British Columbia
Water Quality Guidelines for
Dissolved Gas Supersaturation

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Prepared by

L. E. Fidler and S. B. Miller
of
Aspen Applied Sciences Ltd.
Valemount, BC V0E 2Z0

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1.0 INTRODUCTION

Dissolved Gas Supersaturation (DGS) and Gas Bubble Trauma (GBT) in fish is a physical cause - biological effect relationship which has received the attention of environmental scientists for the past several decades. In British Columbia, DGS has been identified as a potential threat to fish populations in many water courses throughout the province. In this report, DGS is examined in terms of its causes, environmental levels, and potential impacts on fresh water and marine environments. Where sufficient information exists, DGS water quality guidelines are developed for the protection of fresh water and marine life. These guidelines are derived primarily from information describing the adverse physiological effects of DGS on fish and invertebrates. Additional factors, such as environmental variables and organism behavioural patterns which can intensify or mitigate these effects, are considered in the guideline derivation. At this time, no other water uses (*i.e.*, drinking water, agricultural, recreational, or industrial) could be identified which would require guidelines for DGS.

The scientific literature upon which this report is based was identified through computer searches of several North American scientific database providers. These included:

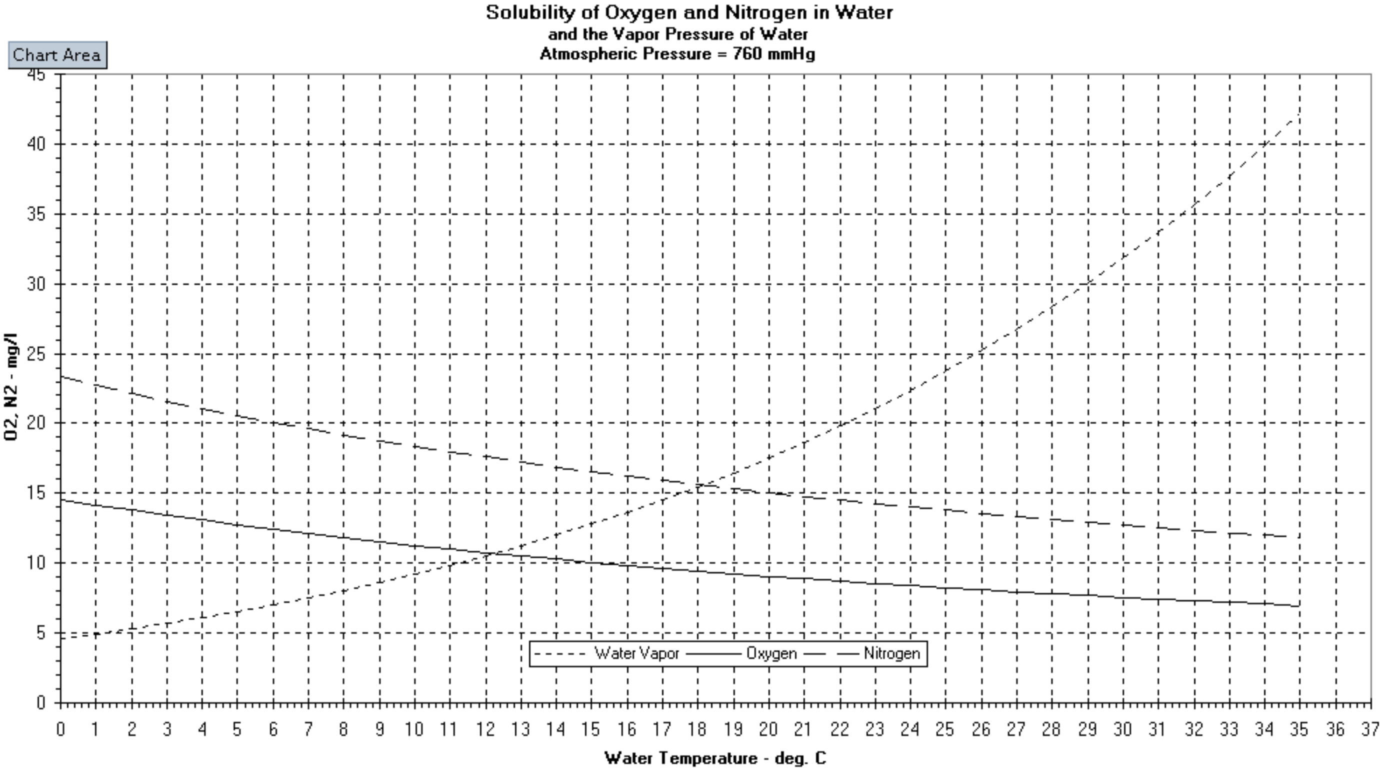
· ASFA (AQUATIC SCIENCES AND FISHERIES ABSTRACTS): 1978 to January, 1993
· AQUAREF (ENVIRONMENT CANADA): 1970 to March, 1993
· BA (BIOSIS PREVIEWS): 1969 to March, 1993
· CA (AMERICAN CHEMICAL SOCIETY): 1977 to March, 1993
· CAB (CAB ABSTRACTS): 1972 to February, 1993
· ELIAS (ENVIRONMENT CANADA LIBRARY NETWORK): 1976 to September, 1992
· ENVIRO (ENVIROLINE DATABASE): 1971 to January, 1993
· NTIS (NATIONAL TECHNICAL INFORMATION SERVICE): 1964 to March, 1993
· WAVES (ENVIRONMENT CANADA): to March, 1993

In addition, many papers were identified in bibliographies from the primary literature. For example the review of DGS and GBT by Weitkamp and Katz (1980) provided 138 references which were not identified by the computer database searches. This was also true of several other papers (Colt *et al.* 1986, White *et al.* 1991). In all, over 380 papers were examined for their suitability for the guideline derivation process.

1.1 Dissolved Gas Supersaturation

Dissolved gas supersaturation is a condition which exists in many natural and man-made water bodies throughout the world. It occurs when the partial pressures of atmospheric gases in solution exceed their respective partial pressures in the atmosphere. Figure 1 shows the relationship between gas solubility and temperature for the two major atmospheric gases, oxygen and nitrogen. When dissolved gas concentrations of oxygen and nitrogen are above their respective saturation lines in the figure, they are in a supersaturated state. Conversely, when concentrations of these gases are below the saturation lines, they are under-saturated. Also shown in Figure 1 is the vapour pressure of water as a function of temperature. Water vapour plays an important role in the reporting of dissolved gas levels and in the biological effects of DGS. However, it is generally treated as always being in a saturated state at the prevailing water temperature.

Figure 1: Solubility of Oxygen and Nitrogen in Water



Individual atmospheric dissolved gases (oxygen, nitrogen, and trace gases such as argon and carbon dioxide) can often be supersaturated without adverse effects on aquatic and marine organisms. However, when the sum of the partial pressures of all dissolved gases exceeds atmospheric pressure, there is the potential for gas bubbles to develop in water and in the aquatic and marine organisms which inhabit the water. This causes a condition known as gas bubble trauma. GBT and its physiological consequences to fish and other organisms will be described more fully in Section 1.2.

Throughout the literature, a variety of methods have been used for the reporting of dissolved gas tensions. The sum of the partial pressures of all dissolved gases is referred to as the Total Gas Pressure (TGP), while the difference between TGP and atmospheric pressure is defined as Delta P. Both TGP and Delta P are usually reported in mm Hg (millimetres of mercury) or sometimes in sea level or local atmospheres. Many authors report TGP as a percent of sea level or local atmospheric pressure (TGP%). For reasons which will be presented in Section 4.1, Colt (1984) recommends that delta P, rather than TGP or TGP%, be used as the preferred method of reporting dissolved gas tensions.

1.2 Gas Bubble Trauma

Dissolved gas super-saturation can produce a variety of physiological signs which are harmful or fatal to fish and other aquatic and marine organisms (Renfro 1963, Stroud and Nebeker 1976, Weitkamp and Katz 1980, Cornacchia and Colt 1984, Johnson and Katavic 1984, Gray *et al.* 1985, Fidler 1988, White *et al.* 1991). As a class, these signs are referred to as gas bubble trauma (Fidler 1984) or gas bubble disease (Bouck 1980). The major signs of GBT which can cause death or high levels of stress in fish are:

- Bubble formation in the cardiovascular system, causing blockage of blood flow and death (Jensen 1980, Weitkamp and Katz 1980, Fidler 1988).
- Overinflation and possible rupture of the swim bladder in young (or small) fish, leading to death or problems of overbuoyancy (Shirahata 1966, Jensen 1980, Fidler 1988, Shrimpton *et al.* 1990a and b).
- Extracorporeal bubble formation in gill lamella of large fish or in the buccal cavity of small fish, leading to blockage of respiratory water flow and death by asphyxiation (Fidler 1988, Jensen 1988).
- Sub-dermal emphysema on body surfaces, including the lining of the mouth. Blistering of the skin of the mouth may also contribute to the blockage of respiratory water flow and death by asphyxiation (Fidler 1988, White *et al.* 1991).

Other signs of GBT include exopthalmia and ocular lesions (Blahm *et al.* 1975, Bouck 1980, Speare 1990), bubbles in the intestinal tract (Cornacchia and Colt 1984), loss of swimming ability (Schiewe 1974), altered blood chemistry (Newcomb 1976), and reduced growth (Jensen 1988, Krise *et al.* 1990), all of which may compromise the survival of fish exposed to DGS over extended periods.

Each sign of GBT involves the growth of gas bubbles internal and/or external to the animal. However, for each sign there is a threshold level of delta P which must be exceeded before bubble formation or swim bladder overinflation can begin (Fidler 1988, Shrimpton *et al.* 1990a). Still, the activation of GBT signs is not an easily demonstrated cause and effect relationship. This is because bubbles which develop internal to the animal may form in many body compartments, disrupting neurological, cardiovascular, respiratory, osmoregulatory, and other physiological functions (Stroud and Nebeker 1976, Weitkamp and Katz 1980, Fidler 1988, Shrimpton *et al.* 1990a and b). Thus, depending on the level of DGS, there may be multiple signs present in affected animals. GBT may also increase the susceptibility of aquatic and marine organisms to other stresses such as bacterial, viral, and fungal infections (Meekin and Turner 1974, Nebeker *et al.* 1976b, Weitkamp and Katz 1980). All signs of GBT weaken fish, especially juvenile life stages, thereby increasing their susceptibility to predation (White *et al.* 1991). Consequently, mortality can result from a variety of both direct and indirect effects caused by DGS.

Figures 2 through 5 show some of the signs of GBT in rainbow trout exposed to high levels of DGS. Figure 2 shows skin blistering which has occurred in the mouth of an adult rainbow trout while Figure 3 shows sub-dermal emphysema on external surfaces of the head. Figure 4 shows a severe case of exopthalmia in a juvenile trout. Figure 5 is a microphotograph of gill lamella from a fish which has died from GBT. Bubbles in the afferent arteries are clearly visible.

Recent research (Fidler 1984 and 1988, Alderdice and Jensen 1985a and b, Colt 1986) suggests that GBT in fish can be divided into acute and chronic responses depending on the levels of DGS.

Acute GBT: Acute GBT usually involves delta P levels in excess of 76 mm Hg (Sea Level TGP% about 110%). However, the susceptibility of fish to these levels of DGS is highly dependent on age class or size. For example, Nebeker *et al.* (1978) found delta P levels up to 200 mm Hg (Sea Level TGP% about 126%) had no effect on eggs or newly hatched fry of steelhead trout (*Oncorhynchus mykiss*). At a delta P of 130 mm Hg, this resistance appeared to continue until the fish were about 16 days old, at which time bubbles began to form in the mouth, gill cavity, and yolk sac (Nebeker *et al.* 1978). The accumulation of bubbles in larval fish compromises swimming and feeding ability and the fish is eventually trapped at the water surface as a result of excess buoyancy. Juvenile and adult fish are more susceptible to GBT, with lethal signs appearing at delta P levels of 76 to 106 mm Hg (Weitkamp and Katz 1980, Gray *et al.* 1982, Fidler 1988). In these fish, sub-dermal emphysema of the mouth lining accompanied by blockage of gill water flow by extra-corporeal inter-lamella bubbles causes death in several days (Fidler 1988). At slightly higher levels of DGS, bubble growth in the cardiovascular system can lead to death in just a few hours (Fidler 1988, also Section 6.1.2).

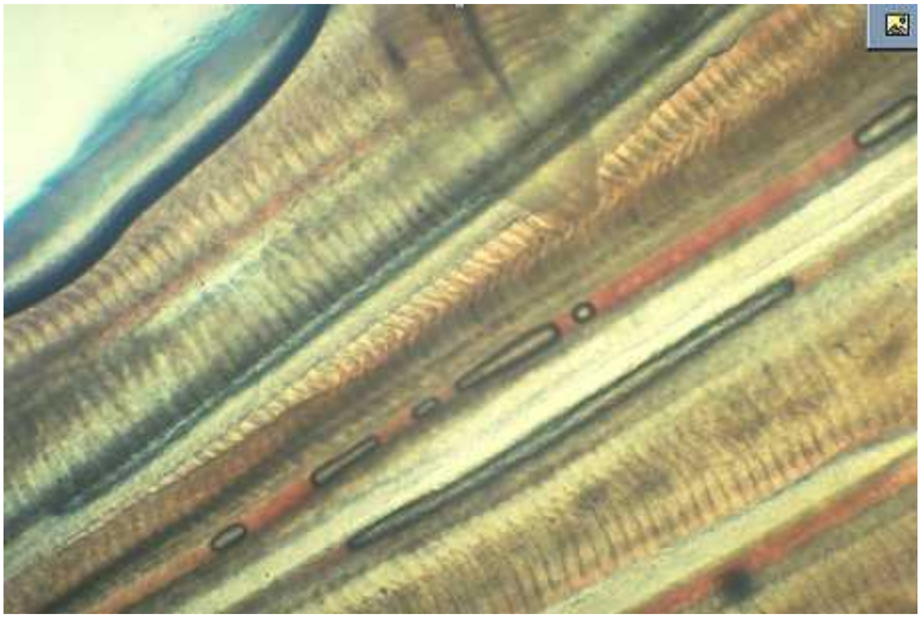
Chronic GBT: Chronic GBT usually involves delta P levels between 20 and 76 mm Hg. Chronic signs include over-inflation of the swim bladder and bubble formation in the gut and buccal cavity (Weitkamp and Katz 1980, Colt 1986, Fidler 1988). Mortality levels are generally low and require extended periods of exposure before they are detected (Peterson 1971, Shrimpton 1985, Wright and McLean 1985, Colt 1986, Shrimpton *et al.* 1990a and b). For example, Wright and McLean (1985) found that exposure of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to delta P levels ranging from 0 to 46 mm Hg for 122 days resulted in a mortality of 4.1% compared to 1.6% in control fish. Peterson (1971) found delta P levels of 15 to 40 mm Hg caused formation of a small bubble in the buccal cavity of incubating Atlantic salmon (*Salmo salar*) and improper development of the operculum. Although the gas bubble disappeared, heavy mortality occurred six to eight weeks later at first feeding. In larval striped bass (*Morone*

Figure 2: Subdermal Emphysema in the Mouth of a Rainbow Trout.

Figure 3: Sub-dermal Emphysema on the Head of a Rainbow Trout.

Figure 4: Severe Exopthalmia in a Juvenile Rainbow Trout.

Figure 5: Intra-corporeal Bubbles in the Lamella of a Rainbow Trout.



saxatilis), gas super-saturation caused over-inflation of the swim bladder and bubbles in the gut (Cornacchia and Colt 1984). Clinical signs of GBT occurred at delta P levels as low as 22 mm Hg and mortality was increased at delta P levels of 42 mm Hg. Excess buoyancy resulting from over-inflation of the swim bladder and the accumulation of gas in the gut are also common clinical signs of GBT in larval marine fish exposed to low levels of DGS (Dannevig and Dannevig 1950, Henly 1952, Kraul 1983).

DGS can affect all aquatic and marine organisms, including fish, invertebrates, and plants. However, most research in the field has been focused on fresh water fish with the major emphasis on trout and Pacific salmon species (Weitkamp and Katz 1980, Colt *et al.* 1986).

1.3 Water Quality Guidelines

Throughout North America water quality criteria and guidelines have been developed for a variety of chemical compounds and water physical parameters. For example, the province of British Columbia has developed water quality criteria for particulate matter, cyanide, nitrogen, lead, microbiological indicators, chlorine, ammonia, PCBs, nutrients, algae, molybdenum, copper, aluminum, mercury, fluoride, and pH (BC Ministry of Environment, Lands and Parks 1992). However, the province has not previously developed water quality guidelines for DGS. While Canadian Water Quality Guidelines have been published by Environment Canada for a wide range of chemical compounds and water physical parameters (CCREM 1987), water quality guidelines for DGS have not been developed.

In the United States, the US Environmental Protection Agency has published DGS water quality guidelines which recommend a maximum TGP of 110% of local atmospheric pressure (US EPA 1986). This guideline is also adopted by most of the states. No guidelines for DGS by other national or international agencies could be found in the literature.

Because of existing high levels of DGS in some British Columbia rivers, lakes, and marine environments (MacDonald and Hyatt 1973, May 1973, Clark 1977, Maxwell 1985, Penney 1987) and the potential for GBT in fish, it is important that guidelines be established to protect these environments. Amplifying this need is the growing interest in the development of small hydroelectric facilities throughout British Columbia and other parts of Canada. These facilities often possess high potential for producing DGS in smaller streams and rivers (Fidler 1992). Consequently, guideline criteria are needed to protect aquatic environments from these installations. Finally, the discharge of nutrients into fresh water and marine environments by industry, municipalities, and agriculture can dramatically increase primary production in these environments. This can lead to high levels of DGS through photosynthesis (Woodbury 1941, Renfro 1963, White *et al.* 1991). When combined with dissolved gas solubility changes which are driven by solar heating, high levels of DGS can occur. Again, guidelines are needed to protect fresh water and marine environments from this form of DGS.

Since the work upon which the US EPA guideline was developed, there has been considerable research into the problem of DGS and GBT in fish (Fidler 1984 and 1988, Alderdice and Jensen 1985a and b, Jensen *et al.* 1986, Schnute and Jensen 1986, Smith 1987, Krise and Herman 1989, Krise *et al.* 1990, Shrimpton *et al.* 1990a and b, Krise and Smith 1991, White *et al.* 1991). More recent information indicates that in many situations the US EPA guideline (TGP = 110%) may not afford adequate protection for some fish populations and especially for juvenile life stages of Pacific salmon, rainbow trout, and other species (Cornacchia and Colt 1984, Fidler 1984 and 1988, Wright and McLean 1985, Shrimpton *et al.* 1990a and b, White *et al.* 1991). However, there is now a broader understanding of the physical and biological phenomena associated with DGS and GBT along with a greater database of detailed information upon which more protective water quality guidelines can be developed.

In the development of water quality guidelines for DGS, it should be recognized that the effects of DGS on fresh water and marine organisms is quite different from the action of most toxic chemicals. For example, water depth plays an important role in protecting fish from the effects of DGS (Section 6.1.3). In addition, many rivers and lakes have naturally occurring levels of DGS which are potentially lethal to fish (Section 5.1). Yet, wild fish appear to have developed strategies for surviving in these environments (Section 8.1.1.3). Fish hatcheries present a unique situation where shallow water depths, extended exposure periods, and crowded conditions may compound the effects of DGS on fish (Section 6.1.4). The passage of fish through turbo machinery in dams presents another unique environment where the effects of DGS are amplified by the low pressure fields in this machinery (Section 3.1). Finally, the signs of GBT in fish is strongly dependent on the size of the animal (Section 6.1.1.2).

As a result of the many mitigating and compounding effects of environmental and biological variables, the procedures for developing water quality guidelines for DGS are more complex than those traditionally used in the development of guidelines for toxic chemicals. Some of the background information which is relevant to the development of water quality guidelines for DGS is reviewed in the following sections.

2.0 BACKGROUND

The potential for animals to develop gas embolisms in blood and body tissues was first proposed by Robert Boyle as early as 1670. However, it wasn't until 1905 that Marsh and Gorham provided the first definitive description of bubble formation in fish and its relationship to DGS. The occurrence of GBT in fish did not receive much attention until the late 1960's when it was recognized as a serious problem in the Columbia and Snake Rivers in the United States (Coutant and Genoway 1968, Ebel 1969, 1971 and 1979, Beiningen and Ebel 1970, Bouck *et al.* 1970, Ebel *et al.* 1971, 1973, 1975, and 1979, Blahm *et al.* 1973 and 1975, Boyer 1974, Meekin and Turner 1974, Weitkamp 1974 and 1976, Dell *et al.* 1975, Dawley *et al.* 1976, Stroud and Nebeker 1976, Clark 1977). Large hydroelectric and impoundment dams along these rivers produced dissolved gas tensions with delta P levels approaching 400 mm Hg. At times, the losses of Pacific salmon migrating through the system of dams have been enormous. For example, Westgard (1964) reported that nearly 88% of the migrating adult chinook salmon died in the McNary spawning channel before spawning could occur. In another incidence, approximately 20,000 spring chinook salmon were lost in the vicinity of the John Day Dam in 1968 (Weitkamp and Katz 1980). The problems of DGS and its effects on fish of the Columbia and Snake Rivers resulted in a wide range of research which attempted to describe, quantify, and correct the problem. Weitkamp and Katz (1980) and Colt *et al.* (1986) provided extensive literature reviews on the subject.

One of the distinguishing features of earlier studies was the belief by many researchers that only dissolved nitrogen was the cause of GBT in fish. Presumably, there was the mistaken assumption that dissolved oxygen in blood could not diffuse into intra-corporeal bubbles or the swim bladder. This led to much of these data being reported in terms of nitrogen supersaturation only. As a result, these data are difficult to interpret and in many cases unusable for developing dose - response relationships.

In the late 1960's and early 1970's, DGS was also recognized as a potential problem in the Columbia River in Canada. Delta P levels approaching 350 mm Hg were measured below the Hugh Keenleyside Dam (Clark 1977). These high levels were found to persist all the way to the US border and into Lake Roosevelt. During the same period, many other rivers and lakes in British Columbia were found to have elevated dissolved gas levels (Clark 1977). Although no major DGS-related fish mortalities have been recorded for the Canadian portion of the Columbia River, significant mortalities in mountain whitefish have occurred below the Libby Dam on the Kootenay River, a tributary of the Columbia River (May 1973).

In Canada, high levels of DGS and GBT have not been restricted to British Columbia. In 1968, 1969, and 1972, GBT was identified as the cause of large mortalities in Atlantic salmon and eels below the hydroelectric generating dam on the Mactaquac River of New Brunswick (MacDonald and Hyatt 1973, Penney 1987). In Manitoba, during the stocking of frozen lakes with rainbow trout, it was found that DGS caused significant levels of mortality before the lake ice melted (Lark *et al.* 1979, Mathias and Barica 1985).

In the early 1980's, it was becoming evident that DGS was also a problem in the shallow water rearing environments of fish hatcheries (Jensen 1980, Wright and McLean 1985, Krise and Herman 1989). Because most of the research was devoted to Pacific salmon, the problem was first identified in salmon hatcheries of the Northwest United States and British Columbia. In most cases, the causes of DGS were of natural origin, involving solar heating of hatchery water sources such as lakes and rivers (Wright and McLean 1985) or ground water which had become supersaturated (MacKinlay 1984, Miller *et al.* 1987). In the hatchery environment it was noticed that the signs of GBT were appearing at dissolved gas levels well below those observed in adult fish in the Columbia and Snake Rivers. Wright and McLean (1985) reported that, over a 122 day exposure period, chinook salmon fry experienced mortalities of about 4.1% at delta P levels ranging from 0 to 46 mm Hg in a rearing environment less than one metre deep. Control animals suffered a mortality level of about 1.6%.

In the mid 1980's, Alderdice and Jensen (1985a and b), Jensen *et al.* (1985 and 1986), Schnute and Jensen (1986), and Jensen (1988), of the Department of Fisheries and Oceans' Pacific Biological Station, conducted a variety of experimental studies and statistical data analysis of GBT in fish. The results of their work confirmed that low levels of TGP could be harmful to fish. Alderdice and Jensen (1985b) were also able to explain the high resistance of salmon eggs to the effects of DGS. They showed that the high capsule (zona radiata) pressure prevented bubble growth at delta P levels above those which normally caused bubble growth in juvenile and adult fish.

At the University of British Columbia, Fidler (1984 and 1988) and Shrimpton *et al.* (1990a and b) conducted theoretical and experimental studies of the physical and physiological causes of GBT in fish. The focus of this research was the definition of dissolved gas thresholds associated with specific signs of GBT in fish and the observation of the behavioural responses to these thresholds. Their results confirmed the existence of three distinct dissolved gas thresholds for certain signs of GBT. The lowest threshold (about 25 mm Hg) was for swim bladder over-inflation and accompanying over-buoyancy in juvenile fish. A second threshold existed at a delta P of about 76 mm Hg and was associated with extra-corporeal bubble growth in gill lamella of adult fish. This was also the threshold at which sub-dermal emphysema occurred. The highest threshold, corresponding to a delta P of about 115 mm Hg, was associated with bubble growth in the cardiovascular system.

In the late 1980's, Krise and Herman (1989), Krise *et al.* (1990), and Krise and Smith (1991) began studying the effects of low levels of DGS on hatchery-reared lake trout and Atlantic salmon. Their results showed that, like other trout and Pacific salmon species, larval life stages of these fish were fairly resistant to the effects of DGS. However, this resistance decreased as fish grew. Their results indicated that for a given fish length, lake trout were more resistant to the effects of DGS than other trout and Pacific salmon species. They also reported that Atlantic salmon were less tolerant of DGS than lake trout.

Starting in 1985, the US Bureau of Reclamation, in conjunction with Montana State University and the Montana Department of Fish and Game began an extensive experimental program on the Bighorn River in Montana (White *et al.* 1991). This river, like the Columbia River, experienced very high levels of DGS. The Bighorn River was distinct in that it was very shallow and had large components of DGS caused by a dam, solar heating, and primary production. Over a four-year period, these studies, involving both field and laboratory experiments, examined virtually every aspect of DGS and GBT in the river, including most river aquatic communities (*i.e.*, all life stages of fish and invertebrates along with predator and prey relationships).

3.0 SOURCES OF DISSOLVED GAS SUPERSATURATION

Dissolved gas supersaturation can result from a surprisingly wide variety of both man-made and natural causes. Hydroelectric and impoundment dams are known to cause high levels of DGS. Other sources include DGS associated with warm water discharges from cooling facilities (*e.g.*, nuclear and fossil fuel power generating plants), oxygen production by aquatic plants (enhanced by nutrients associated with industrial effluents, municipal discharges, and agricultural runoff), solar heating of water bodies, ingestion of air into pumping systems, supplemental oxygen in hatcheries, and air lift re-aeration systems. In the following section, these and other causes of DGS are reviewed and some of the important physical and biological mechanisms involved in the processes are described.

3.1 Dams

Of the many possible sources of DGS, the discharge of water through dams has received the greatest attention in the literature. In these hydraulic structures, DGS is caused by the entrainment of air in water released over dam sluice ways, through low level ports and radial gates, or through turbo machinery associated with power generation. In dam sluice ways and radial gates, air is entrained in falling water which plunges to depth in pools at the base of the dam. There, under elevated hydrostatic pressure, air (in the form of bubbles) is forced into solution at pressures of several atmospheres. In the river downstream from the dam, delta P levels can range up to 400 mm Hg (Ebel 1969 and 1971, Ebel *et al.* 1973 and 1975, Meekin and Turner 1974, Clark 1977, Crunkilton *et al.* 1980, Weitkamp and Katz 1980, Maxwell 1985, Hildebrand 1991, White *et al.* 1991).

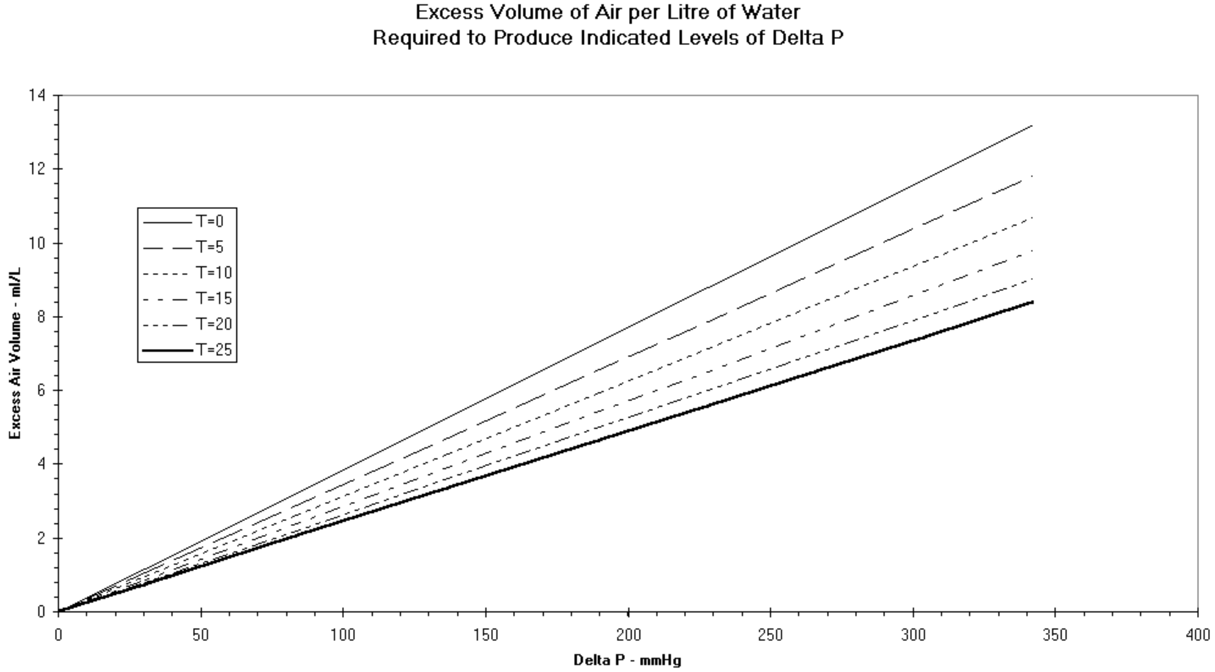
When water is discharged through turbines and low level ports, air is often entrained in vortices near the port or turbine intakes (Johnson 1988). Under conditions of elevated hydrostatic pressure near the face of turbine blades or in the discharge from low level ports, air is again forced into solution under hydrostatic pressures of several atmospheres. Low water conditions in reservoirs can enhance vortex formation and dramatically increase air entrainment.

Occasionally, air is injected into turbines to avoid problems of cavitation or mechanical stress under unfavourable loading conditions. This air, when discharged into deep tailwater regions downstream of the dam, can also contribute to high levels of DGS.

When DGS is produced by hydroelectric or impoundment dams, the ratio of the partial pressures of supersaturated nitrogen to supersaturated oxygen is often close to the ratio of nitrogen to oxygen in air (White *et al.* 1991). However, this can vary depending on the source of the discharge water. For example, water drawn from the hypolimnion of large reservoirs and discharged through low level ports may be very low in oxygen. Although oxygen is added as a result of air entrainment, it may not reach the same levels of saturation or supersaturation as the nitrogen. In other situations, water discharged over spillways may be drawn from the surface of a reservoir where high algae and plant productivity, combined with solar heating, have caused elevated background levels of DGS with oxygen more highly supersaturated than nitrogen.

As Fidler (1984) and Colt (1986) indicated, there is the potential to produce an additional delta P increment of 73 mm Hg for each metre of water depth in a plunge pool below a dam or water falls. Furthermore, the quantities of entrained air required to produce these levels of DGS can be quite small. Figure 6 shows the excess volume of air per litre of water (*i.e.*, above that required to establish atmospheric saturation), needed to produce the indicated delta P levels.

Figure 6: Excess Volume of Air Required for Specified Levels of Delta P



The data of Figure 6 are for ideal conditions. In many situations, larger quantities of air and greater water depths may be needed to force the necessary gas volume into solution. For example, entrained air in the form of large bubbles may, due to bubble buoyancy, escape to the water surface before substantial quantities of gas are dissolved. On the other hand, if bubbles are very small, high surface tension forces may facilitate their collapse and lead to levels approaching those of Figure 6 (Harvey *et al.* 1944, Fox and Herzfeld 1954, Hlastala and Fahri 1973, Yount 1979, Fidler 1984).

The development of DGS and GBT in fish can be compounded when fish pass through turbines in dams (Bonneville Power Administration 1993). In these structures hydrostatic pressures can approach the vapour pressure of water (*e.g.*, on the back side of turbine blades). The effective delta P in these regions can be as high as 750 mm Hg. The Bonneville Power Administration (1993) estimated that in the Columbia River of the United States, there is a 15% loss of migrating salmon smolts for each passage through a turbine structure. Tsvetkov *et al.* (1972) have shown that swim bladders of physostome and physoclyst fish rupture quickly in these low pressure environments. Because the pressures are so low, this condition may occur without pre-existing DGS. With pre-existing DGS the situation would be even more severe.

3.2 Industrial or Power Generation Cooling Water Effluents

When water is heated, the solubility of dissolved gases decreases (Figure 1). For water initially at
0 °C, an increase in delta P of about 20 mm Hg occurs for each degree rise in temperature (Colt 1984). At an initial temperature of 15 °C, the rise is approximately 15 mm Hg per degree increase in temperature. Water is used extensively as a coolant to reduce temperatures in industrial heat generating processes and in nuclear and fossil fuel power generating equipment. In the cooling of these facilities, the temperature of the coolant is increased substantially and the solubility of dissolved gases is decreased. The resulting DGS in the coolant water can be very high with delta P levels approaching 400 mm Hg (Miller 1974). As a result, elevated levels of DGS are often found in receiving waters into which waste cooling water is discharged (DeMont and Miller 1971, Adair and Hains 1974, Miller 1974, Marcello and Fairbanks 1976, Bridges and Anderson 1984). Unless the receiving waters are supersaturated with dissolved gases, the overall dissolved gas levels decline as a result of mixing between the two streams. However, the levels of DGS which are harmful to fish may not be reduced for many kilometres from the facility.

Waste cooling water discharges can pose a serious threat to aquatic and marine organisms independent of DGS (Becker 1973). It is well known that most aquatic and marine organisms have a maximum water temperature above which they cannot survive (Brett 1952, 1956, and 1976, Brett and Glass 1973, Brett *et al.* 1982). Thus, in addition to the effects of potentially high levels of DGS which could result from the discharge of waste cooling waters into rivers, lakes, or oceans, there is an added threat to survival caused by the elevated temperatures.

3.3 Solar Heating

For much of the year, streams and lakes are often subjected to high levels of solar radiation during daylight hours. As a result, surface waters can be heated rapidly with a corresponding rise in dissolved gas levels caused by reduced gas solubility (Colt 1986). If the water is clear and free of suspended particulate matter, the heating can penetrate ten metres or more into the water column (Harvey and Smith 1961). In some situations, the heating of surface waters may be enhanced by the presence of suspended particulate matter. Although the particulate matter reduces the penetration of solar radiation into the water column, it increases the solar absorbency of the water surface layers. Suspended particulate matter may also provide nucleation sites for bubble growth. If these nucleation sites are large, bubble growth could occur at delta P levels much lower than would occur in "clean" water.

The heating of the water column is also enhanced by shallow water depths and dark coloured stream or lake beds. Situations involving the heating of water by solar radiation are often accompanied by plankton and algae blooms (Section 3.5). These blooms contribute to high levels of DGS through the production of biogenic oxygen (Woodbury 1941, Renfro 1963, Stickney 1968, White *et al.* 1991). As with the discharge of heated cooling water, solar heating of lake and river water poses an added threat to most aquatic and marine organisms as a result of elevated temperatures.

3.4 Geothermal Heating

There is the potential for DGS in springs which are heated geothermally (Colt 1986). However, there have been no reported incidence of GBT in fish or other organisms inhabiting these springs. Bouck (1976) found that some alpine streams in Oregon had DGS with TGP % levels of 110%. Fish in the streams showed no signs of GBT, but fish in a trout hatchery which used these springs as a water supply died from GBT.

3.5 Nutrients, Primary Production, and Photosynthesis

Dissolved gas supersaturation can be produced in rivers and lakes which have high densities of plankton, aquatic plants, and algae. In these environments, dissolved oxygen levels can be significantly greater than would occur as a result of equilibration with the atmosphere (Woodbury 1941, White *et al.* 1991). Similar causes of DGS have been reported for coastal marine environments (Renfro 1963, Stickney 1968). During daylight hours, plankton, algae, and vascular plants produce oxygen through photosynthesis, a reaction described by:

$$CO_2 + H_2O = CH_2O + O_2$$

which is mediated by light energy.

During darkness, the reaction is reversed and oxygen is consumed from the water (Colt 1986). As a result, there can be large diurnal fluctuations in dissolved oxygen concentrations (Colt 1986, White *et al.* 1991). At night, in highly productive streams, dissolved oxygen can drop to levels which substantially reduce the amount of DGS (White *et al.* 1991). However, dissolved oxygen levels may also be critically hypoxic to many aquatic organisms (Macan 1974).

The discharge of chemicals and sewage into rivers, lakes, and the ocean by industrial, municipal, and agriculture operations can lead to nutrient enrichment of these environments. This in turn can contribute significantly to primary production and the development of DGS as a result of biogenic oxygen production.

In mariculture operations, fish and crustacean larvae are often raised in a "green water culture" of phytoplankton. In these environments, conditions of high light intensity and high algae density have produced GBT in mullet (*Mugil cephalus*) (Kraul 1983).

3.6 Ground Water

Many wells and springs have been identified as having DGS (Bouck 1984, MacKinlay 1984, Miller *et al.* 1987). However, the delta P of these water sources can be highly variable, depending on the conditions of the recharge area and temperature changes during recharge (Colt 1986). In the recharge process, bacteria can remove substantial amounts of dissolved oxygen and add carbon dioxide as water passes through soil and the unsaturated zone. However, gas may be added by the entrapment of bubbles in the capillary fringe of the boundary between the saturated and unsaturated zones (Herzberg and Mazor 1979, Heaton and Vogel 1981). The effectiveness of this mechanism would depend on the local subsurface conditions in the recharge area as well as the rate of recharge. In deep wells and springs, or in wells and springs close to geothermal zones, thermal heating may also result in significant temperature rises with corresponding increases in delta P.

Marsh (1910) reported a well water source as having dissolved nitrogen at 140 to 180% of air saturation. Well water supplying a hatchery at Leavenworth, Washington showed dissolved nitrogen levels at 144% of saturation (Rucker and Tuttle 1948). Matsue *et al.* (1953) found dissolved nitrogen in 15 artesian wells and two springs ranged from 118 to 159% of air saturation. In Canada, the federal Department of Fisheries and Oceans (MacKinlay 1984, Miller *et al.* 1987) listed elevated levels of DGS in several wells which are used as hatchery water supplies in the Salmonid Enhancement Program.

3.7 Air Lift Aeration and Gas Injection Systems

Injection air lift systems are often used to increase the dissolved oxygen content of lakes as well as hatchery water supplies (Fast *et al.* 1975, Colt and Westers 1982, McQueen and Lean 1983, Parker *et al.* 1984). In some hatcheries, pure oxygen is employed in an injector system to increase the carrying capacity of the hatchery (Edsall and Smith 1991). All of these systems involve the introduction of air or oxygen into the water column. This can take place at depths where elevated hydrostatic pressures can quickly force gas, in the form of bubbles, into solution with the potential for producing DGS. In shallow water environments, air can be injected (as very tiny bubbles) which allows surface tension to force gas into solution. In many ways, the mechanisms involved in producing DGS are the same as those encountered in dams and water falls.

3.8 Water Falls

Naturally occurring DGS may be caused by water falls along streams and rivers. DGS would be a characteristic of rivers downstream of water falls with deep plunge pools at their bases (Clark 1977, Alderdice and Jensen 1985a, Rowland and Jensen 1988). As with dam spillways, air is entrained in falling water and is driven to depth in the plunge pools where it is forced into solution by hydrostatic pressure.

3.9 Pumping Systems

Air entrainment into pressurized water systems is a common mechanism for the production of DGS in hatcheries (Marsh and Gorham 1905, Marsh 1910, Dannevig and Dannevig 1950, Westgard 1964, Serfling *et al.* 1974). The entrainment usually occurs on the suction or low pressure side of pumps. Often the problem is mechanical, involving leaks in the system (Marsh and Gorham 1905, Marsh 1910, Dannevig and Dannevig 1950). In other situations the problem may be seasonal and occur only when water levels are low at the inlet to the system or when the inlet system is poorly designed (Westgard 1964, Harvey 1967, Serfling *et al.* 1974). The over-pumping of wells has also been identified as a source of air entrainment and DGS (Serfling *et al.* 1974)

3.10 Ice Formation

In shallow lakes having a significant proportion of ice volume to total lake volume, solute freeze-out can produce lethal levels of DGS (Mathias and Barica 1985, Craig *et al.* 1992). During freezing, dissolved gases diffuse from the ice phase to the liquid phase. This raises dissolved gas levels in the liquid phase. During the winter, dissolved oxygen is gradually removed from the liquid phase through consumption by aquatic organisms. However, in the spring, photosynthesis may return oxygen levels to normal levels or even to supersaturated conditions. This increase in dissolved oxygen concentration, combined with the already supersaturated nitrogen resulting from the earlier solute freeze-out, can produce delta P levels as high as 560 mm Hg (Mathias and Barica 1985).

3.11 Barometric Pressure Changes

The delta P of a body of water is defined as the difference between the total gas pressure and the local barometric pressure. Thus, changes in barometric pressure would cause a change in delta P. If there is a sudden decrease in barometric pressure (usually resulting from storm activity), a body of water may become supersaturated with dissolved gases. Typical changes in barometric pressure resulting from storm activity are on the order of +5 to -17 mm Hg (Craig and Weiss 1971). Thus, a 17 mm Hg decrease in barometric pressure causes a 17 mm Hg increase in delta P. Normally this increase would not cause signs of GBT in fish. However if there is pre-existing DGS and a condition of incipient GBT present, the change in delta P may be sufficient to activate signs which would not otherwise appear.

3.12 Aircraft Transport

The transport of fish and other marine or aquatic organisms by aircraft can produce GBT as a result of reduced barometric pressures (Hauck 1986). Table 1 lists the US Standard Atmosphere (1976) pressures for various altitudes. Also shown are the delta P levels which would occur as a result of moving water which is equilibrated at sea level to various altitudes without re-equilibration during the transport process. For example, moving water quickly from sea level to 2000 metres results in a delta P change of 167 mm Hg.

The stocking of lakes and streams with fish is often done with helicopters (Hauck 1986). Because of the potential for rapid changes in altitude by these aircraft the effects on fish can be dramatic and occur more quickly than in situations involving DGS in rivers or lakes.

In the case of the swim bladder, the rapid change in altitude actually involves two separate but related processes. First there is the effect of decompression which leads to an immediate response in terms of swim bladder over-inflation and potential rupture. This is followed by the movement of the newly supersaturated dissolved gases from the blood and tissues into the swim bladder, causing additional over-inflation. If fish are in water which is supersaturated with dissolved gases prior to the altitude change, the swim bladder may already be over-inflated. Clearly, the effect of the change in altitude combined with the subsequent movement of gases into the swim bladder could greatly compound the potential for GBT in fish.

Table 1: Variation of Barometric Pressure with Altitude and Changes in Delta P

Elevation - m	Barometric Pressure - mm Hg	Delta P - mm Hg
0	760	0
500	716	44
1000	674	86
1500	634	126
2000	593	167

2500	560	200
3000	526	234
3500	493	267
4000	462	298
5000	405	355
6000	354	406

In addition to the rapid response of the swim bladder, the growth of intra-corporeal and extra-corporeal bubbles would also be enhanced. This is because supersaturated dissolved gases are already present at nucleation sites and there would not be the normal time lapse involving the transport of gases to the site. Again, pre-existing DGS would only intensify the problem.

3.13 Ocean Waves

The entrainment of air in breaking waves and the subsequent cycling of the air to depth can increase dissolved gas concentrations in ocean surface waters (Craig and Weiss 1971, Bieri 1974, Wallace and Wirick 1992). Kanwisher (1963) reported that in large bays, bubbles can be transported to a depth of two to three times the prevailing wave height, thus enhancing gas transfer into the water by way of hydrostatic pressure (Atkinson 1973).

Stickney (1968) reported an occurrence of GBT in fish held in the Booth Bay Biological Laboratory, Maine. It was discovered that Booth Bay itself was supersaturated with oxygen at 130% and nitrogen at 120% of air saturation. The author postulated that the cause of the supersaturation was wave action against a precipitous shoreline, with bubbles of entrained air transported to greater depths where they were forced into solution. Ramsey (1962a) showed that ocean water may be supersaturated with oxygen levels as high as 170% of air saturation. Some of this may be attributed to solar heating and/or photosynthesis; however, Ramsey (1962b) theorized that a large component may also come from bubbles taken to depth by wave action.

4.0 REPORTING AND MEASUREMENT OF DISSOLVED GAS LEVELS

4.1 Reporting of Dissolved Gas Levels

Throughout the literature dealing with DGS and GBT in fish, there are a variety of methods used for calculating and reporting dissolved gas levels. Colt (1983, 1984, and 1986) presents a detailed analysis of these methods along with derivations of many of the equations used in computing dissolved gas tensions. The following is a brief summary of the more common methods.

The level of dissolved gas tension in water is most often expressed in terms of the total gas pressure, defined as:

$TGP = pN_2 + pO_2 + pH_2O$ Eq. 1

Where: pN_2 = partial pressure of dissolved nitrogen - mm Hg

pO_2 = partial pressure of dissolved oxygen - mm Hg
pH_2O = vapour pressure of water - mm Hg.

In this relationship, pN_2 includes the partial pressure of argon and all other trace atmospheric gases.

Another common form of expressing dissolved gas tension is in terms of the percent total gas pressure, defined as:

$TGP\% = 100 \cdot (pN_2 + pO_2 + pH_2O) / pAtm$ Eq. 2

Where: pAtm = atmospheric pressure.

When the sum of the partial pressures of all dissolved gases, including water vapour, exceeds atmospheric pressure, the water is supersaturated with dissolved gases (*i.e.,* TGP is greater than pAtm or TGP% is greater than 100%).

Alternatively, dissolved gas tensions can be expressed as the difference between TGP and atmospheric pressure. This difference is defined as the delta P and is given by:

$\text{Delta } P = pN_2 + pO_2 + pH_2O - pAtm$. Eq. 3

Again, pN_2 includes argon and other trace atmospheric gases. When delta P is greater than 0.0 mm Hg, water is supersaturated with dissolved gases.

There is a distinct advantage to using delta P rather than TGP or TGP% as a measure of water dissolved gas tension. The principal advantage comes when assessing the impacts of DGS on aquatic and marine organisms. The major signs of GBT occur as a result of dissolved gases moving from the water phase into intra-corporeal and extra-corporeal bubbles and hollow organs of aquatic and marine organisms. This movement of gases is driven by water delta P (Colt 1984 and 1986, Fidler 1984 and 1988). Furthermore, before bubble growth or over-inflation of hollow organs can begin, a threshold delta P must be exceeded (Fidler 1984 and 1988, Shrimpton *et al.* 1990a and b). Thus delta P is a direct measure of the potential for aquatic and marine organisms to develop signs of GBT. Another advantage to using delta P is that it can be measured directly with the proper instrumentation (Bouck 1982). On the other hand, TGP or TGP% must be established by measuring delta P or TGP as well as barometric pressure and then calculating TGP or TGP% from the following relationships.

$$\text{TGP} = \text{delta P} + \text{pAtm}$$

or

$$\text{TGP\%} = (\text{delta P} + \text{pAtm}) \cdot 100/\text{pAtm}.$$

The reporting of dissolved gas levels in terms of TGP or TGP% is complicated by the variation of atmospheric pressure with altitude. This is not a problem when dissolved gas tensions are reported in terms of delta P. Figure 7 shows this effect in terms of the thresholds for various signs of GBT. The basis for these thresholds will be examined later in Section 6.1. In the figure it is seen that the thresholds for the GBT signs occur at specific delta P values. Yet, if TGP% is used as a measure of dissolved gas tension, each threshold will vary with altitude. A similar effect is seen when TGP is used for reporting dissolved gas tension.

