% (0700 hrs Aug 23) and averaged 108.6%. There is a positive correlation between discharge at WCS station 08JA017 and moist TGP at Cheslatta Falls (Appendix 1, Fig. 5). A least squares regression line through these points gives a reasonable fit (i.e. r squared = 0.82).

The maximum, average, and minimum daily atmospheric and water quality values recorded at Cheslatta Falls by the data logger during the 1986 GBT experiment are presented in Appendix 2 with calculated moist TGP and discharge at HP#1. Appendix 3 presents spot air and water quality measurements at both sites. In general, the weather was mixed, with extended periods of clear, warm weather during the latter half of the experiment. Data from these appendices, biological results and weather observations are presented graphically in Figures 6 and 7.

TGP values derived from the data logger at Cheslatta Falls ranged from 107.2% to 115.0% averaging 111% (N=414) for the duration of the test at HP#1. Spot measurements (N=5) fell within this range and the O2/N2 ratio ranged from 0.93 to 0.98. TGP values at HP#2 (Frank Schumans') ranged from 106.5% to 111.3% and averaged 108.6% (N=20). The O2/N2 ratio ranged from 0.98 to 1.05 and averaged 1.01 (N=10).

BIOLOGICAL RESULTS

Data on fish length, weight, and mortality rates appear in Appendix 4. Total mortality by treatment (surface, volitional, and depth) at HP#1 and HP#2 appears with physical-chemical and weather data in Figures 6 and 7, respectively. Cumulative mortality by individual cage and treatments are given for HP#1 and HP#2 in Appendices 5 and 6 and Figures 8 and 9. At HP#1 there were three replicate cages of 20 fish each for each treatment for the

