

Dissolved Atmospheric Gases and Reaeration Coefficients for the Nechako River

R. D. Byres and J. A. Servizi

Department of Fisheries and Oceans
Fisheries Research Branch
Cultus Lake Research Laboratory
Cultus Lake, British Columbia V0X 1H0

June 1986

**Canadian Technical Report of
Fisheries and Aquatic Sciences
No. 1459**

Dissolved Atmospheric Gases and Reaeration Coefficients for the Nechako River

R. D. Byres and J. A. Servizi

Department of Fisheries and Oceans
Fisheries Research Branch
Cultus Lake Research Laboratory
Cultus Lake, British Columbia V0X 1H0

June 1986

**Canadian Technical Report of
Fisheries and Aquatic Sciences
No. 1459**

Canadian Technical Report of
Fisheries and Aquatic Sciences No. 1459

June 1986

DISSOLVED ATMOSPHERIC GASES AND REAERATION COEFFICIENTS FOR
THE NECHAKO RIVER

by

R.D. Byres¹ and J.A. Servizi

Department of Fisheries and Oceans
Fisheries Research Branch
Cultus Lake Research Laboratory
Cultus Lake, British Columbia VOX 1H0

¹Water Use Unit
Field Services Branch
1090 West Pender,
Vancouver, B.C.

(c)Minister of Supply and Services Canada 1986

Cat. No. Fs 97-6/1459E

ISSN 0706-6457

Correct citation for this publication:

Byres, R. D. and J. A. Servizi. 1986. Dissolved atmospheric gases and reaeration coefficients for the Nechako River. Can. Tech. Rep. Fish. Aquat. Sci. 1459: 83 p.

ABSTRACT

Byres, R. D. and J. A. Servizi. 1986. Dissolved atmospheric gases and reaeration coefficients for the Nechako River. Can. Tech. Rep. Fish. Aquat. Sci. 1459: 83 p.

In June and August, 1985 field studies were conducted on the Nechako River to investigate the relationship between river discharge and reaeration coefficients (K_2). Dissolved gas and temperature data were collected, from which reaeration coefficients were calculated. The calculations included a procedure designed to account for variable gas solubilities caused by temperature changes within the "parcels" of water studied. Results are presented along with earlier data reported by the International Pacific Salmon Fisheries Commission and Envirocon Ltd, and indicate that there is a nonlinear relationship between K_2 and discharge. K_2 values for the upper reaches of the Nechako appear to increase with discharge up to a maximum value, then decrease as the discharge continues to rise. This relationship should be considered when selecting values of K_2 for modelling dissolved gas levels in the Nechako River.

RESUME

Byres, R. D. and J. A. Servizi. 1986. Dissolved atmospheric gases and reaeration coefficients for the Nechako River. Can. Tech. Rep. Fish. Aquat. Sci. 1459: 83 p.

Des études sur le terrain portant sur la rivière Nechako ont été effectuées en juin et août 1985 dans le but d'étudier les rapports entre le débit du cours d'eau et les coefficients de réaération (K_2). Ces coefficients ont été calculés à partir de données recueillies sur les gaz dissous et la température. On a utilisé au cours des calculs une procédure conçue pour tenir compte de la variabilité de la solubilité des gaz découlant des modifications de température au sein des "parcelles" d'eau étudiées. Les résultats sont présentés de pair avec des données précédemment obtenues par la Commission internationale des pêches du saumon du Pacifique et Envirocon Ltd. Ils indiquent l'existence d'une relation non linéaire entre la valeur de K_2 et le débit. Dans les parties les plus en amont du cours d'eau, les valeurs de K_2 augmentent avec l'importance du débit jusqu'à une valeur maximale, mais diminuent ensuite. On devrait tenir compte de cette relation lors du choix de valeurs de K_2 pour la modélisation des teneurs de gaz dissous dans la rivière Nechako.

TABLE OF CONTENTS

Abstract	iii
Introduction	1
Methodology	3
Flow Travel Times	3
Dissolved Gas Concentrations	6
Dissolved Gas Saturations and Reaeration Coefficients	7
Calculation of Total Gas Pressure values from field data	8
Calculation of saturation concentrations	9
Calculation of reaeration coefficients (K_2)	12
Results	16
Discussion	26
References	28
Appendices	30



Government
of Canada

Gouvernement
du Canada

Fisheries
and Oceans

Pêches
et Océans

Your file

Votre référence

Our file

Notre référence

"The Government of Canada shall have no liability or responsibility to any person or entity with respect to any liability, loss or damage caused or alleged to be caused directly or indirectly by this software, including but not limited to any interruption of service, loss of business or anticipatory profits or consequential damages resulting from the use or operation of this software.