In the sections and appendices which follow, historical data are presented on DGS levels in various water bodies of Canada and the United States. Many of these data were originally reported in terms of TGP or TGP%, but without corresponding barometric pressure or altitude information. As a result, these data cannot be accurately converted to delta P values. Where, for reference purposes, it is desirable to convert these data to delta P levels, the values cited are only approximate.

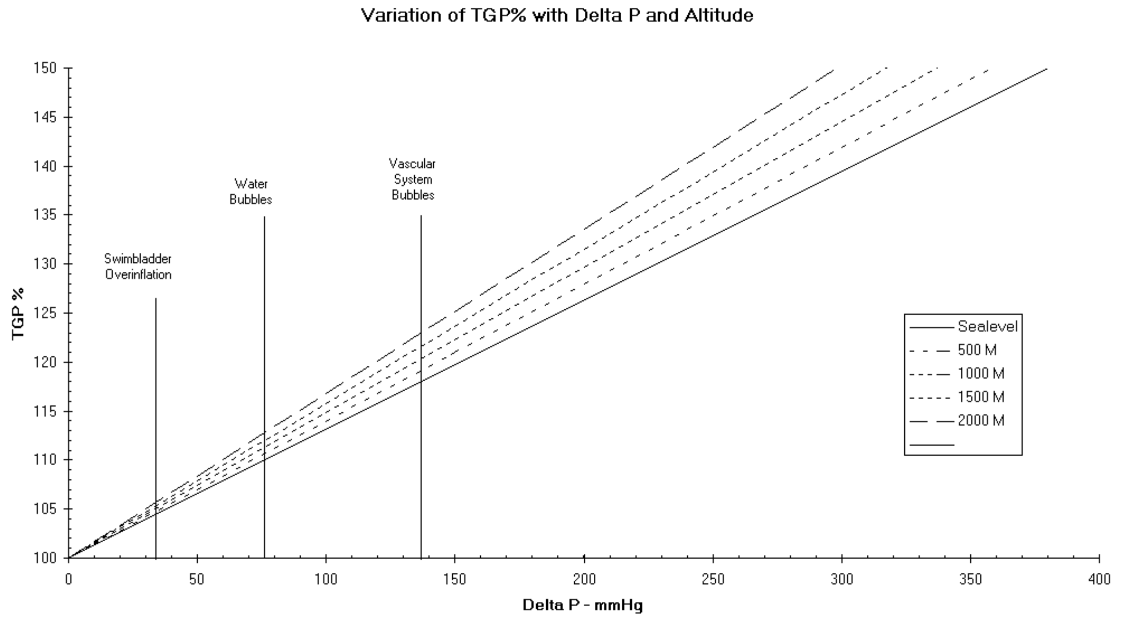
4.2 Measurement of Dissolved Gases

Direct measurement of TGP or delta P is the preferred method for determining total dissolved gas tension. Instruments which provide this measurement are described by Fickeisen *et al.* (1975), D'Aoust *et al.* (1976), and Bouck (1982). As a class, they have been called "Weiss Saturometers". However, as Colt (1983) indicated, the term is a misnomer since they measure either total gas pressure or delta P and not saturation values. Each instrument has distinct advantages and limitations; however, all employ a gas permeable membrane as the primary mechanism for isolating dissolved gases and water vapour from liquid water. Each instrument consists of a gas permeable silicone rubber tube connected to a pressure measuring device (*e.g.*, a manometer or pressure transducer). The instruments are commercially available from ECO Enterprises, Seattle, Washington; Par All, Salem, Oregon; Common Sensing, Clark Fork, Idaho; and Novatech Designs Limited, Victoria, BC Some of the more sophisticated instruments combine a TGP probe, oxygen electrode, barometer, and temperature transducer into a single instrument with extended data recording, analysis, and transmission capabilities (Common Sensing, Clark Fork, Idaho).

Depending on how the instrument is designed, the dissolved gas parameter measured is either delta P or TGP. If the pressure measuring device is a manometer, the parameter measured is delta P (*i.e.*, the difference between TGP and barometric pressure). If the pressure measuring device is an electronic pressure transducer which has been calibrated to absolute pressure, the parameter measured is TGP. In order to obtain delta P, an independent measurement of barometric pressure is required. On the other hand, if the pressure measuring device is a pressure transducer which has been set to zero at the prevailing barometric pressure, the parameter measured is delta P at the calibration barometric pressure. Measurements made with this type of instrument must be corrected for changes in barometric pressure.

In order to distinguish dissolved oxygen tension from other dissolved gas components, an independent measurement of dissolved oxygen is required. This is usually done with an electronic oxygen probe or by titration methods described in Standard Methods for the Examination of Water and Wastewater (APHA/AWWA/WEF 1992).

Figure 7: Variation of TGP% with Delta P and Altitude



5.0 ENVIRONMENTAL LEVELS OF DISSOLVED GASES

In Canada, the monitoring of environmental levels of DGS has for the most part been concentrated on fresh water environments. Some data have been collected for the marine environment, but they are very limited. The data which exist will be described in the following sections. In many aquatic and marine environments where DGS has been shown to cause GBT in fish and invertebrates there are no data for comparable Canadian environments. Where appropriate, data from the United States will be used to provide an indication of the DGS levels which could occur in Canada.

5.1 Fresh Water Environments

5.1.1 Rivers and Lakes

Most data on DGS levels in fresh water environments come from British Columbia. Beginning in 1968, the provincial Ministry of Environment conducted an extensive program of monitoring dissolved gas levels in rivers and lakes throughout the province (Clark 1977). A large part of these data were collected from the Columbia River in the southern part of the province. At the time, there were concerns about dissolved gas levels in the Columbia River resulting from the dams which had been built as a part of the Columbia River Treaty with the United States. As pointed out earlier, delta P levels approaching 350 mm Hg had been observed. Table A1 of Appendix A gives a detailed description of the results of the province-wide monitoring program. Table 2 summarizes the data from Table A1 for specific lakes and river systems. Table 3 further summarizes the data in terms of those river systems having dissolved gas levels which, at the time of measurement, were considered harmful to fish.

In Tables 2 and 3 it is apparent that dissolved gas levels in the Columbia River below the Hugh Keenleyside Dam are very high, with delta P levels above 200 mm Hg occurring many times throughout the year. Data from more recent studies by BC Hydro (Maxwell 1985) are shown in Table 4. Comparing these data with those of Table A1, it is apparent that dissolved gas levels in the Columbia River have not changed significantly since they were first measured in 1968. An important feature of the high levels of DGS in the Columbia River in Canada is that there have been only minor recorded occurrences of GBT in fish (Hildebrand 1991). This contrasts sharply with the Columbia, Snake, and Bighorn Rivers in the United States where massive fish kills have been encountered. The differences between these systems will be considered further in Section 8.1.1.3.

In addition to DGS associated with dams on the Columbia River, it is apparent in Table A1 that very high levels of DGS exist in the Kootenay River below the Upper and Lower Bonnington Dams, below the Slocan Dam, and below the Brilliant Dam. At many times, the levels in the Kootenay River are comparable to those in the Columbia River. The same is true below the Waneta Dam on the Pend d'Oreille River. Occasionally high delta P levels exist in the Peace River below the W.A.C. Bennett Dam, in the Stave River below the Ruskin Dam, below the Aberfeldie Dam on the Bull River, and below the Duncan Dam on the Duncan River (Table A1).

It is interesting to note in Table A1 of Appendix A that although dams are clearly a major source of DGS in some British Columbia rivers, there are numerous rivers (without dams) and lakes where delta P levels range from 40 to above 76 mm Hg (sea level TGP% about 105% to 109%). For example, Clark (1977) reported delta P levels well above 76 mm Hg in the Fraser River at Lillooet, above and

Table 2: Range of TGP% Levels in Some British Columbia Rivers (Adapted from Clark 1977)

TGP% Levels

		Up to 110%	**110-120%**	**120-140%**	**Over 140%**
Water Source	**Number of Measurements**	**Number of Measurements in Each Range**			

Columbia River					
Above Mica Dam	5	5	0	0	0
Mica Dam to Revelstoke	25	17	8	0	0
Revelstoke to Hugh Keenleyside Dam	35	33	2	0	0
Hugh Keenleyside Dam to Castlegar ferry	148	23	20	51	54
Castlegar ferry to border	40	11	9	20	0
Fraser River					
Upstream of Lillooet bridge	43	43	0	0	0
Lillooet to Hope bridge	28	19	9	0	0
Downstream of Hope bridge	33	26	7	0	0
Kootenay River					
Headwater to border	15	15	0	0	0
Porthill to Kootenay Lake	23	21	2	0	0
Kootenay Lake	32	26	6	0	0
Corra Linn Dam to	55	7	24	24	0

border					
Pend d'Oreille River					
Border to Waneta	16	5	7	4	0
Waneta to Columbia	14	6	5	3	0

Table 3: TGP% Levels in British Columbia Waters Considered to be Harmful to Fish (Adapted from Clark 1977)

TGP% Levels

		Up to 110%	**110-120%**	**120-140%**	**Over 140%**
Water Source	**Number of Measurements**	**Number of Measurements in Each Range**			
Rivers and Reservoirs					
Bull River	11	6	5	0	0
Columbia River	253	89	39	71	54
Duncan River	23	22	1	0	0
Fraser River	104	88	16	0	0
Kootenay River	125	69	32	24	0
Nechako River	40	34	6	0	0
Peace River	43	42	1	0	0
Pend d'Oreille	30	11	12	7	0
Stave River	19	18	1	0	0
Thompson River	13	12	1	0	0

Other Waters					
Streams & Reservoirs	69	0	0	0	0
Lakes	20	1	1	0	0
Marine waters	6	0	0	0	0

Table 4: TGP% in the Columbia River Below the Hugh Keenleyside Dam 1983-1984
(Maxwell 1985)

Date	Total Flow m^3/sec	Number of Gates Open	Ports Open (+)	Temperature °C	TGP%	pO$_2$%
31-May-83	291.7	0	+	13.5	106.9	117.8
14-Jun-83	288.26	2	0	13.0	-	126.5
28-Jun-83	140.47	4	0	14.5	117.9	143.3
12-Jul-83	143.84	1	0	15.0	115.8	126.0
26-Jul-83	2411.43	4	0	14.5	124.3	118.4
9-Aug-83	1992.35	4	0	16.5	126.3	130.1
23-Aug-83	1399.4	4	0	16.0	127.7	109.4
7-Sep-83	1551.06	4	0	16.0	124.3	111.5
20-Sep-83	847.8	4	0	15.0	121.9	146.9
4-Oct-83	1000.42	4	0	13.0	126.0	136.6
12-Oct-83	1269.71	4	0	12.0	127.2	127.6
1-Nov-83	284.01	2	0	10.5	125.2	140.3
16-Nov-83	896.5	4	0	9.0	128.4	128.9
28-Nov-83	1210.81	2	0	8.0	128.9	139.2
14-Dec-83	1471.61	4	0	7.0	125.0	108.8

3-Jan-84	1639.84	+	0	5.0	121.9	119.1
30-Jan-84	921.16	+	0	3.5	123.5	118.5
14-Feb-84	2408.18	+	+	3.5	117.5	117.7
27-Feb-84	2427.41	0	+	3.5	103.7	109.8
13-Mar-84	1564.17	0	+	3.5	102.6	106.6
26-Mar-84	144.72	0	+	5.5	104.1	117.3
9-Apr-84	138.64	0	+	6.0	-	123.1
25-Apr-84	244.78	+	0	7.5	114.5	129.6
7-May-84	1432.73	+	+	6.0	109.2	102.7
22-May-84	1222.6	0	+	9.0	105.5	113.4
6-Jun-84	141.13	0	+	11.5	108.0	108.7
13-Jun-84	143.05	0	+	12.5	111.9	117.2
26-Jun-84	142.12	+	0	14.5	125.6	141.2
10-Jul-84	141.21	+	0	16.5	131.1	120.3
24-Jul-84	959.3	+	0	17.0	125.5	129.3
8-Aug-84	2040.55	+	0	15.5	129.1	111.4
22-Aug-84	1849.07	+	0	19.0	128.7	118.7
4-Sep-84	1053.15	+	0	17.0	129.9	118.3

Note: A + indicates that gates or ports are open; however, the number of each is unknown

below Hells Gate, at Yale, at Hunter Creek, and at Agassiz. Clark (1977) also found that both Kootenay Lake and the Kootenay River frequently have delta P levels above 76 mm Hg. It is not clear in many cases why these high levels exist, although solar heating and primary production may be factors. In the case of the Fraser River, the high levels of DGS may be related to the extreme turbulence of the river in the Fraser Canyon where deep plunge pools and large rapids are a common feature. It should be noted that although relatively high levels of DGS appear to be a natural feature of many of the province's water bodies, the majority of the province's natural waters are seldom supersaturated.

Beginning in the late 1970's, the federal Department of Fisheries and Oceans, as part of the Salmonid Enhancement Program, began measuring dissolved gas levels in streams and lakes which were being used or considered for use as salmon hatchery water sources (MacKinlay 1984, Miller *et al.* 1987). Ground water sources were also being developed for hatcheries and these were also examined for DGS. Table B1 of Appendix B summarizes some of the results of these surveys. As with the measurement program of the provincial government (Clark 1977), it was found that DGS is a natural feature of many provincial waters, with delta P levels commonly of 50 to 80 mm Hg. Also evident in Table B1 are the elevated levels of DGS associated with wells which are used as hatchery water sources. Delta P levels of 30 to 50 mm Hg are a characteristic of many well sources with the Chahalis C1 well having delta P levels approaching 70 mm Hg.

High levels of DGS have been reported in other parts of Canada as well. As described earlier, GBT was identified as the cause of large mortalities in Atlantic salmon and eels below the hydroelectric generating dam on the Mactaquac River of New Brunswick (MacDonald and Hyatt 1973, Penney 1987). Subsequent studies found that dissolved gas levels varied greatly depending on power generation levels. Although delta P levels were not reported directly, dissolved oxygen levels ranged from slightly above saturation to slightly below saturation. Dissolved nitrogen levels were found to range from saturation values to 127% of saturation values.

In Manitoba, it was found that during the spring, high levels of DGS (resulting from solute freeze out) in frozen shallow lakes produced significant levels of mortality in rainbow trout which had been stocked through the ice (Lark *et al.* 1979, Mathias and Barica 1985). Total dissolved gas levels were reported as being 1.7 times the atmospheric saturation value.

5.1.2 Water Falls

Surprisingly, there is very little in the literature which describes the production of DGS by water falls or the signs of GBT in fish exposed to this form of DGS. In British Columbia, field research related to the Kemano completion project on the Nechako River has provided an example of this effect. Alderdice and Jensen (1985a) and Rowland and Jensen (1988) have shown that Cheslatta Falls, at the head of the Nechako River, produces significant increases in river DGS. Depending on flow-rate, delta P levels below the falls range from about 13 to 112 mm Hg. Some of the delta P is the result of background levels which exist above the falls. However, up to about 50 mm Hg is added by the falls (Alderdice and Jensen 1985a).

5.1.3 Solar Heating

In Canada, all of the reported occurrences of DGS resulting from solar heating have taken place in British Columbia. These incidents have involved both lakes and rivers in the province. At various times of the year, the Puntledge River on Vancouver Island is known to be supersaturated with dissolved gases as a result of rapid heating of the lake from which the river flows (Wright and McLean 1985, Table B1 of Appendix B). Heating of the river also contributes to the elevated dissolved gas levels. This has led to low, but lethal levels of DGS in a salmon hatchery on the river.

Harvey and Smith (1961) reported that Cultus Lake, a source of water for a provincial trout hatchery, was supersaturated with dissolved gases. The high levels of DGS were identified as the source of GBT outbreaks in the hatchery. At a depth of ten metres, dissolved oxygen was at 126% and nitrogen was at 116% of their respective air saturation values.

Lower Arrow Lake, which forms a reservoir behind the Hugh Keenleyside Dam, exhibits elevated levels of DGS during the spring, summer, and fall months (Table A1, Appendix A). Part of the DGS observed in the lake may be related to solar heating; however, detailed studies have not been conducted to confirm this. DGS has also been observed in several other large lakes in British Columbia, (Table A1 of Appendix A). Although the source of the DGS was not identified, solar heating was likely involved, since dams and water falls were not a contributing factor. In some cases, photosynthesis from primary production may have also contributed to the elevated delta P levels.

Numerous fish kills have occurred in British Columbia lakes with no apparent cause having been identified (Shepherd 1993 - personal communication). These have happened at times when solar heating, perhaps combined with dissolved oxygen supersaturation caused by primary production, could have caused high levels of DGS (Shepherd 1991). However, at the time of the fish kills, water dissolved gas levels were not monitored. As described earlier, a characteristic of DGS resulting from solar heating and primary production is the widely varying levels of dissolved gas tension between daylight hours and darkness (White *et al.* 1991). Thus, the delta P levels which can cause fish mortalities may be easily missed if measurements are done on a periodic spot-check basis only.

An example of a massive fresh water fish kill caused by GBT which was directly associated with solar heating and primary production occurred in 1940 in Lake Waubesa, Wisconsin (Woodbury 1941). Although the full extent of the mortalities was not determined, several thousand fish were involved in a limited observation. Affected fish had clear evidence of sub-dermal emphysema and massive bubble formation in gill filaments with significant damage to the gill structure. Most fish species of the lake were involved; however, only the adult fish of each species were affected. Dissolved oxygen levels were recorded at over 300% of equilibrium with the source identified as heating and photosynthesis involving the algae *Chlamydomonas*. Although delta P levels were not measured, the assumption that dissolved nitrogen levels were at atmospheric saturation values would lead to an estimated delta P of over 300 mm Hg. With the source of the DGS involving solar heating as a component, it is likely that nitrogen was supersaturated as well and that delta P levels were much greater than 300 mm Hg. Delta P levels of 300 mm Hg can kill fish in less than three hours (Section 6.1.2). Woodbury (1941) also reported that mortalities of this nature were common each spring in the lake, but not at the levels observed in 1940.

5.1.4 Industrial or Power Generation Cooling Water Effluents

Although there have been no instances of GBT in Canadian waters as a result of cooling water discharges, there have been several cases documented in the United States. At Cape Cod Bay, Massachusetts in 1973 an estimated 43 000 Atlantic menhaden (*Brevoortia tyrannus*) died from GBT in the heated discharge canal of the Pilgrim Nuclear Station Unit 1 of the Boston Edison Company installation (Marcello and Fairbanks 1976, Bridges and Anderson 1984). Although dissolved gas levels were not reported, there was clear evidence of GBT in the fish examined.

The Duke Power Company Marshall Steam Station (coal fired) on Lake Norman in North Carolina was identified as causing major losses of fish from GBT produced by cooling water discharges (DeMont and Miller 1971, Adair and Hains 1974, Miller 1974). DeMont and Miller (1971) reported that thirteen species of fish in Lake Norman exhibited severe signs of GBT during the winter of 1970-1971. Although delta P levels were not reported, dissolved nitrogen was up to 144% of atmospheric values.

5.2 Marine Environments

There have been only a few measurements of DGS in Canadian marine environments. Again, these come from British Columbia and are summarized in Tables A1 and B1. The measurements, from both the BC Ministry of Environment (Clark 1977) and the federal Department of Fisheries and Oceans (MacKinlay 1984, Miller *et al.* 1987), indicated elevated dissolved gas tensions, but delta P values were not greater than 76 mm Hg. Since these data involved so few measurements, it is unlikely that they represent Canadian marine conditions as a whole.

Very high levels of DGS have been recorded in other marine environments. In January, 1959, approximately 300 seatrout (*Cynoscion nebulosus*) were found dead in Galveston Bay, Texas (Renfro 1963). Other affected fish included largescale menhaden (*Brevoortia patronus*), bay anchovies (*Anchoa mitchilli*), Atlantic croakers (*Micropogon undulatus*), eels (*Myrophis punctatus*), and longnose gar (*Lepisosteus osseus*). GBT was easily identified as the cause of death in these animals. Extensive blistering of the skin and bubble formation in the cardiovascular system was common in most animals. Delta P levels in the bay were measured at 200 to 250 mm Hg. Although fish kills have been reported for British Columbia marine environments (Taylor 1993, Taylor and Haigh 1993), there are no reports in which GBT has been investigated as a possible cause.

6.0 GAS BUBBLE TRAUMA IN FRESH WATER ORGANISMS

Considering the extent to which anadromous fish in the Columbia and Snake River systems in the United States were affected by GBT, it is not surprising that most of the research reported in the literature focuses on GBT in fresh water environments and, in particular, on anadromous salmon and trout species. Although research has been conducted on other fish species and aquatic invertebrates, it has been a small portion of the total effort. The work on fish has taken two distinct directions. There have been numerous experimental programs aimed at describing the signs of GBT and defining levels of DGS which are harmful to fish in terms of time to mortality. Other work has involved theoretical and experimental studies to define the physiological and biological phenomena causing GBT, accompanied by a variety of statistical studies of the available experimental data. These works are examined in the following sections, with emphasis on that information which is relevant to the derivation of water quality guidelines for DGS.

6.1 Pacific Salmon and Cutthroat Trout

For the most part, the studies of DGS and GBT which were conducted on fish in the Columbia and Snake Rivers relates time to mortality to variables such as fish age class (or size), species, water dissolved gas tensions, temperature, and depth. As mentioned earlier, some of these data were obtained with only dissolved nitrogen levels being reported and are of limited use. Another feature of much of the data is that control experiments were not always conducted in conjunction with experiments involving

DGS. In some cases, even though control animals were used, the survival rate of control animals was not reported in the experimental results.

The volume of data (over 1000 records) is such that it would be impractical, in this document, to describe each experimental condition and associated results. Instead, the data (which are summarized in Table C3 of Appendix C) will be reviewed and analyzed in the context adopted by Jensen *et al.* (1985 and 1986) and by Fidler (1988).

In an effort to develop statistical models which describe time to mortality from GBT as a function of dissolved gas tensions and ancillary parameters, Jensen *et al.* (1985 and 1986) collected, summarized, and tabulated over 621 data records reported by 24 separate authors. The data were for three Pacific salmon species (chinook, coho, and sockeye) and two trout species (steelhead, and cutthroat). These data were subsequently reviewed by Fidler (1988) in work directed at defining dissolved gas thresholds for the major signs of GBT. As a result, additional data records were added to the tables covering conditions which were relevant to the threshold studies of Fidler (1988), but not to the statistical time to mortality studies of Jensen *et al.* (1986). For example, data describing exposures to DGS without mortality were as important in identifying thresholds as exposures involving mortalities. These data types were not included in the statistical analyses of Jensen *et al.* (1986). Table C3 of Appendix C includes the original data of Jensen *et al.* (1985) along with the additions by Fidler (1988). Also included in Table C3 is information on time to mortality as a function of TGP and other ancillary factors from more recent experimental studies, including information on fish species not considered in the work of Jensen *et al.* (1985 and 1986) or that of Fidler (1988). In total, Table C3 contains 1059 data records.

6.1.1 GBT Statistical Data Analyses

Jensen *et al.* (1986) applied a multivarient dose-response analysis to their data summaries. Of the data collected by Jensen *et al.* (1985), many experimental results were unusable because fundamental parameters, such as delta P, TGP, or fish size, were not reported in the original papers. Figure 8, based on 171 usable data records, shows Model 1 of Jensen *et al.* (1986) where time to 50% mortality (ET_{50}) is plotted versus TGP%. Also shown are the 95% confidence limits for the model. The model indicates that if the lower 95% confidence limit is used, TGP% levels below 105% are required to completely protect fish from mortalities associated with GBT. One of the qualifying conditions for this model is that, of the 171 data records used in the model, all but one data record involved water depths less than 0.6 m. The other single data record was for a water depth of one metre.

When Jensen *et al.* (1986) included ancillary factors such as water depth, fish size, water temperature, and percent O_2, in their statistical models, several important features of the multivarient analysis appeared. For example, their Model 3 suggested that ET_{50} values were independent of water temperature for temperatures above about 9 degrees Celcius. Below that temperature, ET_{50} increased markedly as temperature decreased. Their Model 4 indicated that ET_{50} values were independent of fish length for fish over about 65 mm in length. Model 2 indicated that ET_{50} values increased as water depth increased, while Model 8 indicated that ET_{50} increased as the ratio of dissolved oxygen to nitrogen increased.

6.1.2 Graphical Analysis of Data

Fidler (1988) examined the data of Table C3, Appendix C by filtering the records based on variables such as fish size, species, pO_2 levels, *etc.* and summarizing the filtered results graphically. The objective was to determine if the data provided information on thresholds in water delta P which could be related to specific signs of GBT. This type of analysis was essential to the validation of threshold equations derived from biophysical studies of the causes of GBT (Section 6.1.3).

6.1.2.1 Lowest Apparent Threshold

The obvious means of detecting thresholds in water delta P is to graph time to mortality values as a function of water delta P. Figure 9 is a plot of these parameters using the data of Table C3. As noted in the figure and in subsequent figures, experiments in which the indicated level of mortality was not achieved over the exposure period are plotted as negative times to mortality. However, the values of these negative times to mortality represent the time of exposure divided by 10.0. The division by 10.0 was done to provide more detail in the mortality data. Clearly evident in the figure is the absence of mortalities at a water delta P less than 76 mm Hg. This would suggest that the lowest threshold for any lethal sign of DGS is 76 mm Hg. To a large extent, this is the basis for the US EPA guideline for DGS (US EPA 1986).

Before proceeding further, it should be noted that the data of Wright and McLean (1985) for chinook salmon have not been included in Table C3 because delta P levels varied somewhat over the experimental period (122 days) and there was also a significant difference in fish size over the experimental period. However, the results of Wright and McLean (1985) along with those of Cornacchia and Colt (1984) will be considered further in Section 6.1.4.

Figure 8: Model 1 of Jensen *et al.* (1986)

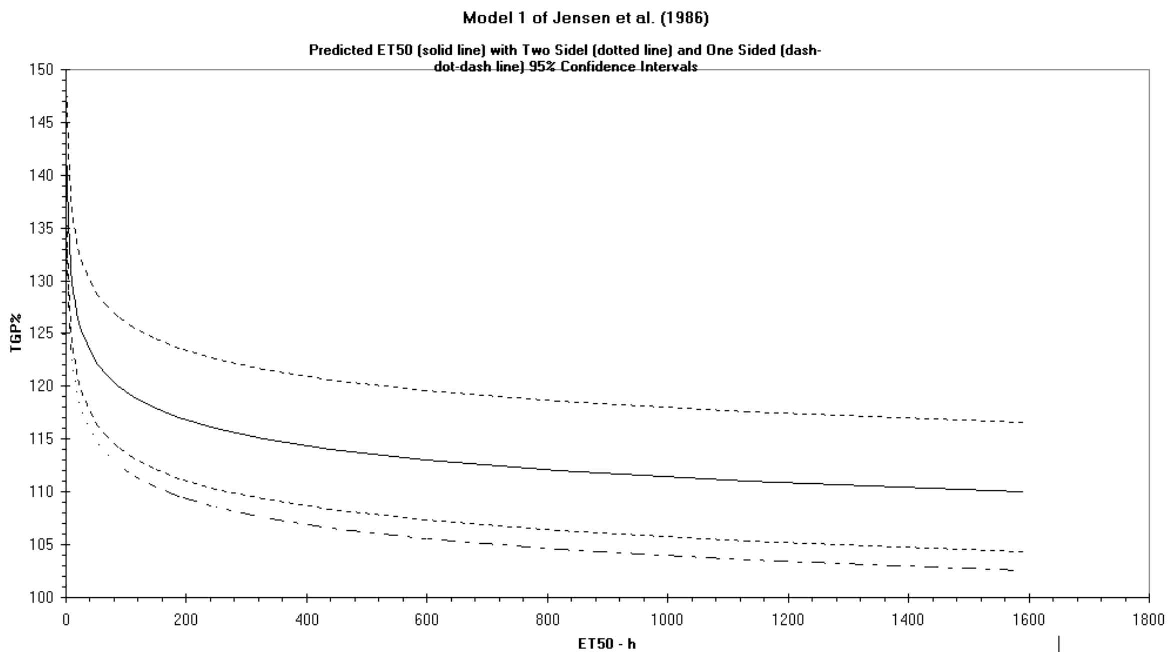
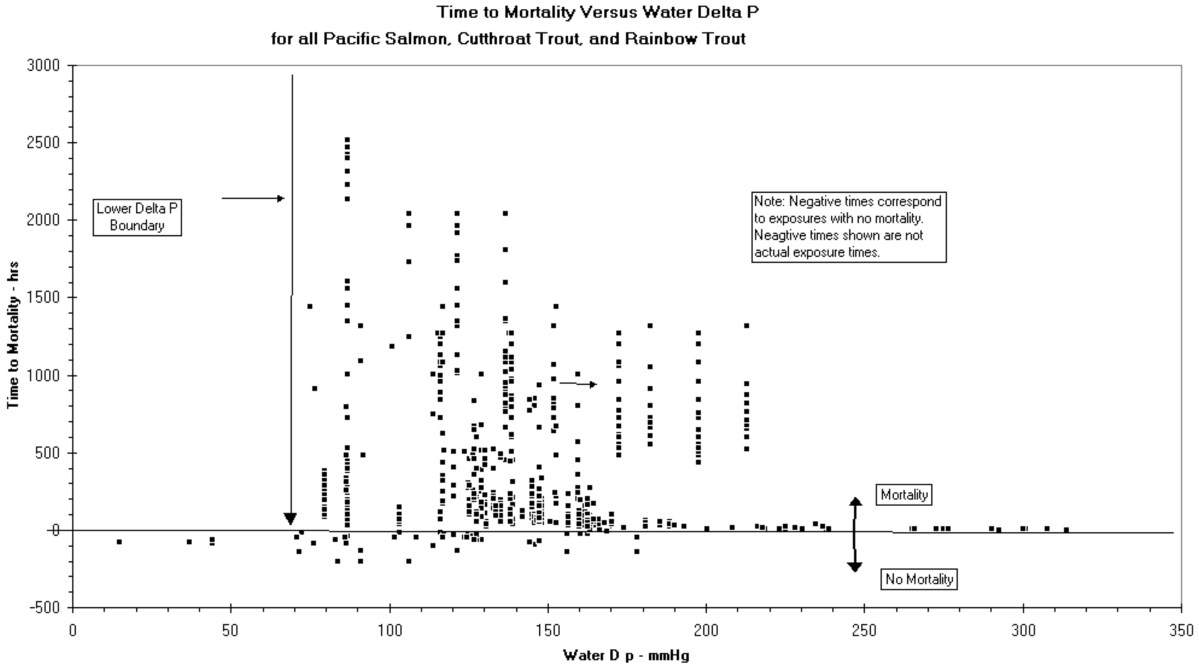


Figure 9: Time to Mortality Versus Water Delta P



6.1.2.2 Effect of Fish Size on Time to Mortality

Although the delta P threshold (76 mm Hg) indicated in Figure 9 is an important benchmark in deriving DGS water quality guidelines, a further refinement of the data analysis provides additional insight into delta P thresholds. As described earlier, Model 4 of Jensen *et al.* (1986) predicted that fish less than about 65 mm in length were not as susceptible to GBT as larger fish. Figure 10 is the result of filtering the data of Table C3 based on recorded values of delta P (*i.e.*, not on N_2% only) , time to mortality, and fish size. The data of the figure clearly indicate that 50 mm is a critical length for fish survival. That is, fish less than 50 mm survive significantly longer than do fish larger than 50 mm. Although this length differs slightly from that predicted by Jensen *et al.* (1986) (*i.e.*, about 65 mm), the data of Figure 10 qualitatively support their predictions. The data further suggest that, because of the significant differences in time to mortality, the mechanisms responsible for mortality in small fish may differ from those responsible for mortality in larger fish. Another feature of the data in Figure 10 is the set of data highlighted by the box. These correspond to conditions of hyperoxia in the experimental environments. Later in this section, additional analysis will be presented which shows hyperoxia can dramatically increase fish survival. This is also a prediction of the GBT threshold equations of Fidler (1984 and 1988) which will be examined in Section 6.1.3.

6.1.2.3 Species Thresholds

A further refinement of the analysis can be achieved by separating the records of Table C3 into two groups, one containing data for fish up to 50 mm in length and the other containing data for fish over 50 mm in length. When the records for fish up to 50 mm in length are plotted as time to mortality versus water delta P, the results are as shown in Figure 11. Although different symbols have been used to distinguish fish species, no species variability is evident from the figure.

When the data records for fish over 50 mm are filtered by fish species and plotted as time to mortality versus water delta P, the results shown in Figures 12 through 16 are obtained. In these figures, data have been restricted to the range of 20% to 70% levels of mortality. The lower limit was set to assure a significant level of response. As was mentioned earlier, much of the data from the literature was generated without control experiments or the response of controls was not reported. It was anticipated that the 20% level of response would distinguish mortality as a result of DGS from mortality due to other causes, had controls been used and/or reported. In the case of the upper limit, there was very little data for mortality above the 70% level.

The data of Figure 12 are for sockeye salmon. It is evident in the figure that fish of this species over 50 mm in length have a delta P threshold for mortality at about 125 mm Hg (sea level TGP% about 116%). The existence of this threshold is supported not only by the absence of mortalities at lower water delta P values, but also by the large number of data points at delta P levels less than 125 mm Hg for which there were no mortalities.

When time to mortality data for cutthroat trout are plotted versus water delta P, the results are as shown in Figure 13. Although the number of data points are not as abundant as for sockeye salmon, a threshold in delta P for mortality is clearly indicated. For this species the threshold is slightly lower at a water delta P of 116 mm Hg (sea level TGP% about 115%).

For steelhead trout, time to mortality versus water delta P is shown in Figure 14. Again, a threshold with characteristics very similar to that for sockeye salmon and cutthroat trout is indicated at a water delta P of

Figure 10: Time to Mortality Versus Fish Length

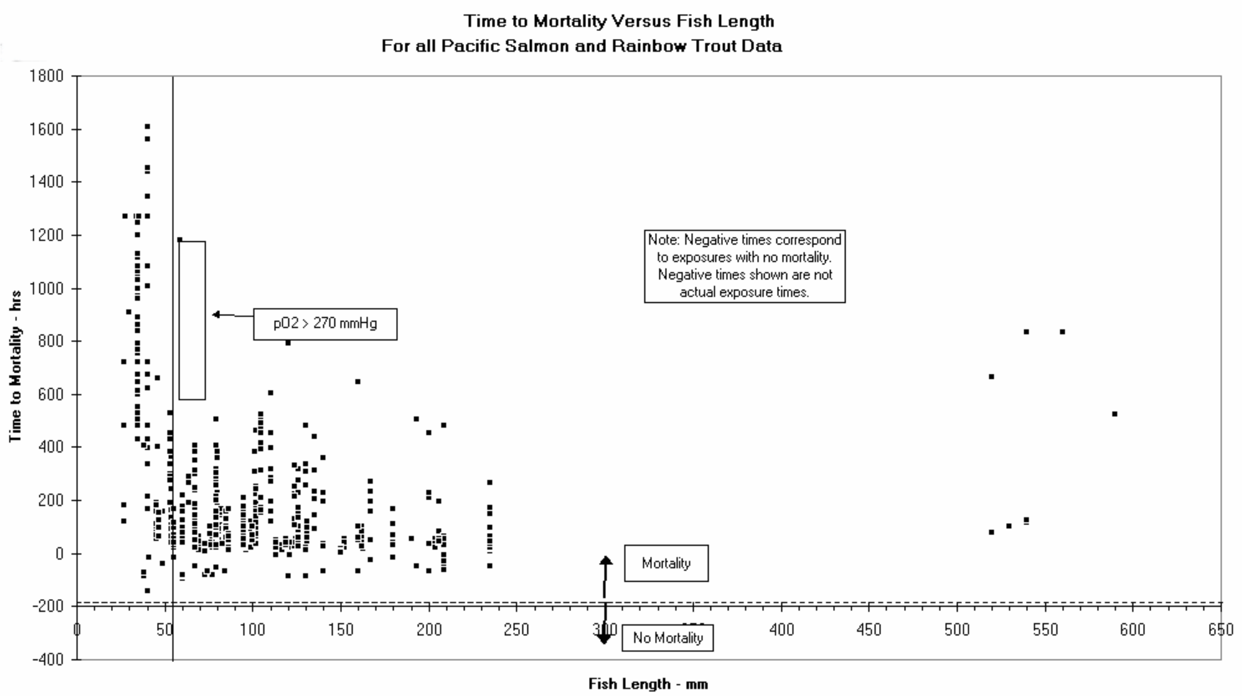


Figure 11: Time to Mortality for Fish up to 50 mm in Length

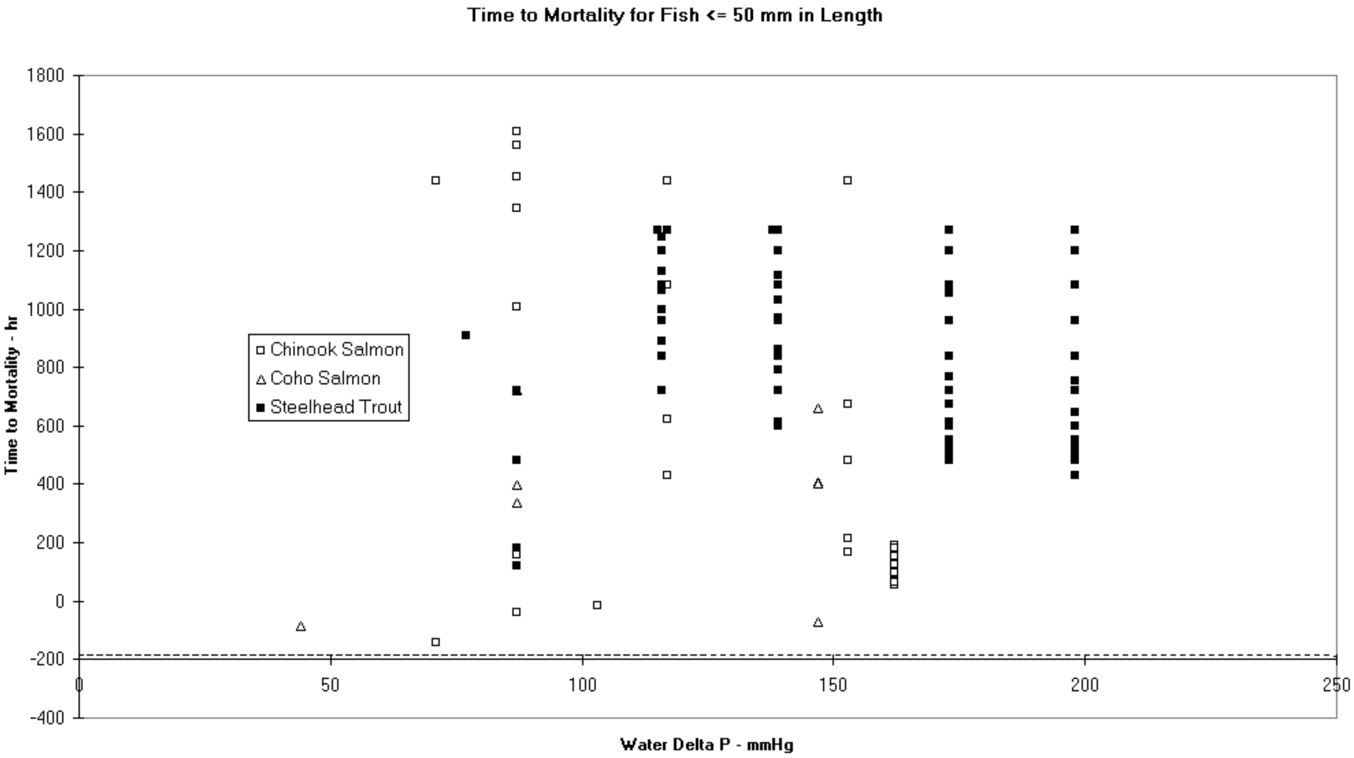


Figure 12: Time to Mortality for Sockeye Salmon over 50 mm in Length

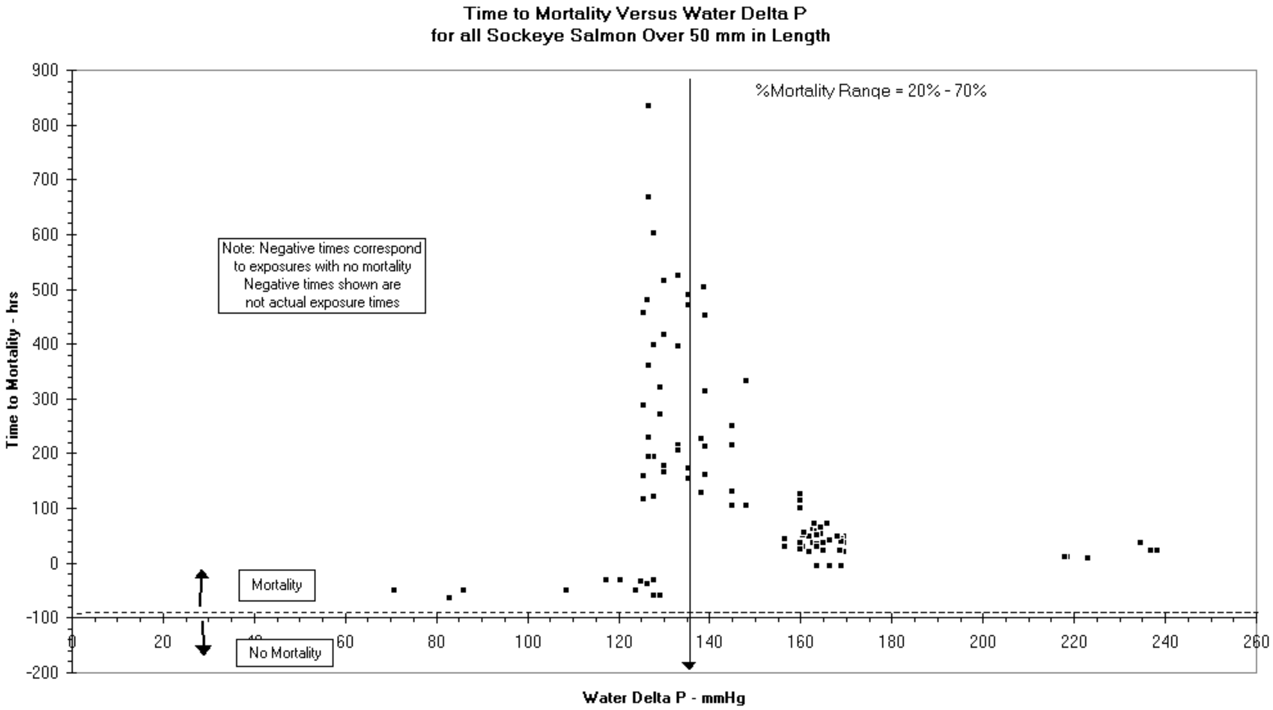


Figure 13: Time to Mortality for Cutthroat Trout over 50 mm in Length

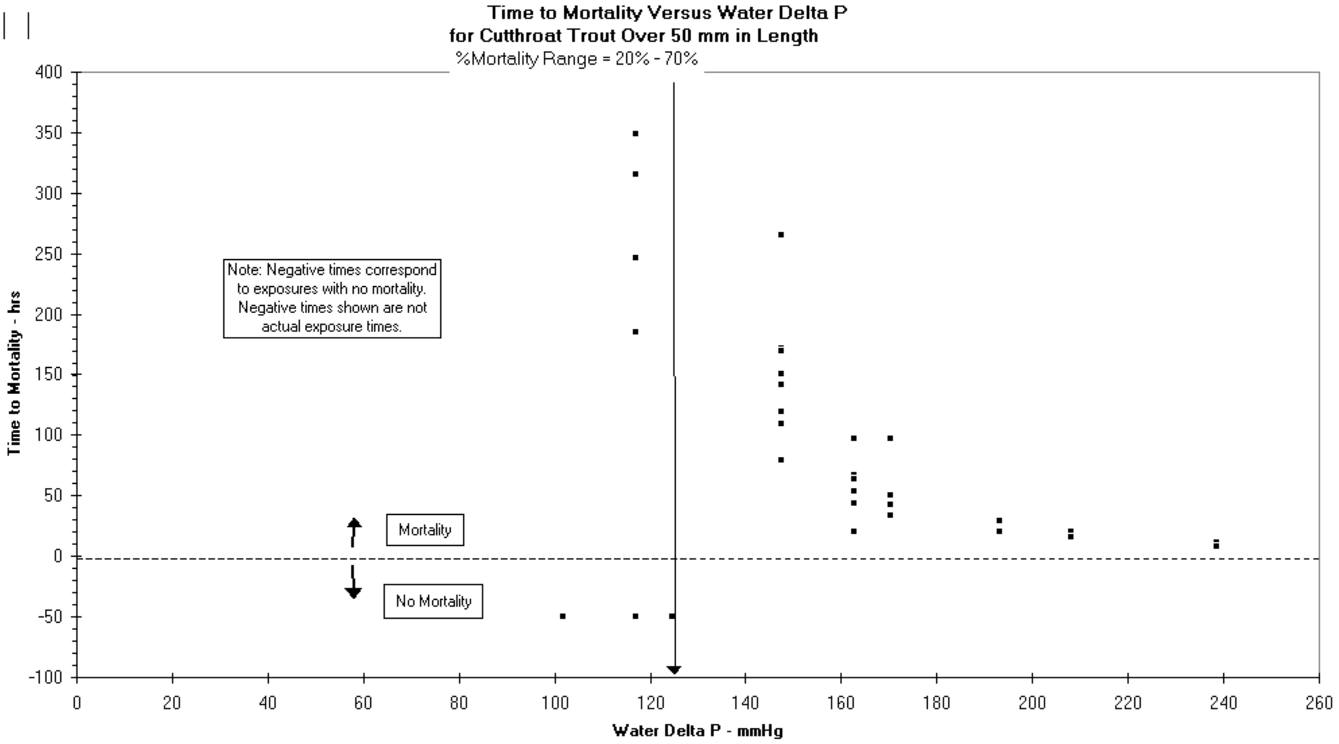
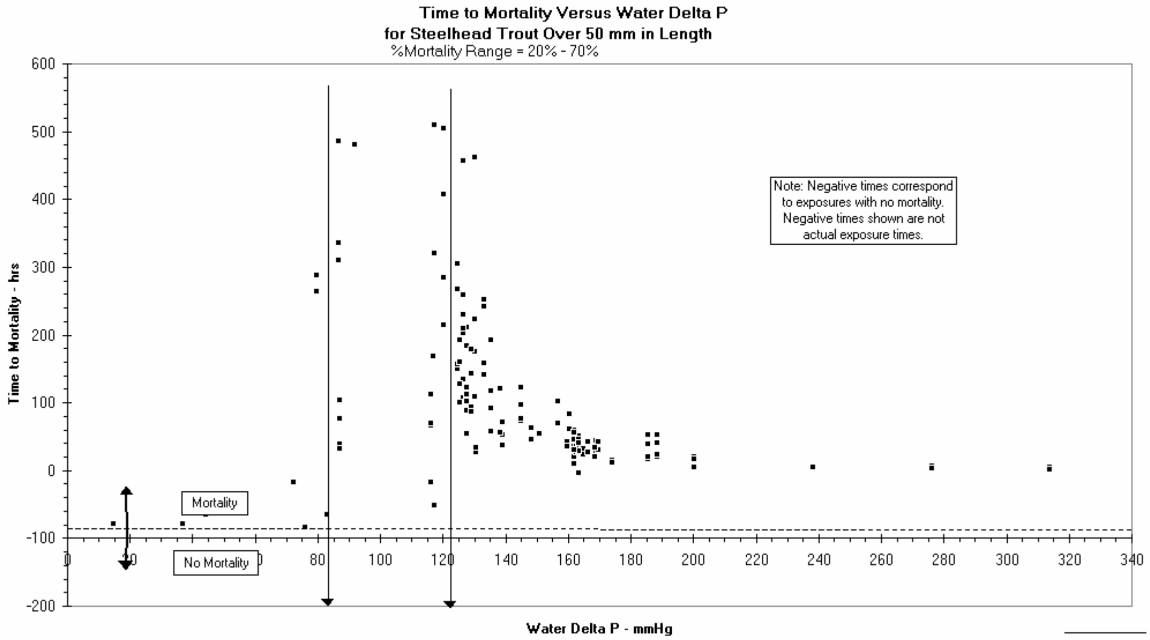


Figure 14: Time to Mortality for Steelhead Trout over 50 mm in Length.