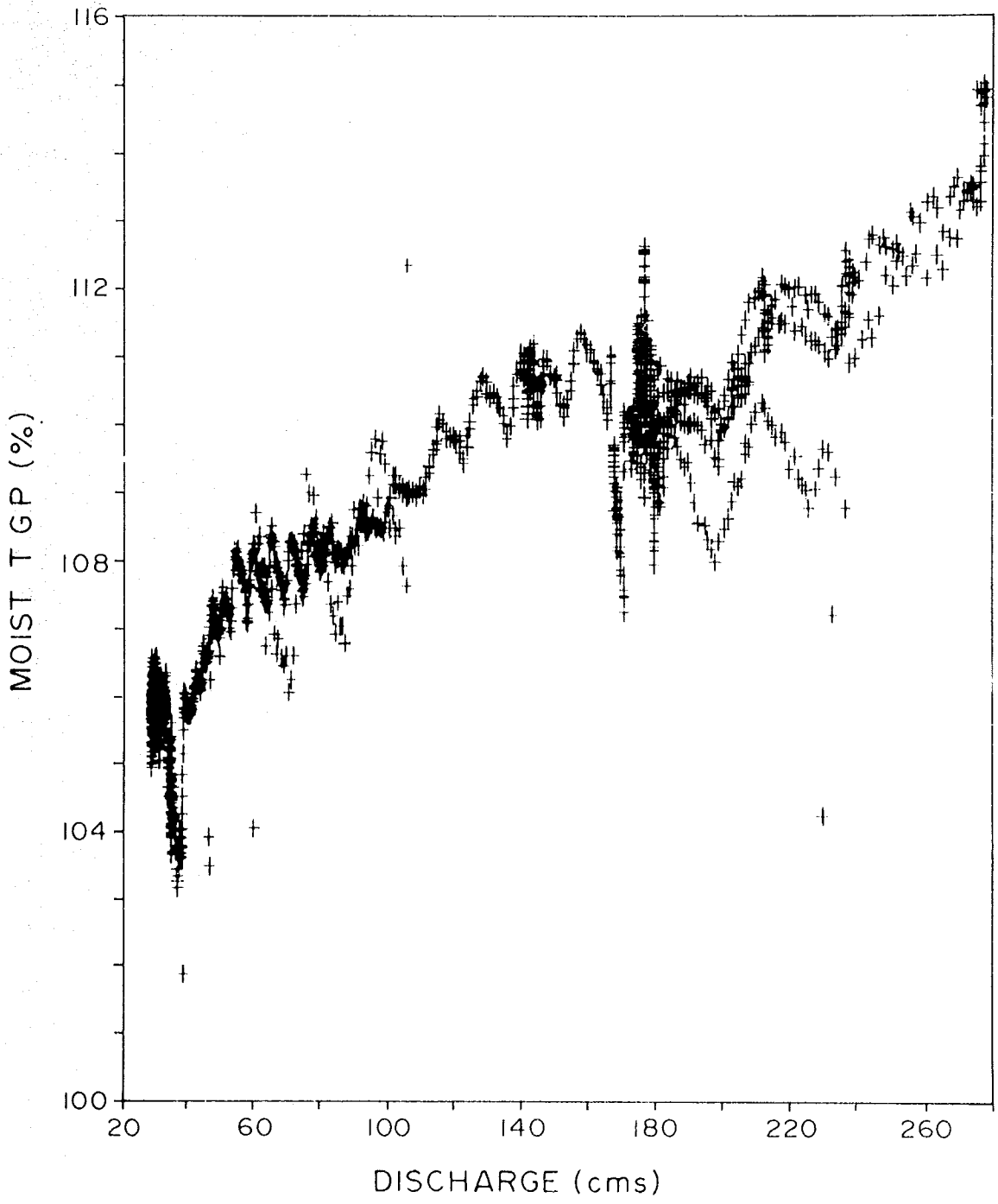

Fig. 5. Moist TGP versus discharge (CMS) at Cheslatta Falls.