There is no service associated with this software and any defect or fault found therein will not be the responsibility of the Government of Canada."

DISSOLVED ATMOSPHERIC GASES AND REAERATION COEFFICIENTS FOR THE NECHARO RIVER

INTRODUCTION

The effects of gas supersaturation on aquatic organisms have recently become a concern on many river systems where high levels of dissolved gases occur. Gas supersaturation in water exists when the water contains dissolved gas in excess of the saturation level for the given conditions. The saturation level is mainly determined by water temperature, barometric pressure, and hydrostatic pressure. Supersaturation of a gas or gases may occur from a number of natural or man-made processes, including gas dissolution under greater-than-atmospheric pressure, heating of water, and the respiration of aquatic plants. For example, when atmospheric air is entrained deep into plunge pools below spillways or waterfalls, it is dissolved under relatively high hydrostatic pressures. When this water returns to the lower hydrostatic pressures near the surface, it is supersaturated (Weitkamp and Katz, 1980). Heating of water is a source of supersaturation because the solubility of gases decreases as water temperature rises. Thus when the temperature of saturated water rises due to thermal inputs, the water becomes supersaturated. The photosynthetic activity of aquatic plants can cause supersaturation if the production of oxygen is faster than the equilibration rate of the water (Weitkamp and Katz, 1980). Supersaturated water is unstable and the excess gas will gradually dissipate to the surrounding water or atmosphere. A curve showing gas content versus time will follow an exponential decay pattern, steepest near the vertical axis and "flattening out" as the gas level asymptotically approaches the 100% saturation level (Appendix 1).

Each constituent gas in the atmosphere exerts a measurable pressure, and the sum of such "partial pressures" is equal to the atmospheric (barometric) pressure. Similarly, each gas dissolved in water, including water vapour, will exert a pressure or "tension" proportionate to the amount of that gas dissolved. The pressure exerted by all the gases in solution is called the Total Gas Pressure (TGP). In supersaturated water, the value of TGP exceeds the barometric pressure. The difference between TGP and barometric pressure is known as the "hyperbaric dissolved gas pressure differential", or ΔP . The

ability to measure or predict TGP levels is of interest since high levels of TGP lead to formation of gas bubbles in tissues of aquatic organisms, a condition known as Gas Bubble Trauma (GBT). Refer to Alderdice and Jensen (1985) for a detailed review of GBT.

Since 1979, studies have been conducted on the Nechako River to determine existing or potential TGP levels as a consequence of supersaturation at Cheslatta Falls and warming downstream. One of these studies led to the production of a computer model which predicts TGP at downstream points given initial TGP, temperature, discharge and weather conditions (Bryan, P. unpubl. DFO 1985). This model requires values of the reaeration coefficient (K_2). A K_2 coefficient describes the rate at which an excess of dissolved gas is dissipated to the atmosphere due to turbulence. A river system with a high value of K_2 will dissipate excess gas, or "reaerate", faster than a river with a low value of K_2 . Studies conducted on the Nechako during June and August 1985 were designed to collect data from which values of K_2 could be determined for various river reaches. These data, along with earlier data obtained by the International Pacific Salmon Fisheries Commission (IPSFC) and Envirocon Ltd. are combined in this report to relate K_2 in each river reach to river discharge.

METHODOLOGY

Determination of K_2 values for a given reach of a river requires knowledge of dissolved gas levels and temperatures in the same parcel of water as it passes both the upstream and downstream ends of the reach. In order to determine the sampling times at the various stations and appropriate flow times for use in the calculations, the discharge-travel time relationship must be known. The methods used are subdivided into three parts: determination of flow travel times, collection of dissolved gas and temperature data, and calculation of reaeration coefficients.

The sampling sites used in 1985 correspond to those chosen earlier by Envirocon and IPSFC as the boundaries of reaches (Figure 1). Site locations are also marked on 1:50,000 scale maps on file in the Water Use Unit at the Department of Fisheries and Oceans (DFO).