About 115 mm Hg. (sea level TGP% about 115%). However, there appears to be another threshold at a delta P of about 76 mm Hg (sea level TGP% about 110%). When time to mortality is plotted versus water delta P for chinook salmon, the result is as shown in Figure 15. There appears to be a water delta P threshold in the vicinity of 130 to 140 mm Hg (sea level TGP% about 117% to 118%), and there may be yet another delta P threshold at 76 to 78 mm Hg. Both of these conceivable thresholds are characterized by a widening span of time to mortality values as water delta P is decreased toward the threshold. Finally, when time to mortality is plotted versus water delta P for coho salmon the result is not as clear as for the previous species (Figure 16). In Figure 16 there may again be a threshold indicated at a water delta P of about 133 mm Hg (sea level TGP% about 117%). However, there are many mortalities indicated at a water delta P of 87 mm Hg which may also represent a lower threshold. There are no mortality data below this level or between this level and the higher 130 mm Hg level to support this hypothesis.

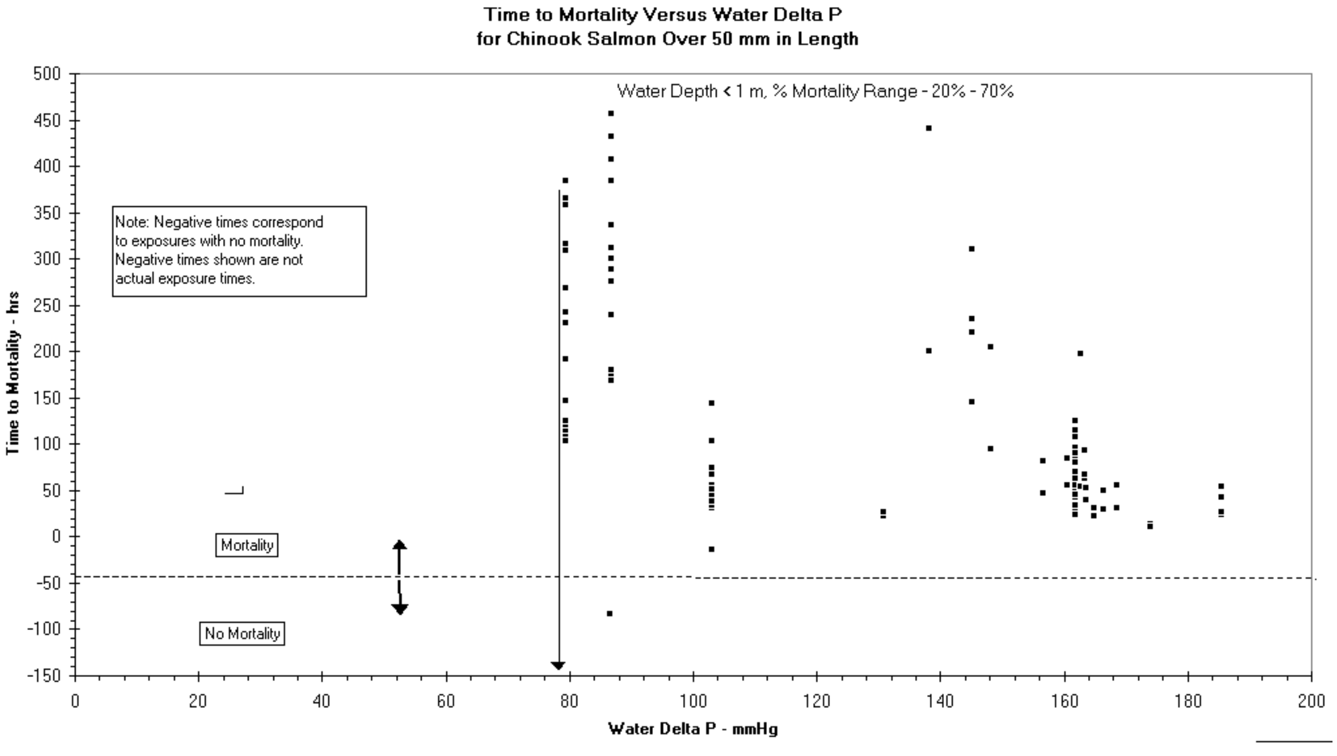
6.1.2.4 Effect of Water Depth

An additional graphical analysis of time to mortality is valuable and involves data of Table C3 obtained by Knittle *et al.* (1980) for cutthroat trout. In these experiments, fish were confined to cages and restricted to specific water depths for a range of water delta P values. Figure 17 shows the result of these experiments, again plotted as time to mortality versus water delta P. The open symbols of the plot are the original data plotted independent of water depth. The closed symbols are the data with delta P corrected for water depth (*i.e.* delta $P_{\textbf{corrected}}$ = delta $P_{\textbf{uncorrected}}$ - 73.89 times water depth in metres). It is clear that the corrected time to mortality data closely follow a classic dose-response curve for toxicants and other stress factors. Furthermore, there is a threshold clearly evident near a water delta P of about 145 mm Hg (sea level delta P about 118%). The vertical line in the figure is the threshold for cardiovascular bubble growth defined by Equation 6 which will be described in Section 6.1.3. The close correlation between theory and experimental data is apparent. Lower values of water delta P were not examined in these experiments and the presence of yet another threshold cannot be assessed. In addition to supporting the existence of theoretically derived thresholds for mortality, the data of Figure 17 show that time to mortality is directly dependent on water depth and that the correction factor for depth is approximately 74 mm Hg per metre.

6.1.2.5 Effect of Water pO_2

One further analysis of the data from Table C3 shows the importance of water pO_2 on time to mortality. Rucker (1975b) examined the effect of water pO_2 on time to mortality in coho salmon. Figure 18 shows the results of these experiments. As indicated in the figure, the water delta P is for the range 146 to 148 mm Hg which is well above the mortality thresholds in delta P which are indicated in Figures 12 through 16 and the theoretical thresholds for cardiovascular bubble growth (Section 6.3.1). As water pO_2 increases beyond normoxic values, there is a gradual rise in time to mortality. This rise indicates a dependency of time to mortality on water pO_2 and that higher levels of pO_2 extend the survival time of fish. This result is consistent with statistical Model 8 of Jensen *et al.* (1986), described earlier. However, between a water pO_2 of 250 and 270 mm Hg there is a dramatic increase in the time to mortality as well as an absence of mortality in some of the experimental animals. This sudden increase in time to mortality is a strong indicator that a threshold condition has been exceeded. In this case, the threshold is one which is dependent on water pO_2 and one beyond which the mechanism responsible for mortality at lower pO_2 levels is no longer effective. Thus, there is clear experimental evidence that thresholds in mortality are dependent on water pO_2 and that water quality

Figure 15: Time to Mortality for Chinook Salmon greater than 50 mm in Length



Note: Negative times correspond to exposures with no mortality. Negative times shown are not actual exposure times.

Figure 16: Time to Mortality for Coho Salmon greater than 50 mm in Length

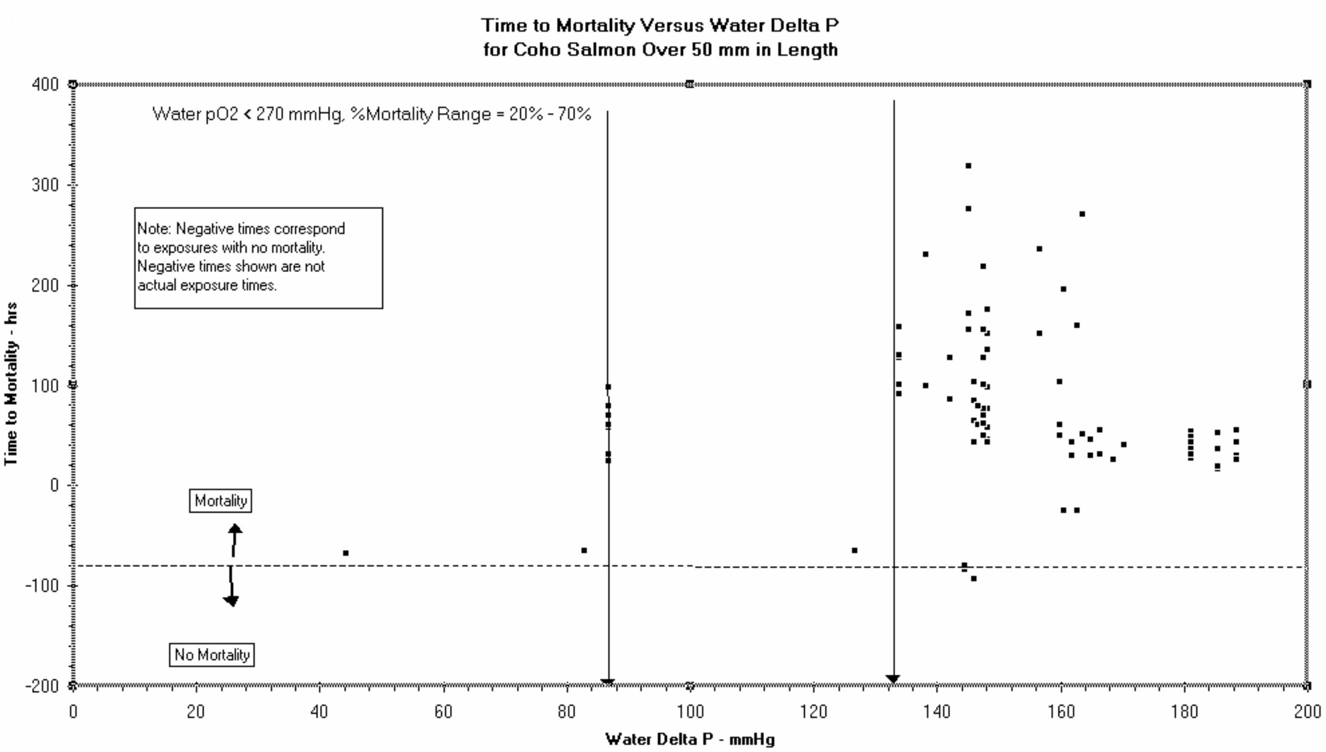


Figure 17: Time to Mortality Data of Knittle *et al.* (1980)

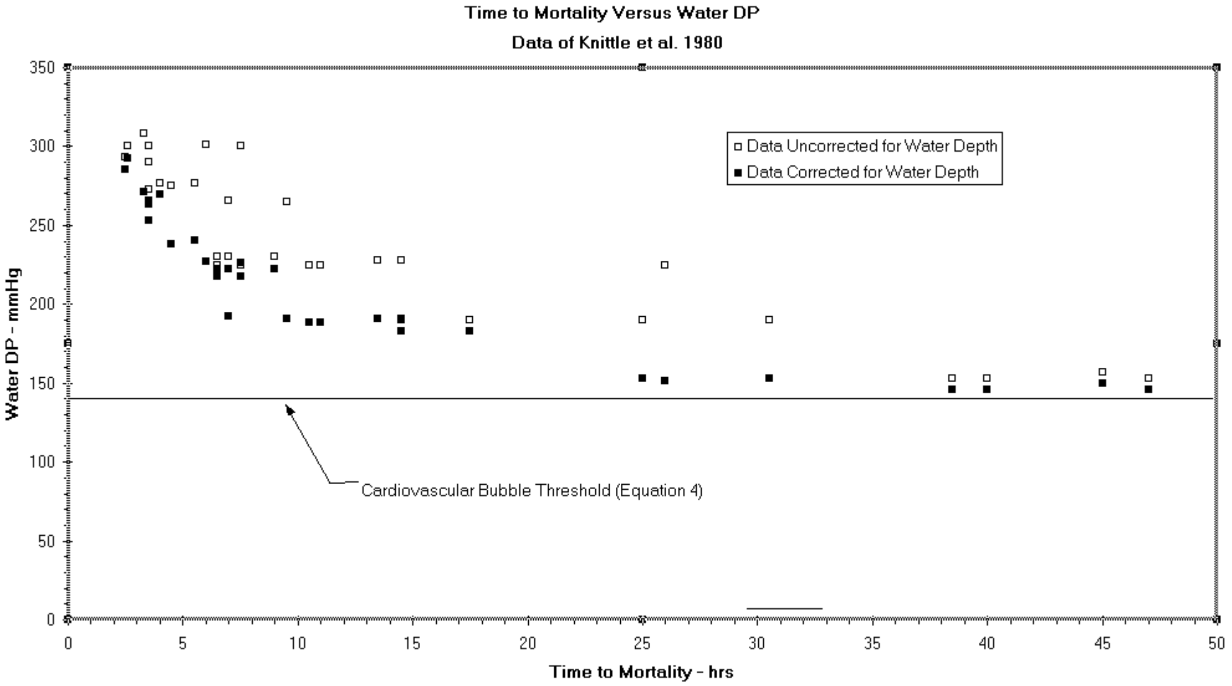
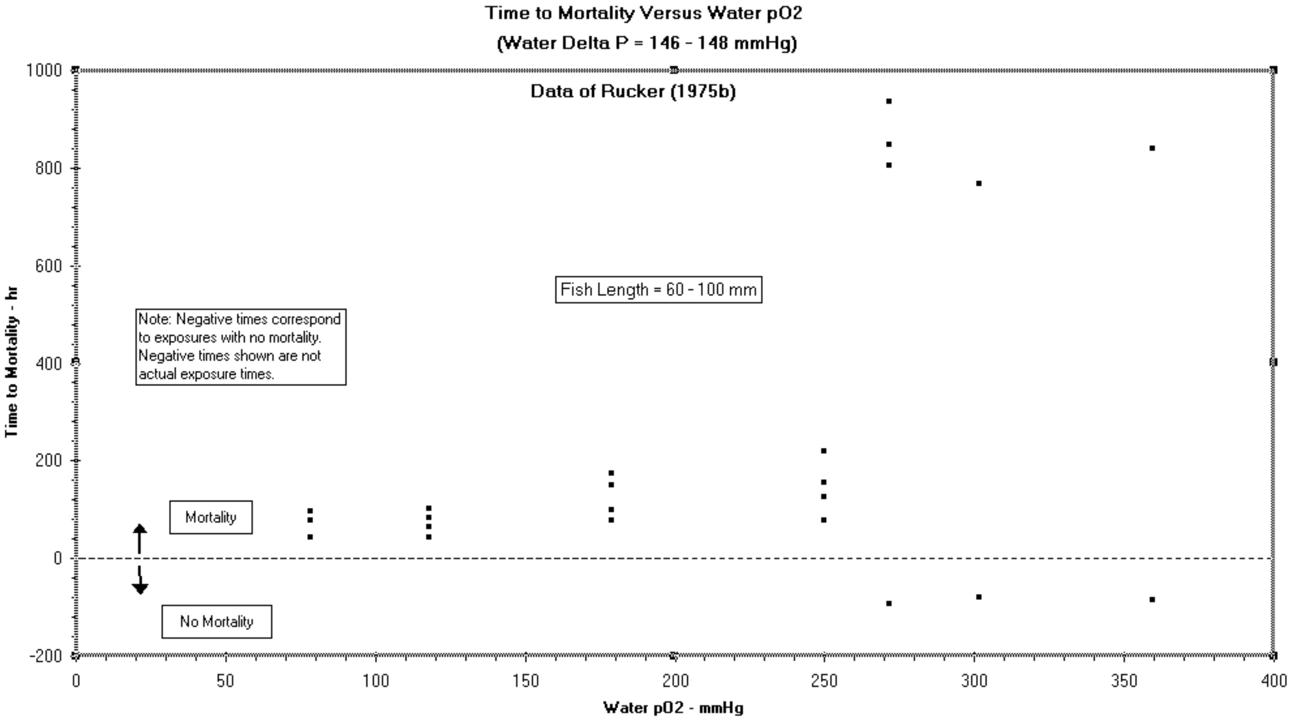


Figure 18: Time to Mortality Versus Water pO_2



guidelines for DGS must account for this effect. The dependency of thresholds for mortality on water pO_2 is also predicted by theoretical models which will be described in Section 6.1.3. The high values of time to mortality beyond a water pO_2 of 250 mmHg are the same points which were outlined in the box in Figure 10.

6.1.2.6 Summary of Graphical Analyses

The above analyses support the hypothesis that the lethal signs of GBT are dependent on thresholds in water delta P, which in turn are dependent on water pO_2 and depth. There is evidence from Figures 12 through 16 that two distinct thresholds for GBT mortality may be present. There is clear evidence of a single threshold in delta P of 125 mm Hg for sockeye salmon. An additional threshold at a lower delta P may be present, but its absence could be due to insufficient data at lower delta P levels. Cutthroat trout and steelhead trout appear to have a threshold at a delta P of about 115 mm Hg. In the case of steelhead trout, there may be a lower threshold as well at a delta P of 76 mm Hg. This lower threshold at a delta P of 76 mm Hg may also be present for cutthroat trout. However, as with sockeye salmon, its presence may be obscured by a lack of data at the lower delta P levels. For chinook salmon there is evidence for a threshold in the range of delta P about 130 to 140 mm Hg and perhaps another threshold at delta P = 76 to 78 mm Hg. The situation involving coho salmon is unclear, but the evidence does not rule out the presence of two thresholds. However, additional experimental studies would be needed before this can be established.

The indication that there may be more than one threshold for mortality implies that different mechanisms may be responsible for mortality. In addition, the higher thresholds in the delta P range of 115 to 145 mm Hg appear to vary with species, suggesting that there are species differences in resistance to GBT. If so, species would be another variable which must be accounted for in assessing the impacts of DGS on fish and in the derivation of water quality guidelines for DGS.

Although the graphical analysis described above demonstrates the existence of thresholds, there is no indication of how the thresholds are associated with the various signs of GBT. In the sections which follow, it will be shown that the lower threshold indicated in Figures 14 and 15, (delta P of about 76 mm Hg) corresponds to that at which the growth of extra-corporeal inter-lamella bubbles and sub-dermal emphysema of skin surfaces begins. The higher thresholds of Figures 12 through 16 (delta P about 115 - 140 mm Hg) correspond to that at which bubble growth in the cardiovascular system begins.

6.1.3 Biophysical Studies

At the University of British Columbia, Fidler (1984 and 1988) and Shrimpton *et al.* (1990a and b) conducted both theoretical and experimental studies of the biophysics of GBT in rainbow trout. The effects of DGS on physiological parameters such as swim bladder pressures, intra-corporeal and extra-corporeal bubble formation, blood pH, blood pO_2, and blood catecholamines were examined in relation to water delta P and pO_2, water depth, and fish size. By combining the results of these studies with those from the graphic analysis described above (Figures 12 through 18), Fidler (1984 and 1988) and Shrimpton *et al.* (1990a and b) were able to establish parameters in a series of equations which predicted the thresholds in water delta P for specific signs of GBT in fish (*i.e.*, bubble formation in the cardiovascular system, over-inflation of the swim bladder in young fish, extra-corporeal bubble formation in gill lamella, and sub-dermal emphysema on body surfaces including the lining of the mouth). These equations and the basis for their development and validation are described next.

Fidler (1984) derived the following equations which define thresholds in dissolved gas levels for the major signs of GBT.

$\text{Delta } P_{SB} = 73.89 \cdot h + 0.15 \cdot pO_2$ Eq. 4

$\text{Delta } P_{EW} = 73.89 \cdot h + 83.0$ Eq. 5

$\text{Delta } P_{CV} = 73.89 \cdot h + 0.21 \cdot pO_2 + 83.0.$ Eq. 6

Where: Delta P_{SB} = water delta P required to initiate over-inflation of the swim bladder in rainbow trout.

Delta P_{EW} = water delta P required to initiate sub-dermal emphysema and extra-corporeal bubble growth between gill lamella.

Delta P_{CV} = water delta P required to initiate bubble growth in the cardiovascular systems of rainbow trout.

H = water depth at which the fish is located - metres.

pO_2 = partial pressure of dissolved oxygen (mm Hg) in the environmental water.

The equations were derived from analyses of bubble growth processes associated with decompression, cavitation, nucleate boiling, and other physical processes (Fidler 1984). The basis for the equations centres on the concept that nucleation sites are involved in phase changes between liquids and gases (Harvey *et al.* 1944, Fox and

Herzfeld 1954, Hlastala and Fahri 1973, Yount 1979). Because surface tension and other surface phenomena impose restrictions on the stability of these nucleation sites, thresholds in water delta P are an immediate consequence. The application of these stability criteria to bubble growth in fish and to over-inflation of the swim bladder involves additional considerations in terms of gas exchange between the fish and the water environment. Diffusive and convective resistance at the gill reduce blood dissolved gas tensions from those of the environmental water (Randall and Daxboeck 1984). As a result, the thresholds for bubble growth in fish differ from those for bubble growth in the environmental water. These principles were incorporated into the derivations presented by Fidler (1984 and 1988) which resulted in Equations 4, 5, and 6.

In Equations 4, 5 and 6, the factor 73.89 converts water depth to hydrostatic pressure in mm Hg. As the equations imply, water depth is a major factor in establishing the thresholds for signs of GBT. Every metre of depth requires approximately 74 mm Hg of additional delta P to initiate a particular sign. Thus, water depth, if available and used by fish, can play an important protective role for fish exposed to high levels of DGS.

The 0.21 coefficient in Equations 6 accounts for the reduction of dissolved oxygen in arterial blood from that in the environmental water. The value 0.21 was established through an analysis of experimental data from the scientific literature which describes blood pO_2 levels in adult rainbow trout (Fidler 1988). In Equation 4, the coefficient multiplying the pO_2 term is 0.15. This value was established from the work of Shrimpton *et al.* (1990a and b) and is based on studies of swim bladder over-inflation in juvenile rainbow trout. The 0.21 and 0.15 coefficients in the equations imply that the delta P required to initiate swim bladder over-inflation and cardiovascular bubble growth increases as water pO_2 increases. Again, this is in agreement with the statistical modeling studies of Jensen *et al.* (1986) and the graphical analysis of GBT data presented earlier. It will be noted that Equation 5, which describes the threshold for extra-corporeal bubble growth and sub-dermal emphysema, is independent of water pO_2. In the case of extra-corporeal bubbles, there is no reduction in dissolved oxygen levels, while for the swim bladder and cardiovascular bubbles there is a reduction. Sub-dermal emphysema appears to involve direct diffusion of gases from the water to nucleation sites just beneath the skin surface. Again, there is no reduction in dissolved oxygen levels (Fidler 1988).

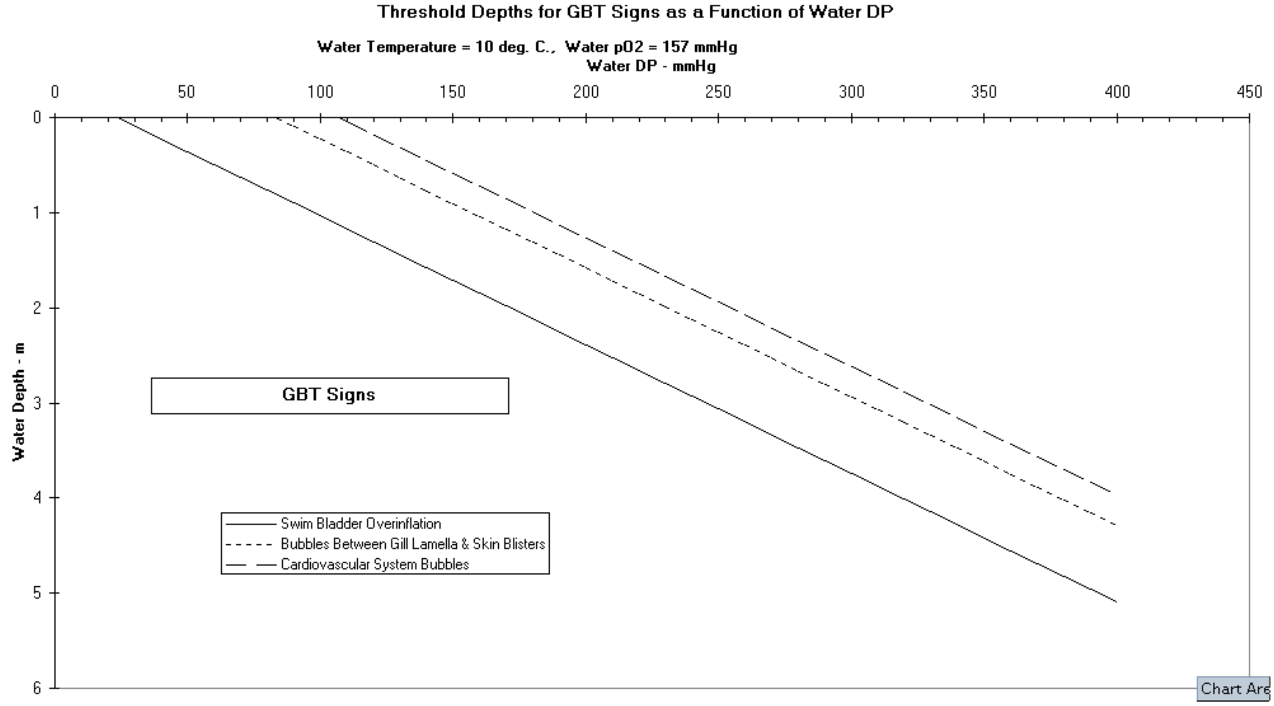
The 83.0 parameter in Equations 5 and 6 accounts for the combined effects of blood or water surface tension, blood pressure, and the size of microscopic nucleation sites upon which bubble growth in the vascular system or in the environmental water is initiated. In the case of the swim bladder, this parameter is zero due to the large size of the swim bladder (Fidler 1988). It was through a series of laboratory experiments using rainbow trout and the graphical analysis of experimental data, described earlier, that a value of 83.0 was established for this parameter (Fidler 1988).

Water temperature does not appear explicitly in Equations 4, 5, and 6. Although the statistical models of Jensen *et al.* (1986) indicated that ET_{50} values were dependent on water temperature for values below 9° C, it is not clear that this should be the case for bubble growth thresholds. There are several reasons why temperature should not have a strong effect on bubble growth thresholds and yet affect time to mortality. First, thresholds for bubble growth are related to conditions of static stability at the gas - water or gas - blood interface (Harvey *et al.* 1944, Fox and Herzfeld 1954, Hlastala and Fahri 1973, Yount 1979, Fidler 1984 and 1988). As such, mass transfer operations are not involved until bubble growth or collapse actually begins (Fidler 1984). There is a weak dependency of GBT delta P thresholds on temperature as a result of the effects of surface tension. However, Fidler (1984) showed that the surface tension of fish blood was very nearly the same as that of water and neither varied significantly over the range of biologically significant temperatures. There is also a small effect of water temperature on GBT delta P thresholds as a result of variations in the vapour pressure of water with temperature (Figure 1). As related in Section 4.1, water vapour is included as a component of delta P and it is always considered to be in a saturated state (Colt 1986, Fidler 1988). By examining Figure 1 it can be seen that even at a temperature of 25 °C, water vapour would account for only 3% or less of any positive delta P. Thus, its effects on thresholds should be small.

On the other hand, ET_{50} values are related to the actual bubble growth or swim bladder inflation processes. These, in turn, are dependent on the rate at which dissolved gases are transferred from water or blood to a bubble or to the swim bladder. These rates are controlled by diffusion coefficients, convective mass transfer coefficients, and oxygen demand of the animal, all of which are strong functions of water temperature.

Figure 19 shows Equations 4, 5, and 6 plotted in terms of GBT delta P's versus threshold water depth for a water temperature of 10 °C and a water pO_2 of 157 mm Hg (sea level normoxic). In some cases, the depths of Figure 19 can be interpreted as compensation depths or those depths below which the particular GBT sign may or may not occur. However, it is important that care be taken in applying this interpretation. For example, depending on the initial inflation pressure in the swim bladder, which in many situations is determined by the fish independently of DGS (Section 8.1.1.5), the swim bladder would over-inflate when a fish moves above the compensation depth. When the fish moves below the compensation depth, the swim bladder would deflate. Thus, the threshold line for swim bladder over-inflation of Figure 19 is a true compensation threshold.

Figure 19: Threshold Depths for GBT Signs Versus Water Delta P



For the growth of intra-corporeal and extra-corporeal bubbles, a slightly different interpretation of the thresholds of Figure 19 is required. If bubble growth has not been initiated and a fish stays below the depth corresponding to the particular bubble growth threshold, bubble growth would not be initiated. However, once the fish moves above the threshold depth and bubble growth begins, moving back below the threshold depth would not necessarily stop bubble growth. This is because once the bubble radius has increased, growth can continue at delta P values lower than those required to initiate growth (Harvey *et al.* 1944, Fox and Herzfeld 1954, Hlastala and Fahri 1973, Yount 1979, Fidler 1984). Bubble growth would stop or reverse only after the fish moves to a depth below that at which growth began. In the case of extra-corporeal water bubbles this could be up to 0.8 metres below the threshold depth and up to 1.2 metres below the threshold depth for cardiovascular bubbles.

Some general observations are important to the application of Equations 4, 5, and 6 and the threshold depths shown in Figure 19. First, in the experimental studies and data analysis which were performed to validate Equations 4, 5, and 6 (Fidler 1988, Shrimpton *et al.* 1990a and b, White *et al.* 1991), it was found that the threshold delta P required for initiation of sub-dermal emphysema was very close to the delta P at which extra-corporeal bubble growth between gill lamella began and the delta P at which swim bladder rupture occurred in small fish. Thus, there is an area of overlap in terms of thresholds and signs of GBT. It should also be noted that mortalities associated with the sign of extracorporeal bubble growth between gill lamella, in combination with sub-dermal emphysema of the lining of the mouth (Fidler 1988), were observed with captive, restrained fish in shallow water environments. It is not known if these signs would produce mortalities in wild fish where swimming activity could periodically dislodge bubbles from between gill lamella and possibly prevent death. This note also applies to the data of Table C1 of Appendix C. Most of the data listed in the table were collected under conditions where fish were not able to swim freely. A final consideration in relation to bubble growth in the environmental water (*i.e.*, extra-corporeal bubbles between gill lamella) is the effect of nucleation site size. This threshold was established in laboratory water which was considered "clean" (*i.e.*, free of suspended particulate matter). In natural environments which contain high concentrations of suspended particulate matter there may be nucleation sites considerably larger than those present in "clean" water supplies. In these environments, it should be expected that bubble growth can begin at delta P levels lower than those predicted by Equations 5.

6.1.4 Chronic GBT and Swim Bladder Overinflation

The graphical analyses presented in Section 6.1.2 imply that water delta P levels below 76 mm Hg should protect fish from the effects of DGS. Yet, Wright and McLean (1985) found that, over a 122-day exposure period, there is increased mortality in juvenile chinook salmon held in a shallow water environment having delta P levels ranging from 0 to 46 mm Hg. In these experiments, no direct relationship was established between the observed mortalities and any specific sign of GBT. Also, Cornacchia and Colt (1984) found increased mortality in striped bass (*Morone saxatilis*) at delta P levels of 42 mm Hg. The mortality appeared to be caused by swim bladder over-inflation and bubbles in the gut. Dannevig and Dannevig (1950), Henly (1952), Peterson (1971), and Kraul (1983) have also observed similar effects in other fish species exposed to low levels of DGS. Over-inflation of the swim bladder was a common sign and was suspected as being indirectly responsible for mortality. It is hypothesized that uncompensated over-buoyancy caused by swim bladder over-inflation imposes additional swimming demands on fish and that the resulting stress eventually leads to increased mortality. To date, there are no data which confirm this hypothesis directly. The data which are available (Cornacchia and Colt 1984, Wright and McLean 1985, and Shrimpton *et al.* 1990a and b) provide only circumstantial evidence. Nevertheless, considering the extent to which experimental conditions were monitored by Wright and McLean (1985), it is unlikely that the increased mortality they reported was due to any other cause.

Accepting that swim bladder over-inflation is a chronic cause of mortality in fish, the water delta P thresholds at which this occurs become crucial to the development of water quality guidelines. As indicated in Figure 19, the delta P threshold for swim bladder over-inflation predicted by Equation 4 is as low as 25 mm Hg. In order to define the conditions under which swim bladder over-inflation occurs and the effects of over-buoyancy on fish, Shrimpton *et al.* (1990 a and b) conducted an extensive series of experiments using rainbow trout. The results of these experiments along with relevant background information are examined in the next section.

6.1.5 Thresholds for Swim Bladder Over-inflation

Like most fresh water fish species, rainbow trout are more dense than water and they possess a swim bladder which is used to control buoyancy. In physostome fish, the swim bladder is connected to the esophagus by a small-diameter pneumatic duct (Fänge 1983). The pneumatic duct serves as a path for filling the swim bladder with atmospheric air (Harvey 1963). Physoclist fish also have swim bladders, but do not have a pneumatic duct. In these fish, the swim bladder is filled by way of a complex gas gland which secretes oxygen directly into the swim bladder (Fänge 1983). When physostome fish are frightened, the pneumatic duct can be used to vent air as a means of quickly reducing buoyancy (Harvey 1963). Presumably, this enhances the fish's ability to swim to deeper water and seek cover. Shrimpton *et al.* (1990 a and b) found that in supersaturated water the swim bladder can become over-inflated as a result of dissolved gases diffusing from the water to the swim bladder by way of the gills and vascular system. When this happens, fish become overbuoyant. It appears that rainbow trout are unable to control the venting of gas through the pneumatic duct under conditions of DGS. This is probably true of other trout and Pacific salmon species as well.

Through their experimental studies, Shrimpton *et al.* (1990 a and b) found that in fish larger than 200 g in weight, swim bladder over-inflation was generally not a problem, with the pressure in the swim bladder seldom exceeding 10 mm Hg. However, in fish much less than 200 g in weight, swim bladder pressures approaching 70 mm Hg were observed and swim bladder rupture was frequently present at these high pressures. Figure 20 shows the results of these studies where swim bladder venting pressure (or pneumatic duct release pressure) is plotted as a function of fish weight. Clearly, as weight (or fish size) decreases, the venting pressure (or swim bladder overpressure) increases sharply. As a possible explanation for this response, it was hypothesized that for fish much less than 200 g in weight, the small diameter of the pneumatic duct created high tension surface forces at the gas - water interface in the duct. This effectively blocked the flow of gas through the duct, allowing the observed high pressures to develop within the swim bladder (Fidler 1984 and 1988).

The results shown in Figure 20 help explain the differences in time to mortality between large and small fish which were identified by Jensen *et al.* (1986) and in the graphical analysis presented in Section 6.1.2. That is, swim bladder over-inflation is a problem for small fish only and the mortalities resulting from this sign are generally chronic in nature. For larger fish, mortality is the result of other signs of GBT (*i.e.*, extra-corporeal inter-lamella bubbles, sub-dermal emphysema, cardiovascular system bubbles, *etc.*) which tend to be more acute in nature.

Other results from the experiments by Shrimpton *et al.* (1990a and b) appear to support the validity of the threshold equation for swim bladder over-inflation (Equation 4). This is based on measurements of the rate of swim bladder inflation or deflation in rainbow trout as a function of water delta P and pO_2 levels. The experimental results are shown in Figure 21 where conditions for increasing or decreasing swim bladder pressure are plotted as a function of water delta P and pO_2 levels. The solid symbols indicate conditions of swim bladder inflation while the open symbols indicate conditions of swim bladder deflation.

Also plotted in the figure is Equation 4, the threshold equation for swim bladder over-inflation. With the coefficient of the pO_2 term set to 0.15, the threshold line forms a boundary between those delta P levels which cause swim bladder inflation and those which lead to swim bladder deflation. Thus, the experimental data support the use of Equation 4 to define the threshold for swim bladder over-inflation in small rainbow trout. Because swim bladder over-inflation occurs at the lowest level of DGS, Equation 4 is a useful relationship for describing the critical delta P and pO_2 for signs of GBT in small trout and Pacific salmon.

Shrimpton (1985) and Shrimpton *et al.* (1990b) addressed one further question related to the sign of swim bladder over-inflation. That is, do fish such as trout and Pacific salmon, use water depth to compensate for over-buoyancy resulting from DGS? Shrimpton (1985) found that for delta P levels up to about 90 mm Hg, coho salmon did compensate for over-buoyancy. However, there was no compensation apparent at higher delta P levels. In subsequent studies using rainbow trout, Shrimpton *et al.* (1990b) established that small fish exposed to DGS would tend to descend in the water column to a location where they were either neutrally buoyant or slightly under-buoyant. That is, as delta P increased, fish would move deeper in the water column. In these studies, there was no indication of a limit in delta P (up to 150 mm Hg) for which compensation took place.

Figure 20: Pneumatic Duct Release Pressure

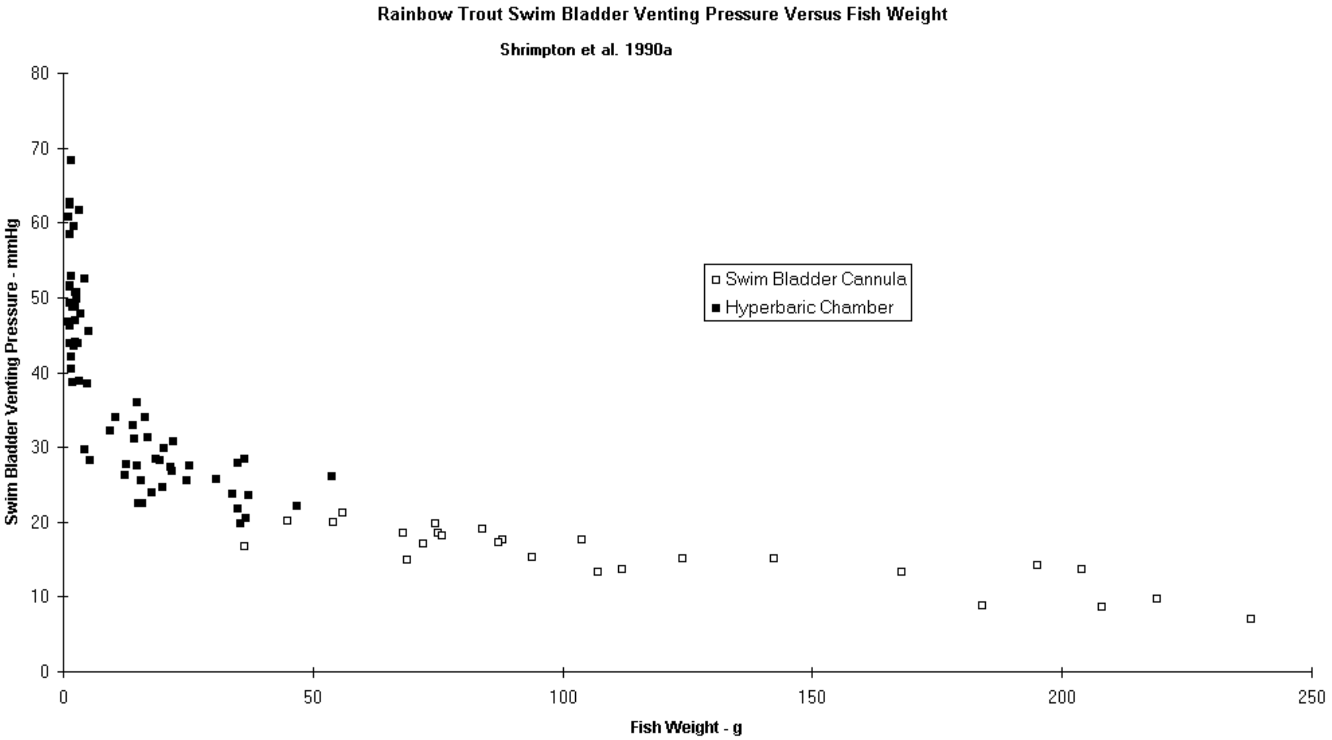
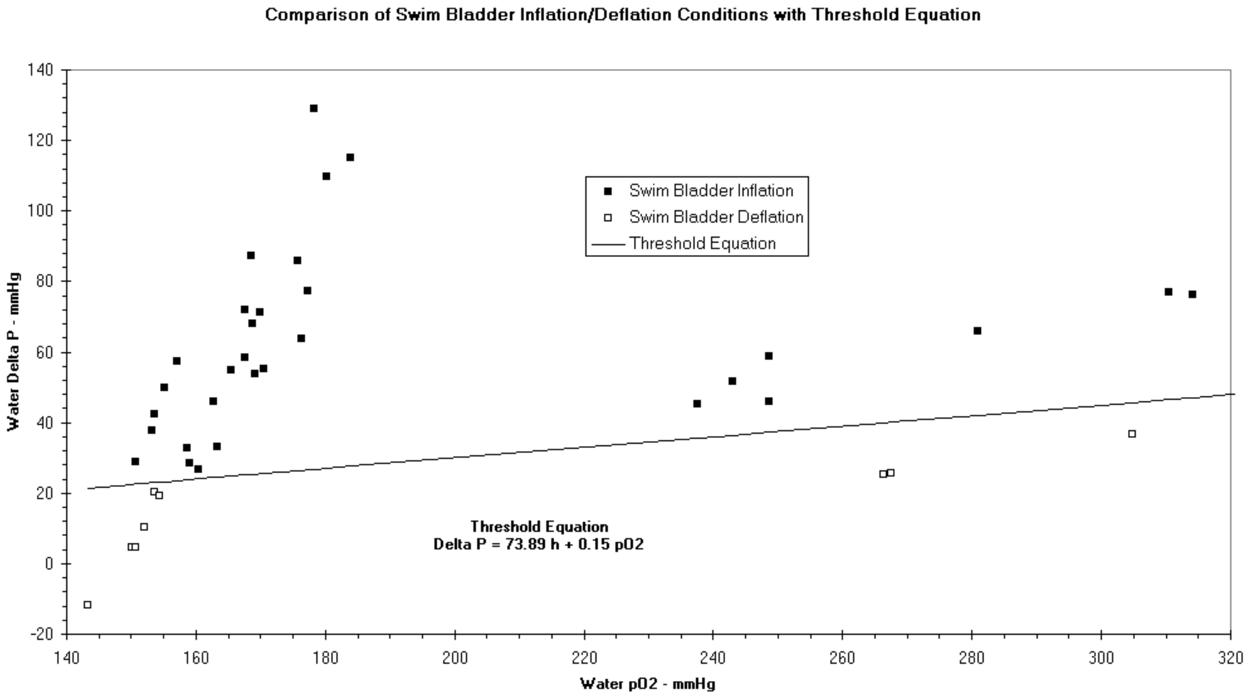


Figure 21: Swim Bladder Inflation/Deflation Conditions.



It should be noted that although fish moved to deeper water, this was not a sounding response. That is, fish tended to use the entire water column; however, on the average, they spent more time at or below the compensation depth corresponding to the prevailing levels of DGS. These results demonstrated that, when available, small fish utilize water depth a means of compensating for the effects of swim bladder over-inflation. In doing so, they may also avoid the other signs of GBT.

These studies also found that as fish grew in size, there was less and less tendency to use depth as a means of compensating for DGS. Presumably, this was a consequence of large fish not experiencing swim bladder over-inflation because of the lower venting pressures of the pneumatic duct (Figure 20). This result implies that without the need for buoyancy compensation, larger fish may stay near the water surface where they would be more prone to other signs of GBT.

6.2 Other Fish Species

In addition to information on the response of trout and salmonid species to the effects of DGS, there is some data for other North American fresh water fish species. Time to mortality data which can be used for the development of water quality guidelines are available for carp (*Cyprinus carpio*), black bullhead (*Ictalurus melas*), channel catfish (*Ictalurus punctatus*), mountain whitefish (*Prosopium williamsoni*), cutthroat trout

(*Salmo clarki*), largescale sucker (*Catostomus machrocheilus*), torrent sculpin (*Cottus rhotheus*), and the northern squawfish (*Ptychocheilus oregonensis*).

6.2.1 Carp and Black Bullhead

Gray *et al.* (1982 and 1983) examined the survival of carp (*Cyprinus carpio*) under various conditions of DGS. Carp from Italy, weighing 20.5 g, survived exposures to a delta P of 107 mm Hg for 96 hours, but suffered a 50% mortality after about 9.9 hours at a delta P of 404 mm Hg. The 96-hour LC_{50} for this species of carp was estimated to be 171 mm Hg. Based on the probit data provided, it appears that the upper limit for delta P which would assure 100% survival is about 114 to 130 mm Hg. Contrasting with these results, Fickeisen *et al.* (1975) found that Columbia River carp of the same species experienced no mortalities after 96 hours at a delta P of 266 mm Hg.

Gray *et al.* (1982) also found that black bullhead (*Ictalurus melas*) from Italy, weighing 27.7 g, survived exposures to a delta P to 55 mm Hg for 96 hours, but experienced a 50% mortality after exposure at a delta P of 435 mm Hg for 5.6 hours. The 96-hour LC_{50} for the black bullhead was estimated to be 109 mm Hg. Based on the probit data provided, it appears that the upper limit for delta P which would assure 100% survival of this species is about 76 to 90 mm Hg. Again, contrasting with these results, Fickeisen *et al.* (1975) reported that the 96-hour LC_{50} for the Columbia River black bullhead was a delta P of 185 to 202 mm Hg.

6.2.2 Squawfish

Bentley *et al.* (1976) examined the effects of DGS on squawfish (*Ptychocheilus oregonensis* Richardson). Fish weighing 534 g (364 mm in length) were held in water at a delta P of 76 mm Hg without mortalities over a 12-day period. However, when water delta P was increased to 129 mm Hg, a 10% mortality occurred in 4.8 days. After 12 days exposure, mortalities had not reached the 50% level. As water delta P was increased to 152 mm Hg, the 10% mortality level decreased to 41 hours and the 50% mortality level was achieved in 9.7 days. At a water delta P of 198 mm Hg, the 10% mortality level decreased to 19 hours while the 50% level dropped to 20 hours.

6.2.3 Channel Catfish

Colt *et al.* (1985) studied the response of channel catfish (*Ictalurus punctatus*) to DGS. These studies determined that juvenile fish (4.80 to 5.03 g) were fairly resistant to delta P levels up to 76 mm Hg. At this level, a 1% mortality occurred in a 35-day exposure period. As delta P was increased to 117 mm Hg, the level of mortality rose to 56% in 35 days.

6.2.4 Whitefish, Cutthroat Trout, Largescale Sucker, and Sculpin

Fickeisen and Montgomery (1978) examined the effects of DGS on mountain whitefish, cutthroat trout, largescale sucker, and torrent sculpin. Their experimental design involved a large tank with a constant water delta P of 222 mm Hg (sea level TGP% about 129%). Variations in delta P were obtained by holding experimental animals at various depths in the experimental tank (*i.e.*, hydrostatic pressure was used to achieve various effective delta P levels). No information was provided on the size or age class of the fish tested. However, all fish which died during the experiments were examined to ensure that signs of GBT were present. Because the technique for achieving various levels of delta P differed from that of all other experimental data reported in Section 6.1, and because of the lack of information on fish size, the data on cutthroat trout were not included in the analyses of Jensen *et al.* (1986) or that of Fidler (1988).

For the mountain whitefish (*Prosopium williamsoni*), they found LT_{50} values of 12 hours at a delta P of 222 mm Hg, 14 hours at a delta P of 192 mm Hg, 50 hours at a delta P of 161 mm Hg, and 48 hours at a delta P of 130 mm Hg. Although this species was the most sensitive to the effects of DGS, Fickeisen and Montgomery (1978) reported that many of the experimental animals developed signs of piscine tuberculosis. Thus, these results are probably not representative of healthy mountain whitefish.

For cutthroat trout (*Salmo clarki*), Fickeisen and Montgomery (1978) found LT_{50} values of 12 hours, 17 hours, 34 hours, and 89 hours at delta P values of 222, 192, 161, and 130 mm Hg, respectively. For largescale sucker (*Catostomus machrocheilus*), they reported LT_{50} values of 34 hours, 67 hours, and 103 hours at delta P values of 222, 192, and 161 mm Hg, respectively. At a delta P of 130 mm Hg, 90% of the fish tested were alive at the end of 10 days. They reported that, of all species tested, torrent sculpin (*Cottus rhotheus*) was the most resistant to the effects of DGS. An LT_{50} value was reached only at a delta P of 222 mm Hg after 10 days. However, loss of equilibrium due to swim bladder over-inflation was observed at most levels of delta P. They reported ET_{50} values for loss of equilibrium as 127 hours, 185 hours, and 233 hours at delta P values of 222, 192, and 161 mm Hg, respectively.