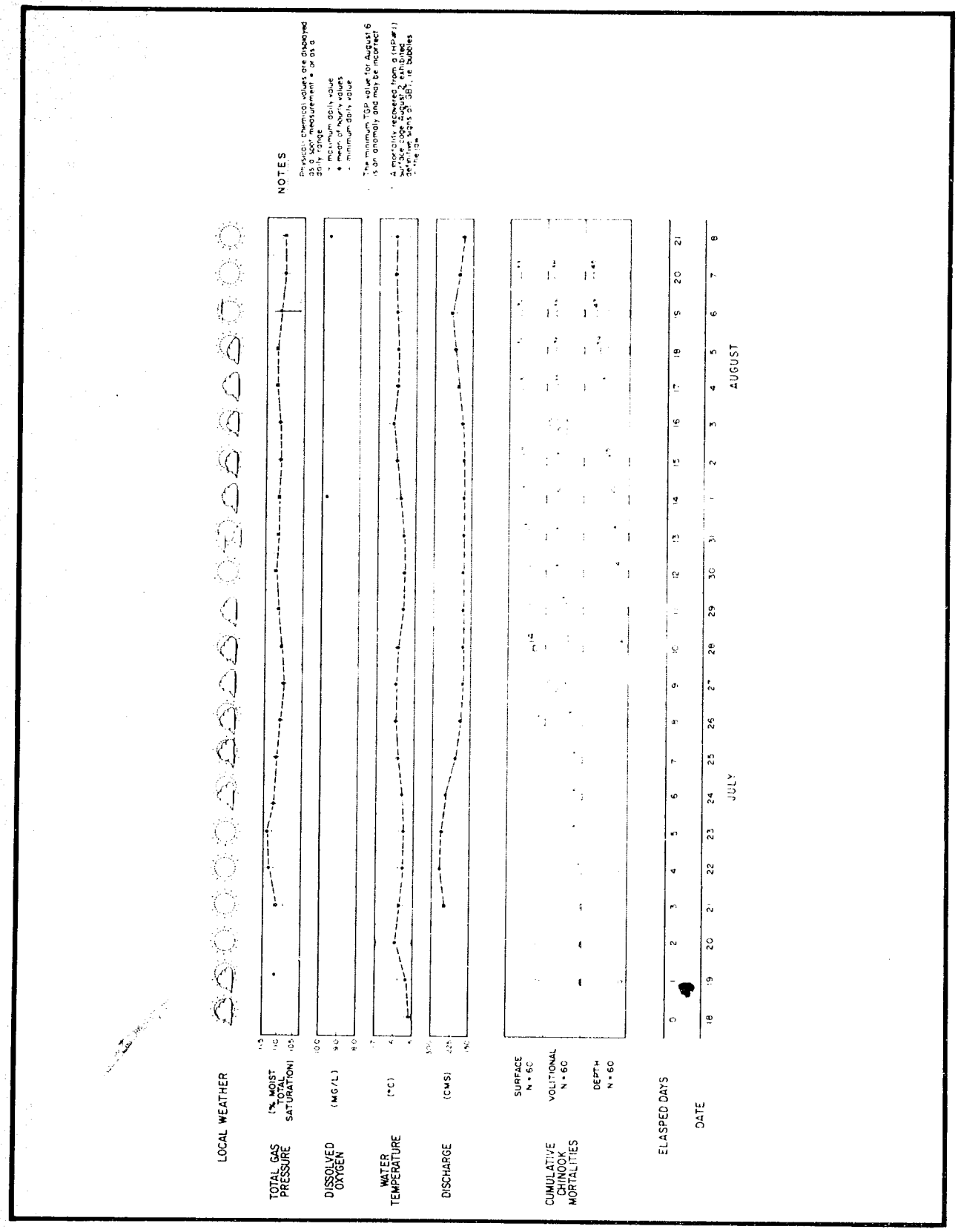

Fig. 6. Physical, chemical and biological data for the 1986 Nechako River in situ Gas Bubble Trauma (GBT) studies holding pen #1 at Cheslatta Falls.

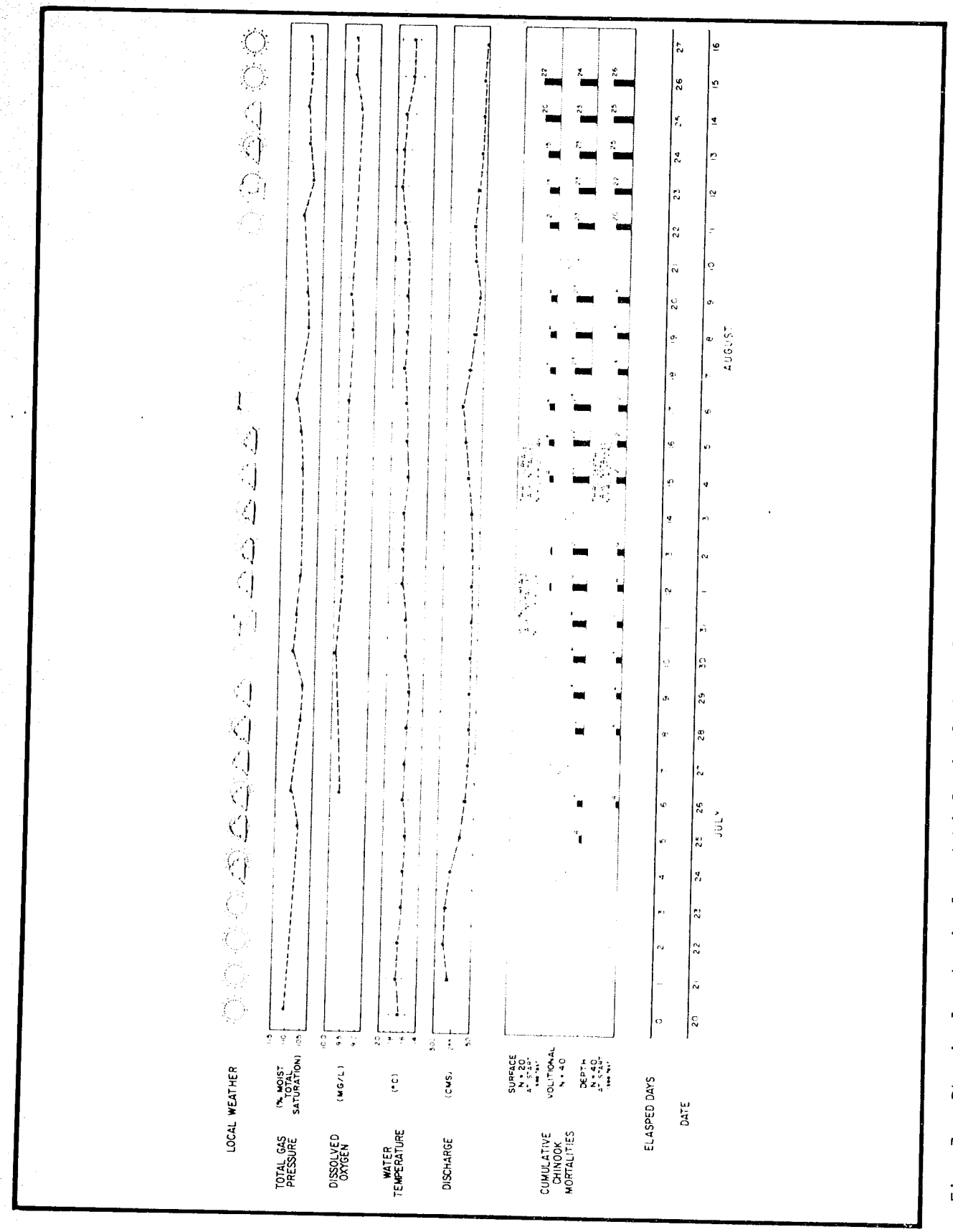

Fig. 7. Physical, chemical and biological data for the 1986 Nechako River in situ Gas Bubble Trauma (GBT) studies holding pen #2 at Frank Schuman's.