FLOW TRAVEL TIMES

Water levels were read manually at three Water Survey of Canada (WSC) stations periodically, and converted to discharges using WSC rating tables. These discharge data are considered preliminary, as WSC may revise the gauge datum or prepare a new rating curve which could alter the final discharge values (P. Langford, WSC Prince George, pers. comm.). The gauge Nechako-below-Cheslatta (STA.NO.08JA017) is linked by a Data Control Platform (DCP) to Vancouver, and field readings were supplemented by daily DCP readings from this station. The river cross section at this gauge is believed to be stable and the gauge readings are considered reliable (P. Langford, pers. comm.). The Nautley-River-near-Fort-Fraser gauge (STA.NO.08JB003) is also considered stable, located approximately 100 m above the rock berm installed by Alcan Ltd. to control the water levels on Fraser Lake. The Nechako-at-Vanderhoof gauge (STA.NO.08JC001) was a manual chain type gauge below the highway bridge but was replaced in September 1985 by a recording manometer gauge. The rating curve for this gauge is likely to be revised due

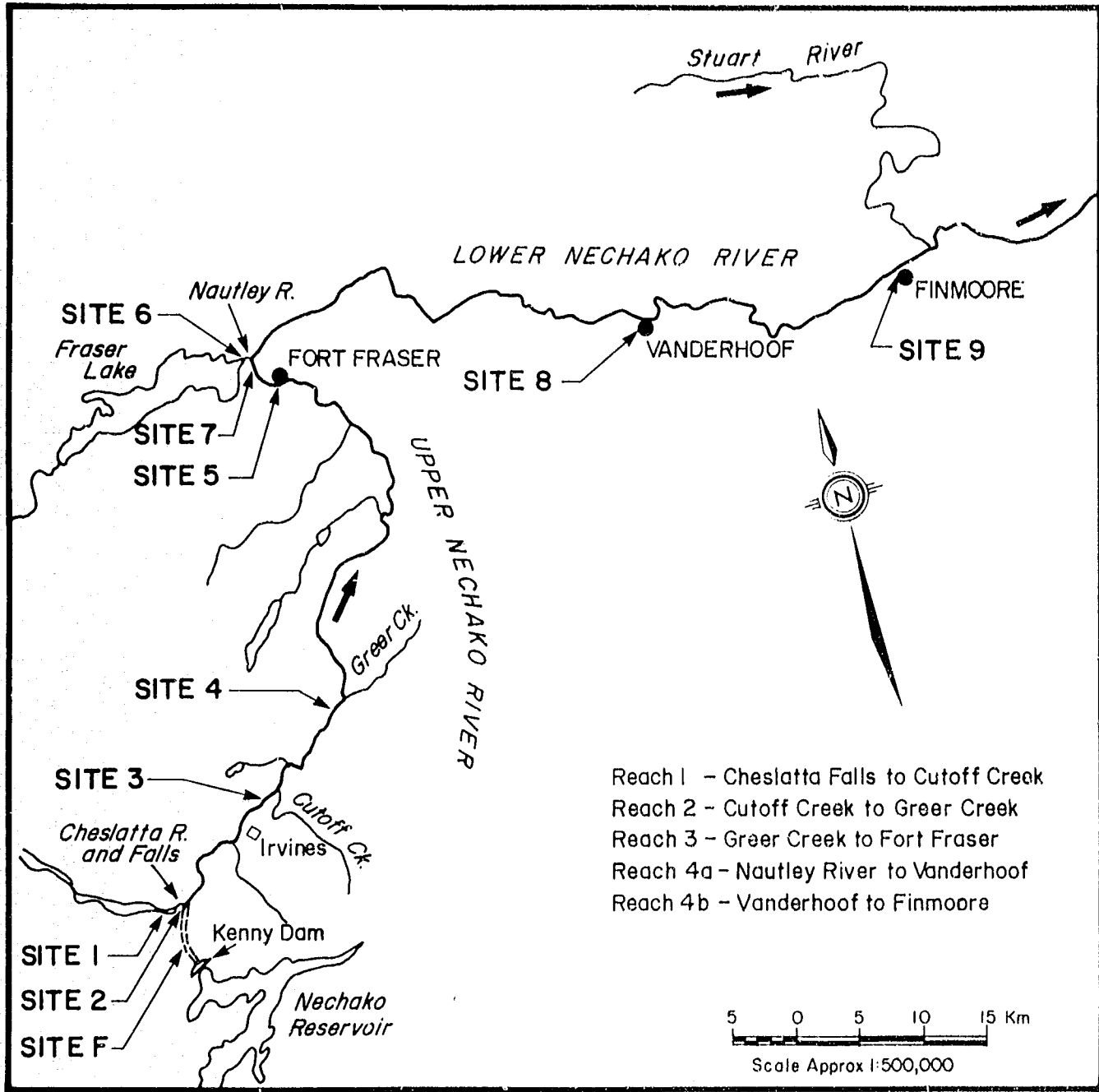


Figure 1 Nechako River TGP Sampling Sites and River Reach Boundaries

to the finer grained, more mobile bed material in this reach. The current stage/discharge relationship is approximately 6% less than the 1983 rating curve (P. Langford, pers. comm.). The hydrologic data collected during June and August 1985 are presented in Appendix 2.