6.2.5 Summary - Other Fish Species

The studies described above show that carp, black bullhead, squawfish, channel catfish, mountain whitefish, largescale sucker, and torrent sculpin are either less sensitive or as sensitive to the effects of DGS as the Pacific salmon and cutthroat trout which were described in Section 6.1. However, because of the short duration of the experiments, chronic responses were not evident in the data. Nevertheless, the threshold criteria developed in Section 6.1 should allow the development of DGS water quality guidelines which are protective of these species as well. The data described above have been entered into Table C3 of Appendix C and will be considered in the derivation of fresh water quality guidelines for DGS.

Although several other studies reported in the literature have dealt with the effects of DGS on species other than cutthroat trout and Pacific salmon (Jones and Lewis 1976, Montgomery and Becker 1980, Kolbeinshavn and Wallace 1985, Boon *et al.* 1987, Tucker 1989, and Backman *et al.* 1991), the information provided is qualitative only and of little value in the derivation of numerical water quality guidelines. For example, Blahm *et al.* (1976) reported on the effects of DGS on largemouth bass, rainbow trout, crappie, squawfish, smelt, and mountain whitefish. However, all dissolved gas levels were reported in terms of nitrogen supersaturation and, as such, are incomplete.

6.3 Invertebrates

In addition to the studies of DGS and GBT in fish, there has also been research directed at defining responses to DGS in aquatic invertebrates. Nebeker *et al.* (1976c) conducted experiments on several species including a Cladoceran (*Daphnia magna*), western crayfish (*Pacifastacus leniusculus*), and three stoneflies (*Acroneuria californica*, *A. pacifica*, and *Pteronarcys californica*). The experiments with *D. magna* involved suspending test animals in small wire cages in a large 0.6 m deep test tank at selected levels of DGS. One aspect of the data which was not reported was the depth at which cages were located in the main tank. The experimental results are summarized in Table 5. The three test series shown reflect differences in the location of the wire cages within the main tank. The authors thought water currents through the cages might affect the response of the animals. This may be the case, as shown by the data in the table; however, it may also be the result of differences in depth at which the cages were located. Examination of the test animals after exposure to the various levels of DGS showed clear evidence of bubbles in the gut and most animals were floating on the water surface. Extrapolated lethal thresholds were given as TGP% = 111% (delta P about 84 mm Hg).

In experiments with western crayfish, Nebeker *et al.* (1976c) obtained the results shown in Table 6. The variations in the test series are due to a variety of factors including animal size and caged versus free animals in the test tank. Again, it is not clear what depth the cages were placed in the large test tank. At the highest delta P levels, most animals had bubbles within the distended membrane between the carapace and abdominal segments. Bubbles were also present in the gills and body fluids. Extrapolated lethal thresholds were given as TGP% about 120 to 127% (delta P about 152 to 205 mm Hg)

Table 5: Time to Mortality Data for *Daphnia magna* (Nebeker *et al.* 1976c)

Test Series	Nominal delta P	Time to 50% Mortality - hr	Time to 20% Mortality - hr
1	152	91	38
1	228	65	45
1	304	71	48
2	152	210	131
2	228	130	92
2	304	123	72
2	380	101	82
3	76	No mortality	No mortality
3	114	No mortality	137
3	152	93	49

Although their studies of aquatic insects produced no mortalities for water delta P's ranging from 114 to 266 mm Hg, Nebeker *et al.* (1976c) found bubbles adhering to ventral tracheal gill masses and in internal body fluids at the higher delta P levels. Several animals were distended like balloons due to internal bubbles.

White *et al.* (1991) examined the effects of DGS on river invertebrate communities of the Bighorn River below the Yellowtail Afterbay Dam. Although the study results were not in a form from which mortality - delta P relationships could be developed, several observations are worth noting. The general effect of DGS on all taxa of invertebrates examined was the presence of both internal and external bubbles at river delta P levels ranging from 76 to 150 mm Hg. As a result, most organisms were trapped at the water surface by excess buoyancy. Advanced signs of GBT included protraction of the head from the thorax, separation of abdominal segments, and loss of torsal mobility.

Table 6: Time to Mortality for Western Crayfish (Nebeker *et al.* 1976c)

Test Series	Nominal delta P	Time to 50%	Time to 20%

		Mortality - hr	**Mortality - hr**
4	190	No mortality	No mortality
5	380	No mortality	35
6	152	No mortality	No mortality
6	228	No mortality	454
6	304	330	130
6	380	94	40
7	308	165	122
7	380	123	66

The above results indicate that fresh water invertebrates are either less sensitive or as sensitive to some of the signs of GBT as fresh water fish. Therefore, the threshold information developed in Section 6.1 should provide a conservative basis for the development of DGS water quality guidelines which are protective of fresh water invertebrates.

6.4 Amphibians

Colt *et al.* (1984a) exposed bullfrog tadpoles (*Rana catesbeiana*) to delta P levels of 160 to 170 mm Hg for four days with no apparent effect. When exposure was increased to ten days, mortalities increased along with a systemic bacteria infection. The intestinal tract and gallbladder were also filled with gas bubbles. Colt *et al.* (1987) exposed adult bullfrogs (*R. catesbeiana*) to several levels of DGS. At the highest level (delta P = 240 mm Hg), a 40% mortality occurred in a 24-hour period. At all levels of delta P above 128 mm Hg, animals had extensive blistering of external skin surfaces and bubbles in the vascular system. Colt *et al.* (1984b) also exposed adult African clawed toad (*Xenopus laevis*) to DGS. The authors reported that extensive bubble formation occurred in inter-digital webbing and sub-cutaneously on body surfaces. Death resulted from bubble formation in the vascular system and secondary bacterial infections. None of these data allowed estimates of time to mortality as a function of DGS levels.

6.5 Plants and Algae

No data were found in the literature which describe the effects of DGS on aquatic plankton, algae, or vascular plants. Nevertheless, based on the signs of GBT in fish and other aquatic organisms, in conjunction with an understanding of the processes involved in bubble formation and growth, some effects of DGS on aquatic plants can be anticipated. For example, if bubbles form in the environmental water and become attached to plankton and algae, these plants may float to the water surface. Since bubble formation in "clean" water appears to occur at a delta P of about 76 mm Hg, this is a threshold which may apply to aquatic plants.

Still, the detrimental effects of excess buoyancy to plants is unknown. One effect which might appear at high levels of DGS is a concentration of plants at the water surface which could enhance oxygen production in the surface water layers through photosynthesis. This would increase the delta P to even higher levels. Although this might cause problems for fish and invertebrates, it may still not affect the survival of the plants themselves. As pointed out earlier, the presence of suspended particulate matter could lower the delta P thresholds at which bubbles would form in the environmental water. However, there is no information presently available on how this would affect aquatic plants and algae. Another sign which could be anticipated in vascular plants is the formation of bubbles internal to the plant. At present, there is no information on the delta P levels at which this would occur.

7.0 GAS BUBBLE TRAUMA IN MARINE ORGANISMS

Very little is known about the response of marine organisms to DGS. There have been numerous observations of GBT in marine fish and invertebrates; however, there is little quantitative data which can serve as a basis for numerical water quality guidelines. The data which do exist are summarized in the following sections.

7.1 Fish

Cornacchia and Colt (1984) reported that 10- to 31-day old striped bass larvae (*Morone saxatilis*) developed over-inflated swim bladders and bubbles in the intestinal lumen at TGP% levels of 102.9% and 105.6%. At a TGP% of 105.6% there was a 33% mortality in a 78-hour period. In other experiments, these authors found that 19-day old fish succumbed to a TGP% of 106.3% with a 35% mortality in a 72-hour period. However, in 29-day old fish TGP% levels of 106.3% did not produce any mortalities over a 72-hour period.

Gray *et al.* (1985) examined the tolerance of sea bass (*Dicentrarchus labrax*) and striped mullet (*Mugil cephalus*) to the effects of DGS at temperatures of 20 °C and 26 °C. They reported that at 20 °C post larval sea bass (30 mm in length) survived 96-hour exposures to a delta P of 152 mm Hg, but experienced 50% mortalities after 96 hours

(LC_{50}) at a delta P of 207 mm Hg. At 26 °C, the 96-hour LC_{50} was a delta P of 166 mm Hg. Fingerling sea bass (100 mm in length) survived a 96-hour exposure at a temperature of 20 °C and a delta P of 114 mm Hg, but suffered a 50% loss after 96 hours at a delta P of 122 mm Hg. Based on these observations, they concluded that the upper delta P limit for 100% survival at 20 °C is 152 mm Hg for post larval sea bass and 114 mm Hg for fingerling sea bass. They also reported that the fish were over-buoyant due to a large bubble inside the body cavity.

Interestingly, Johnson and Katavic (1984) reported a similar condition described as Swim Bladder Stress Syndrome (SBSS) involving over-inflated swim bladders in sea bass (*Dicentrarchus labrax*). Bagarinao and Kungvankij (1986) reported the same condition in hatchery-reared sea bass (*Lates calcarifer*). Although Johnson and Katavic (1984) cautioned that the condition was not related to GBT, they failed to report on dissolved gas levels in their experiments. Similarly, Bagarinao and Kungvankij (1986) described the conditions of SBSS but failed to report on dissolved gas levels.

In experiments with striped mullet (*Mugil cephalus*), Gray *et al.* (1985) found that at 20 °C, post larval fish (31 mm in length) survived 96-hour exposures at a delta P of 144.5 mm Hg, but experienced a 50% mortality after 96 hours at a delta P of 223 mm Hg. Fingerling striped mullet (130 mm in length) survived 96-hour exposures at a delta P of 114 mm Hg, but suffered a 50% mortality after 96 hours at a delta P of 188.5 mm Hg. Based on these observations, they concluded that the upper delta P limit for 100% survival is 144.5 mm Hg for post larval mullet and 114 mm Hg for fingerling mullet. It should be noted that for fingerling sea bass the upper delta P limit for 100% survival is the same as for the striped mullet. For post larval stages of these species, the upper delta P limit for 100% survival of the sea bass is slightly higher than that for the striped mullet. The data described above have been entered into Table D3 of Appendix D.

7.2 Invertebrates

The literature on DGS and GBT in marine invertebrates is also limited. Most studies have involved anecdotal observations with little in the way of mortality information related to levels of DGS. For example, Hughes (1968) reported GBT in lobster which had been exposed to DGS in a hatchery water supply. No information on dissolved gas levels was provided. The occurrence of GBT in three species of bi-valve molluscs (*Crassostrea virginica*, *C. gigas*, and *Mercenaria mercenaria*) was reported by Malouf *et al.* (1972). Massive blisters were found on the valves of oysters and bubbles were observed in gill filaments. DGS was produced by heating water in a closed container; however, dissolved gas levels were not reported. Lightner *et al.* (1974) reported on GBT in the juvenile brown shrimp (*Penaeus aztecus*). Stage II protozoeal, larval shrimp developed GBT after being exposed to DGS. Most animals had bubbles under the carapace and in the gut and there was 100% mortality. No actual dissolved gas levels were reported; however, the water was held at a delta P of 2585 mm Hg with subsequent decompression. Supplee and Lightner (1976) reported on the effects of GBT on California brown shrimp (*Penaeus californiensis*) as a result of exposure to oxygen supersaturation. Oxygen levels up to 309% were reported; however, total gas pressures were not given. Brock (1988) described GBT in the prawn (*Macrobrachium rosenbergii*). No dissolved gas levels were reported, but mortalities were high and many bubbles were present under the dorsal membrane. Johnson (1976) reported on GBT in the blue crab (*Callinectes sapidus*) in a laboratory environment. Air leaks in a water supply line was the cause of DGS. Again dissolved gas levels were not reported, but there were significant mortalities and evidence of gas emboli in gills and in the antennal gland. Elston (1983) described the occurrence of GBT in the red abalone (*Haliotis rufescens* Swainson) as a result of exposure to oxygen supersaturation (150 to 200%). Bubbles (presumed to be oxygen) were observed throughout muscle tissue and various other locations. Total dissolved gas levels were not reported. In another incidence involving a faulty water supply line, Brisson (1985) described GBT in two species of pink shrimp (*Penaeus brasiliensis* and *Penaeus paulensis*). Again, signs were described, but without information on dissolved gas levels.

The only work found in the literature which provided detailed information on mortalities in marine invertebrates and related dissolved gas levels was that by Bisker and Castagna (1985) for three species of clams (*Mercenaria mercenaria* Linne, *Mulinia lateralis* Say, and *Mya arenaria* Linne). Table 7 presents the results of their studies in terms of the mean days of survival (50% mortality) and water TGP levels. The authors report that for TGP% levels above 108%, *M. lateralis* floated to the surface and gas bubbles were visible in tissues. *M. arenaria* showed similar, though less severe, behaviour. Gas bubbles developed in body tissues and caused flotation; however, the percent of clams which floated for a given TGP level were less than for *M. lateralis*. *M. mercenaria* did not appear to be adversely affected by the levels of TGP which were imposed. Some mortalities were observed at a TGP of 120%, but these were not significantly different from those of controls. The data of Table 7 suggest that the upper limit of delta P for 100% survival of *M. lateralis* is somewhere between 109 and 114 mm Hg. Unfortunately, data on water depth was not reported by Bisker and Castagna (1985) for any of the experiments. The data of Table 7 have also been entered into Table D3 of Appendix D.

7.3 Plants and Algae

As with fresh water plants and algae, there is no information in the literature which described the effects of DGS on marine plankton, algae, or vascular plants. However, the discussion of Section 6.5, which provided some predictions of the effects which might be expected, would apply to marine plants and algae as well.

Table 7: Survival of Three Species of Clams for Various Levels of DGS

(Bisker and Castagna 1985)

% TGP (delta P)			**Bivalve Species**		
	M. lateralis	***M. arenaria***		***M. mercenaria***	
120 (152)	13.0	27.8			
114 (106)	21.6	29.7			
108 (61)	27.8	29.7			
102 (15) Control	29.5	29.7			
			5 mm	**10 mm**	**12 mm**
115 (114)	17.4		29.4	29.5	30.0
109 (68)	29.9		30.0	29.7	29.8
104 (30)	29.7		30.0	29.7	29.9
101 (7.6) Control	30.0		30.0	29.7	29.6

8.0 GUIDELINE DEVELOPMENT - FRESH WATER

8.1 Fish

The information presented in Section 6.0 provides a review of experimental results and theoretical methods which describe delta P thresholds for the major signs of GBT in fresh water fish. The evidence suggests the existence of three thresholds which are dependent on environmental variables such as water delta P, depth, and pO_2. However, biological variables such as fish size, species, and behaviour also play important roles in the effects of DGS on fish. It is the goal of this section to use this information, along with information on habitat and other environmental variables, to derive water quality guidelines for DGS.

8.1.1 Factors Affecting Guideline Derivation and Application

There are a variety of factors which must be considered in both the derivation and application of water quality guidelines for DGS. The threshold information described earlier, available water depth, fish species, fish age class, available habitat, habitat usage, the presence of suspended or deposited particulate matter, and in the case of swim bladder over-inflation, the role of the swim bladder under normal conditions, are all important in establishing appropriate guidelines.

8.1.1.1 GBT Thresholds

The first threshold for signs of GBT occurs at low levels of delta P and is related to over-inflation of the swim bladder. As pointed out in Section 6.0 this sign of GBT depends, in part, on the size or age class of the fish. In the case of small rainbow trout (under 50 mm), swim bladder over-inflation can occur at delta P levels of about 25 mm Hg (sea level TGP% about 103% at zero water depth). Swim bladder rupture may occur as water delta P levels approach 76 mm Hg. At delta P levels less than 76 mm, the problem encountered by these animals is primarily one of over-buoyancy. At depths less than the compensation depth for the existing level of DGS, the animal must swim continuously in a head down orientation to maintain its position in the water column. The swimming requirement may lead to elevated stress in the animal and increased mortality, or perhaps make it more prone to predation (White *et al.* 1991). Where sufficient depth is available, small fish may use that depth to compensate for the excess buoyancy. This not only solves the problem of over-buoyancy but also protects the animal from other signs of GBT which occur at higher delta P levels. Swim bladder over-inflation is generally not a problem for fish over about 85 mm in length.

The second GBT threshold occurs at delta P levels of about 76 mm Hg and is associated with extra-corporeal inter-lamella bubbles and sub-dermal emphysema of external skin surfaces. These signs can affect both juvenile and adult fish. Because adult fish do not experience the over-buoyancy problems encountered by juvenile fish, they may not use depth as a compensating mechanism. As a result, they can be exposed to these signs of GBT while their juvenile counterparts are not.

The third threshold for signs of GBT occurs when delta P levels rise above 115 mm Hg. At these delta P levels, bubble growth in the vascular system begins (Figure 19). Mortality is generally rapid with the time to mortality decreasing as delta P levels increase. As with the second threshold for GBT, juvenile fish may be protected from this sign if they are at or below the depth required to compensate for swim bladder over-inflation.

8.1.1.2 Water Depth

As indicated by Equations 4, 5, and 6 and by Figure 19, water depth plays an important role in delta P thresholds for GBT signs. If sufficient depth is available to fish, and they make use of it, GBT signs may not appear at all. As described earlier, Shrimpton *et al.* (1990a and b) found that small fish would seek depth to avoid the problems of swim bladder over-inflation. It is not clear if larger fish, encountering the other signs of GBT (*i.e.*, sub-dermal emphysema and cardiovascular bubbles), would move to deeper water to avoid the signs. It may be that fish stressed by signs of GBT move to depth as a normal response to stress. If so, and there is sufficient depth available, the signs of GBT may again be avoided.

8.1.1.3 Available Habitat and Habitat Usage

The importance of habitat and its usage cannot be overemphasized in the development and application of DGS guidelines. This is best illustrated by comparing two river systems which have similar biological structure and comparable levels of DGS, but very different depth regimes and very different levels of GBT in fish.

The Columbia River below the Hugh Keenleyside Dam in southern British Columbia has levels of DGS approaching a delta P of 360 mm Hg at various times of the year (Clark 1977, Maxwell 1985, Hildebrand 1991). Yet it is a very deep river with depths of ten metres being quite common. Five metres of depth would compensate for the highest delta P levels which have been reported for the river. The Bighorn River in Montana, below the Yellowtail Afterbay Dam, also has DGS levels approaching a delta P of 350 mm Hg for similar periods throughout the year (White *et al.* 1991). In this river, water depth is only about one metre for nearly 20 km downstream of the dam. This depth, even if used by fish, is insufficient to compensate for delta P levels above 74 mm Hg. Numerous fisheries surveys on the Bighorn River have found that at times of high DGS (delta P = 350), up to 90% of all fish captured exhibited severe signs of GBT and high levels of mortality were common (White *et al.* 1991, also Figures 2 through 5). These surveys involved several thousand animals over a four-year period. On the Columbia River, surveys which also involved several thousand fish (both adults and juveniles) conducted over a similar time period found a maximum of 3% of the animals captured show mild signs of GBT (Hildebrand 1991). The only sign observed was sub-dermal bubble formation on the external skin surfaces of the affected animals. In these surveys, no mortalities were found which could be attributed to GBT. Thus, it appears that fish of the Columbia River are taking advantage of the available water depth to avoid the signs of GBT. It should be noted that when delta P levels in the Bighorn River were less than 76 mm Hg, no signs of GBT were observed in fish (White *et al.* 1991).

Depth plays yet another role in terms of specific habitat usage. For example, some species of fish may prefer shallow habitats for spawning and rearing. If water depths over these habitats do not adequately compensate for the prevailing levels of DGS, they may be avoided by spawning fish or the fry may have to move into deeper water to avoid the signs of GBT. The move to deeper water may or may not present adverse conditions to the young fish depending on predators, available cover, and a variety of other factors. Alternatively, if a river is supersaturated with dissolved gases (perhaps as a result of a dam), there may be tributaries flowing into the river which are not supersaturated. Fish may move into the tributaries for refuge from the effects of swim bladder over-inflation and other signs of DGS. Clearly, this would involve a displacement of fish from their normal habitat.

In many rivers and lakes, there can be periods when water levels are high and there is adequate depth to compensate for the signs of GBT. At other times water levels may be low and there is insufficient depth anywhere on the river or lake to provide protection from the signs of GBT.

In other situations, the levels of DGS in a river or lake may vary dramatically throughout the year (Hildebrand 1991, White *et al.* 1991). Thus, the timing of the high levels of DGS, water levels, and habitat use by various species for spawning and rearing can be critical in terms of the appearance of GBT signs.

Finally, there may be streams in which there is no habitat available for fish. Many of the smaller streams in British Columbia which could be used for small hydro-electric projects are inaccessible to fish. Water falls, high water velocities, or other barriers to fish passage isolate the stream or sections of the stream from fish use. Although higher levels of DGS could be tolerated in these streams, the higher delta P levels could affect fish in other streams into which these smaller streams discharge. An additional consideration is that, although a stream may not have fisheries habitat, there will probably be invertebrate and plant communities present. In some situations, it may be desirable to protect these.

8.1.1.4 Fish Species

As described in Section 6.0, the bulk of experimental data which describe the effects of DGS on fresh water fish species is for rainbow trout, cutthroat trout, and three Pacific salmon species. However, the other data which were reviewed in Section 6.2 indicate that species such as carp (*Cyprinus carpio*), black bullhead (*Ictalurus melas*), channel catfish (*Ictalurus punctatus*), mountain whitefish (*Prosopium williamsoni*), largescale sucker (*Catostomus machrocheilus*), torrent sculpin (*Cottus rhotheus*), and northern squawfish (*Ptychocheilus oregonensis*) are not more sensitive to DGS than trout and pacific salmon. Consequently, criteria which are developed from data on trout and Pacific salmon should be protective of these other species as well.

8.1.1.5 The Role of the Swim Bladder

The GBT sign of swim bladder over-inflation has been identified as the sign which occurs at the lowest delta P threshold. At low values of water delta P, it is a chronic sign affecting small or juvenile fish. Because the swim bladder is an organ which is used by fish for buoyancy control, it is important to consider its function independent of DGS and then re-examine this function in the presence of DGS. As Harvey (1963) has shown, sockeye salmon have a tissue density of 1.0634 g/ml. This density is probably characteristic of most species of Pacific salmon and trout and results in a tendency for these fish to sink in the water column. However, the swim bladder can be filled with gas and used to offset the high density and achieve neutral buoyancy. The swim bladders of physostome fish, such as trout and salmon, are filled with air at the water surface. The fish apparently gulps air into its mouth and forces it into the swim bladder by way of the pneumatic duct (Harvey 1963).

An analysis of the volume of gas in the swim bladder required to keep a sockeye salmon at neutral buoyancy shows that the gas volume should be a constant 6% of the total volume of the fish, regardless of water depth (Appendix E). Although the 6% volume is independent of water depth, the pressure within the swim bladder is not and would vary with water depth (*i.e.*, hydrostatic pressure). The actual volume of the swim bladder would also vary with water depth. As a fish goes deeper in the water column, hydrostatic pressure would cause the volume of the swim bladder to decrease. Thus, the deeper a fish is in the water column, the greater must be the volume of the swim bladder at the water surface in order to achieve neutral buoyancy at depth. Figure 22 shows the volume of the swim bladder at the water surface (as a percent of the total fish volume) required to achieve neutral buoyancy, at various water depths.

Considered from another perspective, a fish having a swim bladder volume equal to 6% of its total volume at a depth of two metres would have a larger volume at one metre and an even larger volume at the surface. The reduced hydrostatic pressures at the shallower depths would cause the swim bladder to expand. Thus, at depths less than two metres, the fish would be over-buoyant, with the amount of over-buoyancy increasing as water depth decreases. In order to maintain their position in the water column at the shallower depths, the fish would have to swim in a head down position (Harvey 1963, Shrimpton *et al.* 1990b). Clearly, over-buoyancy is a condition which fish must face in natural environments. On the other hand, if the fish drops below the two metre level it would be under-buoyant and would have to swim in a head up position in order to maintain its position in the water column.

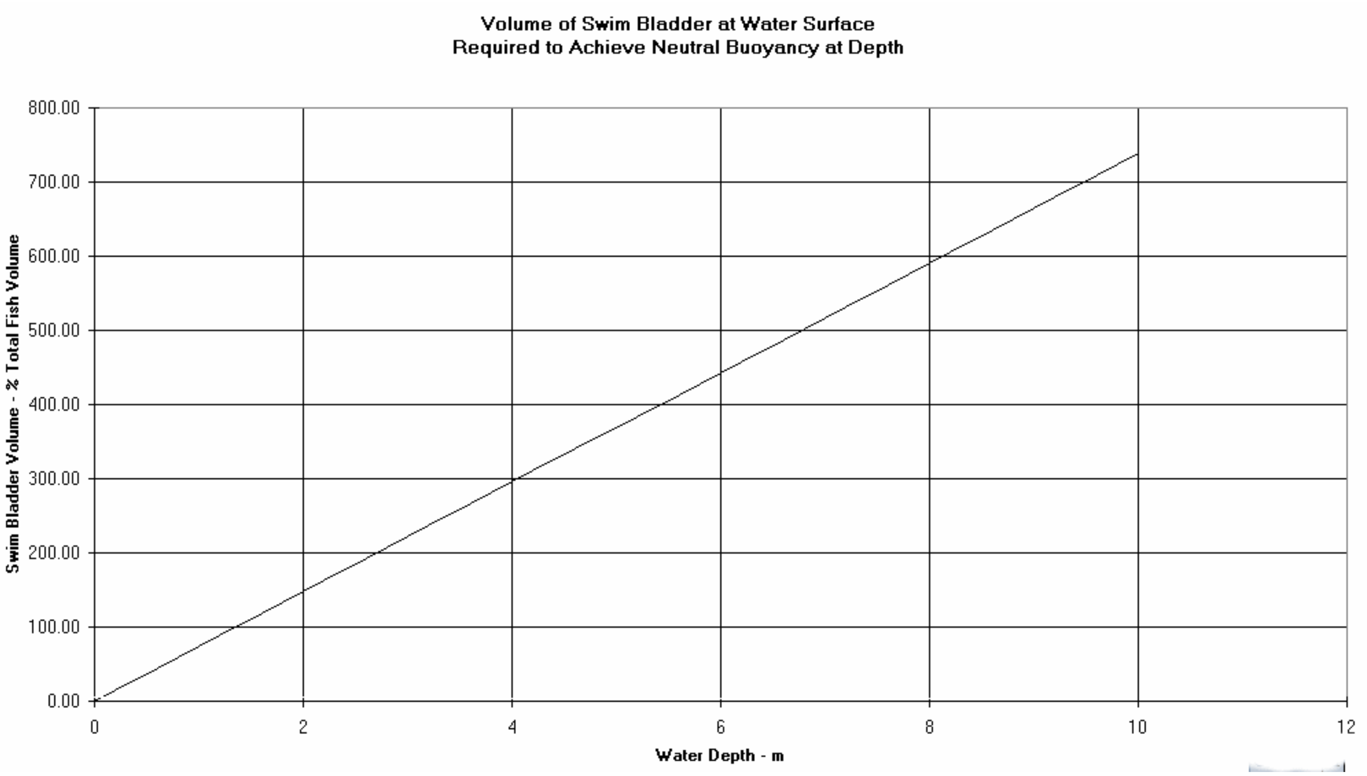
Harvey (1963) has shown that physostome fish, such as sockeye salmon, will vent gas from the swim bladder when frightened in order to change their buoyancy. When this happens the fish must return to the surface to refill the bladder in order to adjust its buoyancy to other depths. Harvey (1963) also found that fish will gradually loose gas from the swim bladder as a result of diffusion into the blood and subsequently to the water by way of the gills. Again, the fish must return to the water surface to refill the swim bladder in order to maintain neutral buoyancy at depth.

When conditions of DGS appear, fish may have to adopt different strategies for dealing with over-buoyancy which occurs as a result of swim bladder over-inflation. They may spend more time at depths which they might otherwise avoid. Depending on the circumstances (*i.e.*, available cover, the presence of predators, *etc.*), this may lead to reduced levels of survival. Conversely, the presence of DGS may allow the swim bladder to remain filled with no gas loss to the water, thus avoiding a trip to the surface to fill the swim bladder. In this situation, the fish may also avoid predators which it would normally encounter on its trip to and from the water surface. In either case, the strategies which fish adopt in these situations have not been examined to date. As a result, it is not possible to assess the net effects of DGS on swim bladder function in terms of the potential for increased or reduced mortality.

8.1.1.6 Water pO_2

It has been shown by Rucker (1975b), Fidler (1988), and Shrimpton *et al.* (1990a and b) that water pO_2 plays an important role in establishing the thresholds for the signs of GBT. In hyperoxic environments, fish are more protected from the effects of DGS. However, in hypoxic environments they may be more exposed than would be suggested by Equations 4 through 6 alone. For example, if water in a river is low in oxygen (as might be the case where water from the hypolimnion of a reservoir is discharged through a dam), Equations 4 through 6 might indicate safe conditions based on pO_2 levels and available water depth. However, the depth factor may not be relevant in this case.

Figure 22: Volume of Swim Bladder for Neutral Buoyancy



This is because the low water pO_2 may override a fish's normal response to compensate for over-buoyancy. As a result, fish may stay near the water surface where dissolved oxygen levels are higher as a result of re-aeration. In doing so, they become exposed not only to the problems associated with over-buoyancy, but to the other signs of GBT which occur at higher levels of delta P.

8.1.1.7 Hatchery Versus River and Lake Environments

Hatcheries present unique environments which are seldom encountered in rivers or lakes. High densities of fish, shallow water depths, long exposure periods, predominantly surface feeding, and high risk of disease all compound the effects of DGS. The shallow water environments and long exposure durations are particularly significant in relation to the results reported by Wright and McLean (1985) for chinook salmon in a hatchery environment. These results, which involved a water depth of 0.5 metres and an exposure period of 122 days were the principal evidence which supported the chronic nature of low levels of DGS and its effects on small fresh water fish (*i.e.*, swim bladder over-inflation). However, it is highly unlikely that small fish in rivers and lakes would be confined to a water depth of 0.5 metres or less for up to 122 days. Thus, the development of water quality guidelines for DGS may require criteria for hatcheries which are different than those for rivers and lakes.

8.1.1.8 Water Temperature

As pointed out in an earlier section, Jensen *et al.* (1986) found that temperature has an effect on time to mortality resulting from exposure to DGS. However, as pointed out in Section 6.1, there is no evidence that temperature affects the thresholds of DGS for the signs of GBT. As will be described, water quality guidelines should be based on avoiding the appearance of the signs of GBT and not on an acceptable level of mortality. Consequently, based on the available evidence, temperature should not be a factor in the derivation of DGS water quality guidelines.

8.1.1.9 Altitude

Altitude becomes a factor in the derivation of DGS water quality guidelines only when water dissolved gas tensions are expressed in terms other than delta P. If TGP or TGP% are used, corrections must be made for altitude. In situations involving rapid changes in barometric pressure as a result of aircraft transport of fish, the guidelines should apply. However, in the case of over-inflation of the swim bladder, there are two components which must be considered in calculating the delta P. The first is the delta P resulting from the change in altitude. The second component is the delta P resulting from any DGS existing before the change in altitude.

8.1.1.10 Background Levels

The final consideration in the derivation and application of water quality guidelines for DGS is the prevailing background level of DGS. As pointed out in earlier sections, many river systems and lakes have naturally occurring DGS at various times of the year. This may be caused by solar heating, primary production, or upstream water falls. It is clear that water quality guidelines must recognize the existence of this form of DGS. It must also be recognized that there may be some levels of naturally occurring DGS which may lead to adverse conditions for fish and perhaps mortalities. Thus, it is not adequate to argue that DGS created by man-made activities at one location are acceptable simply because of naturally occurring levels elsewhere. Clearly guidelines must incorporate natural conditions in some way which can be rationally applied to man-made forms of DGS.

8.1.2 Rationale

Given the wide range of environmental and biological variables which can influence the impact of DGS on fish populations, a single value numerical guideline appears to be impractical. Such a guideline may be too restrictive in some situations and not restrictive enough in others. The first requirement of a guideline is to protect young fish from the chronic effects of swim bladder over-inflation at low levels of DGS. As such, water depth and pO_2 levels as defined by Equation 4, combined with the experimental results of Shrimpton *et al.* (1990a and b), become the central criteria for the derivation of DGS water quality guidelines.

In addition to protecting small fish, it is necessary to protect fish of all sizes from the acute signs of GBT involving sub-dermal emphysema, the blockage of the gill respiratory water flow by extra-corporeal bubbles, and the development of bubbles in the cardiovascular system. Without the need for over-buoyancy compensation, larger fish will be especially prone to these signs at the water surface. In Section 6.1.2.1 it was shown that the lowest delta P from the data of Table C3 for acute mortality was about 76 mm Hg. Thus, a delta P threshold of 76 mm Hg becomes the second criteria for the derivation of a DGS water quality guideline. This is close to the threshold for extra-corporeal bubble growth and sub-dermal emphysema predicted by Equation 5.

The combination of Equation 4, the experimental results of Shrimpton *et al.* (1990a and b), and the delta P threshold of 76 mm Hg will form the basis for a guideline. It should be noted that 76 mm Hg is very close to the hydrostatic compensation pressure corresponding to one metre of water depth (*i.e.,* 73.89 mm Hg). Thus, one meter of water depth can serve as a convenient division (or cross over point) between Equation 4 and the delta P threshold of 76 mm Hg. Additional restrictions will be required for hatchery environments where shallow water depth, crowding, and added exposure to diseases increases stress beyond that encountered in natural environments.

8.1.3 Guideline Derivation

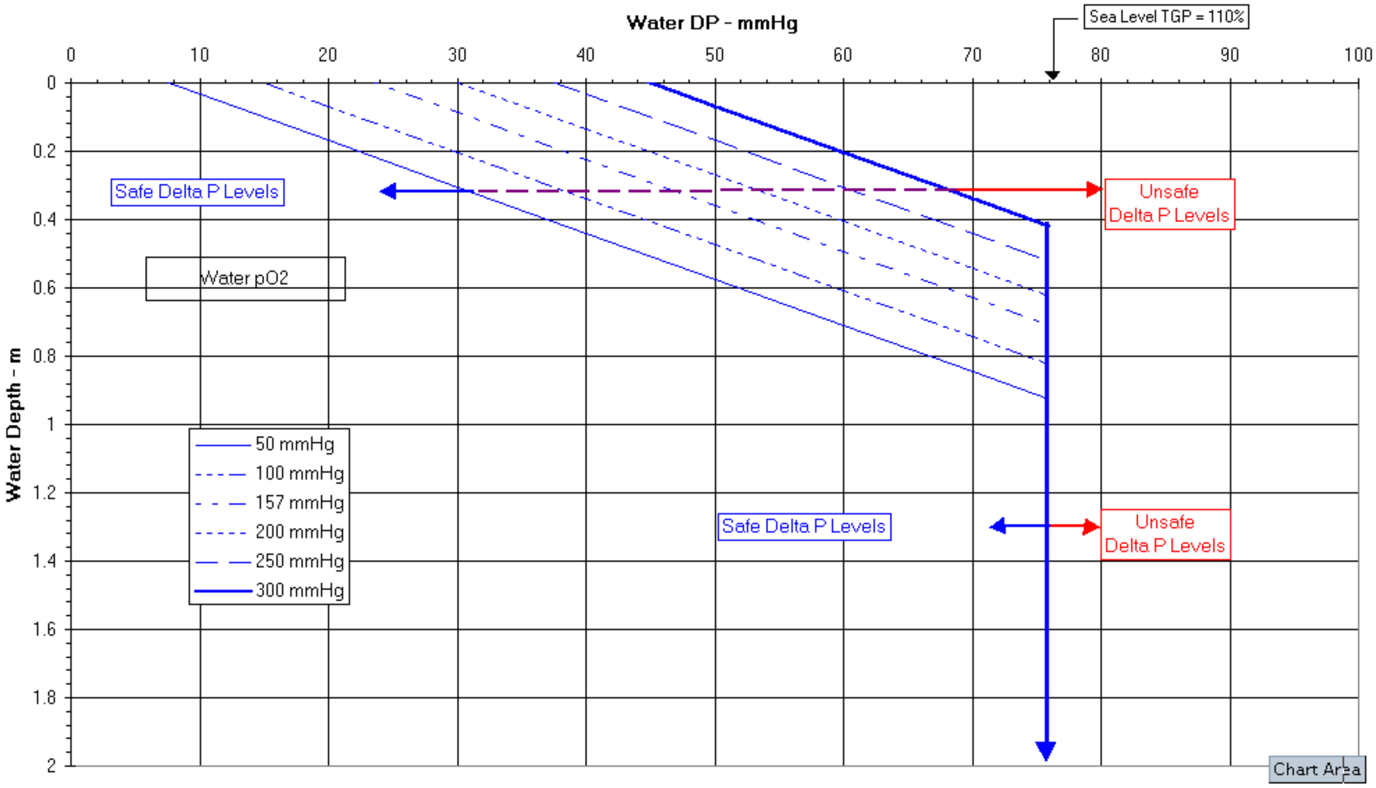
The implementation of the derivation rationale is as follows.

<u>For Water Depths Greater than One Metre:</u> Where available water depths exceed one metre, the maximum delta P should not exceed 76 mm Hg regardless of water pO_2 levels. For sea level conditions, this corresponds to a TGP% of about 110%. This guideline is consistent with observations on the Columbia River in both Canada and the United States and on the Bighorn River in Montana. At delta P levels below 76 mm Hg, no GBT signs involving sub-dermal emphysema or fish mortality have been observed in these systems. This portion of the guideline is also consistent with the US EPA guideline for DGS.

<u>**For Water Depths Less than One Metre:**</u> **For water depths less than one metre, the guideline should be based on Equation 4 which describes the threshold for swim bladder over-inflation as a function of water depth and pO_2 levels.** For example, at a water depth of zero metres and a pO_2 of 157 mm Hg, the delta P must not exceed 24 mm Hg. For sea level conditions, this corresponds to a TGP% of about 103%. As noted earlier, Equation 4 is consistent with the experimental results of Shrimpton *et al.* (1990a and b).

Figure 23 shows the results of combining the two guideline criteria. As shown in the figure, for water depths greater than one metre, delta P levels greater that 76 mm Hg (*i.e.,* to the right of the vertical line at delta P = 76 mm Hg) are unsafe for fish regardless of water pO_2 or depth. For water depths less than one metre, the maximum allowable delta P depends on water pO_2. The region to the right of the diagonal line, corresponding to a given water pO_2, is unsafe for fish while the region to the left is considered safe for fish. This guideline recognizes that young fish may seek depth to avoid swim bladder over-

Figure 23: Water Quality Guidelines for Dissolved Gases



inflation or to compensate for over-buoyancy, and that one metre is not an uncommon depth for fish to use for rearing habitat.

In rivers or lakes where there is a natural background level of DGS, the same guidelines should apply to any man-made alterations to the dissolved gas regime. That is, any changes to the dissolved gas levels, in combination with natural background levels, should not exceed the above guidelines. If natural levels are higher than the recommended guidelines it must be recognized that these levels may also be harmful to fish. Therefore, there is no justification for introducing comparable DGS levels of man-made origin to a river or lake.

In hatchery environments Equation 4 may not apply. With the much higher fish densities in hatcheries, accompanied by declines in pO_2 along the rearing facility and surface feeding, fish may spend more time near the water surface and become subjected to higher stress levels than in natural environments.

<u>**For Hatchery Environments:**</u> **It is recommended that the DGS guideline for hatcheries be set at a maximum delta P of 24 mm Hg (*i.e.*, the threshold for swim bladder over-inflation under sea level normoxic conditions and zero water depth).** This corresponds to a sea level TGP% of 103%. If pO_2 levels in the hatchery drop to 100 mm Hg, the guideline should be a maximum delta P of 0 mm Hg.

8.1.4 Guideline Application

The application of the above DGS water quality guidelines to man-made alterations of aquatic environments must focus on fisheries habitat. The first step in applying the guideline is to assess the habitat which is available for use by the various fish species of a river or lake. This includes assessment of habitats for spawning, rearing, and adult holding along with information on the temporal usage of these habitats. These data, along with information on water depth (which may vary over the year) and pO_2 levels (which may also vary over the year as well as diurnally), provide the necessary information for application of the guideline criteria. The conditions described in Section 8.1.1 will also have to be considered in establishing guideline compliance.

8.1.5 Guideline Application Examples

To provide water managers with guidance in the application of the guideline for dissolved gas supersaturation, two examples will be described. The first involves a small creek in east central British Columbia while the second involves the Columbia River in the southern part of the province.

8.1.5.1 Camp Creek

Camp Creek is a tributary of the Canoe River which flows into the northern reach of Kinbasket Reservoir near Valemount, BC The creek provides important spawning and rearing habitat for many of the sportsfish species of Kinbasket Reservoir (Triton Environmental Consultants Ltd. 1992, Slaney *et al.* 1993, Fidler 1994). The headwaters of Camp Creek lie near Mt. Lulu in the Cariboo Mountains of British Columbia. From its headwaters, Camp Creek flows 12 km east through a steep mountain valley. It then turns north and meanders through a wide flat valley for 18 km where it joins the Canoe River about 7 km south of Valemount, BC Only the lower 18 km of Camp Creek are accessible to migratory fish species. This portion of the creek is relatively low gradient with run-riffle sections separated by slower meandering glide-pool sections (Triton Environmental Consultants Ltd. 1992, Slaney *et al.* 1993). Creek substrate consists of large cobbles with considerable amounts of fine sand and silt deposited in the low velocity sections. Although there are a few deep pools in this section of the creek, they comprise a very small percent of the total habitat. The elevation of this section of the creek is approximately 925 m above sea level. The mean water depth for most of the year is about 0.5 m, with levels dropping to about 0.3 m in the fall and winter months.

Because the upper reaches of the creek (beyond the lower 18 km) are very steep, there is excellent potential for the development of a small hydroelectric facility on the creek. In any hydroelectric facility there are periods when the turbines cannot handle all of the water flow and some of the flow must be spilled. If this is done with a dam sluice-way system, there exists the potential for the creek below the dam to become supersaturated with dissolved gases.

Application of the guideline for dissolved gas supersaturation to this creek must consider the predominantly shallow water of the lower 18 km of the creek and the altitude. At an altitude of 925 m, the atmospheric pressure is approximately 690 mm Hg (US Standard Atmosphere 1976) and the partial pressure for oxygen (dry air) is approximately 145 mm Hg. Assuming that the creek is in equilibrium with the atmosphere, the partial pressure of dissolved oxygen would also be approximately 145 mm Hg. As noted above, most of the creek is at a depth of 0.3 m during the fall and winter months when some fish species will be spawning (*e.g*., Kokanee salmon, burbot, and mountain whitefish) and juvenile fish species will be rearing in the creek. Using this information in conjunction with Figure 23, one would obtain a guideline value of approximately 38 mm Hg. That is, if one moved left along a line parallel to, but between, the 100 mm Hg and 157 mm Hg pO_2 lines of the figure to a point corresponding to a depth of 0.3 m, the guideline delta P would be read from the top axis as 38 mm Hg.

Although this would be the suggested guideline, other factors must be considered. For example, this guideline value would protect juvenile fish if they spent most of their time on the creek bed. Because there are so few areas of deeper water in the creek during this time of year, additional protection should be considered. The situation just described would be very similar to that in a hatchery and a guideline of 20 mm Hg would be more appropriate. This would allow fish to use the full 0.3 m of the water column as needed. In another creek where there may be a more even balance of shallow and deep water, the 38 mm Hg delta P guideline might be more appropriate.

8.1.5.2 Columbia River

The Columbia River, as described earlier, is a large, deep river supporting a wide range of sports and other fish species (Hildebrand 1991). Although the Columbia River itself is presently highly supersaturated with dissolved gases (Tables 2 and 4), there are many tributaries running into the river which are not supersaturated. The one exception is the Kootenay River which flows into the Columbia River near Castlegar, BC At times, this river is also highly supersaturated (Table 30). The DGS of the main stem Columbia River is caused primarily by spilling water at the Hugh Keenleyside Dam and at the Brilliant Dam on the Kootenay River. At times, the main stem dissolved gas levels are also influenced by high background levels of DGS in Lower Arrow Reservoir (Table 2).

The tributaries as well as the main stem of the Columbia River provide important spawning and rearing habitat for most fish species of the river. An exception is the white sturgeon which use the main stem of the river for spawning, rearing, and adult holding. For the Columbia River, the most important considerations in applying the guideline for dissolved gas supersaturation are the large variations in water depth which occur throughout the year and the high background levels of DGS associated with Lower Arrow Reservoir. The variations in water depth are the result of demands placed on river water flow by the Columbia River Treaty. The background DGS of Lower Arrow Reservoir varies throughout the year and appears to have a strong component related to solar heating (Ash *et al.* 1993). As a result of these factors, the guideline for the river may not be a set value for the entire river, but may have to be adjusted at various times of the year. For example, the maximum delta P allowed for any river or lake is 76 mm Hg. At times, the background levels in Lower Arrow Reservoir exceed this value (Table 2). Although this level is permitted in the guideline (*i.e.,* as a result of natural processes), no anthropogenic structures or processes can increase delta P levels beyond this level.

In other situations when water levels are high and there is abundant spawning and rearing habitat available with water depths of 1.0 m or more, the maximum delta P would be 76 mm Hg. If water levels subsequently drop over these areas, dissolved gas levels may have to be reduced to avoid forcing fish into other habitats. For example, if water depth over rearing areas which are in use drops from 1.0 m to less than 0.5 m, the allowable delta P should be reduced to 38 mm Hg. This would afford approximately the same protection as the original 1.0 m of depth.

The application of the guideline in a variable mode, as just described, would permit a more flexible mode of operation for individuals or companies (*e.g.*, power generating companies and agriculture operations) which alter river or lake natural dissolved gas regimes. However, this mode of guideline application would require that river fisheries activities, water depths, and dissolved gas levels be monitored on a regular or even continuous basis. This requirement could be incorporated into the water license for the particular operation. In cases where the individual or company did not wish to take advantage of a variable guideline, the guideline should be set at a conservative value which is protective to fish under all possible operations. In deep rivers (greater than 1 m deep), the most conservative situation will be when the criteria/guideline is expressed in terms of depth at which fish reside rather than water depth, as stipulated in the above example.

8.2 Invertebrates

The information available which describes the effects of DGS on fresh water invertebrates was reviewed in Section 6.3. The data indicate that these organisms are susceptible to signs of GBT at water delta P levels in excess of 76 mm Hg.

8.2.1 Factors Affecting Guideline Derivation and Application

With the exception of those factors involving the swim bladder, most of the other considerations described for fish (Section 8.1.1) would apply to guidelines for aquatic invertebrates. Because invertebrates are rarely raised in a hatchery environment, the shallow depths and crowding associated with fish hatcheries should not impose any added restrictions to the water quality guidelines for aquatic invertebrates.

8.2.2 Rationale

Fish, as a result of swim bladder over-inflation, exhibit a higher degree of sensitivity to the effects of DGS than do aquatic invertebrates. That is, GBT signs in fish appear at lower delta P levels than have been reported for aquatic invertebrates. Thus, water quality guidelines derived for fish should also be protective of aquatic invertebrates.

8.2.3 Guideline Derivation

The guideline for aquatic invertebrates is the same as for aquatic fish species. Where available water depths are one metre or more, the maximum delta P should not exceed 76 mm Hg regardless of water pO_2 levels. For water depths less of than one metre, the guideline should be based on Equation 4 (Section 6.1.3) which describes the threshold for swim bladder over-inflation in fish as a function of water depth and pO_2 levels. Figure 23 shows the results of combining the two guideline criteria. As indicated in the figure, delta P levels greater that 76 mm Hg are unsafe for aquatic invertebrates regardless of water pO_2 or water depth. For water depths less than one metre, the maximum allowable delta P is a function of water pO_2.

In situations where there is a natural background level of DGS, the same guidelines should apply to any man-made alterations to the dissolved gas regime of a river or lake. That is, any changes to the dissolved gas environment, in combination with natural background levels, should not exceed the above guidelines. If natural levels are higher than the recommended guidelines it must be recognized that these levels may also be harmful to invertebrates. Therefore, there is no justification for introducing comparable DGS levels of man-made origin to a river or lake.

8.3 Plants and Algae

To date there are no data which can be used to evaluate the effects of DGS on aquatic plants and algae. As a result, guidelines cannot be derived. However, based on the discussion of Section 6.5, it is not anticipated that aquatic plants and algae would be any more sensitive to DGS than fish.