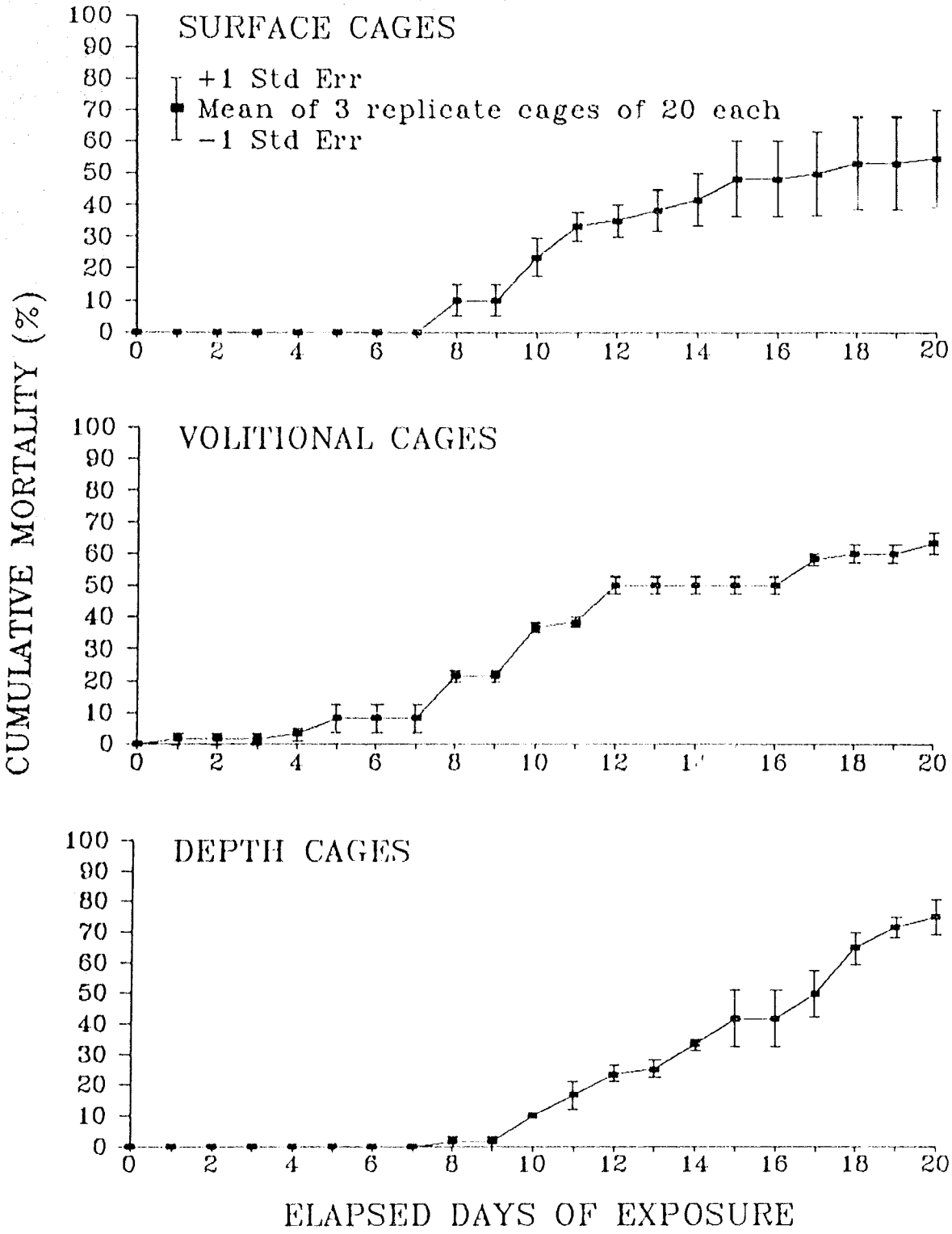

Fig. 8. Cumulative chinook mortality versus elapsed time at holding pen #1.