Curves of discharge versus travel time were prepared using data from a hydraulic routing model (IPSFC 1979), which simulates the average river velocity at a number of discharges for each of 103 cross-sections between Cheslatta Falls and the Stuart River. Flow travel times at some discharges were based on extrapolation of IPSFC data (Envirocon 1984:a). Using these simulated velocities and the known distances between cross-sections, the travel times between the transect boundaries were calculated. The total travel time for a specific reach at a specific discharge was therefore the sum of the times for all the transects within the reach. These data are recorded in Appendix 3 and plotted on curves in Appendix 4. Travel times for discharges other than those determined by IPSFC were obtained by interpolation of curves in Appendix 4. For higher discharges the curves were extrapolated to $283 - 311 \text{ m}^3\text{s}^{-1}$ ($10000-11000 \text{ ft}^3\text{s}^{-1}$) since IPSFC data extended only to $198 \text{ m}^3\text{s}^{-1}$ ($7000 \text{ ft}^3\text{s}^{-1}$). It is estimated that little uncertainty was introduced by this extrapolation since the curves are quite regular and there was little or no overbank flooding at the higher discharges.

The measured river discharges, calculated travel times, and sampling schedule used for the TGP measurements are given in Appendices 5 - 6. The discharge was measured on the same day that the upstream station of a reach was sampled, and the flow travel time calculated to obtain the sampling times for the downstream station. If the discharge was changing from one day to the next and the flow travel time was quite long, the initial measured discharge was assumed to represent that of the entire reach sampling period.

For sampling stations between the WSC gauge locations, the discharge was assumed to be equal to that of the closest, most representative gauge. That is, for reaches 1, 2 and 3 the Nechako-below-Cheslatta gauge was used, and for reaches 4a and 4b the Nechako-at-Vanderhoof gauge was used. Refer to Figure 1 for reach boundaries and sample locations. With the exception of the Nautley River, contributions from tributaries between the gauges were approximately $5.7 \text{ m}^3 \text{ s}^{-1}$ ($200 \text{ ft}^3 \text{ s}^{-1}$) or 2 to 10% of the total discharge, and were not included in the calculation of flow travel times.

DISSOLVED GAS CONCENTRATIONS

For a given discharge, three "parcels" of water were sampled at one-hour intervals at the upstream boundary of each reach. The three parcels were again sampled as they passed the downstream boundary of the reach, according to elapsed times determined from the discharge-travel time curves (Appendix 4).

Water samples were collected at the sites shown in Figure 1. In some instances the August sites did not correspond exactly to those used in June. These changes were necessary since at the higher flows of August some of the original locations were unsuitable or inaccessible due to dense brush along the river bank. The error in elapsed time associated with the slight changes in site was considered negligible.

The raw data required for calculating dissolved gas concentrations included water temperature, total gas pressure, barometric pressure, and dissolved oxygen content. Water temperatures were measured using calibrated total immersion thermometers accurate to 0.1°C , held 5-10 cm below the water surface and shielded from direct sunlight. Sampling was done $> 1 \text{ m}$ away from the shore, to avoid lower water velocities and shallow depths at the river edge. Local barometric pressures were measured using a Paulin altimeter (model A1) and applying a conversion formula (eq. 1). ΔP measurements were made with two Novatech tensionometers (models 300B and 300C) and dissolved oxygen was measured using the Winkler procedure (field techniques are outlined

in Appendix 7). Sampling sites were selected to ensure that well-mixed water was sampled, usually > 1 m from the edge effects near the shoreline. Tensionometers were allowed to equilibrate in air for approximately five minutes before the readings were set to zero and the probes immersed in the river. When it was uncertain whether equilibrium had been reached, a graph of TGP versus time was plotted to define the equilibrium value of TGP (see Appendix 8). Slow drift of ΔP was not major and was generally within the ± 2 mm Hg accuracy of the instrument. Such variation was possibly attributable to the unusually high and variable barometric pressure experienced during sampling. In discussion with Novatech staff (Mr. Korman) a change of < 1 mm Hg in barometric pressure is insufficient to require re-zeroing the instrument. At his suggestion, the probe was left in the water for each three-hour sampling period during the August survey.