9.0 GUIDELINE DEVELOPMENT - MARINE WATER

9.1 Fish

As pointed out in Section 7.0, there are very limited data from the literature which describe the effects of DGS on marine fish. The data which do exist indicate that marine fish display the same signs of GBT as do fresh water fish. Furthermore, the data imply that water delta P thresholds for these signs are essentially the same as for fresh water fish. For example, adult sea bass and striped mullet have a survival threshold near a delta P value of 114 mm Hg (Grey *et al.* 1985). This is nearly the same as that derived from the graphical analysis of Section 6.1 for cutthroat and rainbow trout.

For larval stages of striped bass, Cornacchia and Colt (1984) reported swim bladder over-inflation thresholds of about 22 mm Hg, which is essentially that which would be predicted by Equation 4 and that found for rainbow trout by Shrimpton *et al.* (1990a and b).

9.1.1 Factors Affecting Guideline Derivation and Application

Those factors which would affect the derivation and application of a DGS guideline for marine fish are essentially the same as those described in Section 8.1.1 for fresh water fish.

9.1.2 Rationale

The limited data describing the effects of DGS on marine fish suggest that they are affected by DGS in the same way as fresh water fish and that the delta P thresholds for the signs of GBT are very similar to those for fresh water fish. Thus, the rational which was used in Section 8.1.2 will be applied in the derivation of DGS guidelines for marine fish.

9.1.3 Guideline Derivation

In situations involving water depths of one metre or more, the maximum delta P should not exceed 76 mm Hg. For sea level conditions, this corresponds to a TGP% of about 110%. For water depths less than one metre, the guideline should be based on Equation 4 which describes the threshold for swim bladder over-inflation as a function of water depth and pO_2 levels. Figure 23 shows the results of combining the two guideline criteria. As indicated in the figure, delta P levels greater that 76 mm Hg are unsafe for aquatic invertebrates regardless of water pO_2 or water depth. For water depths less than one metre, the maximum allowable delta P is a function of water pO_2.

In situations where there is a natural background level of DGS, the same guidelines should apply to any man-made alterations to the dissolved gas regime of marine environments. That is, any changes to the dissolved gas environment, in combination with natural background levels, should not exceed the above guidelines. If natural levels are higher than the recommended guidelines it must be recognized that these levels may also be harmful to fish. Therefore, there is no justification for introducing comparable DGS levels of man-made origin to marine environments.

In hatchery environments Equation 4 may not apply. With the much higher fish densities in hatcheries, accompanied by declines in pO_2 along the rearing facility and surface feeding, fish may spend more time near the water surface and become subjected to higher stress levels than in wild environments. Therefore, it is recommended that the guideline for hatcheries be set at a maximum delta P of 24 mm Hg (*i.e.*, the threshold for swim bladder over-inflation under sea level normoxic conditions and zero water depth). This corresponds to a sea level TGP% of 103%. If pO_2 levels in the hatchery drop to 100 mm Hg, the guideline should be a maximum delta P of 0 mm Hg.

9.1.4 Guideline Application

The application of the above DGS water quality guidelines to man-made alterations of marine environments must focus on fisheries habitat. The first step in applying the guideline is to assess the habitat which is available for use by the various marine fish species. This includes assessment of habitats for spawning, rearing, and adult holding along with information on the temporal usage of these habitats. These data, along with information on water depth (which may vary over the year) and pO_2 levels (which may also vary over the year as well as diurnally), provide the necessary information for application of the guideline criteria. The conditions described in Section 9.1.1 will also have to be considered in establishing guideline compliance.

9.2 Invertebrates

The limited data which describe the effects of DGS on marine invertebrates indicate that they have approximately the same sensitivity to DGS as do adult fish. For example, Bisker and Castagna (1985) found that of three species of clams studied, the threshold for 100% survival of the most sensitive species was at a water delta P of about 114 mm Hg. Clams floated to the surface at somewhat lower levels of delta P.

9.2.1 Factors Affecting Guideline Derivation and Application

With the exception of those factors involving the swim bladder, most of the other factors described above for marine fish would apply to guidelines for marine invertebrates.

9.2.2 Rationale

Because guidelines derived for marine fish are based on responses of fish species which are more sensitive than marine invertebrates (*e.g.*, striped bass - Cornacchia and Colt 1984), the water quality guidelines derived for fish should also be protective of marine invertebrates.

9.2.3 Guideline Derivation

The guideline for marine invertebrates should be the same as for freshwater and marine fish species. In situations involving water depths of one metre or more, the maximum delta P should not exceed 76 mm Hg. For sea level conditions, this corresponds to a TGP% of about 110%. For water depths less than one metre, the guideline should be based on Equation 4 which describes the threshold for swim bladder over-inflation as a function of water depth and pO_2 levels. Figure 23 shows the results of combining the two guideline criteria. As indicated in the figure, delta P levels greater that 76 mm Hg are unsafe for marine invertebrates regardless of water pO_2 or water depth. For water depths less than one metre, the maximum allowable delta P is a function of water pO_2.

In situations where there is a natural background level of DGS, the same guidelines should apply to any man-made alterations to the dissolved gas regime of marine environments. That is, any changes to the dissolved gas environment, in combination with natural background levels, should not exceed the above guidelines. If natural levels are higher than the recommended guidelines it must be recognized that these levels may also be harmful to marine invertebrates. Therefore, there is no justification for introducing comparable DGS levels of man-made origin to a marine environment.

9.3 Plants and Algae

As pointed out earlier, there are no data available which would indicate the effects of DGS on marine plants and algae. As a result, guidelines cannot be derived. However, based on the discussion of Section 7.3, it is not anticipated that marine plants and algae would be any more sensitive to DGS than fish.

10.0 RESEARCH AND DEVELOPMENT NEEDS

The vast majority of information describing the effects of DGS on fresh water and marine organisms is for Pacific salmon and trout species. There is only limited information on other fresh water and marine fish species. The situation is much the same for fresh water and marine invertebrates and there is essentially no information on fresh water and marine plants or algae. As a result, it is not certain that the guidelines derived herein would be protective of all fresh water and marine organisms under all environmental conditions. Based on these deficiencies, there is an immediate need for experimental data on fresh water and marine fish species other than Pacific salmon and trout. For example, in British Columbia, white sturgeon inhabit some of the rivers having the highest levels of DGS (Hildebrand 1991). There is no information on the effects of DGS on this species. In addition, experimental data is needed for fresh water and marine invertebrates as well as fresh water and marine plants and algae. Once these data are developed, they should be incorporated into the GBT threshold equations and guidelines where appropriate. This may require revising the equations to apply to specific species or environmental conditions.

DGS resulting from solar heating, perhaps combined with oxygen production from photosynthesis, has been identified as the cause of major fish kills in locations outside British Columbia. Fish kills of unknown source have occurred in lakes and marine environments in British Columbia under conditions which could have involved DGS caused by solar heating and photosynthesis. Since DGS has not been monitored in these situations, an educational program is needed to make fisheries officers and biologists aware of this effect. In addition, instrumentation should be provided along with the necessary expertise for measuring dissolved gas tensions at the time fish kills occur. This should include the availability of personnel with the expertise needed to identify the signs of GBT in fish. In addition, a research program should be initiated which identifies the environmental, physical, chemical, and biological parameters which control the development of DGS under conditions of solar heating and photosynthesis, and which also identifies the mechanisms which lead to fish mortality. If a contributing factor to high levels of DGS is the discharge of nutrients by industry, municipalities, and agriculture into water courses, provisions should be made to either limit these discharges and/or identify the conditions under which they would not threaten aquatic environments from DGS.

There needs to be additional research conducted to establish how DGS affects fish behaviour in terms of the use of the swim bladder. As pointed out earlier, small fish could be forced into deeper water environments to compensate for over-buoyancy caused by DGS. This may represent a greater threat to survival in terms of exposure to predators. On the other hand, the presence of DGS may allow a small fish to stay in deeper water without the need to return to the water surface to refill the swim bladder. This may lead to reduced exposure to predators which might be encountered in the trips to and from the surface. At this point, it is not clear what the net effect on survival may be as a result of these responses.

There needs to be research conducted which would establish the response of young fish to DGS under conditions of low water pO_2. The intent of this research would be to establish if fish would remain at the water surface where dissolved oxygen content is higher or would they move to a lower water depth to compensate for over-buoyancy.

Finally, there is need for research on the effects of DGS on physoclist fishes. To date there is almost no information available for these species.

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APPENDIX A

Table A1: Dissolved Gas Levels in Selected British Columbia Waters

Data from Clark (1977)

Bonaparte River

Location	EQUIS Site	Date	Method	TGP%	pO2%
3 m below falls	0900247	20/8/74	S, P	102.2	97.0
Beside water intake for Boston Flats	0900248	20/8/74	S, P	100.8	85.0

Bowron River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Mainline Road bridge	0400020	8/5/74	S, P	100.6	102.0

Bridge River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Carpenter Lake, Above Terzaghi Dam	0300301	22/5/75	S, P	104.5	100.2
Downton Lake, 30 m above Lajoie Dam	0900302	22/5/75	S, P	102.5	97.6
100 m below powerhouse outlets, Lajoie Dam	0900303	22/5/75	S, P	105.5	102.6

Brunette River

Location	EQUIS Site	Date	Method	TGP%	pO2%
At Hume Park	N/D	12/5/76	S, P	101.1	93.3

Bull River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
30 m above Aberfeldie Dam	0900305	4/6/75	S, P	106.2	100.4
30 m above Aberfeldie Dam	0900305	5/6/75	S, P	106.0	98.3
30 m above Aberfeldie Dam	0900305	18/7/76	S, P	106.2	101.5
Below Aberfeldie Dam and below river canyon	0900306	4/6/75	S, P	114.6	112.0
Below Aberfeldie Dam and below river canyon	0900306	5/6/75	S, P	115.0	111.3
Below Aberfeldie Dam and below river canyon	0900306	29/7/75	S, P	106.7	103.2
Below Aberfeldie Dam and below river canyon	0900306	18/7/76	S, P	113.5	107.5
1000 m below Aberfeldie Dam	0900307	5/6/75	S, P	114.7	109.3
2400 m above mouth	0900308	5/6/75	S, P	110.8	106.2
2100 m above mouth	N/D	5/6/75	S, P	109.5	104.4
2400 m above mouth	0900308	18/7/76	S, P	108.0	99.8

Capilano River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
À 100 m above Cleveland Dam	0900180	20/6/72	S, P	105.7	100.0
Below Cleveland Dam, near pumphouse above hatchery	0900179	20/6/72	S, P	100.8	105.2
Below Cleveland Dam, near pumphouse above hatchery	0900179	25/7/74	S	101.9	N/D
Cable Pool immediately	0900178	25/7/74	S, P	102.5	N/D

above rapids					

Columbia River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Parson	0900420	13/6/76	S, P	100.4	97.9
At Parson	0900420	13/6/76	S, P	100.3	96.5
Above Mica Dam	0900346	23/7/75	S, P	104.7	99.0
Above Mica Dam	0900346	23/8/76	S, H	95.0	69.2
Below confluence with Pend d'Oreille River to border	0900150	11/6/72	S, W	130.6	137.5
À 0.3 km below confluence with Pend d'Oreille River	0900208	25/7/72	S, P	120.1	N/D
À 1 km below confluence with Pend d'Oreille River	0900207	3/7/74	S, P	102.1	129.0
At Beaver Creek Park, boat launch below creek	0900213	18/6/74	S, P	108.7	N/D
At Beaver Creek Park, above creek	0900355	26/7/75	S, P	117.4	113.9
At Beaver Creek Park, boat launch below creek	0900213	16/3/76	S	106.2	N/D
At Beaver Creek Park, boat launch below creek	0900213	15/6/76	S, P	98.1	115.5
At Beaver Creek Park, above creek	0900355	23/7/76	S, P	126.6	127.6
At Beaver Creek Park, above rapids upstream of creek	N/D	20/8/76	S, P, H	133.1	120.1
Midstream, opposite Beaver Creek Park	N/D	20/8/76	S, P, H	126.9	119.0
Rock Island	0900015	21/8/72	S, W	110.5	146.9
Rock Island	0900015	13/9/72	S, W	111.1	134.5
Rock Island	0900015	-/10/72	S, W	N/D	N/D

Rock Island	0900015	-/11/72	S, W	N/D	N/D
Rock Island	0900015	-/12/72	S, W	N/D	N/D
Rock Island	0900015	6/1/73	S, W	105.5	106.1
Rock Island	0900015	25/1/73	S, W	101.4	96.9
Rock Island	0900015	1/3/73	S, W	106.4	118.6
Rock Island	0900015	28/3/73	S, W	104.2	128.0
Rock Island	0900015	4/5/73	S, W	111.5	120.7
At Trail	0900151	11/6/72	S, W	128.5	129.5
At Rivervale	0900211	25/7/72	S, P	114.1	101.0
At Rivervale	0900211	13/6/73	S, P	114.8	139.0
At Rivervale	0900211	21/8/73	S, P	109.8	99.1
At Rivervale	0900211	18/6/74	S, P	110.1	N/D
At Genelle	N/D	18/6/74	S, P	110.4	N/D
At Genelle	N/D	23/7/76	S, P	126.8	103.6
At Genelle	N/D	20/8/76	S, P, H	136.2	127.1
At Robson wharf	0900210	23/7/76	N/D	131.1	135.2
Below Hugh Keenleyside Dam	N/D	11/6/72	S, W	132.0	126.5
Below Hugh Keenleyside Dam	N/D	22/6/72	S, W	135.8	119.0
Below Hugh Keenleyside Dam	N/D	22/6/72	S, W	135.1	117.2
À 0.3 km below Hugh Keenleyside Dam	0200183	25/7/72	S, P	131.6	108.0
À 0.3 km below Hugh Keenleyside Dam	0200183	25/7/72	S, P	133.8	116.0
À 1 km below Hugh Keenleyside Dam	0900210	25/7/72	S, P	116.0	89.0
Below Hugh Keenleyside Dam	N/D	21/8/72	S, W	128.7	140.2
Below Hugh Keenleyside Dam	N/D	13/9/72	S, W	115.4	144.1
Below Hugh Keenleyside	N/D	6/10/72	S, W	N/D	N/D

Dam					
Below Hugh Keenleyside Dam	N/D	24/10/72	S, W	N/D	N/D
Below Hugh Keenleyside Dam	N/D	1/11/72	S, W	N/D	N/D
Below Hugh Keenleyside Dam	N/D	8/11/72	S, W	N/D	N/D
Below Hugh Keenleyside Dam	N/D	6/1/73	S, W	111.8	107.8
Below Hugh Keenleyside Dam	N/D	25/1/73	S, W	99.3	100.4
Below Hugh Keenleyside Dam	N/D	1/3/73	S, W	100.0	105.8
Below Hugh Keenleyside Dam	N/D	28/3/73	S, W	100.8	99.3
Below Hugh Keenleyside Dam	N/D	4/5/73	S, W	104.4	100.3
À 0.3 km below Hugh Keenleyside Dam	0200183	13/6/73	S, P	105.7	98.0
À 0.3 km below Hugh Keenleyside Dam	0200183	13/6/73	S, P	105.7	98.0
À 0.3 km below Hugh Keenleyside Dam	0200183	22/8/73	S, P	104.3	98.0
À 0.3 km below Hugh Keenleyside Dam	0200183	17/6/74	S, P	113.2	N/D
À 0.3 km below Hugh Keenleyside Dam	0200183	18/6/74	S, P	110.3	N/D
À 0.3 km below Hugh Keenleyside Dam	0200183	3/7/74	S, P	100.6	128.7
Below Hugh Keenleyside Dam	N/D	24/10/74	S, P	115.8	132.8
À 0.3 km below Hugh Keenleyside Dam	0200183	13/6/75	S, P	129.7	131.9
À 0.3 km below Hugh Keenleyside Dam	0200183	15/6/75	S, P	132.8	128.0

À 0.3 km below Hugh Keenleyside Dam	0200183	25/7/75	S, P	134.1	134.4
À 0.3 km below Hugh Keenleyside Dam	0200183	16/3/76	S, P	103.7	107.2
À 0.3 km below Hugh Keenleyside Dam	0200183	16/3/76	S, P	103.7	109.9
À 0.3 km below Hugh Keenleyside Dam	0200183	17/6/76	S, P	131.0	115.3
À 0.3 km below Hugh Keenleyside Dam	0200183	8/7/76	S, P	138.4	128.8
À 0.3 km below Hugh Keenleyside Dam	0200183	22/7/76	S, P	133.1	N/D
À 0.3 km below Hugh Keenleyside Dam	0200183	7/8/76	S, P	>127.7	129.1
Upstream of Cancel, below Hugh Keenleyside Dam	N/D	7/8/76	S, P	121.8	130.4
Hugh Keenleyside forebay	N/D	11/6/72	S, W	106.4	106.4
Hugh Keenleyside forebay	N/D	22/6/72	S, W	107.6	102.4
Hugh Keenleyside forebay	N/D	22/6/72	S, W	105.1	96.6
South wharf, À 0.2 km above Hugh Keenleyside	0900209	25/7/72	S, P	107.1	94.0
Hugh Keenleyside forebay	N/D	6/10/72	S, W	N/D	N/D
Hugh Keenleyside forebay	N/D	24/10/72	S, W	N/D	N/D
Hugh Keenleyside forebay	N/D	1/11/72	S, W	N/D	N/D
Hugh Keenleyside forebay	N/D	8/11/72	S, W	N/D	N/D
Hugh Keenleyside forebay	N/D	14/12/72	S, W	N/D	N/D
Hugh Keenleyside forebay	N/D	21/8/72	S, W	106.3	126.6
Hugh Keenleyside forebay	N/D	13/9/72	S, W	103.9	128.9
Hugh Keenleyside forebay	N/D	6/1/73	S, W	95.1	91.0
Hugh Keenleyside forebay	N/D	25/1/73	S, W	97.8	111.7
Hugh Keenleyside forebay	N/D	1/3/73	S, W	100.0	105.8
Hugh Keenleyside forebay	N/D	28/3/73	S, W	101.0	101.1
Hugh Keenleyside forebay	N/D	4/5/73	S, W	103.5	103.2

South wharf, À 0.2 km above Hugh Keenleyside	0900209	22/8/73	S, P	105.5	99.0
South wharf, À 0.2 km above Hugh Keenleyside	0900209	17/6/74	S, P	103.8	N/D
North bank, À 1 km above Hugh Keenleyside	0900212	18/6/74	S, P	106.9	N/D
South wharf, À 0.2 km above Hugh Keenleyside	0900209	3/7/74	S, P	99.4	106.4
South wharf, À 0.2 km above Hugh Keenleyside	0900209	24/10/74	S, P	100.1	125.7
North wharf, À 0.2 km above Hugh Keenleyside	0900326	13/6/75	S, P	108.6	111.7
Concrete wharf, just above dam	0900354	25/7/75	S, P	103.3	108.2
North wharf, À 0.2 km above Hugh Keenleyside	0900326	25/7/75	S, P	101.7	104.0
South wharf, À 0.2 km above Hugh Keenleyside	0900209	16/3/76	S	99.9	N/D
Syringa Park	0900353	25/7/75	S, P	103.9	101.0
At marina downstream of Syringa Park	0900429	16/3/76	S	94.3	N/D
At Farquier	N/D	14/6/75	S, P	108.6	110.5
At Nakusp	0900328	14/6/75	S, P	111.8	115.4
At Nakusp	0900328	24/7/75	S, P	108.7	110.2
At Shelter Bay	0900351	24/7/75	S, P	105.3	102.5
At Shelter Bay	0900351	22/8/76	S, W	104.5	81.0
At Galena Bay	0900352	24/7/75	S, P	107.1	107.2
At Galena Bay	0900352	4/8/76	S, P	112.8	98.8
At Galena Bay	0900352	22/8/76	S	101.9	N/D
At Revelstoke, between RR and wooden bridges	0900350	24/7/75	S, P	102.2	98.2
At Revelstoke, south shore at hwy. bridge	0900350	13/6/76	S, P	100.4	100.6
At Revelstoke, north shore	0900350	13/6/76	S, P	98.9	97.0

at hwy. bridge					
At Revelstoke, north shore at hwy. bridge	0900350	14/7/76	S, P	100.1	98.4
At Revelstoke, north shore at hwy. bridge	0900350	5/8/76	S, P	109.3	95.9
At Revelstoke, north shore at hwy. bridge	0900350	23/8/76	S	104.8	N/D
À 48 km from Revelstoke (lower ferry)	0900349	23/7/75	S, P	104.0	97.6
À 48 km from Revelstoke (lower ferry)	0900349	5/8/76	S, P	111.1	104.9
Below Mica Dam to bridge	0900347	23/7/75	S, P	114.3	105.0
Below Mica Dam, 2/3 distance to bridge	0900417	12/6/76	S, P	102.3	116.8
Below Mica Dam, 2/3 distance to bridge	0900417	12/6/76	S, P	102.5	118.4
Below Mica Dam, 1/3 distance to bridge	0900422	13/7/76	S, P	>103.2	105.7
Below Mica Dam, 1/3 distance to bridge	0900422	13/7/76	S, P	105.7	101.3
Below Mica Dam, 2/3 distance to bridge	0900417	13/7/76	S, P	109.7	101.6
Below Mica Dam, lumberyard midway to bridge	0900432	21/7/76	S, P	113.0	110.8
Below Mica Dam, lumberyard midway to bridge	0900432	21/7/76	S, P	109.0	110.8
Below Mica Dam, 1/3 distance to bridge	0900422	5/8/76	S, P	118.8	110.3
Below Mica Dam, 2/3 distance to bridge	0900417	5/8/76	S, P	118.5	106.9
Below Mica Dam, 2/3 distance to bridge	0900417	23/8/76	S, W	108.3	102.4
Below Mica Dam, lumberyard midway to	0900432	23/8/76	S, W	110.0	103.9

bridge					
At Mica Creek	0900425	5/8/76	S, P	116.9	110.6
95 km above Revelstoke	0900348	23/7/75	S, P	106.8	97.5
Turnoff near 105 km marker above Revelstoke	0900423	13/7/76	S, P	104.2	97.0
Turnoff near 105 km marker above Revelstoke	0900423	5/8/76	S, P	116.0	106.4
Turnoff near 105 km marker above Revelstoke	0900423	23/8/76	S, H, W	107.1	107.0

Duncan River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Above Duncan Dam	0900018	26/7/72	S, P	107.0	91.0
Above Duncan Dam	0900018	23/8/72	S, W	107.5	129.6
Above Duncan Dam	0900018	12/9/72	S, W	102.8	135.2
Above Duncan Dam	0900018	5/1/73	S, W	96.8	94.1
Above Duncan Dam	0900018	23/1/73	S, W	98.3	90.7
Above Duncan Dam	0900018	26/2/73	S, W	96.3	94.1
Above Duncan Dam	0900018	26/3/73	S, W	102.7	105.8
Above Duncan Dam	0900018	2/5/73	S, W	108.3	118.4
Above Duncan Dam	0900018	20/8/73	S, P	106.3	108.9
Above Duncan Dam	0900018	12/6/75	S, P	109.0	112.5
Below Duncan Dam, downstream of portal spill	0900019	26/7/72	S, P	104.4	93.0
Below Duncan Dam, downstream of portal spill	0900019	23/8/72	S, W	105.9	107.8
Below Duncan Dam, downstream of portal spill	0900019	12/9/72	S, W	104.7	115.6
Below Duncan Dam, downstream of portal spill	0900019	5/1/73	S, W	102.5	102.4
Below Duncan Dam, downstream of portal spill	0900019	23/1/73	S, W	102.3	111.2

Below Duncan Dam, downstream of portal spill	0900019	26/2/73	S, W	109.6	115.1
Below Duncan Dam, downstream of portal spill	0900019	26/3/73	S, W	103.5	101.7
Below Duncan Dam, downstream of portal spill	0900019	2/5/73	S, W	106.5	111.0
Below Duncan Dam, downstream of portal spill	0900019	20/8/73	S, P	108.3	105.3
Below Duncan Dam, downstream of sluiceway spill	0900424	12/6/75	S, P	107.6	95.6
Below Duncan Dam, downstream of portal spill	0900019	16/6/76	S, P	101.8	103.2
Below Duncan Dam, downstream of sluiceway spill	0900424	4/8/76	S, P, W	114.4	107.0
Below Duncan Dam, downstream of portal spill	0900019	4/8/76	S, P, W	107.7	103.0

Elk River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Above Elko Dam	0900311	6/6/75	S, P	101.3	97.2
Below Elko Dam	0900312	6/6/75	S, P	106.0	102.0

Fraser River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Red Pass, under CNR bridge	0400003	6/5/74	S, P	100.2	86.0
At Red Pass, under CNR bridge	0400003	31/7/74	S, P	102.3	110.0
At Robson Meadows	0920052	31/7/74	S, P	104.2	116.0
At Tête-Jaune	0920053	6/5/74	S, P	102.9	92.0

At Tête-Jaune	0900335	19/7/75	S, P	107.3	104.9
At Dunster	0920054	7/5/74	S, P	100.8	91.0
At Dunster	0920054	31/7/74	S, P	102.2	97.0
At McBride	0400010	8/5/74	S, P	101.7	90.0
At McBride	0400010	31/7/74	S, P	103.5	97.0
At McBride	0900334	19/7/75	S, P	103.8	97.9
At Crescent Spur	0400287	8/5/74	S, P	101.7	94.0
At Crescent Spur	0400287	14/6/74	S, P	102.1	98.0
At Crescent Spur	0400287	30/7/74	S, P	100.6	96.0
At Crescent Spur	0400287	1/8/74	S, P	101.9	107.0
At Dome Creek	0920057	8/5/74	S, P	101.0	95.0
At Dome Creek	0920057	14/6/74	S, P	103.3	100.0
At Dome Creek	0920057	30/6/74	S, P	102.8	101.0
At Hansard	0400023	8/5/74	S, P	101.0	99.0
At Hansard	0400023	1/8/74	S, P	100.8	102.0
At Prince George, beside Hydro intake near bridge	0900227	14/7/72	S, P	100.1	106.0
At Prince George,	0920061	9/5/74	S, P	101.6	95.0
At Prince George,	0400190	16/5/74	S, P	101.3	88.0
At Prince George,	0400190	3/6/74	S, P	100.7	105.0
At Prince George,	0920061	3/6/74	S, P	101.7	102.0
At Prince George,	0400190	19/7/74	S, P	103.1	110.0
At Prince George,	0920061	19/7/74	S, P	101.0	107.0
At Prince George,	0400190	2/8/74	S, P	100.0	104.0
At Prince George,	0920061	2/8/74	S, P	100.6	105.0
At Prince George,	0900227	19/7/75	S, P	102.1	93.2
At Prince George,	0900332	19/7/75	S, P	98.9	91.4
At Shelly	0400030	9/5/74	S, P	101.4	98.0
At Shelly	0400030	16/5/74	S, P	101.5	75.0
At Shelly	0400030	3/6/74	S, P	102.4	105.0
At Shelly	0400030	2/8/74	S, P	100.8	106.0

At Red Rock Canyon	0400036	9/5/74	S, P	101.7	95.0
At Stoner	0900228	13/7/72	S, P	100.0	97.0
At Stoner	0900228	9/5/74	S, P	101.9	95.0
At Stoner	0900228	3/6/74	S, P	101.1	99.0
At Stoner	0900228	19/7/74	S, P	102.8	95.0
At Stoner	0900228	2/8/74	S, P	100.8	106.0
At Quesnel, above confluence with Quesnel River	0900229	13/7/72	S, P	100.0	96.0
At Quesnel, above confluence with Quesnel River	0900229	18/7/75	S, P	101.5	103.1
At Margarite	0900362	18/7/75	S, P	102.0	103.4
At Lillooet	0300117	2/8/72	S, P	108.8	105.0
At Lillooet	0300117	3/7/74	S, P	103.4	N/D
At Lillooet	0900331	18/7/75	S, P	113.6	113.2
At Lytton, above confluence with Thompson River	0900230	2/8/72	S, P	103.3	108.0
At Lytton, above confluence with Thompson River	0900230	21/5/74	S, P	109.1	93.2
At Lytton, above confluence with Thompson River	0900230	9/7/74	S, P	107.5	N/D
At Lytton, above confluence with Thompson River	0900230	19/8/74	S, P	105.4	101.0
At Lytton, above confluence with Thompson River	0900230	7/5/75	S, P	108.4	106.2
At Lytton, above confluence with Thompson River	0900230	17/7/75	S, P	110.2	114.2
At Lytton, above confluence with Thompson River	0900230	21/7/75	S, P	110.9	98.6
At Lytton, above confluence with Thompson River	0900230	10/6/76	S, P	100.1	101.1
Above Hell's Gate, east bank	0900232	5/7/72	S, P	115.2	100.0

Above Hell's Gate, west bank	0900231	5/7/72	S, P	114.8	100.0
Above Hell's Gate, west bank	0900231	2/8/72	S, P	104.3	110.0
Above Hell's Gate, west bank	0900231	2/3/73	S, P	105.1	91.0
Above Hell's Gate, west bank	0900231	7/6/73	S, P	108.7	102.0
Above Hell's Gate, west bank	0900231	21/5/74	S, P	109.6	93.7
Above Hell's Gate, west bank	0900231	9/7/74	S, P	104.4	N/D
Above Hell's Gate, east bank	0900232	23/5/75	S, P	109.0	100.9
Above Hell's Gate, west bank	0900231	10/6/76	S, P	99.8	105.1
Below Hell's Gate, À 30 m below rapids	0900233	5/7/72	S, P	115.2	100.0
Below Hell's Gate, À 150 m below rapids	0900304	23/5/75	S, P	111.7	103.1
At Yale	0900234	5/7/72	S, P	106.0	106.0
At Yale	0900234	18/3/74	S, P	105.6	N/D
At Yale	0900234	18/3/74	S, P	105.7	N/D
At Yale	0900234	21/5/74	S, P	110.9	105.4
At Yale	0900234	9/7/74	S, P	104.3	N/D
At Yale	0900234	17/7/75	S, P	118.7	121.4
At park immediately at Hope	0900235	5/7/72	S, P	111.9	97.0
At park immediately at Hope	0900235	2/8/72	S, P	106.3	103.0
At park immediately at Hope	0900235	3/8/72	S, P	103.2	88.0
At park immediately at Hope	0900235	27/3/73	S, P	107.3	92.0
At park immediately at	0900235	7/6/73	S, P	103.7	95.0

Hope					
At park immediately at Hope	0900235	18/3/74	S, P	106.0	N/D
At park immediately at Hope	0900235	21/5/74	S, P	104.0	90.6
At park immediately at Hope	0900235	9/7/74	S, P	103.4	N/D
At park immediately at Hope	0900235	19/8/74	S, P	105.1	89.0
At park immediately at Hope	0900235	7/5/75	S, P	106.5	100.8
At park immediately at Hope	0900235	7/5/75	S, P	106.5	102.6
At park immediately at Hope	0900235	2/6/75	S, P	104.8	96.9
At park immediately at Hope	0900235	10/6/76	S, P	100.0	107.7
Downstream of Hope, north shore	N/D	19/3/76	S	100.7	N/D
Near Hunter Creek	0900236	22/5/74	S, P	111.6	99.5
Near Hunter Creek	0900236	9/7/74	S, P	102.1	N/D
Near Hunter Creek	0900236	21/5/75	S, P	112.3	105.9
Near Hunter Creek	0900300	2/6/75	S, P	112.7	105.0
Near Hunter Creek	0900300	17/7/75	S, P	115.9	118.1
At Agassiz Bridge, south bank	0900237	10/7/74	S, P	104.2	N/D
At Agassiz Bridge, south bank	0900237	19/8/74	S, P	104.0	95.0
At Agassiz Bridge, south bank	0900237	4/11/74	S, P	105.3	98.0
At Agassiz Bridge, south bank	0900237	7/5/75	S, P	106.5	104.4
At Agassiz Bridge, south bank	0900237	2/6/75	S, P	111.8	103.9
At Agassiz Bridge, south	0900237	17/7/75	S, P	113.7	110.2

bank					
At Agassiz Bridge, south bank	0900237	19/3/76	S	99.5	N/D
At Agassiz Bridge, south bank	0900237	9/6/76	S, P	99.1	107.8
At Agassiz Bridge, south bank	0900237	9/6/76	S, P	99.1	109.3
At Agassiz Bridge, south bank	0900237	9/6/76	S, P	99.1	107.1
End of MacClean Road: below Mission, above confluence with Sooke River	0900299	8/5/75	S, P	103.5	98.9
At Albion	0900238	10/7/74	S, P	107.0	N/D
At Albion	0900238	8/5/75	N/D	102.6	101.1
South arm opposite downsteam end of Annacis Island	0900239	10/7/74	S, P	104.3	N/D

Goat River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Above Dam #1	0900315	8/6/75	S, P	102.2	98.6
Below Dam #1	0900316	8/6/75	S, P	109.9	106.9
Below Dam #1	0900316	29/7/75	S, P	102.4	108.4
Below Dam #2	0900317	8/6/75	S, P	107.5	104.2

Illecillewaet River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
N/D	N/D	13/6/76	S, P	101.0	96.0

Jordan River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Above Elliott Dam	0900362	15/7/75	S, P	102.2	99.8

Kicking Horse River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Golden	N/D	13/6/76	S, P	99.7	99.3

Kootenay Lake

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Boat wharf at Balfour	N/D	12/6/72	S, W	105.8	106.3
Boat wharf at Balfour	N/D	12/6/72	S, W	106.3	107.2
Boat wharf at Balfour	N/D	19/8/72	S, W	106.2	119.4
Boat wharf at Balfour	N/D	12/9/72	S, W	102.2	128.5
Boat wharf at Balfour	N/D	7/1/73	S, W	93.9	71.3
Boat wharf at Balfour	N/D	23/1/73	S, W	96.5	93.5
Boat wharf at Balfour	N/D	26/2/73	S, W	98.2	103.1
Boat wharf at Balfour	N/D	27/3/73	S, W	99.0	99.3
Boat wharf at Balfour	N/D	3/5/73	S, W	103.7	107.9
Boat wharf at Balfour	N/D	9/6/75	S, P	109.0	111.5
At Nelson	0900027	25/8/72	S, W	110.1	150.5
At Nelson	0900027	24/9/72	S, W	104.8	130.3
Opposite Nelson, above bridge	0900215	19/6/74	S, P	110.9	N/D
Lakeshore Park wharf at Nelson	0900324	11/6/75	S, P	110.7	116.4
Lakeshore Park wharf at Nelson, 0.5 m	0900324	15/3/76	S, P, H	101.0	56.2
Lakeshore Park wharf at Nelson, 1 m	0900324	15/3/76	S	100.3	N/D

Lakeshore Park wharf at Nelson, 1.5 m	0900324	15/3/76	S	100.3	N/D
Near Hwy. 6 bridge at Taghum	N/D	12/6/72	S, W	104.6	107.4
Near Hwy. 6 bridge at Taghum	N/D	26/7/72	S, P	106.8	91.0
Near Hwy. 6 bridge at Taghum	N/D	14/6/73	S, P	107.6	121.0
Near Hwy. 6 bridge at Taghum, 1.5 m	N/D	14/6/73	S, P	107.3	180.0
Near Hwy. 6 bridge at Taghum	N/D	21/8/73	S, P	104.0	107.4
Near Hwy. 6 bridge at Taghum	N/D	17/6/74	S, P	110.8	N/D
Near Hwy. 6 bridge at Taghum	N/D	19/6/74	S, P	103.3	N/D
Near Hwy. 6 bridge at Taghum	N/D	4/7/74	S, P	100.3	115.2
Near Hwy. 6 bridge at Taghum	N/D	24/10/74	S, P	100.6	110.5
Near Hwy. 6 bridge at Taghum, 1 m	N/D	24/10/74	S, P	100.6	164.7
Near Hwy. 6 bridge at Taghum, 0.3 m	N/D	17/6/76	S, P	106.5	95.4
Near Hwy. 6 bridge at Taghum	N/D	6/8/76	S, P	107.0	108.9
2 km below Taghum Bridge	0900323	11/6/75	S, P	110.3	115.4
2 km below Taghum Bridge	0900323	27/7/75	S, P	111.3	107.8
2 km below Taghum Bridge	0900323	21/8/76	S, P	103.1	104.3

Kootenay River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Skookumchuck bridge	N/D	14/6/76	S, P	99.9	100.4

At bridge downstream of Fort Steele	0900314	6/6/75	S, P	103.2	99.0
At park downstream of bridge, opposite Fort Steele	N/D	14/6/76	S, P	101.3	99.1
At park downstream of bridge, opposite Fort Steele	N/D	14/6/76	S, P	100.1	99.3
At park downstream of bridge, opposite Fort Steele	N/D	14/6/76	S, P	100.1	N/D
At park downstream of bridge, opposite Fort Steele	N/D	14/6/76	S, P	100.0	99.4
At bridge upstream of Fort Steele	N/D	14/6/76	S, P	99.8	98.4
At Wardner, near hatchery	0900043	13/6/72	S, P	102.2	97.6
At Wardner (old bridge)	0200017	27/7/72	S, P	103.7	91.0
At Wardner (old bridge)	0200017	20/7/73	S, P	101.5	95.0
At Wardner (old bridge)	0200017	1/11/73	S, P	100.4	100.0
At Wardner (old bridge)	0200017	19/6/74	S, P	100.4	N/D
At Wardner	0900313	6/6/75	S, P	103.1	97.7
At Wardner	0900313	29/7/75	S, P	100.2	97.8
At Wardner (old bridge)	0200017	18/7/76	S, P	102.9	94.4
Ferry at Porthill, Idaho	N/D	11/5/72	S, W	107.0	102.9
Ferry at Porthill, Idaho	N/D	30/5/72	S, W	109.6	105.8
Ferry at Porthill, Idaho	N/D	15/6/72	S, W	109.8	106.7
Ferry at Porthill, Idaho	N/D	30/6/72	S, W	109.4	109.9
Ferry at Porthill, Idaho	N/D	14/7/72	S, W	101.8	95.6
Ferry at Porthill, Idaho	N/D	31/7/72	S, W	110.7	106.1
Ferry at Porthill, Idaho	N/D	15/8/72	S, W	108.2	107.3
Ferry at Porthill, Idaho	N/D	24/8/72	S, W	107.7	115.2
Ferry at Porthill, Idaho	N/D	14/9/72	S, W	103.5	116.7
Ferry at Porthill, Idaho	N/D	8/1/73	S, W	97.5	98.1
Ferry at Porthill, Idaho	N/D	24/1/73	S, W	98.6	95.6
Ferry at Porthill, Idaho	N/D	27/2/73	S, W	99.2	103.1
Ferry at Porthill, Idaho	N/D	27/3/73	S, W	103.8	106.7

Ferry at Porthill, Idaho	N/D	3/5/73	S, W	106.0	105.8
Ferry at Porthill, Idaho	N/D	22/8/73	S, P	108.5	105.0
Ferry at Porthill, Idaho	N/D	1/11/73	S, P	100.1	94.0
Ferry at Porthill, Idaho	N/D	31/5/74	S, P	103.0	N/D
Ferry at Porthill, Idaho	N/D	19/6/74	S, P	107.0	N/D
Ferry at Porthill, Idaho	N/D	19/6/74	S, P	110.0	N/D
Near Creston	0900038	12/6/72	N/D	107.5	104.0
At Creston reservation ferry	0900204	27/7/72	S, P	106.6	91.0
At Creston reservation ferry	0900204	9/6/75	S, P	104.7	93.7
At Creston bridge	N/D	14/6/76	S, P	100.2	104.9
À 300 m below Corra Linn	0900216	17/6/74	S, P	106.0	N/D
À 300 m below Corra Linn	0900216	24/10/74	S, P	110.0	103.9
350 m above Upper Bonnington	0900322	11/6/75	S, P	116.6	117.0
Below Upper Bonnington Dam	0900217	17/6/74	S, P	121.0	N/D
Below Upper Bonnington Dam	0900217	19/6/74	S, P	114.8	N/D
Below Upper Bonnington Dam	0900217	10/6/75	S, P	128.1	143.5
Below Upper Bonnington Dam	0900217	11/6/75	S, P	128.4	126.2
Below Upper Bonnington Dam	0900217	17/6/76	S, P	108.9	103.3
Below Lower Bonnington Dam	0900218	17/6/74	S, P	119.1	N/D
Below Lower Bonnington Dam	0900218	10/6/75	S, P	132.8	130.6
Below Lower Bonnington Dam	0900218	27/7/75	S, P	111.7	113.2
Below Slocan Dam	N/D	26/7/72	S, P	115.6	117.8
Below Slocan Dam	N/D	25/8/72	S, W	117.7	114.7
Below Slocan Dam	N/D	25/9/72	S, W	114.5	107.1

Below Slocan Dam	N/D	14/6/73	S, P	120.7	116.3
Below Slocan Dam	N/D	21/8/73	S, P	122.5	124.7
Below Slocan Dam	N/D	17/6/74	S, P	117.5	N/D
Below Slocan Dam	N/D	19/6/74	S, P	118.9	N/D
Below Slocan Dam	N/D	4/7/74	S, P	99.7	90.5
Below Slocan Dam	N/D	24/10/74	S, P	113.8	107.5
Below Slocan Dam	N/D	10/6/75	S, P	128.4	126.4
Below Slocan Dam	N/D	17/6/76	S, P	121.4	124.8
Below Slocan Dam	N/D	6/8/76	S, P	122.5	125.2
Above Brilliant Dam	N/D	11/6/72	S, W	131.2	127.4
Above Brilliant Dam	N/D	25/8/72	S, W	112.8	129.6
Above Brilliant Dam	N/D	25/8/72	S, W	116.0	129.8
Above Brilliant Dam	N/D	13/9/72	S, W	112.2	134.2
Above Brilliant Dam	N/D	13/9/72	S, W	108.3	165.6
Wharf À 500 m above Brilliant Dam	0900219	17/6/74	S, P	120.7	N/D
Wharf À 500 m above Brilliant Dam	0900219	19/6/74	S, P	117.7	N/D
Wharf À 500 m above Brilliant Dam	0900219	19/6/74	S, P	114.7	N/D
Above Brilliant Dam	N/D	24/10/74	S, P	113.1	120.3
Wharf À 500 m above Brilliant Dam	0900219	10/6/75	S, P	127.5	125.9
Wharf À 500 m above Brilliant Dam	0900219	16/3/76	S	101.7	N/D
Wharf À 500 m above Brilliant Dam	0900219	17/6/76	S, P	121.1	113.4
Wharf À 500 m above Brilliant Dam	0900219	23/7/76	S, P	123.4	123.2
Wharf À 500 m above Brilliant Dam	0900219	6/8/76	S, P	124.5	121.2
Wharf À 500 m above Brilliant Dam	0900219	6/8/76	S, P	123.6	121.2

Below Brilliant Dam	ND	11/6/72	S, W	132.5	123.6
Below Brilliant Dam	N/D	22/6/72	S, W	132.9	117.8
Below Brilliant Dam, under hwy. bridge	0900205	26/7/72	S, P	115.3	109.0
Below Brilliant Dam	N/D	25/8/72	S, W	115.7	124.7
Below Brilliant Dam	N/D	13/9/72	S, W	115.3	138.9
Below Brilliant Dam, under hwy. bridge	0900205	14/6/73	S, P	122.1	161.0
Below Brilliant Dam	N/D	31/8/73	S, P	120.1	110.9
Below Brilliant Dam, under hwy. bridge	0900205	17/6/74	S, P	119.7	N/D
Below Brilliant Dam, under hwy. bridge	0900205	19/6/74	S, P	119.3	N/D
Below Brilliant Dam, beside drive-in screen	0200178	4/7/74	S, P	100.4	139.0
Below Brilliant Dam	N/D	24/10/74	S, P	112.3	122.9
Below Brilliant Dam, under hwy. bridge	0900205	10/6/75	S, P	132.1	132.2
Below Brilliant Dam, under hwy. bridge	0900205	27/7/75	S, P	114.2	108.8
Below Brilliant Dam, under hwy. bridge	0900205	16/3/76	S	104.4	N/D
Below Brilliant Dam, under hwy. bridge	0900205	17/6/76	S, P	123.2	114.7
Below Brilliant Dam	N/D	22/7/76	S, P	123.8	N/D
Below Brilliant Dam	N/D	6/8/76	S, P	123.7	113.9

Lardeau River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At hwy. bridge, above confluence with Duncan River	0900325	12/6/75	S, P	102.4	97.6
At hwy. bridge, above	0900325	16/6/76	S, P	101.2	94.8

confluence with Duncan River					
At hwy. bridge, above confluence with Duncan River	0900325	4/8/76	S, P	102.9	97.8

Moyie River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Yahk Campsite	0900318	8/6/75	S, P	102.8	97.4
At Yahk Campsite	0900318	29/7/75	S, P	101.8	109.2

Nechako River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Kenney Reservoir, À 15 m	None	27/7/71	MG	N/D	99.77
Kenney Reservoir, À 15 m	None	27/7/71	MG	N/D	99.44
Kenney Reservoir, À 15 m	None	27/7/71	MG	N/D	98.45
Kenney Reservoir, À 30 m	None	27/7/71	MG	N/D	86.74
Kenney Reservoir, À 30 m	None	27/7/71	MG	N/D	84.09
Kenney Reservoir, À 30 m	None	27/7/71	MG	N/D	89.31
Kenney Reservoir, À 46 m	None	27/7/71	MG	N/D	68.14
Kenney Reservoir, À 46 m	None	27/7/71	MG	N/D	68.02
Kenney Reservoir, À 61 m	None	27/7/71	MG	N/D	60.97
Kenney Reservoir, À 61 m	None	27/7/71	MG	N/D	59.46
Kenney Reservoir, À 61 m	None	27/7/71	MG	N/D	59.46
Kenney Reservoir, À 15 m	None	22/8/71	MG	N/D	92.20
Kenney Reservoir, À 15 m	None	22/8/71	MG	N/D	85.69
Kenney Reservoir, À 30 m	None	22/8/71	MG	N/D	73.45
Kenney Reservoir, À 30 m	None	22/8/71	MG	N/D	73.86
Kenney Reservoir, À 30 m	None	22/8/71	MG	N/D	73.19

Kenney Reservoir, À 46 m	None	22/8/71	MG	N/D	61.49
Kenney Reservoir, À 46 m	None	22/8/71	MG	N/D	65.30
Kenney Reservoir, À 46 m	None	22/8/71	MG	N/D	62.03
Kenney Reservoir, À 61 m	None	22/8/71	MG	N/D	57.60
Kenney Reservoir, À 61 m	None	22/8/71	MG	N/D	57.69
Kenney Dam	0920067	10/5/74	S, P	101.3	106.0
At Cheslatta Falls	None	22/8/75	MG	N/D	106.35
At Cheslatta Falls	None	22/8/75	MG	N/D	100.68
At Cheslatta Falls	None	22/8/75	MG	N/D	99.20
At Greer Creek	None	22/8/75	MG	N/D	98.30
At Greer Creek	None	22/8/75	MG	N/D	96.63
At Greer Creek	None	22/8/75	MG	N/D	95.53
At Fort Fraser	0920068	5/7/74	S, P	101.3	109.0
At Fort Fraser	0920068	18/7/74	S, P	101.4	107.0
At Fort Fraser	None	22/8/75	MG	N/D	92.60
At Fort Fraser	None	22/8/75	MG	N/D	90.88
At Vanderhoof	0920069	5/7/74	S, P	101.7	102.0
At Vanderhoof	0920069	5/7/74	S, P	101.1	114.0
At Hulatt Road	0920070	18/7/74	S, P	99.7	114.0
At Isle Pierre	0400040	5/7/74	S, P	99.9	94.0
At Isle Pierre	0400040	18/7/74	S, P	100.6	105.0
At Prince George	0900187	14/7/72	S, P	100.0	97.0
At Prince George	0920066	18/7/74	S, P	99.6	116.0
At Prince George	0900333	19/7/74	S, P	99.8	95.6

Nicola River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At bridge above confluence with the Thompson River	N/D	10/6/76	S, P	100.0	96.6