DISSOLVED GAS SATURATIONS AND REAERATION COEFFICIENTS

Values of K_2 were calculated for each reach using data obtained at the upstream and downstream ends of the reach for a specific parcel of water. The process of converting field measurements to estimates of K_2 involved a series of three calculations. First, TGP values and the relative contributions from oxygen and the other atmospheric gases were calculated in the field, using the raw data sheets (Appendix 9). It was assumed that oxygen, nitrogen and argon were the only gases in solution, the contribution of other trace gases being negligible (Colt 1983). (For practical purposes the behaviour of nitrogen and argon in solution are the same, and these were therefore considered as one gas.) The second calculation determined the temperature-dependent saturation concentrations of N_2+Ar , and converted the gas concentrations into convenient units of milligrams per litre (mgL^{-1}). Finally, reaeration coefficients were calculated for each reach using gas concentrations at each end of the reach and the corresponding travel times and temperatures.

Calculation of TGP values from field data

Barometric pressure was determined using a conversion specific to the Paulin altimeter:

$$(1) \quad BP = (30.0 - \frac{\text{Altimeter Reading}}{933.3}) 25.4 \text{ mm Hg}$$

Percent Total Saturation (moist air) was often used interchangeably with TGP since it was more convenient to refer to TGP as a relative percentage supersaturation rather than a value in pressure units, and was calculated as follows:

$$(2) \quad \text{TGP (moist)} = \frac{(BP + \Delta P) 100}{BP} \%$$

where ΔP is the equilibrium reading on the tensionometer. Percent Saturation in dry air was calculated the same way, except that the contribution of water vapour pressure (WVP) was subtracted (Colt 1983):

$$(3) \quad \text{TGP (dry)} = \frac{(BP - \text{WVP} + \Delta P) 100}{BP} \%$$

Water vapour pressure is temperature dependent and was obtained from Colt (1984).

Partial Pressure of Oxygen was determined by (Colt 1983):

$$(4) \quad P_{[O_2]} = \frac{DO (0.5318)}{B_{[O_2]}} \quad \text{mm Hg}$$

where DO = dissolved oxygen from Winkler test (mgL^{-1})

$B_{[O_2]}$ = Bunsen coefficient for Oxygen

Bunsen coefficients were generated from the following regression equations (after Weiss, 1970):

$$(5) \ln B_i = A_1 + A_2 (100/T) + A_3 \ln\left(\frac{T}{100}\right) + \text{Salinity terms}$$

where T = absolute temperature (°C + 273.15);

A_i = constants specific for each gas (see Appendix 10); and

B_i = Bunsen coefficient for each gas.

Salinity terms were neglected since fresh water was tested.

Percent saturation of oxygen was determined as follows (Colt 1983):

$$(6) \%O_2 = \frac{100 P[O_2]}{(BP-WVP)(0.2095)} \%$$

Partial pressure and percent saturation of N₂ + Ar were based on subtracting all other gas contributions from the total (Colt 1983):

$$(7) P[N_2+Ar] = BP + \Delta P - WVP - P[O_2] \text{ mm Hg}$$

$$(8) \% [N_2+Ar] = \frac{100 P[N_2+Ar]}{(BP-WVP)(0.79018)} \%$$

The above calculations were performed in the field using a programmable hand calculator and the results checked before proceeding.

Calculation of saturation concentrations

For a given temperature and barometric pressure there is a saturation concentration for each dissolved gas. The solubility of a gas at saturation is equal to its Bunsen coefficient multiplied by the partial pressure of that gas in the atmosphere. For the combined N₂+Ar gas a weighted mean calculation was used to obtain ambient and saturation concentrations (Colt 1983):

$$(9) \text{Concentration of } N_2+Ar(mgL^{-1}) = P \frac{B_{[N_2+Ar]}}{A_{[N_2+Ar]}}$$

where B_[N₂+Ar] is the Bunsen coefficient for N₂+Ar

$$(10) B_{[N_2+Ar]} = \frac{(0.78084)B_{[N_2]} + (0.00934)B_{[Ar]}}{0.79018},$$

and

$$(11) A_{[N_2+Ar]} = \frac{760}{1000} \left[\frac{(0.78084)B_{[N_2]} + (0.00934)B_{[Ar]}}{(0.78084)K_{[N_2]} B_{[N_2]} + (0.00934)K_{[Ar]} B_{[Ar]}} \right]$$

Where 0.78084, 0.00934, and 0.79018 are the mole fractions of N₂, Ar, and N₂ + Ar respectively;

K_[N₂] and K_[Ar] are the ratios of molecular weight to molecular volume for N₂ and Ar respectively (Appendix 10)

(Since the mole fraction of Argon is very small compared to that of Nitrogen, the Argon terms do not significantly affect the calculations. For calculating K₂, the contribution of Argon can be neglected and equations (10) and (11) can be approximated using only Nitrogen. Similarly, saturation concentrations and K₂ coefficients for N₂ + Ar can be approximated as those for N₂ alone.)

Saturation concentrations of gases were obtained by using the following regression equations (after Weiss 1970):

$$(12) CS_i(\text{mg/l}) = CS_i(\text{ml/l})K_i(\text{mg/ml})$$

$$(13) \ln CS_i(\text{ml/l}) = A_1 + A_2 \left(\frac{100}{T} \right) + A_3 \ln \left(\frac{T}{100} \right) + A_4 \left(\frac{T}{100} \right) + \text{salinity terms}$$

where T = absolute temperature (°C + 273.15)

CS_i = solubility of ith gas at STP

A_i = constants (see Appendix 10)

K_i = ratio of molecular weight to volume (Appendix 10)

Salinity terms neglected for fresh water.

Finally, the saturation concentration of N_2+Ar is (Colt 1984):

$$(14) \quad CS_{[N_2+Ar]} = CS_{[N_2]} + CS_{[Ar]}$$

These values are only valid for an atmospheric pressure of 760 mm Hg. The results were therefore corrected for the local barometric pressure as follows (Standard Methods 1976):

$$(15) \quad CS_{[N_2 + Ar]}^{(local)} = CS_{[N_2 + Ar]} \frac{(BP-WVP)}{(760-WVP)}$$

Calculation of reaeration coefficients (K_2)

The following development of K_2 calculations has been largely extracted from Servizi (1981):

Using the Streeter-Phelps (1925) expression for the "oxygen sag" equation, reaeration is expressed in terms of supersaturation as follows:

$$(16) S_1 = S_0 10^{-k_2 t}$$

where S_1 = percent saturation exceeding 100% at Station 1

S_0 = percent saturation exceeding 100% at Station 0

t = flow travel time between stations, (hours)

k_2 = reaeration coefficient based on \log_{10} (hr^{-1})

The value of k_2 represents the rate at which excess dissolved gas is dissipated to the atmosphere due to turbulence. The higher the value of k_2 , the faster gas transfer occurs. The values of dissolved gas saturation are also influenced by barometric pressure and temperature.

In addition to turbulence, temperature, and barometric pressure, values of dissolved oxygen saturation levels are affected by biochemical oxygen demand (BOD) and the respiration of aquatic plants and algae. To avoid these biological influences, calculation of k_2 was based on changes in nitrogen and argon concentrations only. The value of k_2 is related to the inverse ratio of the molecular diameters of oxygen and nitrogen (Tsivoglou et al. 1965, 1968), and therefore k_2 for oxygen can be calculated from k_2 for nitrogen and argon as follows:

$$(17) k_2[\text{O}_2] = 1.068 k_2[\text{N}_2 + \text{Ar}]$$

Rearranging equation 2-16 and solving for k_2 yields:

$$(18) k_2 = -\frac{1}{t} \log_{10} \frac{(S_1)}{(S_0)}$$

To evaluate k_2 for a particular river reach, S_0 , S_1 and t must be known. The calculated value of k_2 corresponds to the temperature at which sampling was done. Reaeration coefficients determined at one temperature can be converted for another as follows (Dysart 1970):

$$(19) \quad k_2(T) = k_2(20) (1.024)^{T-20}$$

where $k_2(20)$ is the value of the reaeration coefficient at 20°C , and

T is the local temperature ($^\circ\text{C}$).

Conversely, rearranging equation (19) allows k_2 at field temperatures to be converted to a common base of 20°C for comparison purposes:

$$(20) \quad k_2(20^\circ\text{C}) = \frac{k_2(T)}{1.024^{T-20}}$$

Equations (16), (18), (19) and (20) are based on the assumption that temperatures remain constant over the reach. In practice this is rarely the case, and mean temperatures are not theoretically acceptable substitutes for constant temperatures when calculating values of k_2 .