North Thompson River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Under Hwy. 5 bridge, À 47 km from Valemount	0900336	20/7/75	S, P	100.1	98.0
At Blue River	0900337	20/7/75	S, P	101.5	102.1
À 58 km south of Blue River	0900338	20/7/75	S, P	104.7	101.5
At Clearwater	0900229	20/7/75	S, P	103.0	97.3
At Barriere	0900341	20/7/75	S, P	106.8	102.7
At Heffely Station	0900340	20/7/75	S, P	105.1	98.8
Opposite Moose Tot Lot, Juniper Street, North Kamloops	0900246	22/5/74	S, P	102.4	94.5
Opposite Moose Tot Lot, Juniper Street, North Kamloops	0900246	21/8/74	S, P	100.0	67.0
Opposite Moose Tot Lot, Juniper Street, North Kamloops	0900246	11/6/76	S, P	99.6	104.5

Okanagan River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Above Osoyoos Lake	0900090	15/6/72	S, W	104.1	106.7

Parsnip River

Location	EQUIS Site	Date	Method	TGP%	pO2%
At Hwy. 97 bridge	0900188	12/7/72	S, P	100.7	102.0

Peace River

Location	EQUIS Site	Date	Method	TGP%	pO2%

Williston Lake, À 2 km above dam	0920072	20/6/74	S, P	105.4	100.7
Williston Lake, À 2 km above dam	0920072	7/8/74	S, P	103.4	105.5
Williston Lake, À 2 km above dam	0920072	8/8/74	S, P	101.7	119.1
Williston Lake, above WAC Bennett Dam, west bank	0900189	11/7/72	S, P	110.3	121.0
Williston Lake, above WAC Bennett Dam, east bank	0900190	11/7/72	S, P	105.9	104.0
Williston Lake, above WAC Bennett Dam, west bank	0900189	12/7/72	S, P	102.3	97.0
Williston Lake, above WAC Bennett Dam, east bank	0900190	12/7/72	S, P	105.8	104.0
Williston Lake, above WAC Bennett Dam	0920073	31/5/74	S, P	100.3	85.6
Williston Lake, above WAC Bennett Dam,	0920073	20/6/74	S, P	104.9	93.7
Below WAC Bennett Dam, turbine outflow	N/D	11/7/72	S, P	101.6	104.0
Below WAC Bennett Dam, spillway outflow	N/D	11/7/72	S, P	114.1	N/D
Below WAC Bennett Dam, turbine outflow	N/D	12/7/72	S, P	100.7	96.2
Below WAC Bennett Dam	N/D	12/7/72	S, P	106.7	97.2
Below WAC Bennett Dam, turbine outflow	N/D	7/8/74	S, P	102.4	102.4
Below WAC Bennett Dam, spillway outflow	N/D	7/8/74	S, P	102.6	98.1
Below WAC Bennett Dam, turbine outflow	N/D	8/8/74	S, P	101.0	96.6
Below WAC Bennett Dam, spillway outflow	N/D	8/8/74	S, P	101.2	95.2
À 0.5 km below WAC Bennett Dam	0920076	25/5/74	S, P	99.0	95.4

À 0.5 km below WAC Bennett Dam	0920076	31/5/74	S, P	100.3	84.3
À 0.5 km below WAC Bennett Dam	0920076	18/6/74	S, P	102.0	87.0
À 0.5 km below WAC Bennett Dam	0920076	20/6/74	S, P	101.6	90.4
À 0.5 km below WAC Bennett Dam	0920076	7/8/74	S, P	102.5	119.3
À 0.5 km below WAC Bennett Dam	0920076	8/8/74	S, P	102.5	102.3
End of mine road, À 12 km downstream of WAC Bennett Dam	0900193	11/7/72	S, P	108.1	104.0
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	12/7/72	S, P	109.3	108.0
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	27/5/74	S, P	103.8	101.4
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	31/5/74	S, P	103.5	88.2
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	19/6/74	S, P	102.2	104.4
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	20/6/74	S, P	105.9	95.5
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	26/6/74	S, P	103.8	118.6
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	7/8/74	S, P	103.7	97.6
At Alwin Holland Park, À 23 km downstream of WAC Bennett Dam	N/D	8/8/74	S, P	102.3	91.2

At Attachie Rodeo Grounds	0400493	31/5/74	S, P	109.0	103.4
At Attachie Rodeo Grounds	0400493	18/6/74	S, P	104.9	112.2
At Attachie Rodeo Grounds	0400493	19/6/74	S, P	104.6	116.9
At Attachie Rodeo Grounds	0400493	20/6/74	S, P	103.5	101.0
At Attachie Rodeo Grounds	0400493	7/8/74	S, P	104.0	100.0
At Attachie Rodeo Grounds	0400493	8/8/74	S, P	101.5	101.6
At Fort St. John (old fort)	0400492	28/5/74	S, P	101.8	84.3
At Fort St. John (old fort)	0400492	18/6/74	S, P	104.6	95.6
At Fort St. John (old fort)	0400492	19/6/74	S, P	104.0	104.5
At Fort St. John (old fort)	0400492	20/6/74	S, P	103.2	96.8
At Fort St. John (old fort)	0400492	24/6/74	S, P	101.7	103.2
At Fort St. John (old fort)	0400492	7/6/74	S, P	101.8	92.8
At Fort St. John (old fort)	0400492	8/8/74	S, P	101.5	91.2
At Taylor	0920080	28/5/74	S, P	101.5	77.5
At Taylor	0920080	18/6/74	S, P	100.7	89.6
At Taylor	0920080	20/6/74	S, P	102.6	79.5
At Raspberry Island	0400147	28/5/74	S, P	101.9	88.4

Pend d'Oreille River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Remac bridge	0900200	18/6/74	S, P	119.4	N/D
At Remac bridge	0900200	23/10/74	S, P	99.9	122.5
At Remac bridge	0900200	26/7/75	S, P	114.3	111.3
Between Remac and Waneta Dam, at first pulloff driving east to west	0900199	18/6/74	S, P	110.6	N/D
Between Remac and Waneta Dam, at first pulloff driving east to west	0900199	23/10/74	S, P	109.8	113.2
Between Remac and Waneta Dam, at first pulloff	0900199	26/7/75	S, P	125.7	127.3

driving east to west					
Between Remac and Waneta Dam, at first pulloff driving east to west	0900199	15/6/76	S, P	101.0	122.0
Between Remac and Waneta Dam, at first pulloff driving east to west	0900199	23/7/76	S, P	123.6	125.3
Waneta forebay	0900119	22/8/73	S, P	114.9	113.0
Waneta forebay	0900119	3/7/74	S, P	101.1	113.0
Waneta forebay	0900119	23/10/74	S, P	104.9	86.4
Waneta forebay	0900119	26/7/75	S, P	120.47	115.08
Waneta forebay	0900119	15/6/76	S, P	103.3	117.2
Waneta forebay	0900119	23/7/76	S, P	119.8	121.9
Below Waneta Dam to confluence with Columbia River	N/D	11/6/72	S, W	124.2	132.6
Below Waneta Dam to confluence with Columbia River	N/D	22/6/72	S, W	131.8	117.6
Below Waneta Dam to confluence with Columbia River	N/D	22/6/72	S, W	131.1	115.6
Below Waneta Dam, midway between bridge and Columbia River	0900197	25/7/72	S, P	115.0	N/D
Below Waneta Dam, under bridge	0200021	25/7/72	S, P	119.1	N/D
Below Waneta Dam, 2/3 of the way to bridge	0900195	13/6/73	S, P	118.5	130.0
Below Waneta Dam, 1/3 of the way to bridge	0900196	13/6/73	S, P	114.2	159.0
Below Waneta Dam, between dam and bridge	0900198	13/6/73	S, P	121.0	175.0
Below Waneta Dam, under bridge	0200021	22/8/73	S, P	114.1	105.0

Below Waneta Dam, under bridge	0200021	18/6/74	S, P	102.5	N/D
Below Waneta Dam, under bridge	0200021	3/7/74	S, P	101.8	124.7
Below Waneta Dam, between dam and bridge	0900198	23/10/74	S, P	102.5	126.1
Below Waneta Dam, 2/3 of the way to bridge	0900195	26/7/75	S, P	115.4	109.7
Below Waneta Dam, under bridge	0200021	16/3/76	S	103.4	N/D
Below Waneta Dam, under bridge	0200021	15/6/76	S, P	103.4	111.8
Below Waneta Dam, under bridge	0200021	23/7/76	S, P	117.3	118.3

Quesnel River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Hwy. 97 bridge	0900186	13/7/72	S, P	102.0	100.0

Robson River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
N/D	0400006	6/5/74	S, P	101.2	82.0

Salmo River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Hwy. 3 bridge	0900329	15/6/75	S, P	102.1	101.5
Below confluence with South Salmo River	0900330	15/6/75	S, P	101.9	101.1

Shuswap River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Sugar Lake Dam	0900357	31/7/75	S, P	103.2	102.4
Below Sugar Lake Dam	0900358	31/7/75	S, P	105.2	101.9
Below Shuswap Falls Dam	0900360	31/7/75	S, P	103.4	100.5
Below Shuswap Falls Dam, À 1 km above Whiskey Jack farm	0900360	12/3/76	S, P	102.2	88.6
Below Shuswap Falls Dam, À 0.5 km downstream of falls	0900360	19/7/76	S, P	106.0	103.7

Slocan River

Location	EQUIS Site	Date	Method	TGP%	pO2%
Above confluence with Kootenay River	0900025	25/8/72	S, W	103.5	132.5
Above confluence with Kootenay River	0900025	25/9/72	S, W	100.6	118.6
Above confluence with Kootenay River, near RCMP station	0900220	19/6/74	S, P	100.2	N/D
Above confluence with Kootenay River, near bridge	0900321	10/6/75	S, P	102.9	103.6

Sooke River

Location	EQUIS Site	Date	Method	TGP%	pO2%
At Sooke Pot Holes	0900412	13/10/76	S, P, H	99.4	93.6

South Thompson River

Location	EQUIS	Date	Method	TGP%	pO2%

	Site				
At Fort Kamloops	0900244	21/5/74	S, P	105.2	81.3
At Kamloops, under bridge to Jasper	0900245	21/8/74	S, P	100.5	133.0
At Kamloops, end of Peter Road	0900344	22/7/75	S, P	106.0	100.4
Chase	0900345	22/7/75	S, P	108.9	102.7

Stave River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
100 m above Stave Falls Dam at wharf	0900221	21/6/72	S, P	105.1	109.0
Near side of Upper Dam	0900426	15/5/75	S	99.1	N/D
Far side of Upper Dam	0900427	15/5/75	S	106.6	N/D
Below Upper Dam	0900428	15/5/75	S	>107.9	N/D
150 m below Stave Falls Dam	0900222	21/6/72	S,P	101.3	93.0
Near wooden bridge below Stave Falls Dam	0900223	19/3/74	S,P	101.7	89.3
Near wooden bridge below Stave Falls Dam	0900223	10/7/74	S,P	101.2	N/D
Near wooden bridge below Stave Falls Dam	0900223	14/5/75	S	106.9	N/D
Near wooden bridge below Stave Falls Dam	0900223	14/5/75	S	107.3	N/D
150 m below Stave Falls Dam	0900222	16/5/75	S,P	102.0	93.2
Near wooden bridge below Stave Falls Dam	0900223	16/5/75	S	>100.6	N/D
Above Ruskin Dam	0900224	21/6/72	S, P	101.4	105.0
Beside fence right below Ruskin Dam	0900225	21/6/72	S, P	108.2	107.0
À 400 m below Ruskin Dam	0900226	21/6/72	S, P	110.5	109.0

Beside fence right below Ruskin Dam	0900225	19/3/74	S, P	100.6	94.2
À 400 m below Ruskin Dam	0900226	19/3/74	S, P	99.8	88.6
Beside fence right below Ruskin Dam	0900225	10/7/74	S, P	104.5	N/D
Beside fence right below Ruskin Dam	0900225	15/5/75	S, P	111.5	N/D
À 400 m below Ruskin Dam	0900226	15/5/75	S, P	108.9	N/D

Thompson River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Lytton, À 100 m above confluence with Fraser River	0900240	2/8/72	S, P	102.2	107.0
At Lytton, À 100 m above confluence with Fraser River	0900240	21/5/74	S, P	106.2	93.4
At Lytton, À 100 m above confluence with Fraser River	0900240	17/7/75	S, P	110.4	115.7
At Lytton, À 100 m above confluence with Fraser River	0900240	21/7/75	S, P	109.4	99.2
À 500 m upstream of centre-of-channel rock	0900241	21/5/74	S, P	102.9	N/D
À 500 m upstream of centre-of-channel rock	0900241	21/8/74	S, P	100.7	89.0
Near Big Horn fruitstand, À 5 km downstream of Spences Bridge	0900242	22/5/74	S, P	101.7	91.5
At Goldpan Provincial Park, downstream of Spences Bridge	N/D	10/6/76	S, P	100.2	97.6
À 2 km downstream of	0900243	21/5/74	S, P	103.8	82.0

confluence of North and South Thompson Rivers					
Savona	0900250	22/5/74	S, P	103.3	91.4
Savona	0900250	21/7/75	S, P	104.8	95.4
At Ashcroft	0900342	21/7/75	S, P	103.9	94.6
At Spences Bridge	0900343	21/7/75	S, P	103.5	95.4

Willow River

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
At Buckhorn Road	0400027	6/5/74	S, P	100.4	78.0
At Hwy. 16	0920065	6/5/74	S, P	102.6	95.0

Miscellaneous Streams and Creeks

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Goldstream, at bridge	0900410	24/9/76	P, H, W	100.0	96.3
Hanna Creek, at Rivervale above confluence with Columbia River	None	18/6/74	S, P	101.2	N/D
At pool below Hell's Gate Creek waterfall	None	9/7/74	S, P	99.9	N/D
Interurban Creek, Victoria	0900182	9/3/73	S, P	100.4	N/D
At intake to fish hatchery, Little Bull Creek	None	4/6/75	S, P	104.3	108.7
At hwy. bridge, Meadow Creek	N/D	16/6/76	N/D	101.2	94.3
Niagara Creek, below falls, Victoria	0900184	27/6/72	N/D	N/D	N/D
Niagare Creek, below falls, Victoria	0900361	27/6/72	S	N/D	N/D
Penticton Creek, at Greyback Mountain Dam	0900361	1/8/75	S, P	100.9	95.7

Sheep Creek, À 5 km west of Salmo on Hwy. 3	0900364	15/6/75	S, P	101.7	102.0
Smith Falls Creek, behind Cultus Lake Fisheries Station	None	4/11/74	S, P	100.0	102.0
Viaduct Creek, Victoria	0900183	9/3/73	S, P	100.0	N/D

Miscellaneous Lakes

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Cultus Lake, midlake, 0.3 m	0300037	8/5/74	S, P	100.5	N/D
Cultus Lake, midlake, 1 m	0300037	8/5/74	S, P	100.5	115.2
Duck Lake	0900021	24/8/72	S, W	107.3	112.1
Duck Lake	0900021	14/9/72	S, W	102.5	113.7
Elk Lake, south-east shore	N/D	3/7/76	S	100.3	N/D
Kalamalka Lake, west arm of Rotary pier, 0.3 m	N/D	12/3/76	N/D	100.6	96.5
Kalamalka Lake, west arm of Rotary pier, 1 m	N/S	12/3/76	N/D	100.6	95.7
Thetis Lake at south-east wharf	0900181	27/6/72	S	N/D	N/D
Thetis Lake at south-east wharf	0900181	27/6/72	S	N/D	N/D
Thetis Lake at south-east wharf	0900181	27/6/72	S	N/D	N/D
Thetis Lake at south-east wharf	0900181	9/3/73	S	104.4	N/D
Thetis Lake at south-east wharf, 2 m	0900181	9/3/73	S	105.0	N/D
Thetis Lake at south-east wharf, 1 m	0900181	9/3/73	S	105.3	N/D
Thetis Lake at south-east wharf	0900181	15/4/76	S, P	99.3	104.3

Miscellaneous Marine

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Shoal Bay (*no salinity correction)	0900430	4/7/76	S, P	99.7	71.2*
Rotary Park, Sidney, rise/fall of tide	0900413	14/10/76	N/D	101.4	92.7
Rotary Park, Sidney, rise/fall of tide	0900413	14/10/76	N/D	101.8	101.0
Rotary Park, Sidney, rise/fall of tide	0900413	14/10/76	N/D	103.9	107.3
Rotary Park, Sidney, rise/fall of tide	0900413	14/10/76	N/D	104.5	120.2
Victoria breakwater	0900411	26/10/76	T	96.0	N/D

Miscellaneous other

Location	**EQUIS Site**	**Date**	**Method**	**TGP%**	**pO2%**
Flow from pumphouse below Cleveland Dam, pool below waterfall	0900185	20/6/72	S, P	100.8	107.0

Note: H = Hydrolab DO Probe

MG = Scholander Microgasometric Method
N/D = Not Determined
P = DO Probe (YSI model 54 or 57)
S = Weiss Saturometer
T = Tensiometer
W = Winkler Titration

APPENDIX B

Table B1: Dissolved Gas Measurements Taken at Selected SEP Hatcheries

(MacKinlay 1984 and Miller *et al.* 1987)

Birkenhead

Date	**Temperature**	**Pre-Aeration**		**Post-Aeration**		**Comments**
	°C	**TGP %**	**O_2 %**	**TGP %**	**O_2 %**	
November 15, 1978	7.0	103.0	50.0	N/G	N/G	Test Well #3.
April 29, 1980	7.6	N/G	N/G	104.0	86.0	Trough inlet.
July 24, 1980	7.6	N/G	N/G	105.0	90.0	Trough inlet.
August 6, 1980	7.6	N/G	N/G	103.0	87.0	Trough #2 inlet.
August 6, 1980	7.6	N/G	N/G	103.0	85.0	Trough #3 inlet.

Bowron

Date	**Temperature**	**Pre-Aeration**		**Post-Aeration**		**Comments**
	°C	**TGP %**	**O_2 %**	**TGP %**	**O_2 %**	
June 26, 1979	7.0	107.0	90.0	N/A	N/A	In sidechannel downstream of pond (during active heating).
August 19, 1980	6.2	102.0	78.0	N/A	N/A	At incubation box intake on ground water fed stream upstream of pond.

Capilano

Date	**Temperature**	**Pre-Aeration**	**Post-Aeration**	**Comments**

	°C	TGP %	O_2 %	TGP %	O_2 %	
March 27, 1972	7.5	107.0	75.0	N/G	N/G	At tunnel - average of two readings.
March 13, 1974	11.0	108.0	92.0			At top trough.
September 30, 1980	8.0	109.0	82.0			At tower outlet and inlet.
September 30, 1980	16.0	N/M	N/M	105.0	107.0	At tower outlet and top of trough.

Chehalis

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
February 17, 1980	8.9	107-108	86-95	N/A	N/A	Chehalis Well C1
February 19, 1980	3.6	104.0	103.0	N/A	N/A	Chehalis River spotcheck (in flood).
February 21, 1980	3.5	103.0	95.0	N/A	N/A	Chehalis River spotcheck (post-flood).
April 6, 1980	8.5	104.0	77.0	N/A	N/A	Production Well #1 pumptest.
April 6, 1980	8.0	103.0	76.0	N/A	N/A	Production Well #3 pumptest.

Crazy

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
March 18, 1980	2.0	102.0	97.0	N/A	N/A	Crazy Creek spotcheck.

March 18, 1980	3.1	103.0	99.0	N/A	N/A	Eagle River spotcheck.

Fulton

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
May 22, 1980	9.2	105.4	99.0	N/G	N/G	Top end of channel #2.
May 22, 1980	9.5	104.2	100.7	N/G	N/G	Bottom end of channel #2.
May 22, 1980	10.3	104.1	89.9	N/G	N/G	Surface at intake.

Inches

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
April 10, 1980	9.5	N/G	N/G	106.0	95.0	Inlet pool #1 (some recirculation).
April 21, 1980	8.5	N/G	N/G	106.0	86.0	Inlet pool #1 (some recirculation).
April 21, 1980	8.5	N/G	N/G	105.0	75.0	Inlet pool #2 (some recirculation).
May 13, 1980	7.0	105.0	84.0			Inlet pool #1 (some recirculation).
May 13, 1980	7.0	105.0	84.0			Inlet pool #2 (some recirculation).

Kalum

Date	Temperature	Pre-Aeration	Post-Aeration	Comments

	°C	TGP %	O_2 %	TGP %	O_2 %	
November 20, 1978	6.0	102.0	72.0	N/A	N/A	Dry Creek at upper source.
November 20, 1978	4.5	101.0	73.0	N/A	N/A	Dry Creek at lower source.

Kemano

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
December 12, 1979	4.3	106.0	97.0	N/A	N/A	Middle Kemano River (1350m below Tailrace confluence).
December 16, 1979	3.5	102.0	96.0	N/A	N/A	Lower Kemano River (2700m below Tailrace confluence).
December 17, 1979	3.7	107.0	97.0	N/A	N/A	Tailrace.
December 17, 1979	-0.1	100.0	92.0	N/A	N/A	Upper Kemano River (above Tailrace).

Kitimat

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
November 3, 1979	3.7	102.0	95.0	N/A	N/A	Kitimat River spotcheck.
August 20, 1980	6.5	104.0	54.0	N/A	N/A	1 hr pumptest, Well 79-1 @ 600gpm.
August 20, 1980	10.7	103.0	97.0	N/A	N/A	Kitimat River spotcheck.

Mathers

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
October 8, 1978	7.5	104.0	2.0	N/A	N/A	Samples at 7 and 11 hr of pumptesting Well #2.
August 11, 1980	19.4	109.0	113.0	N/A	N/A	Saltwater spotcheck (off Mathers).

Nechako

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
March 19-23, 1979	9.5 decreasing to 8.5	105.0-109.0	133.0-139.0	N/A	N/A	5 samples taken during 96 hr pumptest of Well #7.

Nitinat Hatchery

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
June 12, 1979	8.0	104.0	88.0	N/A	N/A	Pumptest of DH #3.
May 6, 1980	11.3	104.9	99.0	N/A	N/A	Little Nitinat River.
May 6, 1980	10.85	104.4	100.4	N/A	N/A	Big Nitinat River.
May 21, 1980	9.2	102.5	98.0	N/A	N/A	Big Nitinat River.
June 18,	8.7	103.1	71.2	N/A	N/A	Well #4.

1980						

Penny

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
July 23, 1980	10.1	102.0	95.0	N/A	N/A	At incubation box site (from pipeline).
September 22, 1980	7.9	101.0	77.0	N/A	N/A	In incubation header box.
September 22, 1980	7.3	101.0	80.0	N/A	N/A	At pipeline intake ponds.

Pinkut

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
May 24, 1980	11.0	106.4	105.6	N/G	N/G	Top of leg #1.
May 24, 1980	11.0	103.8	114.5	N/G	N/G	Bottom of leg #10.

Puntledge Hatchery (lower site)

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
March 11, 1980	5.5	103.4	N/G	N/A	N/A	Puntledge River intake to spawning channel at upper site (before Hydro pumps).
April 16,	6.25	105.0	94.7	N/A	N/A	Puntledge River before

1980						hydro dam at Comox Lake.
April 16, 1980	6.4	108.8	98.3	N/A	N/A	Puntledge River downstream from hydro dam.
April 22, 1980	7.45	109.1	101.2	N/A	N/A	Hydro increased river flow to 1600 cfs.

Puntledge Hatchery (upper site)

Date	**Temperature**	**Pre-Aeration (?)**		**Post-Aeration**		**Comments**
	°C	**TGP %**	**O_2 %**	**TGP %**	**O_2 %**	
March 7, 1980	5.7	104.3	N/G			Inflow to spawning channel.
March 27, 1980	5.6	105.3	N/G			Inflow to ponds (Pump-house #2).
March 28, 1980	5.8	105.9	N/G			Inflow to spawning channel.
March 31, 1980	5.3	104.4	N/G			Inflow to spawning channel.
March 31, 1980	6.3	106.9	103.4			Inflow to spawning channel.
March 31, 1980	6.4	106.8	103.3			Inflow to ponds (Pump-house #2).
April 16, 1980	6.9	109.0	100.9			Inflow to spawning channel.
April 16, 1980	7.0	108.9	100.9			Inflow to ponds (Pump-house #2).
April 22, 1980	7.45	110.8	102.1			Inflow to spawning channel.
April 22, 1980	7.65	110.9	102.8			Inflow to ponds (Pump-house #2).
April 23, 1980	7.3	109.4	98.8			Inflow to ponds (Pump-house #2).

April 23, 1980	7.5	109.7	105.3			Inflow to ponds (Pump-house #2).
May 2, 1980	9.0	108.8	109.9			Inflow to ponds (Pump-house #2).

Quinsam Hatchery

Date	**Temperature**	**Pre-Aeration (?)**		**Post-Aeration**		**Comments**
	°C	**TGP %**	**O_2 %**	**TGP %**	**O_2 %**	
January 28, 1980	3.2	104.4	100.9			Inflow to heath stacks, Quinsam supply.

Robertson Creek Hatchery

Date	**Temperature**	**Pre-Aeration**		**Post-Aeration**		**Comments**
	°C	**TGP %**	**O_2 %**	**TGP %**	**O_2 %**	
April 2, 1980	8.6	105.5	99.5	N/A	N/A	Surface Great Central Lake water at Robertson Creek Hatchery.
April 2, 1980	8.5	104.4	99.5	N/A	N/A	Surface Great Central Lake water in front of first drop structure in Robertson Creek.
April 21, 1980	11.3	108.4	100.5	N/A	N/A	Surface Great Central Lake water at hatchery intake.
April 25, 1980	10.7	106.7	101.9	N/A	N/A	Surface Great Central Lake water at hatchery intake.

Robertson Creek Hatchery

Date	Temperature	Pre-Aeration (?)		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
April 2, 1980	9.1	106.5	N/G			Inflow to heath stack.
April 21, 1980	N/G	107.1	N/G			Inflow to heath stack.
April 25, 1980	10.8	106.4	101.4			Inflow to heath stack.
April 30, 1980	11.35	103.7	89.8			Inflow to heath stack, mixed ground/surface water.
April 30, 1980	12.8	109.4	106.1			Inflow to heath stack, surface water.
April 30, 1980	N/G	109.8	N/G			Inflow to heath stack, surface water.
May 8, 1980	13.8	108.3	105.7			Inflow to heath stack, surface water.
May 8, 1980	N/G	109.1	N/G			Inflow to heath stack, surface water.

Snootli

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	
August 22, 1980	9.4	101.6	98.9	N/G	N/G	Creek water at intake.

Stuart

Date	Temperature	Pre-Aeration		Post-Aeration		Comments
	°C	TGP %	O_2 %	TGP %	O_2 %	

April 8-10, 1980	8.4-8.6	104.0	4.0-13.0	N/A	N/A	4 samples taken during 3-day pumptest of Well #2.

N/A = Not Applicable
N/M = Not Measured
N/G = Not Given

APPENDIX C

Author Code	Author(s)
1	Rucker (1975a)
2	Nebeker *et al*. (1978)
3	Jensen (1980)
4	Ebel (1971)
5	Ebel (1969)
6	Rucker and Kangas (1974)
7	Ebel *et al.* (1971)
8	Dawley *et al.* (1976)
9	Weitkamp (1976)
10	Wyatt and Beiningen (1969)
11	Blahm *et al.* (1973)
12	Meekin and Turner (1974)
13	Dawley and Ebel (1975)
14	Nebeker *et al.* (1979a)
15	Rucker (1975b)
16	Blahm *et al.* (1975)
17	Knittel *et al.* (1980)
18	Stroud and Nebeker (1976)
19	Nebeker *et al.* (1976a)
20	Coutant and Genoway (1968)
21	Nebeker *et al.* (1976b)
22	Nebeker and Brett (1976)
23	Nebeker *et al.* (1979b)
24	Nebeker *et al.* (1980)
25	Krise and Herman (1989)
26	Krise and Smith (1991)
27	Krise *et al.* (1990)

28 Gray *et al.* (1982)
29 Fickeisen *et al.* (1975)
30 Bentley *et al.* (1976)
31 Colt *et al.* (1985)
32 Fickeisen and Montgomery (1978)

TABLE C2: LIST OF ABBREVIATIONS USED IN TABLE C3

Record Number: Record number in database

Author Code: Author data set identity number

Author Number: Author Number from Table C1

Species Code: 1 = Chinook salmon, 2 = Coho salmon, 3 = Sockeye salmon, 4 = Steelhead trout, 5 = Cutthroat trout,

6 = Lake trout, 7 = Carp, 8 = Black bullhead, 9 = Channel catfish, 10 = Squawfish, 11 = Mountain whitefish

12 = Largescale sucker, 13 = Torrent sculpin

S**tage Code:** 0 = Eggs, 1 = Alevins, 2 = Fry, 3 = Adult

Length: Fish length in mm.

Weight: Fish weight in gr.

Temp.C.: Water temperature in deg. C.

Patm.: Atmospheric pressure in mmHg.

Depth: Water depth in M.

Morts %: Percent mortality.

Time: Time to mortality in hrs. Note: Negative time means that indicated percent mortality was not reached.

Negative times are actual times / 10.0

Delta P: TGP - pAtm in mmHg.

O2: Partial pressure of dissolved oxygen in mmHg.

N2: Partial pressure of dissolved nitrogen in mmHg.

Note: NR = Not Reported
Table C3: Time to Mortality for Freshwater Fish Exposed to Dissolved Gas Supersaturation

RECORD	**AUTHOR CODE**	**AUTHOR NUMBER**	**SPECIES CODE**	**STAGE CODE**	**LENGTH mm**	**WEIGHT g**	**TEMP ·C**	**PATM mmHg**	**DEPTH m**	**MORTS %**	**TIME hr**	**DELTA P mmHg**	**Oxygen mmHg**	**Nitrogen mmHg**
1	1.001	1	1	0	NR	NR	7.2	758	0	11	1032	-7.58	149.63	592.88
2	1.001	1	1	0	NR	NR	7.2	758	0	19	1560	-7.58	149.63	592.88
3	1.002	1	1	0	NR	NR	7.2	758	0	1.4	1560	73.53	154.35	668.96
4	1.002	1	1	0	NR	NR	7.2	758	0	1.8	1032	73.53	154.35	668.96
5	1.003	1	1	0	NR	NR	7.2	758	0	0.6	1032	140.99	162.23	729.24
6	1.003	1	1	0	NR	NR	7.2	758	0	0.4	1032	140.99	162.23	729.24
7	1.003	1	1	0	NR	NR	7.2	758	0	0.1	1560	140.99	162.23	729.24
8	1.003	1	1	0	NR	NR	7.2	758	0	0.1	1560	140.99	162.23	729.24
9	2.001	2	4	1	35	0.35	10	754	0.08	60	600	197.55	NR	NR
10	2.001	2	4	1	35	0.35	10	754	0.08	90	1080	197.55	NR	NR
11	2.001	2	4	1	35	0.35	10	754	0.08	60	600	197.	NR	NR

												55		
12	2.001	2	4	1	35	0.35	10	754	0.08	50	552	197.55	NR	NR
13	2.001	2	4	1	35	0.35	10	754	0.08	84	840	197.55	NR	NR
14	2.001	2	4	1	35	0.35	10	754	0.08	70	648	197.55	NR	NR
15	2.001	2	4	1	35	0.35	10	754	0.08	90	1080	197.55	NR	NR
16	2.001	2	4	1	35	0.35	10	754	0.08	10	432	197.55	NR	NR
17	2.001	2	4	1	35	0.35	10	754	0.08	78	720	197.55	NR	NR
18	2.001	2	4	1	35	0.35	10	754	0.08	25	492	197.55	NR	NR
19	2.001	2	4	1	35	0.35	10	754	0.08	20	480	197.55	NR	NR
20	2.001	2	4	1	35	0.35	10	754	0.08	18	480	197.55	NR	NR
21	2.001	2	4	1	35	0.35	10	754	0.08	30	504	197.55	NR	NR
22	2.001	2	4	1	35	0.35	10	754	0.08	88	960	197.55	NR	NR
23	2.001	2	4	1	35	0.35	10	754	0.08	93	1200	197.55	NR	NR
24	2.001	2	4	1	35	0.35	10	754	0.08	40	528	197.55	NR	NR
25	2.001	2	4	1	35	0.35	10	754	0.08	80	756	197.55	NR	NR
26	2.002	2	4	1	35	0.35	10	754	0.08	10	480	172.67	NR	NR
27	2.002	2	4	1	35	0.35	10	754	0.08	50	672	172.67	NR	NR
28	2.002	2	4	1	35	0.35	10	754	0.08	20	504	172.67	NR	NR

29	2.002	2	4	1	35	0.35	10	754	0.08	10	480	172.67	NR	NR
30	2.002	2	4	1	35	0.35	10	754	0.08	68	840	172.67	NR	NR
31	2.002	2	4	1	35	0.35	10	754	0.08	55	720	172.67	NR	NR
32	2.002	2	4	1	35	0.35	10	754	0.08	40	612	172.67	NR	NR
33	2.002	2	4	1	35	0.35	10	754	0.08	60	768	172.67	NR	NR
34	2.002	2	4	1	35	0.35	10	754	0.08	38	600	172.67	NR	NR
35	2.002	2	4	1	35	0.35	10	754	0.08	70	1056	172.67	NR	NR
36	2.002	2	4	1	35	0.35	10	754	0.08	68	960	172.67	NR	NR
37	2.002	2	4	1	35	0.35	10	754	0.08	30	552	172.67	NR	NR
38	2.002	2	4	1	35	0.35	10	754	0.08	74	1200	172.67	NR	NR
39	2.002	2	4	1	35	0.35	10	754	0.08	25	528	172.67	NR	NR
40	2.002	2	4	1	35	0.35	10	754	0.08	71	1080	172.67	NR	NR
41	2.003	2	4	1	35	0.35	10	754	0.08	63	1200	138.74	NR	NR
42	2.003	2	4	1	35	0.35	10	754	0.08	30	864	138.74	NR	NR
43	2.003	2	4	1	35	0.35	10	754	0.08	30	840	138.74	NR	NR
44	2.003	2	4	1	35	0.35	10	754	0.08	7.5	600	138.74	NR	NR
45	2.003	2	4	1	35	0.35	10	754	0.08	20	720	138.74	NR	NR
46	2.003	2	4	1	35	0.35	10	754	0.08	40	972	138.74	NR	NR

47	2.003	2	4	1	35	0.35	10	754	0.08	20	720	138.74	NR	NR
48	2.003	2	4	1	35	0.35	10	754	0.08	25	792	138.74	NR	NR
49	2.003	2	4	1	35	0.35	10	754	0.08	10	612	138.74	NR	NR
50	2.003	2	4	1	35	0.35	10	754	0.08	50	1032	138.74	NR	NR
51	2.003	2	4	1	35	0.35	10	754	0.08	38	960	138.74	NR	NR
52	2.003	2	4	1	35	0.35	10	754	0.08	58	1080	138.74	NR	NR
53	2.003	2	4	1	35	0.35	10	754	0.08	60	1116	138.74	NR	NR
54	2.004	2	4	1	35	0.35	10	754	0.08	4	720	116.12	NR	NR
55	2.004	2	4	1	35	0.35	10	754	0.08	17	960	116.12	NR	NR
56	2.004	2	4	1	35	0.35	10	754	0.08	30	1128	116.12	NR	NR
57	2.004	2	4	1	35	0.35	10	754	0.08	25	1062	116.12	NR	NR
58	2.004	2	4	1	35	0.35	10	754	0.08	35	1200	116.12	NR	NR
59	2.004	2	4	1	35	0.35	10	754	0.08	40	1248	116.12	NR	NR
60	2.004	2	4	1	35	0.35	10	754	0.08	27	1080	116.12	NR	NR
61	2.004	2	4	1	35	0.35	10	754	0.08	20	996	116.12	NR	NR
62	2.004	2	4	1	35	0.35	10	754	0.08	8	840	116.12	NR	NR
63	2.004	2	4	1	35	0.35	10	754	0.08	10	888	116.12	NR	NR
64	2.005	2	4	1	33	0.3	10	754	0.08	76	1272	172.67	NR	NR

65	2.008	2	4	1	36.3	0.4	10	754	0.08	90	1272	197.55	NR	NR
66	2.01	2	4	1	27.8	0.2	10	754	0.08	76	1272	172.67	NR	NR
67	2.011	2	4	1	34.3	0.4	10	754	0.08	32	1272	116.87	NR	NR
68	2.012	2	4	1	35.4	0.4	10	754	0.08	65	1272	137.98	NR	NR
69	2.013	2	4	1	36.4	0.5	10	754	0.08	67	1272	138.74	NR	NR
70	2.015	2	4	1	35.5	0.4	10	754	0.08	45	1272	115.36	NR	NR
71	3.001	3	4	1	29.7	0.2	12	766	0.03	11.8	909.6	76.6	174.59	659.58
72	4.001	4	1	2	NR	NR	12.2	749	0.75	100	168	NR	NR	740.87
73	4.001	4	1	2	NR	NR	12.2	749	0.75	92	48	NR	NR	740.87
74	4.001	4	1	2	NR	NR	12.2	749	0.75	60	24	NR	NR	740.87
75	4.003	4	1	2	NR	NR	13.1	749	4.5	68	168	NR	NR	754.79
76	4.004	4	1	2	NR	NR	14.8	749	0.75	74	24	NR	NR	753.45
77	4.004	4	1	2	NR	NR	14.8	749	0.75	82	48	NR	NR	753.45
78	4.004	4	1	2	NR	NR	14.8	749	0.75	86	48	NR	NR	753.45
79	4.004	4	1	2	NR	NR	14.8	749	0.75	100	168	NR	NR	753.45
80	4.004	4	1	2	NR	NR	14.8	749	0.75	58	24	NR	NR	753.45
81	4.004	4	1	2	NR	NR	14.8	749	0.75	100	168	NR	NR	753.45
82	4.005	4	1	2	NR	NR	14.8	749	1.75	86	168	NR	NR	753.45

83	4.007	4	1	2	NR	NR	14.8	749	4.5	50	168	NR	NR	753.45
84	4.008	4	1	2	NR	NR	18.3	749	0.75	100	24	NR	NR	756.02
85	4.009	4	1	2	NR	NR	18.3	749	1	100	24	NR	NR	756.02
86	4.009	4	1	2	NR	NR	18.3	749	1	56	168	NR	NR	756.02
87	4.01	4	1	2	NR	NR	18.3	749	4	34	24	NR	NR	756.02
88	4.011	4	1	2	NR	NR	18.3	749	4.5	38	168	NR	NR	756.02
89	4.012	4	1	2	NR	NR	12.2	749	4	6	168	NR	NR	740.87
90	4.013	4	1	2	NR	NR	12.2	749	4.5	45	168	NR	NR	740.87
91	4.014	4	1	2	NR	NR	13.1	749	0.75	100	168	NR	NR	754.79
92	4.014	4	1	2	NR	NR	13.1	749	0.75	98	48	NR	NR	754.79
93	4.014	4	1	2	NR	NR	13.1	749	0.75	98	24	NR	NR	754.79
94	4.015	4	1	2	NR	NR	13.1	749	1	98	48	NR	NR	754.79
95	4.015	4	1	2	NR	NR	13.1	749	1	100	168	NR	NR	754.79
96	4.015	4	1	2	NR	NR	13.1	749	1	64	24	NR	NR	754.79
97	4.016	4	1	2	NR	NR	13.1	749	2	40	168	NR	NR	754.79
98	4.017	4	1	2	NR	NR	16.3	749	0.75	50	19.7	216.46	NR	NR
99	5.001	5	1	2	NR	NR	15.9	749	1.5	8	2280	NR	NR	685.68
100	5.002	5	1	2	NR	NR	15.9	749	6	11	2280	NR	NR	685.68

101	5.003	5	1	2	NR	NR	15.9	749	3	2	2280	NR	NR	685.68
102	5.004	5	2	2	NR	NR	NR	749	1.5	10	240	NR	NR	705.8
103	5.005	5	2	2	NR	NR	NR	749	3	3	240	NR	NR	705.8
104	5.007	5	2	2	NR	NR	NR	749	6	11	240	NR	NR	705.8
105	5.008	5	2	2	NR	NR	NR	749	3	70	240	NR	NR	823.43
106	5.009	5	2	2	NR	NR	NR	749	1.5	100	240	NR	NR	823.43
107	5.01	5	2	2	NR	NR	NR	749	3.5	3	240	NR	NR	823.43
108	5.011	5	2	2	NR	NR	NR	749	6	18	240	NR	NR	823.43
109	6.001	6	1	1	NR	NR	10	760	0.14	6	1320	91.2	176.5	664.38
110	6.001	6	1	1	NR	NR	10	760	0.14	20	-132	91.2	176.5	664.38
111	6.001	6	1	1	NR	NR	10	760	0.14	25	-132	91.2	176.5	664.38
112	6.001	6	1	1	NR	NR	10	760	0.14	5	1090	91.2	176.5	664.38
113	6.002	6	1	1	NR	NR	10	760	0.14	5	1010	121.6	182.81	688.11
114	6.002	6	1	1	NR	NR	10	760	0.14	10	1320	121.6	182.81	688.11
115	6.002	6	1	1	NR	NR	10	760	0.14	20	-132	121.6	182.81	688.11
116	6.002	6	1	1	NR	NR	10	760	0.14	25	-132	121.6	182.81	688.11
117	6.003	6	1	1	NR	NR	10	760	0.14	25	817.5	152	189.11	711.84
118	6.003	6	1	1	NR	NR	10	760	0.14	20	785	152	189.11	711.84
119	6.003	6	1	1	NR	NR	10	760	0.14	50	1070	152	189.11	711.84

120	6.003	6	1	1	NR	NR	10	760	0.14	10	725	152	189.11	711.84
121	6.003	6	1	1	NR	NR	10	760	0.14	30	850	152	189.11	711.84
122	6.003	6	1	1	NR	NR	10	760	0.14	53	1320	152	189.11	711.84
123	6.003	6	1	1	NR	NR	10	760	0.14	40	970	152	189.11	711.84
124	6.003	6	1	1	NR	NR	10	760	0.14	5	640	152	189.11	711.84
125	6.004	6	1	1	NR	NR	10	760	0.14	5	550	182.4	195.41	735.57
126	6.004	6	1	1	NR	NR	10	760	0.14	60	1050	182.4	195.41	735.57
127	6.004	6	1	1	NR	NR	10	760	0.14	30	720	182.4	195.41	735.57
128	6.004	6	1	1	NR	NR	10	760	0.14	40	800	182.4	195.41	735.57
129	6.004	6	1	1	NR	NR	10	760	0.14	20	660	182.4	195.41	735.57
130	6.004	6	1	1	NR	NR	10	760	0.14	10	610	182.4	195.41	735.57
131	6.004	6	1	1	NR	NR	10	760	0.14	50	910	182.4	195.41	735.57
132	6.004	6	1	1	NR	NR	10	760	0.14	25	690	182.4	195.41	735.57
133	6.004	6	1	1	NR	NR	10	760	0.14	70	1320	182.4	195.41	735.57
134	6.005	6	1	1	NR	NR	10	760	0.14	70	940	212.8	201.72	759.3
135	6.005	6	1	1	NR	NR	10	760	0.14	10	600	212.8	201.72	759.3
136	6.005	6	1	1	NR	NR	10	760	0.14	50	815	212.8	201.72	759.3
137	6.005	6	1	1	NR	NR	10	760	0.14	20	650	212.8	201.72	759.3

138	6.005	6	1	1	NR	NR	10	760	0.14	40	760	212.8	201.72	759.3
139	6.005	6	1	1	NR	NR	10	760	0.14	25	680	212.8	201.72	759.3
140	6.005	6	1	1	NR	NR	10	760	0.14	5	520	212.8	201.72	759.3
141	6.005	6	1	1	NR	NR	10	760	0.14	78	1320	212.8	201.72	759.3
142	6.005	6	1	1	NR	NR	10	760	0.14	30	710	212.8	201.72	759.3
143	6.005	6	1	1	NR	NR	10	760	0.14	60	870	212.8	201.72	759.3
144	6.006	6	1	1	NR	NR	8	760	0.14	25	-204	83.6	157.84	677.3
145	6.006	6	1	1	NR	NR	8	760	0.14	10	-204	83.6	157.84	677.3
146	6.006	6	1	1	NR	NR	8	760	0.14	20	-204	83.6	157.84	677.3
147	6.007	6	1	1	NR	NR	8	760	0.14	10	-204	83.6	157.84	689.18
148	6.007	6	1	1	NR	NR	8	760	0.14	20	-204	91.2	157.84	689.18
149	6.007	6	1	1	NR	NR	8	760	0.14	25	-204	91.2	157.84	689.18
150	6.008	6	1	1	NR	NR	8	760	0.14	25	-204	106.4	159.41	701.06
151	6.008	6	1	1	NR	NR	8	760	0.14	20	1960	106.4	159.41	701.06
152	6.008	6	1	1	NR	NR	8	760	0.14	22	2040	106.4	159.41	701.06
153	6.008	6	1	1	NR	NR	8	760	0.14	10	1730	106.4	159.41	701.06
154	6.009	6	1	1	NR	NR	8	760	0.14	30	1550	121.6	160.99	712.94
155	6.009	6	1	1	NR	NR	8	760	0.14	25	1450	121.6	160.99	712.94

156	6.009	6	1	1	NR	NR	8	760	0.14	10	1130	121.6	160.99	712.94
157	6.009	6	1	1	NR	NR	8	760	0.14	55	2040	121.6	160.99	712.94
158	6.009	6	1	1	NR	NR	8	760	0.14	40	1770	121.6	160.99	712.94
159	6.009	6	1	1	NR	NR	8	760	0.14	20	1350	121.6	160.99	712.94
160	6.009	6	1	1	NR	NR	8	760	0.14	50	1960	121.6	160.99	712.94
161	6.01	6	1	1	NR	NR	8	760	0.14	20	890	136.8	162.57	724.83
162	6.01	6	1	1	NR	NR	8	760	0.14	50	1080	136.8	162.57	724.83
163	6.01	6	1	1	NR	NR	8	760	0.14	80	1350	136.8	162.57	724.83
164	6.01	6	1	1	NR	NR	8	760	0.14	10	800	136.8	162.57	724.83
165	6.01	6	1	1	NR	NR	8	760	0.14	60	1110	136.8	162.57	724.83
166	6.01	6	1	1	NR	NR	8	760	0.14	25	925	136.8	162.57	724.83
167	6.01	6	1	1	NR	NR	8	760	0.14	30	960	136.8	162.57	724.83
168	6.01	6	1	1	NR	NR	8	760	0.14	40	1020	136.8	162.57	724.83
169	6.01	6	1	1	NR	NR	8	760	0.14	70	1150	136.8	162.57	724.83
170	6.01	6	1	1	NR	NR	8	760	0.14	90	2040	136.8	162.57	724.83
171	6.011	6	2	1	NR	NR	8	760	0.14	10	-204	83.6	157.84	677.3
172	6.011	6	2	1	NR	NR	8	760	0.14	25	-204	83.6	157.84	677.3
173	6.011	6	2	1	NR	NR	8	760	0.14	20	-204	83.6	157.84	677.3

174	6.012	6	2	1	NR	NR	8	760	0.14	10	-204	91.2	157.84	689.18
175	6.012	6	2	1	NR	NR	8	760	0.14	25	-204	91.2	157.84	689.18
176	6.012	6	2	1	NR	NR	8	760	0.14	20	-204	91.2	157.84	689.18
177	6.013	6	2	1	NR	NR	8	760	0.14	25	-204	106.4	159.41	701.06
178	6.013	6	2	1	NR	NR	8	760	0.14	20	2040	106.4	159.41	701.06
179	6.013	6	2	1	NR	NR	8	760	0.14	10	1250	106.4	159.41	701.06
180	6.014	6	2	1	NR	NR	8	760	0.14	20	1560	121.6	160.99	712.94
181	6.014	6	2	1	NR	NR	8	760	0.14	10	1030	121.6	160.99	712.94
182	6.014	6	2	1	NR	NR	8	760	0.14	30	1920	121.6	160.99	712.94
183	6.014	6	2	1	NR	NR	8	760	0.14	35	2040	121.6	160.99	712.94
184	6.014	6	2	1	NR	NR	8	760	0.14	25	1740	121.6	160.99	712.94
185	6.015	6	2	1	NR	NR	8	760	0.14	40	950	136.8	162.57	724.83
186	6.015	6	2	1	NR	NR	8	760	0.14	50	1150	136.8	162.57	724.83
187	6.015	6	2	1	NR	NR	8	760	0.14	30	870	136.8	162.57	724.83
188	6.015	6	2	1	NR	NR	8	760	0.14	60	1360	136.8	162.57	724.83
189	6.015	6	2	1	NR	NR	8	760	0.14	10	660	136.8	162.57	724.83
190	6.015	6	2	1	NR	NR	8	760	0.14	70	1600	136.8	162.57	724.83
191	6.015	6	2	1	NR	NR	8	760	0.14	87	2040	136.8	162.57	724.83