A method of calculation was developed which corrects for temperature changes between stations (Servizi 1981). This method was applied to IPSFC and DFO data (August, October 1980, and June, August 1985) as follows:

If the temperature of the water increases between sampling stations, dissolved gases become less soluble. This causes a tendency to reduce the gas content more rapidly than if temperatures had remained constant, thereby overestimating the value of k_2 . The reverse occurs if the temperature decreases downstream. Since the tendency for change in gas content is an exchange reaction, it can be expressed as follows:

$$(21) \quad \Delta_1 = \Delta_0 10^{-k_2 t}$$

where Δ_0 = the difference between 100% saturation of nitrogen plus argon at the two stations at prevailing temperatures and pressures (mgL^{-1})

Δ_1 = the portion of the difference remaining to be exerted (mgL^{-1})

t = flow travel time between stations (hr)

k_2 = reaeration coefficient as in equation (16) (hr^{-1})

The change in nitrogen plus argon concentration actually exerted due to temperature change will be $\Delta_0 - \Delta_1$, expressed as "d". Substituting this into equation (21) yields:

$$(22) \quad d = \Delta_0 - \Delta_1 = \Delta_0(1 - 10^{-k_2 t})$$

If the temperature does not change between stations, the value of this expression is zero and no correction is needed.

When supersaturated water flowing in a river undergoes a temperature change the nitrogen and argon content observed at the downstream station will be the net result of gas exchanges due to both reaeration and temperature change. If the temperature increases, the gas content measured will be less than if the temperature had remained constant. To obtain the gas content that would have resulted had the temperature been constant (i.e. due to reaeration only), the decrease due to temperature rise must be added to the measured value at the downstream end. The value of this correction is equal to "d" in equation (22) above. Since this correction removes the effect of temperature change from the gas content at the downstream station, the percent saturation (S_1 in equation (16)) is calculated by comparing the corrected downstream gas content with the upstream saturation concentration.

To calculate k_2 , an estimated value of k_2 would be used in equation (22) to calculate a value of "d". The measured downstream concentration of nitrogen and argon would be corrected by this

amount, and using the corrected value, S_1 would be determined. A new value of k_2 would then be calculated using equation (18) and the result compared with the original estimate. Trial and error bring the estimated and calculated values into agreement.

Values of k_2 calculated by the trial-and-error temperature correcting method used a fixed-point iteration method algorithm adapted for computer. Convergence to a final value was possible for most data pairs, except where the temperature differences between upstream and downstream ends of the reach exceeded approximately 2.5°C. For these cases, a modified version of the secant method (see Appendix 11) produced satisfactory results. The latter method has since been adapted to the Apple II computer since it converges well for almost all data pairs. A sample hand calculation using the trial-and-error method is included for reference (Appendix 12).

Values of k_2 were converted from \log_{10} to \log_e as follows:

$$(23) K_2(\text{base}_e) = \frac{k_2(\text{base } 10)}{0.43429}$$

This final step was performed to enable comparison of K_2 values with other values previously published (IPSC 1979, Envirocon 1984:b). (Note that upper-case K_2 refers to the "base e" form of the coefficient, while the lower case version refers to the "base 10" form.)

RESULTS

The field data and TGP values measured during June and August 1985 are summarized in Appendices 2-6 and 13-14, attached.

Dissolved gas data collected in June and August 1985 indicate that supersaturation increased by approximately 4% after passing over Cheslatta Falls at $62.3 \text{ m}^3\text{s}^{-1}$ (Table 1). Samples A, B, C, and 114 indicate supersaturation increased approximately 10 to 12% due to Cheslatta Falls at $289 \text{ m}^3\text{s}^{-1}$. Since measurements above Cheslatta Falls indicate similar levels of supersaturation at both 62.3 and $289 \text{ m}^3\text{s}^{-1}$, this suggests that the amount of supersaturation downstream of Cheslatta Falls increases with discharge. At both discharges, values of TGP observed to decrease to near "background" levels when the water reached Vanderhoof (samples 34, 128).

The effect of temperature on supersaturation was demonstrated by samples 15 and 18 (Table 1). Although the dissolved gas content decreased between Cutoff Creek and Greer Creek, a temperature rise of 3.4°C resulted in an increase in % TGP from 103.1% to 107.9%. Such variation in water temperature and supersaturation was more pronounced during June than in August due to the lower flows during June.