192	6.015	6	2	1	NR	NR	8	760	0.14	20	760	136.8	162.57	724.83
193	6.015	6	2	1	NR	NR	8	760	0.14	25	815	136.8	162.57	724.83
194	6.015	6	2	1	NR	NR	8	760	0.14	80	1810	136.8	162.57	724.83
195	6.016	6	2	1	NR	NR	8	760	0.14	10	750	114	157.84	707
196	6.016	6	2	1	NR	NR	8	760	0.14	14	1008	114	157.84	707
197	6.016	6	2	1	NR	NR	8	760	0.14	20	-100.8	114	157.84	707
198	6.016	6	2	1	NR	NR	8	760	0.14	25	-100.8	114	157.84	707
199	6.017	6	2	1	NR	NR	8	760	0.14	40	680	129.2	160.99	724.83
200	6.017	6	2	1	NR	NR	8	760	0.14	30	515	129.2	160.99	724.83
201	6.017	6	2	1	NR	NR	8	760	0.14	10	250	129.2	160.99	724.83
202	6.017	6	2	1	NR	NR	8	760	0.14	25	452.5	136.8	160.99	724.83
203	6.017	6	2	1	NR	NR	8	760	0.14	50	1008	129.2	160.99	724.83
204	6.017	6	2	1	NR	NR	8	760	0.14	20	390	129.2	160.99	724.83
205	6.018	6	2	1	NR	NR	8	760	0.14	10	120	159.6	162.57	748.59
206	6.018	6	2	1	NR	NR	8	760	0.14	30	275	159.6	162.57	748.59
207	6.018	6	2	1	NR	NR	8	760	0.14	70	800	159.6	162.57	748.59
208	6.018	6	2	1	NR	NR	8	760	0.14	20	200	159.6	162.57	748.59

209	6.018	6	2	1	NR	NR	8	760	0.14	60	570	159.6	162.57	748.59
210	6.018	6	2	1	NR	NR	8	760	0.14	40	360	159.6	162.57	748.59
211	6.018	6	2	1	NR	NR	8	760	0.14	50	450	159.6	162.57	748.59
212	6.018	6	2	1	NR	NR	8	760	0.14	74	1008	159.6	162.57	748.59
213	6.018	6	2	1	NR	NR	8	760	0.14	25	237.5	159.6	162.57	748.59
214	7.006	7	1	2	134	23	15	760	0.2	50	11.3	NR	NR	752.73
215	7.006	7	1	2	134	23	15	760	0.2	15	8.5	NR	NR	752.73
216	7.006	7	1	2	134	23	15	760	0.2	5	8.5	NR	NR	752.73
217	7.006	7	1	2	134	23	15	760	0.2	100	15	NR	NR	752.73
218	7.007	7	1	2	134	23	20	760	0.2	100	13	NR	NR	747.94
219	7.007	7	1	2	134	23	20	760	0.2	5	4.3	NR	NR	747.94
220	7.007	7	1	2	134	23	20	760	0.2	15	6	NR	NR	747.94
221	7.007	7	1	2	134	23	20	760	0.2	50	7.5	NR	NR	747.94
222	7.008	7	1	2	134	23	23	760	0.2	5	2.5	NR	NR	744.38
223	7.008	7	1	2	134	23	23	760	0.2	15	5.8	NR	NR	744.38
224	7.008	7	1	2	134	23	23	760	0.2	50	7.3	NR	NR	744.38
225	7.008	7	1	2	134	23	23	760	0.2	100	11.5	NR	NR	744.38
226	7.014	7	2	2	122.7	19.1	23	760	0.2	5	9.3	NR	NR	744.38

227	7.014	7	2	2	122.7	19.1	23	760	0.2	100	17.3	NR	NR	744.38
228	7.014	7	2	2	122.7	19.1	23	760	0.2	15	8.5	NR	NR	744.38
229	7.014	7	2	2	122.7	19.1	23	760	0.2	50	13	NR	NR	744.38
230	7.015	7	2	2	122.7	19.1	20	760	0.2	100	15.3	NR	NR	747.94
231	7.015	7	2	2	122.7	19.1	20	760	0.2	15	8.3	NR	NR	747.94
232	7.015	7	2	2	122.7	19.1	20	760	0.2	50	13.5	NR	NR	747.94
233	7.015	7	2	2	122.7	19.1	20	760	0.2	5	6.3	NR	NR	747.94
234	7.016	7	2	2	122.7	19.1	15	760	0.2	50	9.3	NR	NR	752.73
235	7.016	7	2	2	122.7	19.1	15	760	0.2	50	18.1	NR	NR	752.73
236	7.016	7	2	2	122.7	19.1	15	760	0.2	15	7.9	NR	NR	752.73
237	7.016	7	2	2	122.7	19.1	15	760	0.2	5	6.9	NR	NR	752.73
238	7.016	7	2	2	122.7	19.1	15	760	0.2	5	7	NR	NR	752.73
239	7.016	7	2	2	122.7	19.1	15	760	0.2	15	7.2	NR	NR	752.73
240	7.017	7	2	2	122.7	19.1	10	760	0.2	5	12.9	NR	NR	756.33
241	7.017	7	2	2	122.7	19.1	10	760	0.2	15	14.6	NR	NR	756.33
242	7.017	7	2	2	122.7	19.1	10	760	0.2	100	16.5	NR	NR	756.33
243	7.017	7	2	2	122.7	19.1	10	760	0.2	5	6.9	NR	NR	756.33
244	7.017	7	2	2	122.7	19.1	10	760	0.2	50	10	NR	NR	756.33

245	7.017	7	2	2	122.7	19.1	10	760	0.2	15	7.6	NR	NR	756.33
246	7.018	7	2	2	122.7	19.1	5	760	0.2	15	10.3	NR	NR	759.02
247	7.018	7	2	2	122.7	19.1	5	760	0.2	5	8.8	NR	NR	759.02
248	7.018	7	2	2	122.7	19.1	5	760	0.2	50	13.5	NR	NR	759.02
249	7.02	7	1	2	129	19	10	760	0.2	5	10	NR	NR	756.33
250	7.028	7	4	2	179	54	15	760	0.2	100	11	NR	NR	752.73
251	7.028	7	4	2	179	54	15	760	0.2	50	14	NR	NR	752.73
252	7.028	7	4	2	179	54	15	760	0.2	50	5.7	NR	NR	752.73
253	7.028	7	4	2	179	54	15	760	0.2	100	22	NR	NR	752.73
254	7.028	7	4	2	179	54	15	760	0.2	15	3.6	NR	NR	752.73
255	7.028	7	4	2	179	54	15	760	0.2	15	10.8	NR	NR	752.73
256	7.028	7	4	2	179	54	15	760	0.2	5	2.9	NR	NR	752.73
257	7.028	7	4	2	179	54	15	760	0.2	5	9.5	NR	NR	752.73
258	7.03	7	4	2	179	54	10	760	0.2	5	3.3	NR	NR	756.33
259	7.03	7	4	2	179	54	10	760	0.2	15	4.7	NR	NR	756.33
260	7.03	7	4	2	179	54	10	760	0.2	100	11	NR	NR	756.33
261	7.03	7	4	2	179	54	10	760	0.2	50	5.1	NR	NR	756.33
262	8.001	8	4	2	180	54.8	10	760	0.25	57	168	117.04	182.02	686.33

263	8.003	8	1	2	40	0.4	10	760	0.25	80	1440	117.04	182.02	686.33
264	8.004	8	1	2	40	0.4	10	760	0.25	97	1440	152.76	191.79	711.84
265	8.005	8	1	2	40	0.4	10	760	0.25	18	1440	71.44	170.2	652.52
266	8.007	8	4	2	180	54.8	10	760	0.25	100	48	168.72	210.78	708.87
267	8.013	8	1	2	40	0.4	10	760	0.25	20	168	152.76	191.79	711.84
268	8.014	8	1	2	40	0.4	10	760	0.25	25	216	152.76	191.79	711.84
269	8.015	8	1	2	40	0.4	10	760	0.25	50	480	152.76	191.79	711.84
270	8.016	8	1	2	40	0.4	10	760	0.25	70	672	152.76	191.79	711.84
271	8.017	8	1	2	40	0.4	10	760	0.25	20	432	117.04	182.02	686.33
272	8.018	8	1	2	40	0.4	10	760	0.25	25	624	117.04	182.02	686.33
273	8.019	8	1	2	40	0.4	10	760	0.25	50	1080	117.04	182.02	686.33
274	8.02	8	1	2	40	0.4	10	760	0.25	70	1272	117.04	182.02	686.33
275	8.021	8	1	2	40	0.4	10	760	0.25	20	-144	71.44	170.2	652.52
276	8.022	8	1	2	40	0.4	10	760	0.25	25	-144	71.44	170.2	652.52
277	8.023	8	1	2	40	0.4	10	760	0.25	50	-144	71.44	170.2	652.52
278	8.024	8	1	2	40	0.4	10	760	0.25	70	-144	71.44	170.2	652.52
279	8.025	8	4	2	180	54.8	10	760	0.25	20	18	168.72	210.78	708.87
280	8.026	8	4	2	180	54.8	10	760	0.25	25	21.6	168.72	210.78	708.87

281	8.027	8	4	2	180	54.8	10	760	0.25	50	28.8	168.72	210.78	708.87
282	8.028	8	4	2	180	54.8	10	760	0.25	70	31.2	168.72	210.78	708.87
283	8.029	8	4	2	180	54.8	10	760	0.25	20	66	116.28	189.42	677.44
284	8.03	8	4	2	180	54.8	10	760	0.25	25	69.6	116.28	189.42	677.44
285	8.031	8	4	2	180	54.8	10	760	0.25	50	112.8	116.28	189.42	677.44
286	8.032	8	4	2	180	54.8	10	760	0.25	70	-16.8	116.28	189.42	677.44
287	8.033	8	4	2	180	54.8	10	760	0.25	20	-16.8	72.2	170.83	652.52
288	8.034	8	4	2	180	54.8	10	760	0.25	25	-16.8	72.2	170.83	652.52
289	8.035	8	4	2	180	54.8	10	760	0.25	50	-16.8	72.2	170.83	652.52
290	8.036	8	4	2	180	54.8	10	760	0.25	70	-16.8	72.2	170.83	652.52
291	9.001	9	1	2	NR	NR	NR	743	4	20	-144	156.03	NR	NR
292	9.001	9	1	2	NR	NR	NR	743	4	0	-144	156.03	NR	NR
293	9.002	9	1	2	NR	NR	NR	743	3	0	-144	156.03	NR	NR
294	9.002	9	1	2	NR	NR	NR	743	3	20	-24	156.03	NR	NR
295	9.003	9	1	2	NR	NR	NR	743	4	0	-144	178.32	NR	NR
296	9.004	9	1	2	NR	NR	NR	743	3	20	-48	178.	NR	NR

												32		
297	9.005	9	1	2	NR	NR	NR	743	0.1	53	240	156.03	NR	NR
298	9.006	9	1	2	NR	NR	NR	743	0.25	50	48	185.75	NR	NR
299	9.007	9	1	2	NR	NR	NR	743	0.25	50	240	152.32	NR	NR
300	9.03	9	1	2	NR	NR	NR	743	4	20	-48	178.32	NR	NR
301	10.001	10	1	2	NR	NR	NR	NR	0.6	100	5	NR	NR	NR
302	11.001	11	1	2	NR	NR	NR	759	2.5	11	1320	NR	NR	718.26
303	11.002	11	1	2	NR	NR	NR	759	1	80	1320	NR	NR	718.26
304	11.003	11	4	2	NR	NR	NR	759	2.5	6	1320	NR	NR	718.26
305	11.004	11	4	2	NR	NR	NR	759	1	80	1320	NR	NR	718.26
306	12.001	12	1	1	NR	NR	11.1	736	0.17	25	2316	86.85	112.78	699.89
307	12.001	12	1	1	NR	NR	11.1	736	0.17	40	2424	86.85	112.78	699.89
308	12.001	12	1	1	NR	NR	11.1	736	0.17	30	2400	86.85	112.78	699.89
309	12.001	12	4	0	NR	NR	11.1	736	0.17	54	792	86.85	112.78	699.89
310	12.001	12	1	1	NR	NR	11.1	736	0.17	10	2136	86.85	112.78	699.89
311	12.001	12	4	0	NR	NR	11.1	736	0.17	77.3	648	86.85	112.78	699.89
312	12.001	12	1	1	NR	NR	11.1	736	0.17	60	2520	86.85	112.78	699.89
313	12.001	12	1	1	NR	NR	11.1	736	0.17	50	2472	86.85	112.78	699.89

314	12.001	12	1	1	NR	NR	11.1	736	0.17	20	2232	86.85	112.78	699.89
315	12.001	12	4	0	NR	NR	11.1	736	0.17	68	744	86.85	112.78	699.89
316	12.002	12	1	2	54	NR	11.1	736	0.17	36	384	79.49	117.35	688.42
317	12.002	12	1	2	54	NR	11.1	736	0.17	30	364.8	79.49	117.35	688.42
318	12.002	12	1	2	0	NR	11.1	736	0.17	10	76.8	79.49	117.35	688.42
319	12.002	12	1	2	54	NR	11.1	736	0.17	20	120	79.49	117.35	688.42
320	12.002	12	1	2	54	NR	11.1	736	0.17	25	242.4	79.49	117.35	688.42
321	12.003	12	1	2	49	NR	11.1	736	0.17	20	-38.4	86.85	112.78	699.89
322	12.003	12	1	2	49	NR	11.1	736	0.17	10	156	86.85	112.78	699.89
323	12.003	12	1	2	49	NR	11.1	736	0.17	25	-38.4	86.85	112.78	699.89
324	12.004	12	1	2	101	NR	11.1	736	0.17	30	112.8	79.49	117.35	688.42
325	12.004	12	1	2	101	NR	11.1	736	0.17	70	309.6	79.49	117.35	688.42
326	12.004	12	1	2	101	NR	11.1	736	0.17	25	108	79.49	117.35	688.42
327	12.004	12	1	2	101	NR	11.1	736	0.17	40	124.8	79.49	117.35	688.42
328	12.004	12	1	2	101	NR	11.1	736	0.17	10	84	79.49	117.35	688.42
329	12.004	12	1	2	101	NR	11.1	736	0.17	76	384	79.49	117.35	688.42
330	12.004	12	1	2	101	NR	11.1	736	0.17	20	103.2	79.49	117.35	688.42

331	12.004	12	1	2	101	NR	11.1	736	0.17	60	192	79.49	117.35	688.42
332	12.004	12	1	2	101	NR	11.1	736	0.17	50	146.4	79.49	117.35	688.42
333	12.005	12	1	2	80	NR	11.1	736	0.17	10	134.4	79.49	117.35	688.42
334	12.005	12	1	2	80	NR	11.1	736	0.17	20	192	79.49	117.35	688.42
335	12.005	12	1	2	80	NR	11.1	736	0.17	40	316.8	79.49	117.35	688.42
336	12.005	12	1	2	80	NR	11.1	736	0.17	25	230.4	79.49	117.35	688.42
337	12.005	12	1	2	80	NR	11.1	736	0.17	30	268.8	79.49	117.35	688.42
338	12.005	12	1	2	80	NR	11.1	736	0.17	57	384	79.49	117.35	688.42
339	12.005	12	1	2	80	NR	11.1	736	0.17	50	357.6	79.49	117.35	688.42
340	12.006	12	1	2	67	NR	11.1	736	0.17	50	312	86.85	112.78	699.89
341	12.006	12	1	2	67	NR	11.1	736	0.17	62	408	86.85	112.78	699.89
342	12.006	12	1	2	67	NR	11.1	736	0.17	25	174	86.85	112.78	699.89
343	12.006	12	1	2	67	NR	11.1	736	0.17	20	168	86.85	112.78	699.89
344	12.006	12	1	2	67	NR	11.1	736	0.17	30	180	86.85	112.78	699.89
345	12.006	12	1	2	67	NR	11.1	736	0.17	40	240	86.85	112.78	699.89
346	12.006	12	1	2	67	NR	11.1	736	0.17	60	384	86.85	112.78	699.89
347	12.006	12	1	2	67	NR	11.1	736	0.17	10	144	86.85	112.78	699.89
348	12.006	12	1	2	67	NR	11.1	736	0.17	50	300	86.85	112.78	699.89

349	12.007	12	1	2	53	NR	11.1	736	0.17	60	432	86.85	112.78	699.89
350	12.007	12	1	2	53	NR	11.1	736	0.17	30	300	86.85	112.78	699.89
351	12.007	12	1	2	53	NR	11.1	736	0.17	25	288	86.85	112.78	699.89
352	12.007	12	1	2	53	NR	11.1	736	0.17	10	192	86.85	112.78	699.89
353	12.007	12	1	2	53	NR	11.1	736	0.17	20	276	86.85	112.78	699.89
354	12.007	12	1	2	53	NR	11.1	736	0.17	50	384	86.85	112.78	699.89
355	12.007	12	1	2	53	NR	11.1	736	0.17	40	336	86.85	112.78	699.89
356	12.007	12	1	2	53	NR	11.1	736	0.17	70	456	86.85	112.78	699.89
357	12.007	12	1	2	53	NR	11.1	736	0.17	75	528	86.85	112.78	699.89
358	12.008	12	1	2	101	NR	11.1	736	0.17	25	32.4	103.04	111.26	717.11
359	12.008	12	1	2	101	NR	11.1	736	0.17	20	31.2	103.04	111.26	717.11
360	12.008	12	1	2	101	NR	11.1	736	0.17	10	26.4	103.04	111.26	717.11
361	12.008	12	1	2	101	NR	11.1	736	0.17	100	144	103.04	111.26	717.11
362	12.008	12	1	2	101	NR	11.1	736	0.17	40	39.6	103.04	111.26	717.11
363	12.008	12	1	2	101	NR	11.1	736	0.17	80	86.4	103.04	111.26	717.11
364	12.008	12	1	2	101	NR	11.1	736	0.17	90	115.2	103.04	111.26	717.11
365	12.008	12	1	2	101	NR	11.1	736	0.17	30	33.6	103.04	111.26	717.11
366	12.008	12	1	2	101	NR	11.1	736	0.17	50	46.8	103.04	111.26	717.11

367	12.008	12	1	2	101	NR	11.1	736	0.17	70	67.2	103.04	111.26	717.11
368	12.008	12	1	2	101	NR	11.1	736	0.17	60	55.2	103.04	111.26	717.11
369	12.009	12	1	2	82	NR	11.1	736	0.17	40	74.4	103.04	111.26	717.11
370	12.009	12	1	2	82	NR	11.1	736	0.17	56	144	103.04	111.26	717.11
371	12.009	12	1	2	82	NR	11.1	736	0.17	25	45	103.04	111.26	717.11
372	12.009	12	1	2	82	NR	11.1	736	0.17	10	27.6	103.04	111.26	717.11
373	12.009	12	1	2	82	NR	11.1	736	0.17	50	103.2	103.04	111.26	717.11
374	12.009	12	1	2	82	NR	11.1	736	0.17	20	38.4	103.04	111.26	717.11
375	12.009	12	1	2	82	NR	11.1	736	0.17	30	51.6	103.04	111.26	717.11
376	12.01	12	1	2	97	NR	11.1	736	0.17	100	72	161.92	112.78	774.47
377	12.01	12	1	2	97	NR	11.1	736	0.17	60	37.2	161.92	112.78	774.47
378	12.01	12	1	2	97	NR	11.1	736	0.17	70	39.6	161.92	112.78	774.47
379	12.01	12	1	2	97	NR	11.1	736	0.17	40	28.8	161.92	112.78	774.47
380	12.01	12	1	2	97	NR	11.1	736	0.17	25	24	161.92	112.78	774.47
381	12.01	12	1	2	97	NR	11.1	736	0.17	10	9.6	161.92	112.78	774.47
382	12.01	12	1	2	97	NR	11.1	736	0.17	30	25.2	161.92	112.78	774.47
383	12.01	12	1	2	97	NR	11.1	736	0.17	80	44.4	161.92	112.78	774.47
384	12.01	12	1	2	97	NR	11.1	736	0.17	20	22.8	161.92	112.78	774.47

385	12.01	12	1	2	97	NR	11.1	736	0.17	50	32.4	161.92	112.78	774.47
386	12.01	12	1	2	97	NR	11.1	736	0.17	90	52.8	161.92	112.78	774.47
387	12.011	12	1	2	96	NR	11.1	736	0.17	100	96	161.92	112.78	774.47
388	12.011	12	1	2	96	NR	11.1	736	0.17	60	45.6	161.92	112.78	774.47
389	12.011	12	1	2	96	NR	11.1	736	0.17	80	60	161.92	112.78	774.47
390	12.011	12	1	2	96	NR	11.1	736	0.17	30	28.8	161.92	112.78	774.47
391	12.011	12	1	2	96	NR	11.1	736	0.17	25	26.4	161.92	112.78	774.47
392	12.011	12	1	2	96	NR	11.1	736	0.17	50	38.4	161.92	112.78	774.47
393	12.011	12	1	2	96	NR	11.1	736	0.17	70	52.8	161.92	112.78	774.47
394	12.011	12	1	2	96	NR	11.1	736	0.17	40	32.4	161.92	112.78	774.47
395	12.011	12	1	2	96	NR	11.1	736	0.17	10	10.8	161.92	112.78	774.47
396	12.011	12	1	2	96	NR	11.1	736	0.17	20	24	161.92	112.78	774.47
397	12.011	12	1	2	96	NR	11.1	736	0.17	90	67.2	161.92	112.78	774.47
398	12.012	12	1	2	95	NR	11.1	736	0.17	25	34.2	161.92	112.78	774.47
399	12.012	12	1	2	95	NR	11.1	736	0.17	30	37.2	161.92	112.78	774.47
400	12.012	12	1	2	95	NR	11.1	736	0.17	40	43.2	161.92	112.78	774.47
401	12.012	12	1	2	95	NR	11.1	736	0.17	70	60	161.92	112.78	774.47
402	12.012	12	1	2	95	NR	11.1	736	0.17	50	50.4	161.92	112.78	774.47

403	12.012	12	1	2	95	NR	11.1	736	0.17	10	26.4	161.92	112.78	774.47
404	12.012	12	1	2	95	NR	11.1	736	0.17	20	31.2	161.92	112.78	774.47
405	12.012	12	1	2	95	NR	11.1	736	0.17	87	69.6	161.92	112.78	774.47
406	12.012	12	1	2	95	NR	11.1	736	0.17	80	66	161.92	112.78	774.47
407	12.012	12	1	2	95	NR	11.1	736	0.17	60	55.2	161.92	112.78	774.47
408	12.013	12	1	2	45	NR	11.1	736	0.17	64	192	161.92	112.78	774.47
409	12.013	12	1	2	45	NR	11.1	736	0.17	30	90	161.92	112.78	774.47
410	12.013	12	1	2	45	NR	11.1	736	0.17	10	52.8	161.92	112.78	774.47
411	12.013	12	1	2	45	NR	11.1	736	0.17	25	79.8	161.92	112.78	774.47
412	12.013	12	1	2	45	NR	11.1	736	0.17	50	156	161.92	112.78	774.47
413	12.013	12	1	2	45	NR	11.1	736	0.17	60	180	161.92	112.78	774.47
414	12.013	12	1	2	45	NR	11.1	736	0.17	40	110.4	161.92	112.78	774.47
415	12.013	12	1	2	45	NR	11.1	736	0.17	20	69.6	161.92	112.78	774.47
416	12.014	12	2	2	77	NR	11.1	736	0.61	25	29.4	181.06	184.41	722.84
417	12.014	12	2	2	77	NR	11.1	736	0.61	70	54	181.06	184.41	722.84
418	12.014	12	2	2	77	NR	11.1	736	0.61	20	27.6	181.06	184.41	722.84
419	12.014	12	2	2	77	NR	11.1	736	0.61	40	38.4	181.06	184.41	722.84
420	12.014	12	2	2	77	NR	11.1	736	0.61	80	57.6	181.06	184.41	722.84

421	12.014	12	2	2	77	NR	11.1	736	0.61	60	48	181.06	184.41	722.84
422	12.014	12	2	2	77	NR	11.1	736	0.61	30	31.2	181.06	184.41	722.84
423	12.014	12	2	2	77	NR	11.1	736	0.61	50	43.2	161.92	192.03	694.16
424	12.014	12	2	2	77	NR	11.1	736	0.61	100	69.6	181.06	184.41	722.84
425	12.014	12	2	2	77	NR	11.1	736	0.61	90	64.8	181.06	184.41	722.84
426	12.014	12	2	2	77	NR	11.1	736	0.61	50	43.2	181.06	184.41	722.84
427	12.014	12	2	2	77	NR	11.1	736	0.61	10	21.6	181.06	184.41	722.84
428	12.015	12	4	2	69	NR	11.1	736	0.61	90	69.6	161.92	178.32	711.37
429	12.015	12	4	2	69	NR	11.1	736	0.61	10	28.8	161.92	178.32	711.37
430	12.015	12	4	2	69	NR	11.1	736	0.61	50	50.4	163.39	178.32	711.37
431	12.015	12	4	2	69	NR	11.1	736	0.61	70	60	161.92	178.32	711.37
432	12.015	12	4	2	69	NR	11.1	736	0.61	20	31.2	161.92	178.32	711.37
433	12.015	12	4	2	69	NR	11.1	736	0.61	60	55.2	161.92	178.32	711.37
434	12.015	12	4	2	69	NR	11.1	736	0.61	80	64.8	161.92	178.32	711.37
435	12.015	12	4	2	69	NR	11.1	736	0.61	30	38.4	161.92	178.32	711.37
436	12.015	12	4	2	69	NR	11.1	736	0.61	25	34.8	161.92	178.32	711.37
437	12.015	12	4	2	69	NR	11.1	736	0.61	40	43.2	161.92	178.32	711.37
438	12.016	12	1	2	99	NR	11.1	736	0.61	80	84	161.92	178.32	711.37

439	12.016	12	1	2	99	NR	11.1	736	0.61	50	62.4	163.39	178.32	711.37
440	12.016	12	1	2	99	NR	11.1	736	0.61	25	42.6	161.92	178.32	711.37
441	12.016	12	1	2	99	NR	11.1	736	0.61	30	48	161.92	178.32	711.37
442	12.016	12	1	2	99	NR	11.1	736	0.61	90	91.2	161.92	178.32	711.37
443	12.016	12	1	2	99	NR	11.1	736	0.61	100	120	161.92	178.32	711.37
444	12.016	12	1	2	99	NR	11.1	736	0.61	70	76.8	161.92	178.32	711.37
445	12.016	12	1	2	99	NR	11.1	736	0.61	20	37.2	161.92	178.32	711.37
446	12.016	12	1	2	99	NR	11.1	736	0.61	60	69.6	161.92	178.32	711.37
447	12.016	12	1	2	99	NR	11.1	736	0.61	40	55.2	161.92	178.32	711.37
448	12.016	12	1	2	99	NR	11.1	736	0.61	50	62.4	161.92	178.32	711.37
449	12.016	12	1	2	99	NR	11.1	736	0.61	10	21.6	161.92	178.32	711.37
450	12.017	12	1	2	82	NR	11.1	736	0.61	60	84	161.92	178.32	711.37
451	12.017	12	1	2	82	NR	11.1	736	0.61	80	144	161.92	178.32	711.37
452	12.017	12	1	2	82	NR	11.1	736	0.61	10	28.8	161.92	178.32	711.37
453	12.017	12	1	2	82	NR	11.1	736	0.61	25	41.4	161.92	178.32	711.37
454	12.017	12	1	2	82	NR	11.1	736	0.61	30	45.6	161.92	178.32	711.37
455	12.017	12	1	2	82	NR	11.1	736	0.61	90	153.6	161.92	178.32	711.37
456	12.017	12	1	2	82	NR	11.1	736	0.61	50	69	161.92	178.32	711.37

457	12.017	12	1	2	82	NR	11.1	736	0.61	20	37.2	161.92	178.32	711.37
458	12.017	12	1	2	82	NR	11.1	736	0.61	50	67.2	163.39	178.32	711.37
459	12.017	12	1	2	82	NR	11.1	736	0.61	70	108	161.92	178.32	711.37
460	12.017	12	1	2	82	NR	11.1	736	0.61	40	54	161.92	178.32	711.37
461	12.017	12	1	2	82	NR	11.1	736	0.61	100	168	161.92	178.32	711.37
462	12.018	12	1	2	54	NR	11.1	736	0.61	20	56.4	161.92	178.32	711.37
463	12.018	12	1	2	54	NR	11.1	736	0.61	70	124.8	161.92	178.32	711.37
464	12.018	12	1	2	54	NR	11.1	736	0.61	30	69.6	161.92	178.32	711.37
465	12.018	12	1	2	54	NR	11.1	736	0.61	40	80.4	161.92	178.32	711.37
466	12.018	12	1	2	54	NR	11.1	736	0.61	90	160.8	161.92	178.32	711.37
467	12.018	12	1	2	54	NR	11.1	736	0.61	60	108	161.92	178.32	711.37
468	12.018	12	1	2	54	NR	11.1	736	0.61	80	136.8	161.92	178.32	711.37
469	12.018	12	1	2	54	NR	11.1	736	0.61	50	93.6	163.39	178.32	711.37
470	12.018	12	1	2	54	NR	11.1	736	0.61	50	94.2	161.92	178.32	711.37
471	12.018	12	1	2	54	NR	11.1	736	0.61	25	63	161.92	178.32	711.37
472	12.018	12	1	2	54	NR	11.1	736	0.61	10	43.2	161.92	178.32	711.37
473	12.019	12	1	2	40	NR	11.1	736	0.17	32	1608	86.85	112.78	699.89
474	12.019	12	1	2	40	NR	11.1	736	0.17	10	1008	86.85	112.78	699.89

475	12.019	12	1	2	40	NR	11.1	736	0.17	20	1344	86.85	112.78	699.89
476	12.019	12	1	2	40	NR	11.1	736	0.17	25	1452	86.85	112.78	699.89
477	12.019	12	1	2	40	NR	11.1	736	0.17	25	1452	86.85	112.78	699.89
478	12.019	12	1	2	40	NR	11.1	736	0.17	30	1560	86.85	112.78	699.89
479	12.02	12	1	2	55	NR	11.1	736	0.17	10	67.2	103.04	111.26	717.11
480	12.02	12	1	2	55	NR	11.1	736	0.17	20	-14.4	103.04	111.26	717.11
481	12.02	12	1	2	55	NR	11.1	736	0.17	25	-14.4	103.04	111.26	717.11
482	12.021	12	1	2	41	NR	11.1	736	0.17	25	-14.4	103.04	111.26	717.11
483	12.021	12	1	2	41	NR	11.1	736	0.17	20	-14.4	103.04	111.26	717.11
484	12.022	12	1	2	83	NR	11.1	736	0.17	10	26.4	161.92	112.78	774.47
485	12.022	12	1	2	83	NR	11.1	736	0.17	60	62.4	161.92	112.78	774.47
486	12.022	12	1	2	83	NR	11.1	736	0.17	70	70.8	161.92	112.78	774.47
487	12.022	12	1	2	83	NR	11.1	736	0.17	50	55.2	161.92	112.78	774.47
488	12.022	12	1	2	83	NR	11.1	736	0.17	80	81.6	161.92	112.78	774.47
489	12.022	12	1	2	83	NR	11.1	736	0.17	30	42	161.92	112.78	774.47
490	12.022	12	1	2	83	NR	11.1	736	0.17	90	93.6	161.92	112.78	774.47

491	12.022	12	1	2	83	NR	11.1	736	0.17	40	50.4	161.92	112.78	774.47
492	12.022	12	1	2	83	NR	11.1	736	0.17	20	33.6	161.92	112.78	774.47
493	12.022	12	1	2	83	NR	11.1	736	0.17	25	37.8	161.92	112.78	774.47
494	12.023	12	1	2	55	NR	11.1	736	0.17	60	96	161.92	112.78	774.47
495	12.023	12	1	2	55	NR	11.1	736	0.17	50	69.6	161.92	112.78	774.47
496	12.023	12	1	2	55	NR	11.1	736	0.17	40	55.2	161.92	112.78	774.47
497	12.023	12	1	2	55	NR	11.1	736	0.17	10	24	161.92	112.78	774.47
498	12.023	12	1	2	55	NR	11.1	736	0.17	25	38.4	161.92	112.78	774.47
499	12.023	12	1	2	55	NR	11.1	736	0.17	76	168	161.92	112.78	774.47
500	12.023	12	1	2	55	NR	11.1	736	0.17	20	33.6	161.92	112.78	774.47
501	12.023	12	1	2	55	NR	11.1	736	0.17	30	43.2	161.92	112.78	774.47
502	12.023	12	1	2	55	NR	11.1	736	0.17	70	115.2	161.92	112.78	774.47
503	12.024	12	1	2	47	NR	11.1	736	0.17	25	124.8	161.92	112.78	774.47
504	12.024	12	1	2	47	NR	11.1	736	0.17	10	64.8	161.92	112.78	774.47
505	12.024	12	1	2	47	NR	11.1	736	0.17	30	153.6	161.92	112.78	774.47
506	12.024	12	1	2	47	NR	11.1	736	0.17	20	96	161.92	112.78	774.47
507	12.025	12	4	2	73	NR	11.1	736	0.17	25	-79.2	14.72	132.59	608.11
508	12.02	12	4	2	73	NR	11.	736	0.17	20	-	14.7	132.	608.1

	5						1				79.2	2	59	1
509	12.026	12	4	2	77	NR	11.1	736	0.17	20	-79.2	36.8	129.55	631.05
510	12.026	12	4	2	77	NR	11.1	736	0.17	25	-79.2	36.8	129.55	631.05
511	12.027	12	4	2	74	NR	11.1	736	0.17	25	-64.8	44.16	129.55	642.53
512	12.027	12	4	2	74	NR	11.1	736	0.17	20	-64.8	44.16	129.55	642.53
513	12.028	12	4	2	64	NR	11.1	736	0.17	20	264	79.49	117.35	688.42
514	12.028	12	4	2	64	NR	11.1	736	0.17	25	288	79.49	117.35	734.32
515	12.028	12	4	2	64	NR	11.1	736	0.17	10	192	79.49	117.35	688.42
516	12.029	12	4	2	27	NR	11.1	736	0.17	50	480	86.85	112.78	699.89
517	12.029	12	4	2	27	NR	11.1	736	0.17	25	180	86.85	112.78	699.89
518	12.029	12	4	2	27	NR	11.1	736	0.17	20	120	86.85	112.78	699.89
519	12.029	12	4	2	27	NR	11.1	736	0.17	70	720	86.85	112.78	699.89
520	12.03	12	4	2	76	NR	11.1	736	0.17	25	39.6	86.85	112.78	699.89
521	12.03	12	4	2	76	NR	11.1	736	0.17	70	103.2	86.85	112.78	699.89
522	12.03	12	4	2	76	NR	11.1	736	0.17	50	75.6	86.85	112.78	699.89
523	12.03	12	4	2	76	NR	11.1	736	0.17	20	31.2	86.85	112.78	699.89

524	12.031	12	4	2	69	NR	11.1	736	0.17	20	10.8	161.92	112.78	774.47
525	12.031	12	4	2	69	NR	11.1	736	0.17	50	28.8	161.92	112.78	774.47
526	12.031	12	4	2	69	NR	11.1	736	0.17	70	45.6	161.92	112.78	774.47
527	12.031	12	4	2	69	NR	11.1	736	0.17	25	13.8	161.92	112.78	774.47
528	12.032	12	4	2	73	NR	11.1	736	0.17	20	8.4	161.92	112.78	774.47
529	12.032	12	4	2	73	NR	11.1	736	0.17	50	19.2	161.92	112.78	774.47
530	12.032	12	4	2	73	NR	11.1	736	0.17	25	10.2	161.92	112.78	774.47
531	12.032	12	4	2	73	NR	11.1	736	0.17	70	36	161.92	112.78	774.47
532	12.033	12	2	2	38	NR	11.1	736	0.17	20	-86.4	44.16	129.55	642.53
533	12.033	12	2	2	38	NR	11.1	736	0.17	25	-86.4	44.16	129.55	642.53
534	12.034	12	2	2	84	NR	11.1	736	0.17	25	-67.2	44.16	129.55	642.53
535	12.034	12	2	2	84	NR	11.1	736	0.17	20	-67.2	44.16	129.55	642.53
536	12.035	12	2	2	40	NR	11.1	736	0.17	25	396	86.85	112.78	699.89
537	12.035	12	2	2	40	NR	11.1	736	0.17	50	720	86.85	112.78	699.89
538	12.035	12	2	2	40	NR	11.1	736	0.17	20	336	86.85	112.78	699.89
539	12.036	12	2	2	84	NR	11.1	736	0.17	20	57.6	86.85	112.78	699.89

540	12.036	12	2	2	84	NR	11.1	736	0.17	70	96	86.85	112.78	699.89
541	12.036	12	2	2	84	NR	11.1	736	0.17	25	61.2	86.85	112.78	699.89
542	12.036	12	2	2	84	NR	11.1	736	0.17	50	79.2	86.85	112.78	699.89
543	12.037	12	2	2	79	NR	11.1	736	0.17	20	24	86.85	112.78	699.89
544	12.037	12	2	2	79	NR	11.1	736	0.17	50	69.6	86.85	112.78	699.89
545	12.037	12	2	2	79	NR	11.1	736	0.17	25	31.8	86.85	112.78	699.89
546	12.037	12	2	2	79	NR	11.1	736	0.17	70	98.4	86.85	112.78	699.89
547	12.038	12	2	2	163	NR	11.1	736	0.61	25	29.4	188.42	179.84	734.32
548	12.038	12	2	2	163	NR	11.1	736	0.61	70	55.2	188.42	179.84	734.32
549	12.038	12	2	2	163	NR	11.1	736	0.61	20	26.4	188.42	179.84	734.32
550	12.038	12	2	2	163	NR	11.1	736	0.61	50	43.2	188.42	179.84	734.32
551	12.039	12	4	2	152	NR	11.1	736	0.61	20	19.2	188.42	179.84	734.32
552	12.039	12	4	2	152	NR	11.1	736	0.61	70	52.8	188.42	179.84	734.32
553	12.039	12	4	2	152	NR	11.1	736	0.61	25	24	188.42	179.84	734.32
554	12.039	12	4	2	152	NR	11.1	736	0.61	50	40.8	188.42	179.84	734.32
555	12.04	12	2	2	163	NR	11.1	736	0.61	20	16	185.47	182.89	728.58
556	12.04	12	2	2	163	NR	11.1	736	0.61	25	19.8	185.47	182.89	728.58
557	12.04	12	2	2	163	NR	11.1	736	0.61	70	52.8	185.47	182.89	728.58

558	12.04	12	2	2	163	NR	11.1	736	0.61	50	36	185.47	182.89	728.58
559	12.041	12	4	2	204	NR	11.1	736	0.61	70	52.8	185.47	182.89	728.58
560	12.041	12	4	2	204	NR	11.1	736	0.61	20	16.8	185.47	182.89	728.58
561	12.041	12	4	2	204	NR	11.1	736	0.61	50	38.4	185.47	182.89	728.58
562	12.041	12	4	2	204	NR	11.1	736	0.61	25	20.4	185.47	182.89	728.58
563	12.042	12	1	2	114	NR	11.1	736	0.61	50	42	185.47	182.89	728.58
564	12.042	12	1	2	114	NR	11.1	736	0.61	20	24	185.47	182.89	728.58
565	12.042	12	1	2	114	NR	11.1	736	0.61	25	27	185.47	182.89	728.58
566	12.042	12	1	2	114	NR	11.1	736	0.61	70	54	185.47	182.89	728.58
567	13.001	13	1	2	120	16.2	15	760	0.25	10	19.3	130.72	167.03	708.45
568	13.001	13	1	2	120	16.2	15	760	0.25	20	21.05	130.72	167.03	708.45
569	13.001	13	1	2	120	16.2	15	760	0.25	25	22	130.72	167.03	708.45
570	13.001	13	1	2	120	16.2	15	760	0.25	100	55	130.72	167.03	708.45
571	13.001	13	1	2	120	16.2	15	760	0.25	50	26.9	130.72	167.03	708.45
572	13.002	13	4	2	124	20.6	15	760	0.25	25	28.6	130.72	167.03	708.45
573	13.002	13	4	2	124	20.6	15	760	0.25	20	27.7	130.72	167.03	708.45
574	13.002	13	4	2	124	20.6	15	760	0.25	50	33.3	130.72	167.03	708.45
575	13.002	13	4	2	124	20.6	15	760	0.25	10	26	130.72	167.03	708.45

576	13.002	13	4	2	124	20.6	15	760	0.25	100	40	130.72	167.03	708.45
577	13.003	13	4	2	130	19.8	15	760	0.25	10	258	86.64	153.7	678.93
578	13.003	13	4	2	130	19.8	15	760	0.25	50	486	86.64	153.7	678.93
579	13.003	13	4	2	130	19.8	15	760	0.25	25	335	86.64	153.7	678.93
580	13.003	13	4	2	130	19.8	15	760	0.25	100	-84	86.64	153.7	678.93
581	13.003	13	4	2	130	19.8	15	760	0.25	20	310	86.64	153.7	678.93
582	13.004	13	1	2	120	13.6	15	760	0.25	25	-84	86.64	153.7	678.93
583	13.004	13	1	2	120	13.6	15	760	0.25	7	792	86.64	153.7	678.93
584	13.004	13	1	2	120	13.6	15	760	0.25	20	-84	86.64	153.7	678.93
585	13.004	13	1	2	120	13.6	15	760	0.25	10	-84	86.64	153.7	678.93
586	13.005	13	1	2	117	16.8	15	760	0.25	25	11.5	174.04	180.37	737.97
587	13.005	13	1	2	117	16.8	15	760	0.25	50	13.6	174.04	180.37	737.97
588	13.005	13	1	2	117	16.8	15	760	0.25	100	32.1	174.04	180.37	737.97
589	13.005	13	1	2	117	16.8	15	760	0.25	20	11.1	174.04	180.37	737.97
590	13.005	13	1	2	117	16.8	15	760	0.25	10	10.6	174.04	180.37	737.97
591	13.007	13	4	2	130	20	15	760	0.25	25	11.7	174.04	180.37	737.97
592	13.007	13	4	2	130	20	15	760	0.25	50	14.2	174.04	180.37	737.97
593	13.007	13	4	2	130	20	15	760	0.25	100	23	174.04	180.37	737.97

594	13.007	13	4	2	130	20	15	760	0.25	10	10.3	174.04	180.37	737.97
595	13.007	13	4	2	130	20	15	760	0.25	20	11.2	174.04	180.37	737.97
596	13.008	13	4	2	130	20	15	760	0.25	50	480	91.96	154.96	684.83
597	13.008	13	4	2	130	20	15	760	0.25	25	-84	76	138.33	684.83
598	14.001	14	4	2	79	5.8	10	756.5	0.6	20	320	117.26	NR	NR
599	14.001	14	4	2	79	5.8	10	756.5	0.6	50	-51	117.26	NR	NR
600	14.001	14	4	2	79	5.8	10	756.5	0.6	50	510	117.26	NR	NR
601	14.002	14	4	2	79	5.8	12	756.5	0.6	50	408	120.28	NR	NR
602	14.002	14	4	2	79	5.8	12	756.5	0.6	50	505	120.28	NR	NR
603	14.002	14	4	2	79	5.8	12	756.5	0.6	20	285	120.28	NR	NR
604	14.002	14	4	2	79	5.8	12	756.5	0.6	20	215	120.28	NR	NR
605	14.003	14	4	2	79	5.8	15	756.5	0.6	20	150	124.82	NR	NR
606	14.003	14	4	2	79	5.8	15	756.5	0.6	20	156	124.82	NR	NR
607	14.003	14	4	2	79	5.8	15	756.5	0.6	50	305	124.82	NR	NR
608	14.003	14	4	2	79	5.8	15	756.5	0.6	50	268	124.82	NR	NR
609	14.004	14	4	2	79	5.8	18	756.5	0.6	20	135	126.34	NR	NR
610	14.004	14	4	2	79	5.8	18	756.5	0.6	50	202	126.34	NR	NR
611	14.004	14	4	2	79	5.8	18	756.5	0.6	20	107	126.34	NR	NR

612	14.004	14	4	2	79	5.8	18	756.5	0.6	50	258	126.34	NR	NR
613	14.005	14	4	2	102	11.7	9	756.2	0.6	50	462	130.07	NR	NR
614	14.005	14	4	2	102	11.7	9	756.2	0.6	20	175	130.07	NR	NR
615	14.005	14	4	2	102	11.7	9	756.2	0.6	20	108	130.07	NR	NR
616	14.005	14	4	2	102	11.7	9	756.2	0.6	50	223	130.07	NR	NR
617	14.006	14	3	2	105	13.9	9	756.2	0.6	50	515	130.07	NR	NR
618	14.006	14	3	2	105	13.9	9	756.2	0.6	20	177	130.07	NR	NR
619	14.006	14	3	2	105	13.9	9	756.2	0.6	20	165	130.07	NR	NR
620	14.006	14	3	2	105	13.9	9	756.2	0.6	50	418	130.07	NR	NR
621	14.007	14	4	2	102	11.7	12	756.2	0.6	20	158	133.09	NR	NR
622	14.007	14	4	2	102	11.7	12	756.2	0.6	20	141	133.09	NR	NR
623	14.007	14	4	2	102	11.7	12	756.2	0.6	50	252	133.09	NR	NR
624	14.007	14	4	2	102	11.7	12	756.2	0.6	50	242	133.09	NR	NR
625	14.008	14	3	2	105	13.9	12	756.2	0.6	20	214	133.09	NR	NR
626	14.008	14	3	2	105	13.9	12	756.2	0.6	50	395	133.09	NR	NR
627	14.008	14	3	2	105	13.9	12	756.2	0.6	50	525	133.09	NR	NR
628	14.008	14	3	2	105	13.9	12	756.2	0.6	20	205	133.09	NR	NR
629	14.009	14	4	2	102	11.7	15	756.2	0.6	50	118	135.36	NR	NR

630	14.009	14	4	2	102	11.7	15	756.2	0.6	50	193	135.36	NR	NR
631	14.009	14	4	2	102	11.7	15	756.2	0.6	20	92	135.36	NR	NR
632	14.009	14	4	2	102	11.7	15	756.2	0.6	20	57	135.36	NR	NR
633	14.01	14	3	2	105	13.9	15	756.2	0.6	50	470	135.36	NR	NR
634	14.01	14	3	2	105	13.9	15	756.2	0.6	20	173	135.36	NR	NR
635	14.01	14	3	2	105	13.9	15	756.2	0.6	50	490	135.36	NR	NR
636	14.01	14	3	2	105	13.9	15	756.2	0.6	20	154	135.36	NR	NR
637	14.011	14	4	2	102	11.7	18	756.2	0.6	50	52	139.14	NR	NR
638	14.011	14	4	2	102	11.7	18	756.2	0.6	20	39	139.14	NR	NR
639	14.011	14	4	2	102	11.7	18	756.2	0.6	20	37	139.14	NR	NR
640	14.011	14	4	2	102	11.7	18	756.2	0.6	50	72	139.14	NR	NR
641	14.012	14	3	2	105	13.9	18	756.2	0.6	50	453	139.14	NR	NR
642	14.012	14	3	2	105	13.9	18	756.2	0.6	20	162	139.14	NR	NR
643	14.012	14	3	2	105	13.9	18	756.2	0.6	50	313	139.14	NR	NR
644	14.012	14	3	2	105	13.9	18	756.2	0.6	20	212	139.14	NR	NR
645	14.013	14	4	2	95	10.4	9	760.2	0.6	50	193	125.43	NR	NR
646	14.013	14	4	2	95	10.4	9	760.2	0.6	50	160	125.43	NR	NR
647	14.013	14	4	2	95	10.4	9	760.2	0.6	20	127	125.43	NR	NR

648	14.013	14	4	2	95	10.4	9	760.2	0.6	20	101	125.43	NR	NR
649	14.014	14	3	2	110	18	9	760.2	0.6	50	287	125.43	NR	NR
650	14.014	14	3	2	110	18	9	760.2	0.6	20	158	125.43	NR	NR
651	14.014	14	3	2	110	18	9	760.2	0.6	20	116	125.43	NR	NR
652	14.014	14	3	2	110	18	9	760.2	0.6	50	456	125.43	NR	NR
653	14.015	14	4	2	95	10.4	12	760.2	0.6	20	122	127.71	NR	NR
654	14.015	14	4	2	95	10.4	12	760.2	0.6	20	88	127.71	NR	NR
655	14.015	14	4	2	95	10.4	12	760.2	0.6	50	183	127.71	NR	NR
656	14.015	14	4	2	95	10.4	12	760.2	0.6	50	211	127.71	NR	NR
657	14.016	14	3	2	110	18	12	760.2	0.6	20	122	127.71	NR	NR
658	14.016	14	3	2	110	18	12	760.2	0.6	20	195	127.71	NR	NR
659	14.016	14	3	2	110	18	12	760.2	0.6	50	397	127.71	NR	NR
660	14.016	14	3	2	110	18	12	760.2	0.6	50	603	127.71	NR	NR
661	14.017	14	4	2	95	10.4	15	760.2	0.6	50	143	129.23	NR	NR
662	14.017	14	4	2	95	10.4	15	760.2	0.6	50	178	129.23	NR	NR
663	14.018	14	4	2	95	10.4	15	760.2	0.6	20	93	129.23	NR	NR
664	14.018	14	4	2	95	10.4	15	760.2	0.6	20	87	129.23	NR	NR
665	14.019	14	4	2	95	10.4	18	760.2	0.6	20	54	127.71	NR	NR

666	14.019	14	4	2	95	10.4	18	760.2	0.6	50	113	127.71	NR	NR
667	14.019	14	4	2	95	10.4	18	760.2	0.6	50	102	127.71	NR	NR
668	14.019	14	4	2	95	10.4	18	760.2	0.6	20	55	127.71	NR	NR
669	14.02	14	4	2	113	16.6	9	760.6	0.6	20	35	163.53	NR	NR
670	14.02	14	4	2	113	16.6	9	760.6	0.6	50	-4.5	163.53	NR	NR
671	14.02	14	4	2	113	16.6	9	760.6	0.6	50	45	163.53	NR	NR
672	14.02	14	4	2	113	16.6	9	760.6	0.6	20	29	163.53	NR	NR
673	14.021	14	4	2	113	16.6	12	760.6	0.6	20	27	168.85	NR	NR
674	14.021	14	4	2	113	16.6	12	760.6	0.6	20	28	168.85	NR	NR
675	14.021	14	4	2	113	16.6	12	760.6	0.6	50	40	168.85	NR	NR
676	14.021	14	4	2	113	16.6	12	760.6	0.6	50	44	168.85	NR	NR
677	14.022	14	4	2	113	16.6	15	760.6	0.6	20	28	169.61	NR	NR
678	14.022	14	4	2	113	16.6	15	760.6	0.6	50	40	169.61	NR	NR
679	14.022	14	4	2	113	16.6	15	760.6	0.6	50	43	169.61	NR	NR
680	14.022	14	4	2	113	16.6	15	760.6	0.6	20	30	169.61	NR	NR
681	14.023	14	3	2	113	17.1	15	760.6	0.6	50	49	169.61	NR	NR
682	14.023	14	3	2	113	17.1	15	760.6	0.6	20	34	169.61	NR	NR
683	14.023	14	3	2	113	17.1	15	760.6	0.6	50	36	169.61	NR	NR

684	14.023	14	3	2	113	17.1	15	760.6	0.6	20	21	169.61	NR	NR
685	14.024	14	4	2	162	40.5	8	756.7	0.6	50	102	156.64	NR	NR
686	14.024	14	4	2	162	40.5	8	756.7	0.6	20	70	156.64	NR	NR
687	14.025	14	3	2	209	111.5	8	756.7	0.6	50	45	156.64	NR	NR
688	14.025	14	3	2	209	111.5	8	756.7	0.6	20	29	156.64	NR	NR
689	14.026	14	1	2	206	95.8	8	756.7	0.6	50	82	156.64	NR	NR
690	14.027	14	2	2	167	51.6	8	756.7	0.6	20	152	156.64	NR	NR
691	14.027	14	2	2	167	51.6	8	756.7	0.6	50	235	156.64	NR	NR
692	14.028	14	4	2	124	19.8	18	763.3	0.6	50	32	164.87	NR	NR
693	14.028	14	4	2	124	19.8	18	763.3	0.6	20	24	164.87	NR	NR
694	14.029	14	3	2	121	19.2	18	763.3	0.6	50	37	164.87	NR	NR
695	14.029	14	3	2	121	19.2	18	763.3	0.6	20	22	164.87	NR	NR
696	14.03	14	1	2	126	23.8	18	763.3	0.6	50	31	164.87	NR	NR
697	14.03	14	1	2	126	23.8	18	763.3	0.6	20	22	164.87	NR	NR
698	14.031	14	2	2	119	20.5	18	763.3	0.6	50	46	164.87	NR	NR
699	14.031	14	2	2	119	20.5	18	763.3	0.6	20	30	164.87	NR	NR
700	14.032	14	4	2	162	40.5	12	756.7	0.6	50	84	160.42	NR	NR
701	14.032	14	4	2	162	40.5	12	756.7	0.6	20	61	160.42	NR	NR

702	14.033	14	3	2	209	111.5	12	756.7	0.6	50	51	160.42	NR	NR
703	14.033	14	3	2	209	111.5	12	756.7	0.6	20	30	160.42	NR	NR
704	14.034	14	1	2	206	95.8	12	756.7	0.6	50	84	160.42	NR	NR
705	14.034	14	1	2	206	95.8	12	756.7	0.6	20	55	160.42	NR	NR
706	14.035	14	2	2	167	51.6	12	756.7	0.6	20	195	160.42	NR	NR
707	14.035	14	2	2	167	51.6	12	756.7	0.6	50	-25	160.42	NR	NR
708	14.036	14	4	2	162	40.5	16	756.7	0.6	50	35	162.69	NR	NR
709	14.036	14	4	2	162	40.5	16	756.7	0.6	20	27	162.69	NR	NR
710	14.037	14	3	2	209	111.5	16	756.7	0.6	50	63	162.69	NR	NR
711	14.037	14	3	2	209	111.5	16	756.7	0.6	20	37	162.69	NR	NR
712	14.038	14	1	2	206	95.8	16	756.7	0.6	20	54	162.69	NR	NR
713	14.038	14	1	2	206	95.8	16	756.7	0.6	50	198	162.69	NR	NR
714	14.039	14	2	2	167	51.6	16	756.7	0.6	20	160	162.69	NR	NR
715	14.039	14	2	2	167	51.6	16	756.7	0.6	50	-25	162.69	NR	NR
716	14.04	14	4	2	162	40.5	20	756.7	0.6	50	40	163.45	NR	NR
717	14.04	14	4	2	162	40.5	20	756.7	0.6	20	28	163.45	NR	NR
718	14.041	14	3	2	209	111.5	20	756.7	0.6	20	34	163.45	NR	NR
719	14.041	14	3	2	209	111.5	20	756.7	0.6	50	57	163.45	NR	NR

720	14.042	14	1	2	206	95.8	20	756.7	0.6	20	40	163.45	NR	NR
721	14.042	14	1	2	206	95.8	20	756.7	0.6	50	53	163.45	NR	NR
722	14.043	14	2	2	167	51.6	20	756.7	0.6	50	270	163.45	NR	NR
723	14.043	14	2	2	167	51.6	20	756.7	0.6	20	51	163.45	NR	NR
724	14.044	14	4	2	124	19.8	10	756.3	0.6	50	56	161.85	NR	NR
725	14.044	14	4	2	124	19.8	10	756.3	0.6	20	31	161.85	NR	NR
726	14.045	14	3	2	121	19.2	10	756.3	0.6	20	20	161.85	NR	NR
727	14.045	14	3	2	121	19.2	10	756.3	0.6	50	49	161.85	NR	NR
728	14.046	14	1	2	126	23.8	10	756.3	0.6	20	46	161.85	NR	NR
729	14.046	14	1	2	126	23.8	10	756.3	0.6	50	90	161.85	NR	NR
730	14.047	14	2	2	119	20.5	10	756.3	0.6	50	43	161.85	NR	NR
731	14.047	14	2	2	119	20.5	10	756.3	0.6	20	30	161.85	NR	NR
732	14.048	14	4	2	124	19.8	12	756.3	0.6	20	20	168.65	NR	NR
733	14.048	14	4	2	124	19.8	12	756.3	0.6	50	33	168.65	NR	NR
734	14.049	14	3	2	121	19.2	12	756.3	0.6	20	23	168.65	NR	NR
735	14.049	14	3	2	121	19.2	12	756.3	0.6	50	46	168.65	NR	NR
736	14.05	14	1	2	126	23.8	12	756.3	0.6	20	31	168.65	NR	NR
737	14.05	14	1	2	126	23.8	12	756.3	0.6	50	55	168.65	NR	NR

738	14.051	14	2	2	119	20.5	12	756.3	0.6	20	26	168.65	NR	NR
739	14.052	14	4	2	124	19.8	15	756.3	0.6	20	27	166.39	NR	NR
740	14.052	14	4	2	124	19.8	15	756.3	0.6	50	42	166.39	NR	NR
741	14.053	14	1	2	126	23.8	15	756.3	0.6	20	29	166.39	NR	NR
742	14.053	14	1	2	126	23.8	15	756.3	0.6	50	50	166.39	NR	NR
743	14.054	14	2	2	119	20.5	15	756.3	0.6	50	55	166.39	NR	NR
744	14.054	14	2	2	119	20.5	15	756.3	0.6	20	31	166.39	NR	NR
745	14.055	14	3	2	121	19.2	15	756.3	0.6	20	41	166.39	NR	NR
746	14.055	14	3	2	121	19.2	15	756.3	0.6	50	-4.5	166.39	NR	NR
747	14.056	14	4	2	131	26.3	9	755.4	0.6	50	121	138.24	NR	NR
748	14.056	14	4	2	131	26.3	9	755.4	0.6	20	56	138.24	NR	NR
749	14.057	14	3	2	124	22.2	9	755.4	0.6	50	226	138.24	NR	NR
750	14.057	14	3	2	124	22.2	9	755.4	0.6	20	128	138.24	NR	NR
751	14.058	14	1	2	135	32.3	9	755.4	0.6	20	200	138.24	NR	NR
752	14.058	14	1	2	135	32.3	9	755.4	0.6	50	440	138.24	NR	NR
753	14.059	14	2	2	126	24.1	9	755.4	0.6	20	100	138.24	NR	NR
754	14.059	14	2	2	126	24.1	9	755.4	0.6	50	230	138.24	NR	NR
755	14.06	14	4	2	131	26.3	12	755.4	0.6	20	73	145.04	NR	NR

756	14.06	14	4	2	131	26.3	12	755.4	0.6	50	123	145.04	NR	NR
757	14.061	14	3	2	124	22.2	12	755.4	0.6	20	131	145.04	NR	NR
758	14.061	14	3	2	124	22.2	12	755.4	0.6	50	250	145.04	NR	NR
759	14.062	14	1	2	135	32.3	12	755.4	0.6	20	220	145.04	NR	NR
760	14.062	14	1	2	135	32.3	12	755.4	0.6	50	311	145.04	NR	NR
761	14.063	14	2	2	126	24.1	12	755.4	0.6	20	156	145.04	NR	NR
762	14.063	14	2	2	126	24.1	12	755.4	0.6	50	276	145.04	NR	NR
763	14.064	14	4	2	131	26.3	15	755.4	0.6	50	96	145.04	NR	NR
764	14.064	14	4	2	131	26.3	15	755.4	0.6	20	76	145.04	NR	NR
765	14.065	14	3	2	124	22.2	15	755.4	0.6	20	104	145.04	NR	NR
766	14.065	14	3	2	124	22.2	15	755.4	0.6	50	216	145.04	NR	NR
767	14.066	14	1	2	135	32.3	15	755.4	0.6	50	235	145.04	NR	NR
768	14.066	14	1	2	135	32.3	15	755.4	0.6	20	145	145.04	NR	NR
769	14.067	14	2	2	126	24.1	15	755.4	0.6	20	172	145.04	NR	NR
770	14.067	14	2	2	126	24.1	15	755.4	0.6	50	319	145.04	NR	NR
771	14.068	14	4	2	131	26.3	18	755.4	0.6	20	45	148.06	NR	NR
772	14.068	14	4	2	131	26.3	18	755.4	0.6	50	62	148.06	NR	NR
773	14.069	14	3	2	124	22.2	18	755.4	0.6	20	105	148.06	NR	NR

774	14.069	14	3	2	124	22.2	18	755.4	0.6	50	332	148.06	NR	NR
775	14.07	14	1	2	135	32.3	18	755.4	0.6	50	205	148.06	NR	NR
776	14.07	14	1	2	135	32.3	18	755.4	0.6	20	94	148.06	NR	NR
777	14.071	14	2	2	126	24.1	18	755.4	0.6	20	58	148.06	NR	NR
778	14.071	14	2	2	126	24.1	18	755.4	0.6	50	136	148.06	NR	NR
779	14.072	14	4	2	150	32	12	758.4	0.6	50	5	238.14	201.56	781.76
780	14.073	14	4	2	150	32	12	758.4	0.6	50	4.5	238.14	157.61	825.49
781	14.074	14	4	2	150	32	12	758.4	0.6	50	6	238.14	219.77	763.45
782	14.075	14	4	2	150	32	12	758.4	0.6	50	5.5	238.14	218.2	764.63
783	14.076	14	4	2	150	32	12	758.4	0.6	50	4.2	238.14	202.82	779.99
784	14.077	14	4	2	150	32	12	758.4	0.6	50	4.2	238.14	155.72	827.26
785	14.078	14	4	2	150	32	12	758.4	0.6	50	3.7	238.14	72.05	910.58
786	14.079	14	4	2	150	32	12	758.4	0.6	50	16.5	200.22	203.13	742.76
787	14.08	14	4	2	150	32	12	758.4	0.6	50	20	200.22	194.34	751.04
788	14.081	14	4	2	150	32	12	758.4	0.6	50	12	200.22	194.34	751.04
789	14.082	14	4	2	150	32	12	758.4	0.6	50	16.7	200.22	188.69	756.95
790	14.083	14	4	2	150	32	12	758.4	0.6	50	16.5	200.22	184.3	761.08
791	14.084	14	4	2	150	32	12	758.4	0.6	50	5	200.22	156.2	789.45

792	14.085	14	4	2	150	32	12	758.4	0.6	50	8.2	200.22	150.23	795.35
793	14.086	14	4	2	150	32	12	758.4	0.6	50	5.9	200.22	145.99	799.49
794	14.087	14	4	2	150	32	12	758.4	0.6	50	4.7	200.22	69.39	875.72
795	14.088	14	4	2	150	32	12	758.4	0.6	50	5	313.98	483.34	574.95
796	14.089	14	4	2	150	32	12	758.4	0.6	50	2	313.98	221.19	836.72
797	14.09	14	4	2	150	32	12	758.4	0.6	50	2.2	313.98	216.95	840.85
798	14.091	14	4	2	150	32	12	758.4	0.6	50	1.7	313.98	163.42	894.63
799	14.092	14	4	2	150	32	12	758.4	0.6	50	1.9	313.98	155.41	902.31
800	14.093	14	4	2	150	32	12	758.4	0.6	50	1.7	313.98	88.85	968.49
801	14.094	14	4	2	150	32	12	758.4	0.6	50	5.7	276.06	427.77	593.27
802	14.095	14	4	2	150	32	12	758.4	0.6	50	1.5	276.06	253.05	767.58
803	14.096	14	4	2	150	32	12	758.4	0.6	50	1.8	276.06	212.87	807.76
804	14.097	14	4	2	150	32	12	758.4	0.6	50	2.7	276.06	212.39	808.35
805	14.098	14	4	2	150	32	12	758.4	0.6	50	3	276.06	206.74	813.67
806	14.099	14	4	2	150	32	12	758.4	0.6	50	2.3	276.06	172.84	847.35
807	14.1	14	4	2	150	32	12	758.4	0.6	50	1.6	276.06	169.23	850.9
808	14.101	14	4	2	150	32	12	758.4	0.6	50	2.5	276.06	63.58	956.67
809	14.102	14	4	2	150	32	12	758.4	0.6	50	5.5	238.14	261.22	722.08

810	14.103	14	4	2	150	32	12	758.4	0.6	50	5	238.14	219.77	763.45
811	14.104	14	4	2	150	32	12	758.4	0.6	50	4.5	313.98	373.46	684.86
812	14.105	14	4	2	150	32	12	758.4	0.6	50	1.7	313.98	293.71	764.63
813	14.106	14	4	2	150	32	12	758.4	0.6	50	1.9	313.98	329.66	728.58
814	14.107	14	3	2	110	18	15	760.2	0.6	20	272	129.23	NR	NR
815	14.107	14	3	2	110	18	15	760.2	0.6	20	320	129.23	NR	NR
816	14.108	14	3	2	209	111.5	10	756.5	0.6	50	-31	117.26	NR	NR
817	14.108	14	3	2	209	111.5	10	756.5	0.6	20	-30	117.26	NR	NR
818	14.109	14	3	2	209	111.5	12	756.5	0.6	50	-33	120.28	NR	NR
819	14.109	14	3	2	209	111.5	12	756.5	0.6	20	-32	120.28	NR	NR
820	14.11	14	3	2	209	111.5	15	756.5	0.6	50	-35	124.82	NR	NR
821	14.11	14	3	2	209	111.5	15	756.5	0.6	20	-34	124.82	NR	NR
822	14.111	14	3	2	209	111.5	18	756.5	0.6	20	480	126.34	NR	NR
823	14.111	14	3	2	209	111.5	18	756.5	0.6	20	-36	126.34	NR	NR
824	14.111	14	3	2	209	111.5	18	756.5	0.6	50	-37	126.34	NR	NR
825	14.112	14	3	2	209	11.5	15	760.2	0.6	50	-60	129.23	NR	NR
826	14.113	14	3	2	209	11.5	18	760.2	0.6	50	-60	127.71	NR	NR
827	14.113	14	3	2	209	11.5	18	760.2	0.6	20	-30	127.71	NR	NR

828	14.114	14	3	2	209	111.5	9	760.6	0.6	20	30	163.53	NR	NR
829	14.114	14	3	2	209	111.5	9	760.6	0.6	20	-3	163.53	NR	NR
830	14.114	14	3	2	209	111.5	9	760.6	0.6	50	-5	163.53	NR	NR
831	14.115	14	3	2	209	111.5	12	760.6	0.6	50	-5.1	168.85	NR	NR
832	14.2	14	1	2	206	95.8	8	756.7	0.6	20	47	156.64	NR	NR
833	14.201	14	3	2	113	17.1	12	760.6	0.6	20	43	168.85	NR	NR
834	14.201	14	3	2	113	17.1	12	760.6	0.6	20	39	168.85	NR	NR
835	14.202	14	2	2	119	20.5	12	763.3	0.6	50	41	170.22	NR	NR
836	15.001	15	2	2	60	NR	13.6	760	0.14	50	76.8	148.2	78.54	815.92
837	15.001	15	2	2	60	NR	13.6	760	0.14	25	45.6	148.2	78.54	815.92
838	15.001	15	2	2	60	NR	13.6	760	0.14	50	96	148.2	78.54	815.92
839	15.001	15	2	2	60	NR	13.6	760	0.14	25	43.2	148.2	78.54	815.92
840	15.002	15	2	2	60	NR	13.6	760	0.14	25	64.8	145.92	117.8	774.53
841	15.002	15	2	2	60	NR	13.6	760	0.14	50	103.2	145.92	117.8	774.53
842	15.002	15	2	2	60	NR	13.6	760	0.14	25	43.2	145.92	117.8	774.53
843	15.002	15	2	2	60	NR	13.6	760	0.14	50	84	145.92	117.8	774.53
844	15.003	15	2	2	60	NR	13.6	760	0.14	25	76.8	148.2	179.06	715.41
845	15.003	15	2	2	60	NR	13.6	760	0.14	50	175.2	148.2	179.06	715.41

846	15.003	15	2	2	60	NR	13.6	760	0.14	50	151.2	148.2	179.06	715.41
847	15.003	15	2	2	60	NR	13.6	760	0.14	25	98.4	148.2	179.06	715.41
848	15.004	15	2	2	60	NR	13.6	760	0.14	50	156	147.44	249.75	644.46
849	15.004	15	2	2	60	NR	13.6	760	0.14	25	76.8	147.44	249.75	644.46
850	15.004	15	2	2	60	NR	13.6	760	0.14	28	936	147.44	271.74	620.81
851	15.004	15	2	2	60	NR	13.6	760	0.14	50	218.4	147.44	249.75	644.46
852	15.004	15	2	2	60	NR	13.6	760	0.14	25	127.2	147.44	249.75	644.46
853	15.005	15	2	2	60	NR	13.6	760	0.14	25	804	145.92	271.74	620.81
854	15.005	15	2	2	60	NR	13.6	760	0.14	50	-93.6	145.92	271.74	620.81
855	15.006	15	2	2	85	NR	13.6	760	0.14	50	79.2	146.68	177.49	715.41
856	15.006	15	2	2	60	NR	13.6	760	0.14	25	847.2	145.92	271.74	620.81
857	15.006	15	2	2	85	NR	13.6	760	0.14	25	60	146.68	177.49	715.41
858	15.007	15	2	2	85	NR	13.6	760	0.14	25	86.4	142.12	172.78	715.41
859	15.007	15	2	2	85	NR	13.6	760	0.14	50	127	142.12	172.78	715.41
860	15.008	15	2	2	85	NR	13.6	760	0.14	25	101	133.76	164.93	715.41
861	15.008	15	2	2	85	NR	13.6	760	0.14	50	127	133.76	164.93	715.41
862	15.008	15	2	2	85	NR	13.6	760	0.14	25	91.2	133.76	164.93	715.41
863	15.00	15	2	2	85	NR	13.	760	0.14	50	158	133.	164.	715.4

	8						6					76	93	1
864	15.008	15	2	2	85	NR	13.6	760	0.14	25	130	133.76	164.93	715.41
865	15.008	15	2	2	85	NR	13.6	760	0.14	50	158	133.76	164.93	715.41
866	15.009	15	2	2	38	NR	13.6	760	0.14	25	406	147.44	179.06	715.41
867	15.01	15	2	2	46	NR	13.6	760	0.14	50	658	147.44	179.06	715.41
868	15.01	15	2	2	46	NR	13.6	760	0.14	25	401	147.44	179.06	715.41
869	15.011	15	2	2	100	NR	13.6	760	0.14	50	62	147.44	179.06	715.41
870	15.011	15	2	2	100	NR	13.6	760	0.14	50	101	147.44	179.06	715.41
871	15.011	15	2	2	100	NR	13.6	760	0.14	25	50	147.44	179.06	715.41
872	15.011	15	2	2	100	NR	13.6	760	0.14	25	69.6	147.44	179.06	715.41
873	15.012	15	2	2	60	NR	13.6	760	0.14	25	-84	144.4	359.7	532.12
874	15.012	15	2	2	60	NR	13.6	760	0.14	20	840	144.4	359.7	532.12
875	15.013	15	2	2	60	NR	13.6	760	0.14	25	768	144.4	301.58	591.25
876	15.014	15	2	2	60	NR	13.6	760	0.14	50	-84	144.4	359.7	532.12
877	15.015	15	2	2	60	NR	13.6	760	0.14	50	-79.2	144.4	301.58	591.25
878	15.016	15	2	2	38	NR	13.6	760	0.14	50	-72	147.44	179.06	715.41
879	16.001	16	1	2	59	2.3	8.3	759	1	50	1182	100.95	168.78	682.18
880	17.001	17	4	2	NR	NR	10	760	0.1	50	38.5	152.76	NR	NR

881	17.001	17	4	2	NR	NR	10	760	0.1	50	40	152.76	NR	NR
882	17.001	17	4	2	NR	NR	10	760	0.1	50	47	152.76	NR	NR
883	17.001	17	4	2	NR	NR	10	760	0.1	50	45	156.56	NR	NR
884	17.002	17	4	2	NR	NR	10	760	0.1	50	6.5	224.96	NR	NR
885	17.002	17	4	2	NR	NR	10	760	0.1	50	14.5	190	NR	NR
886	17.002	17	4	2	NR	NR	10	760	0.1	50	7	230.28	NR	NR
887	17.002	17	4	2	NR	NR	10	760	0.1	50	6.5	230.28	NR	NR
888	17.002	17	4	2	NR	NR	10	760	0.1	50	7.5	224.96	NR	NR
889	17.002	17	4	2	NR	NR	10	760	0.1	50	3.5	272.84	NR	NR
890	17.002	17	4	2	NR	NR	10	760	0.1	50	17	190	NR	NR
891	17.002	17	4	2	NR	NR	10	760	0.1	50	9	230.28	NR	NR
892	17.002	17	4	2	NR	NR	10	760	0.1	50	4	276.64	NR	NR
893	17.003	17	4	2	NR	NR	10	760	0.1	50	2.5	292.6	NR	NR
894	17.003	17	4	2	NR	NR	10	760	0.1	50	2.6	300.2	NR	NR
895	17.004	17	4	2	NR	NR	10	760	1	50	6	300.96	NR	NR
896	17.005	17	4	2	NR	NR	10	760	0.5	50	11	224.96	NR	NR
897	17.006	17	4	2	NR	NR	10	760	0.5	50	3.5	300.2	NR	NR
898	17.007	17	4	2	NR	NR	10	760	0.5	50	25	190	NR	NR

899	17.007	17	4	2	NR	NR	10	760	0.5	50	10.5	224.96	NR	NR
900	17.007	17	4	2	NR	NR	10	760	0.5	50	13.5	228	NR	NR
901	17.007	17	4	2	NR	NR	10	760	0.5	50	3.5	290.32	NR	NR
902	17.007	17	4	2	NR	NR	10	760	0.5	50	14.5	228	NR	NR
903	17.007	17	4	2	NR	NR	10	760	0.5	50	30.5	190	NR	NR
904	17.007	17	4	2	NR	NR	10	760	0.5	50	4.5	275.12	NR	NR
905	17.007	17	4	2	NR	NR	10	760	0.5	50	3.3	307.8	NR	NR
906	17.007	17	4	2	NR	NR	10	760	0.5	50	5.5	276.64	NR	NR
907	17.008	17	4	2	NR	NR	10	760	1	50	7.5	300.2	NR	NR
908	17.009	17	4	2	NR	NR	10	760	1	50	26	224.96	NR	NR
909	17.009	17	4	2	NR	NR	10	760	1	50	9.5	265.24	NR	NR
910	17.009	17	4	2	NR	NR	10	760	1	50	7	266	NR	NR
911	18.001	18	4	2	190	NR	10	754	0.6	50	54	150.8	NR	NR
912	19.001	19	3	2	86	7.7	16	754	0.6	50	10	218.66	186.95	758.7
913	19.002	19	3	2	86	7.7	16	754	0.6	50	57.8	164.37	170.32	721.26
914	19.003	19	3	2	86	7.7	16	754	0.6	50	9.2	223.18	196.43	754.02
915	19.004	19	3	2	86	7.7	16	754	0.6	50	52.8	164.37	178.09	713.65
916	19.005	19	3	2	86	7.7	16	754	0.6	50	73.2	162.86	181.04	708.97

917	19.006	19	3	2	86	7.7	16	754	0.6	50	51.3	163.62	178.09	712.48
918	19.007	19	3	2	86	7.7	16	754	0.6	50	56.3	160.6	186.02	701.37
919	19.008	19	3	2	86	7.7	15	754	0.6	50	37	234.49	289.69	671.13
920	19.009	19	3	2	86	7.7	15	754	0.6	50	22.3	238.26	201.48	761.91
921	19.01	19	3	2	86	7.7	15	754	0.6	50	23.3	236.76	198.37	764.25
922	19.011	19	3	2	86	7.7	16	754	0.6	50	48.5	168.14	174.98	720.09
923	19.012	19	3	2	86	7.7	15	754	0.6	7	167	164.37	265.26	626.63
924	19.013	19	3	2	86	7.7	15	754	0.6	50	71.6	165.88	182.34	710.37
925	19.014	19	3	2	86	7.7	15	754	0.6	50	65.8	164.37	178.14	713.3
926	19.015	19	3	2	86	7.7	16	754	0.6	50	12.1	217.91	196.58	748.17
927	20.001	20	1	3	NR	NR	NR	756	0.6	50	240	NR	NR	700.56
928	21.001	21	3	3	530	1700	12	754	0.6	20	100	159.85	NR	NR
929	21.002	21	3	3	540	1800	12	754	0.6	30	115	159.85	NR	NR
930	21.003	21	3	3	540	1900	12	754	0.6	40	127	159.85	NR	NR
931	21.004	21	3	3	520	1600	12	754	0.6	10	77	159.85	NR	NR
932	21.005	21	3	3	520	1700	12	754	0.6	20	667	126.67	NR	NR
933	21.006	21	3	3	560	1700	12	754	0.6	40	835	126.67	NR	NR
934	21.007	21	3	3	540	1500	12	754	0.6	30	835	126.67	NR	NR

935	21.008	21	3	3	590	2300	12	754	0.6	10	523	126.67	NR	NR
936	22.001	22	2	2	160	51	12	754	0.6	50	104	159.85	NR	NR
937	22.002	22	2	2	160	51	12	754	0.6	7	648	126.67	NR	NR
938	22.003	22	4	2	200	74	12	754	0.6	50	456	126.67	NR	NR
939	22.004	22	4	2	200	74	12	754	0.6	50	43	159.85	NR	NR
940	22.005	22	3	2	140	36	12	754	0.6	50	38	159.85	NR	NR
941	22.006	22	3	2	140	36	12	754	0.6	50	360	126.67	NR	NR
942	22.007	22	3	2	160	51	12	754	0.6	50	-64.8	82.94	NR	NR
943	22.008	22	3	2	140	36	12	754	0.6	50	-64.8	82.94	NR	NR
944	22.009	22	4	2	200	74	12	754	0.6	50	-64.8	82.94	NR	NR
945	22.01	22	2	2	160	51	12	754	0.6	20	-64.8	82.94	NR	NR
946	22.011	22	2	2	160	51	12	754	0.6	20	-64.8	126.67	NR	NR
947	22.012	22	2	2	160	51	12	754	0.6	20	50	159.85	NR	NR
948	22.013	22	2	2	160	51	12	754	0.6	25	-64.8	82.94	NR	NR
949	22.014	22	2	2	160	51	12	754	0.6	25	-64.	126.67	NR	NR

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950	22.015	22	2	2	160	51	12	754	0.6	25	60	159.85	NR	NR
951	22.016	22	3	2	140	36	12	754	0.6	20	-64.8	82.94	NR	NR
952	22.017	22	3	2	140	36	12	754	0.6	20	195	126.67	NR	NR
953	22.018	22	3	2	140	36	12	754	0.6	20	25	159.85	NR	NR
954	22.019	22	3	2	140	36	12	754	0.6	25	-64.8	82.94	NR	NR
955	22.02	22	3	2	140	36	12	754	0.6	25	230	126.67	NR	NR
956	22.021	22	3	2	140	36	12	754	0.6	25	26	159.85	NR	NR
957	22.022	22	4	2	200	74	12	754	0.6	20	-64.8	82.94	NR	NR
958	22.023	22	4	2	200	74	12	754	0.6	20	210	126.67	NR	NR
959	22.024	22	4	2	200	74	12	754	0.6	20	35	159.85	NR	NR
960	22.025	22	4	2	200	74	12	754	0.6	25	-64.8	82.94	NR	NR
961	22.026	22	4	2	200	74	12	754	0.6	25	230	126.67	NR	NR
962	22.027	22	4	2	200	74	12	754	0.6	25	36	159.85	NR	NR
963	23.001	23	3	2	193	95.5	12.5	754	0.28	80	504	138.74	NR	NR
964	23.002	23	3	2	193	95.5	12.5	754	0.28	60	504	138.74	NR	NR
965	23.00	23	3	2	193	95.5	12.	754	0.28	10	504	123.	NR	NR

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966	23.004	23	3	2	193	95.5	12.5	754	0.28	50	-50.4	123.66	NR	NR
967	23.005	23	3	2	193	95.5	12.5	754	0.28	20	-50.4	123.66	NR	NR
968	23.006	23	3	2	193	95.5	12.5	754	0.28	50	-50.4	108.58	NR	NR
969	23.007	23	3	2	193	95.5	12.5	754	0.28	20	-50.4	108.58	NR	NR
970	23.008	23	3	2	193	95.5	12.5	754	0.28	50	-50.4	85.96	NR	NR
971	23.009	23	3	2	193	95.5	12.5	754	0.28	20	-50.4	85.96	NR	NR
972	23.01	23	3	2	193	95.5	12.5	754	0.28	50	-50.4	70.88	NR	NR
973	23.011	23	3	2	193	95.5	12.5	754	0.28	20	-50.4	70.88	NR	NR
974	24.001	24	5	3	235	121.5	12	760	0.6	50	11	238.64	NR	NR
975	24.002	24	5	3	235	121.5	12	760	0.6	50	20	208.24	NR	NR
976	24.003	24	5	3	235	121.5	12	760	0.6	50	29	193.04	NR	NR
977	24.004	24	5	3	235	121.5	12	760	0.6	50	97	162.64	NR	NR
978	24.005	24	5	3	235	121.5	12	760	0.6	50	42	170.24	NR	NR
979	24.00	24	5	3	235	121.5	12	760	0.6	50	265	147.	NR	NR

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980	24.007	24	5	3	235	121.5	12	760	0.6	50	-50.4	117.04	NR	NR
981	24.008	24	5	3	235	121.5	12	760	0.6	50	-50.4	101.84	NR	NR
982	24.009	24	5	3	235	121.5	12	760	0.6	50	67	162.64	NR	NR
983	24.01	24	5	3	235	121.5	12	760	0.6	50	172	147.44	NR	NR
984	24.011	24	5	3	235	121.5	12	760	0.6	50	-50.4	124.64	NR	NR
985	24.012	24	5	3	235	121.5	12	760	0.6	50	-50.4	101.84	NR	NR
986	24.013	24	5	2	67	3.5	12	760	0.6	50	97	170.24	NR	NR
987	24.014	24	5	2	67	3.5	12	760	0.6	50	170	147.44	NR	NR
988	24.015	24	5	2	67	3.5	12	760	0.6	50	349	117.04	NR	NR
989	24.016	24	5	2	67	3.5	12	760	0.6	50	-50.4	101.84	NR	NR
990	24.017	24	5	2	67	3.5	12	760	0.6	50	54	162.64	NR	NR
991	24.018	24	5	2	67	3.5	12	760	0.6	50	119	147.44	NR	NR
992	24.019	24	5	2	67	3.5	12	760	0.6	50	315	117.04	NR	NR
993	24.02	24	5	2	67	3.6	12	760	0.6	50	-50.4	101.84	NR	NR
994	24.02	24	5	3	235	121.5	12	760	0.6	20	8	238.	NR	NR

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995	24.022	24	5	3	235	121.5	12	760	0.6	20	16	208.24	NR	NR
996	24.023	24	5	3	235	121.5	12	760	0.6	20	20	193.04	NR	NR
997	24.024	24	5	3	235	121.5	12	760	0.6	20	64	162.64	NR	NR
998	24.025	24	5	3	235	121.5	12	760	0.6	20	34	170.24	NR	NR
999	24.026	24	5	3	235	121.5	12	760	0.6	20	142	147.44	NR	NR
1000	24.027	24	5	3	235	121.5	12	760	0.6	20	-50.4	117.04	NR	NR
1001	24.028	24	5	3	235	121.5	12	760	0.6	20	-50.4	101.84	NR	NR
1002	24.029	24	5	3	235	121.5	12	760	0.6	20	44	162.64	NR	NR
1003	24.03	24	5	3	235	121.5	12	760	0.6	20	151	147.44	NR	NR
1004	24.031	24	5	3	235	121.5	12	760	0.6	20	-50.4	124.64	NR	NR
1005	24.032	24	5	3	235	121.5	12	760	0.6	20	-50.4	101.84	NR	NR
1006	24.033	24	5	2	67	3.5	12	760	0.6	20	50	170.24	NR	NR
1007	24.034	24	5	2	67	3.5	12	760	0.6	20	109	147.44	NR	NR
1008	24.035	24	5	2	67	3.5	12	760	0.6	20	246	117.04	NR	NR
1009	24.036	24	5	2	67	3.5	12	760	0.6	20	-50.4	101.84	NR	NR

1010	24.037	24	5	2	67	3.5	12	760	0.6	20	20	162.64	NR	NR
1011	24.038	24	5	2	67	3.5	12	760	0.6	20	79	147.44	NR	NR
1012	24.039	24	5	2	67	3.5	12	760	0.6	20	185	117.04	NR	NR
1013	24.04	24	5	2	67	3.5	12	760	0.6	20	-50.4	101.84	NR	NR
1014	25.001	25	6	1	NR	NR	10	730	NR	NR	960	8.03	NR	NR
1015	25.002	25	6	1	NR	NR	10	730	NR	NR	960	41.61	NR	NR
1016	25.003	25	6	1	NR	NR	10	730	NR	NR	960	75.92	NR	NR
1017	25.004	25	6	1	NR	NR	10	730	NR	NR	960	100.01	NR	NR
1018	25.005	25	6	1	NR	NR	10	730	NR	NR	960	118.99	NR	NR
1019	25.006	25	6	1	NR	NR	10	730	NR	NR	960	148.19	NR	NR
1020	26.001	26	6	2	38	0.37	9.3	730	NR	3	720	8.76	NR	NR
1021	26.002	26	6	2	38	0.34	9.3	730	NR	7	720	41.61	NR	NR
1022	26.003	26	6	2	39	0.34	9.3	730	NR	4	720	75.19	NR	NR
1023	26.004	26	6	2	39	0.33	9.3	730	NR	4	720	125.56	NR	NR
1024	26.005	26	6	2	40	0.37	9.3	730	NR	4	720	159.14	NR	NR
1025	27.001	27	6	2	77.4	3.3	8.2	730	NR	NR	840	10.95	NR	NR
1026	27.002	27	6	2	77.4	3.3	8.2	730	NR	NR	840	45.99	NR	NR
1027	27.00	27	6	2	77.4	3.3	8.2	730	NR	NR	840	78.1	NR	NR

	3											1		
1028	27.004	27	6	2	77.4	3.3	8.2	730	NR	10.6	840	108.04	NR	NR
1029	27.005	27	6	2	77.4	3.3	8.2	730	NR	55.4	840	159.14	NR	NR
1030	28.001	28	7	2	NR	20.5	19	760	0.37	NR	96	107.16	NR	NR
1031	28.002	28	7	2	NR	20.5	19	760	0.37	50	9.9	404.32	NR	NR
1032	28.003	28	7	2	NR	20.5	19	760	0.37	50	96	171	NR	NR
1033	28.004	28	8	2	NR	27.7	19	760	0.37	NR	96	54.72	NR	NR
1034	28.005	28	8	2	NR	27.7	19	760	0.37	50	5.6	434.72	NR	NR
1035	28.006	28	8	2	NR	27.7	19	760	0.37	50	96	109.44	NR	NR
1036	29.001	29	7	3	NR	NR	NR	760	NR	NR	96	266	NR	NR
1037	29.002	29	8	3	NR	NR	NR	760	NR	50	96	185.44	NR	NR
1038	30.001	30	10	3	364	534	10	760	0.25	50	-28.8	76	NR	NR
1039	30.002	30	10	3	364	534	10	760	0.25	10	115	129.2	NR	NR
1040	30.003	30	10	3	364	534	10	760	0.25	50	-28.8	129.2	NR	NR
1041	30.004	30	10	3	364	534	10	760	0.25	10	41	152	NR	NR
1042	30.005	30	10	3	364	534	10	760	0.25	50	233	152	NR	NR
1043	30.006	30	10	3	364	534	10	760	0.25	10	19	197.6	NR	NR
1044	30.00	30	10	3	364	534	10	760	0.25	50	20	197.	NR	NR

	7											6		
1045	31.001	31	9	1	NR	4.69	24	760	0.28	NR	840	35.72	NR	NR
1046	31.002	31	9	1	NR	4.72	24	760	0.28	1	840	76	NR	NR
1047	31.003	31	9	1	NR	5.03	24	760	0.28	56	840	117.04	NR	NR
1048	32.001	32	11	NR	NR	NR	10	760	NR	50	12	220.4	NR	NR
1049	32.002	32	11	NR	NR	NR	10	760	NR	50	14	190	NR	NR
1050	32.003	32	11	NR	NR	NR	10	760	NR	50	50	159.6	NR	NR
1051	32.004	32	11	NR	NR	NR	10	760	NR	50	48	129.2	NR	NR
1052	32.005	32	5	NR	NR	NR	10	760	NR	50	12	220.4	NR	NR
1053	32.006	32	5	NR	NR	NR	10	760	NR	50	17	190	NR	NR
1054	32.007	32	5	NR	NR	NR	10	760	NR	50	34	159.6	NR	NR
1055	32.008	32	5	NR	NR	NR	10	760	NR	50	89	129.2	NR	NR
1056	32.009	32	12	NR	NR	NR	10	760	NR	50	34	220.4	NR	NR
1057	32.01	32	12	NR	NR	NR	10	760	NR	50	67	190	NR	NR
1058	32.011	32	12	NR	NR	NR	10	760	NR	50	103	159.6	NR	NR
1059	32.012	32	13	NR	NR	NR	10	760	NR	50	240	220.4	NR	NR

APPENDIX D

TABLE D1: SOURCE OF DATA FOR TABLE D3

Author code Author(s)

1 Cornacchia and Colt (1984)
2 Gray *et al.* (1985)
3 Bisker and Castagna (1985)

TABLE D2: LIST OF ABBREVIATIONS USED IN TABLE D3

Record Number: Record number in database

Author Code: Author data set identity number

Author Number: Author Number from Table D1

Species Code: 1 = Striped Bass, 2 = Sea bass, 3 = Striped mullet

4 = Mercenaria mercenaria, 5 = Mulinia lateralis, 6 = Mya arenaria

Stage Code: 0 = Eggs, 1 = Alevins, 2 = Fry, 3 = Adult

Length: Fish length in mm.

Age: Fish age in days

Temp.C.: Water temperature in deg. C.

Patm. : Atmospheric pressure in mm Hg.

Depth: Water depth in M.

Morts %: Percent mortality.

Time: Time to mortality in hrs.

Delta P: TGP - pAtm in mm Hg.

O2: Partial pressure of dissolved oxygen in mm Hg.

N2: Partial pressure of dissolved nitrogen in mm Hg.

Table D3: Time to Mortality for Marine Fish and Invertebrates Exposed to Dissolved Gas Supersaturation

RECORD NUMBER	AUTHOR CODE	AUTHOR NUMBER	SPECIES CODE	STAGE CODE	LENGTH mm	WEIGHT g	TEMP Deg C	PATM mm Hg	DEPTH m	MORTS %	TIME Hr	DELTA P mm Hg	O_2 Mm Hg	N_2 Mm Hg
1	1.001	1	1	NR	NR	10.00	19.00	760.00	0.10	33.00	78.00	42.56	164.00	NR
2	1.002	1	1	NR	NR	19.00	18.50	760.00	0.10	35.00	72.00	47.88	164.00	NR
3	1.003	1	1	NR	NR	29.00	18.00	760.00	NR	0.00	72.00	47.88	164.00	NR
4	2.001	2	2	2	30.00	NR	20.00	760.00	0.37	0.00	96.00	152.00	NR	NR
5	2.002	2	2	2	30.00	NR	20.00	760.00	0.37	50.00	96.00	212.80	NR	NR
6	2.003	2	2	3	100.00	NR	20.00	760.00	0.37	0.00	96.00	114.00	NR	NR
8	2.005	2	3	3	31.00	NR	20.00	760.00	0.37	0.00	96.00	144.40	NR	NR
9	2.006	2	3	3	31.00	NR	20.00	760.00	0.37	50.00	96.00	223.44	NR	NR
10	2.007	2	3	3	130.00	NR	20.00	760.00	0.37	0.00	96.00	114.00	NR	NR
11	2.008	2	3	3	130.00	NR	20.00	760.00	0.37	50.00	96.00	188.48	NR	NR
12	2.009	2	2	3	30.00	NR	26.00	760.00	0.37	50.00	96.00	165.68	NR	NR
13	3.001	3	4	NR	5.00	NR	8.00	760.00	NR	50.00	704.00	114.00	NR	NR
14	3.002	3	4	NR	5.00	NR	8.00	760.00	NR	50.00	720.00	68.40	NR	NR

15	3.003	3	4	NR	5.00	NR	8.00	760.00	NR	50.00	720.00	30.40	NR	NR
16	3.004	3	4	NR	5.00	NR	8.00	760.00	NR	50.00	720.00	7.60	NR	NR
17	3.005	3	4	NR	10.00	NR	8.00	760.00	NR	50.00	708.00	114.00	NR	NR
18	3.006	3	4	NR	10.00	NR	8.00	760.00	NR	50.00	712.00	68.40	NR	NR
19	3.007	3	4	NR	10.00	NR	8.00	760.00	NR	50.00	712.00	30.40	NR	NR
21	3.009	3	4	NR	12.00	NR	8.00	760.00	NR	50.00	720.00	114.00	NR	NR
22	3.010	3	4	NR	12.00	NR	8.00	760.00	NR	50.00	715.00	68.40	NR	NR
23	3.011	3	4	NR	12.00	NR	8.00	760.00	NR	50.00	717.00	30.40	NR	NR
24	3.012	3	4	NR	12.00	NR	8.00	760.00	NR	50.00	710.00	7.60	NR	NR
25	3.013	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	417.00	114.00	NR	NR
26	3.014	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	717.00	68.40	NR	NR
27	3.015	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	712.00	30.40	NR	NR
28	3.016	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	720.00	7.60	NR	NR
29	3.017	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	312.00	152.00	NR	NR
30	3.018	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	518.00	106.40	NR	NR
31	3.019	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	667.00	60.80	NR	NR
32	3.020	3	5	NR	9.00	NR	8.00	760.00	NR	50.00	708.00	7.60	NR	NR
33	3.021	3	6	NR	9.00	NR	8.00	760.00	NR	50.00	667.00	152.00	NR	NR

34	3.022	3	6	NR	9.00	NR	8.00	760.00	NR	50.00	712.00	106.40	NR	NR
35	3.023	3	6	NR	9.00	NR	8.00	760.00	NR	50.00	712.00	60.80	NR	NR
36	3.024	3	6	NR	9.00	NR	8.00	760.00	NR	50.00	712.00	15.20	NR	NR

APPENDIX E

Volume of Fish Swim Bladder to Achieve Neutral Buoyancy

$D_f = M_f / V_t$ where: D_f is the density of the fish M_f is the mass of the fish
V_t is the total volume of the fish.
but,
$V_t = V_{f(wosb)} + V_{sb}$
where: $V_{f(wosb)}$ is the volume of the fish without the volume of swim bladder gas
V_{sb} is the volume of swim bladder gas.
and,
$M_f = D_{ft} \_ V_{f(wosb)} + D_{air} \_ V_{sb}$
where: D_{ft} is the density of fish tissue
D_{air} is the density of air.
Since the density of air is 3 orders of magnitude less than the density of fish and V_{sb} is an order of magnitude less than $V_{f(wosb)}$,
$M_f = D_{ft} \_ V_{f(wosb)}$
For neutral buoyancy, $D_f = 1.0$, independent of depth. Thus,
$D_f = 1.0 = D_{ft} \_ V_{f(wosb)} / (V_{f(wosb)} + V_{sb})$
$D_{ft} \_ V_{f(wosb)} = V_{f(wosb)} + V_{sb}$
or
$V_{sb} = (D_{ft} - 1) \_ V_{f(wosb)} = (D_{ft} - 1) \_ (V_t - V_{sb})$
Dividing both sides by V_t yields:
$V_{sb} / V_t = (D_{ft} - 1) \_ [1 - (V_{sb} / V_t)]$ or
$V_{sb} / V_t = (D_{ft} - 1) / [1 + (D_{ft} - 1)]$
According to Harvey (1963), the density of sockeye fish tissue is 1.0634 g/ml.
Therefore, for neutral buoyancy at any depth, $V_{sb} / V_t = 0.596$ or 5.96%.