Measurements near the base of Cheslatta Falls on August 8, 1985 were variable and were not used to calculate K_2 (Appendix 5). These measurements were taken directly at the base of the Falls and indicated a variable supersaturation of 110-112%, while the downstream values at Cutoff Creek were recorded as more than 113% at almost the same temperature and barometric pressure. In addition, a sample taken approximately 200 m downstream of the Falls on August 2 had a TGP value near 115%. Consequently, to assure data were representative of the effects of the falls on TGP, a site approximately 500 m downstream of the falls was chosen, which produced consistent TGP values near 115%. It seemed apparent that much of the gas dissolution took place downstream of the initial sampling location at the base of the falls.

At least three parcels of water were followed in each reach to obtain values of K_2 (Table 2). For reach 4a at $138 \text{ m}^3\text{s}^{-1}$ ($4870 \text{ ft}^3\text{s}^{-1}$), samples 31, 32, and 35 were combined with 30 to yield flow-weighted mixed samples (Appendices 15, 16). This was necessary since the Nautley River (sample 30) contributed a significant portion of the total flow for reach 4a. Similarly, at $311 \text{ m}^3\text{s}^{-1}$ ($11,000 \text{ ft}^3\text{s}^{-1}$) samples 122, 123, 124 were combined with 125 to yield starting conditions for reach 4a. Combining the samples at $138 \text{ m}^3\text{s}^{-1}$ resulted in a starting gas content lower than at the downstream end, and thus K_2 for reach 4a could not be calculated at $138 \text{ m}^3\text{s}^{-1}$. Mean values of K_2 were calculated for each reach (Table 3) using values of K_2 from Table 2 with two exceptions. For reach 1 at $62.3 \text{ m}^3\text{s}^{-1}$ ($2,200 \text{ ft}^3\text{s}^{-1}$) and for reach 3 at $289 \text{ m}^3\text{s}^{-1}$ ($10,200 \text{ ft}^3\text{s}^{-1}$), values of 0.043 and 0.173, respectively, were well outside the data trends (Figs. 2a and 2c) and were excluded from the means. Values of K_2 reported earlier by IPSFC and Envirocon Ltd. (Table 4) for each parcel of water in each reach were plotted with data from Table 2 to give curves of K_2 versus river flow (Figs. 2a, 2b and 2c) and these were combined in Figure 2d. Although values of K_2 were obtained only at $311 \text{ m}^3\text{s}^{-1}$ for reaches 4a and 4b, (as well as $138 \text{ m}^3\text{s}^{-1}$ for reach 4b), tentative curves were proposed with curvatures similar to reach 3 since these reaches appear physically similar. In each case the curves were fit visually to the data.

Table 1. Selected Values of Nechako River Dissolved Gas Data
June and August, 1985

Sample No.	Location	Discharge m^3s^{-1}	Date DY/MO	Time 24 Hr.	Water Temp ($^{\circ}C$)	Dissolved O_2 mgL^{-1}	Dissolved N_2+Ar mgL^{-1}	% TGP (moist air)
1	Above Ches. Falls	62.3	15/06	0935	12.5	9.95	16.86	102.7
2	Below Ches. Falls	62.3	15/06	1100	12.4	10.25	17.81	106.8
6	Cutoff Cr.	62.3	15/06	1630	14.4	10.40	16.91	106.8
9	Cutoff Cr.	62.3	16/06	0800	10.7	10.25	17.95	102.8
12	Greer Cr.	62.3	16/06	1645	14.7	10.20	17.01	107.6
15	Cutoff Cr.	62.3	17/06	0800	11.7	10.20	17.60	103.1
18	Greer Cr.	62.3	17/06	1545	15.1	10.00	16.92	107.9
24	Ft. Fraser	62.3	15/06	1500	16.8	9.50	15.81	105.6
34	Vanderhoof	138	20/06	0912	15.5	9.15	15.82	100.8
A*	Above Falls	289	07/08	1430	16.6	-	-	105.6
B*	Above Falls	289	09/08	1315	16.2	-	-	104.3
C*	Above Falls	289	11/08	1330	16.0	-	-	103.0
114	Below Falls	289	10/08	1245	16.3	10.20	17.83	115.2
117	Cutoff Creek	289	10/08	1640	16.4	10.20	17.30	112.6
128	Vanderhoof	311	13/08	0115	16.7	8.75	15.62	103.0

* Samples A, B and C were collected as part of a separate experiment (Rowland 1986). They were not numbered and no dissolved oxygen measurements were made.