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Response on submission citing dioxin calculation concerns

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Introduction

Many submissions to Gunns Limited's proposed Bell Bay Pulp Mill Preliminary Documentation (assessment under the Commonwealth EPBC Act) have cited concerns, or require clarification of the issues and potential impacts associated with dioxins in the effluent proposed to be discharged to sea. The most substantive submission in relation to this was from Dr Andrew Wadsley of Australian Risk Audit. Many submitters refer in their submissions to Dr Wadsley's work on this topic. This paper addresses the issues raised by Dr Wadsley and the other submissions received in relation to the potential impacts of dioxins in the effluent from the proposed mill.

Summary

It is important to understand the history of pulp mill development. This is so the dioxin problems of the past can be put into proper perspective with respect to perceptions held about dioxin discharges from the proposed Bell Bay mill. This contextual information provides appreciation of why it is considered dioxins from the proposed mill will not pose a threat to the local environment or to human health. Many of the submitters expressing concern about dioxins may not be aware of the following:

- The fact that modern ECF mills have negligible amounts of dioxins in their effluents. This is much different from pulp mills of the past.
- Regulatory authorities around the world have set discharge limits for dioxins in pulp mill effluents on the basis that the dioxins should not be measurable using a sensitive regulatory nominated analytical assay. This includes the effluent dioxin limits established by the RPDC.
- The level of dioxins in the effluent of the proposed Bell Bay mill will be negligible, non-measurable by the analytical method nominated by the authorities, and will be below the regulatory limits.
- Since elemental chlorine (Cl_2) has been replaced by chlorine dioxide (ClO_2) in elemental chlorine free (ECF) mills and other engineering process changes have been implemented, the amounts of dioxins in the effluent of previous Cl_2 bleaching pulp mills has decreased to below measurable levels.
- Environments previously impacted by mill operations in the 1970s and 1980s have recovered after the introduction of ClO_2 for bleaching.
- After the introduction of ClO_2, previously high concentrations of dioxins in biota (e.g. fish, crab, prawns and shrimp) collected from around pulp mill outfalls have decreased to be

below regulatory guidelines and are at, or approaching the concentrations observed in biota collected from control locations.

- Uptake of dioxins by biota is directly related to the amount of dioxin that is in their environment. High levels in the environment are reflected by high concentrations in biota, low environmental levels result in low concentrations in biota. The Bell Bay mill will be releasing negligible amounts of dioxins.
- Overseas regulatory authorities are now not concerned about the levels of dioxins discharged in the effluent produced by modern ECF mills.
- The amount of dioxin in effluent from the Bell Bay mill will be less than the amount allowed by the US EPA in drinking water.
- The proposed Bell Bay mill will use ClO_2 and best available technology. It will not have the legacy of past high dioxin contamination.
- From all the above it follows there will be negligible impact in Bass Strait from dioxins in the effluent proposed to be discharged.

The information in the above dot points provides the best foundation for making an informed decision regarding the potential impact of effluent dioxins on the marine environment. The information, expanded further in the main text of this commentary, shows what ECF mills are capable of achieving with regards to environmental performance. The proposed Bell Bay mill is designed to attain equivalent environmental outcomes as that of the best of modern ECF mills overseas.

Many submitters have focused on the theoretical dioxin calculations in the Draft IIS and marine impact assessment without recognition of the above information. However the calculations are of secondary importance in judging the impact of the proposed mill on the marine environment. They were undertaken to meet the expectation of some stakeholders for a quantitative risk assessment. Unfortunately, the many submitters have deferred to, and/or accepted the criticisms and calculations contained in the press releases and submission of Dr Wadsley without referral to the above contextual information. The information allows the calculated dioxin predictions of the both the proponent and Dr Wadsley to be placed into perspective.

The following summary comments are made regarding Dr Wadsley's submission.

- The claims in the submission of extraordinarily high fish dioxin concentrations if effluent from the proposed mill is discharged to sea are unsupported by, and in fact are inconsistent with, global observations of dioxin concentrations in coastal fish following various dioxin loads to their environments. This reality check shows that what is alleged to happen doesn't happen.

- Dr Wadsley's calculations were undertaken on the assumption that the dioxin concentration in the effluent would be at the allowed regulatory limit. This is the same limit, or is lower than applied in the USA, Canada and Japan. However he is claiming that at this concentration there will be distressing impacts on the environment, human health and economic viability of fishing industries in the greater area around the proposed outfall. Dr Wadsley is tacitly saying the regulatory limits for dioxins in pulp mills in Australia, North America and Japan are wrong. We find this difficult to believe.
- Because of lack of transparency and clarity it is difficult to follow the logic of various arguments which are claimed to underpin the assertions of catastrophic consequences if the proposed Bell Bay effluent outfall becomes operational. It is noted that at assorted places in the submission the reasoning, equations and parameter values are inconsistent.
- In the submission, the assumed background concentrations of dioxin in sediments around the proposed outfall have been prejudiced by sediment dioxin concentrations from areas in Australia that have been impacted by industrial activity. This is inappropriate for proposed outfall location and affects the calculations undertaken in the submission. Site specific information should be used.
- The assumed background concentrations include PCBs. The way the background sediment concentrations have been incorporated into the calculations of this submission is inappropriate, both where they have been incorporated and by inclusion of PCBs. Note PCBs will not be in the Bell Bay mill effluent.
    - Assumed background concentrations of dioxin, and the dioxin-like PCBs, in the submission have been added to the calculated incremental increases in sediment dioxin concentrations prior to working out the potential fish concentrations. This is inconsistent with health based risk assessment methodology.
    - Furthermore PCBs are taken up differently by animals than are dioxins.
    - Integration of the background information at the calculation point where it has been done in the submission inflates the apparent dioxin concentrations in fish.
- It is claimed background dioxin concentrations have been ignored in the Draft IIS and marine impact assessment calculations. This is incorrect. Background dioxin concentrations (plus the dioxin-like PCBs) existing *in fish* were added to the calculated incremental increases in fish.
- Inclusion of the 'missing equation' (or 'missing factor') makes no difference to the conclusions of negligible environmental impact reached in the Draft IIS or marine impact

assessment. Calculations with and without the ‘missing factor’ are provided in this commentary.

- The calculations in Dr Wadsley’s submission claim there will be a dioxin concentration of 0.072 pg/L throughout water of an area of 110 km^2 and average depth of 20m. This implies that in this body of water, the concentration of dioxin that the mill design engineers estimate might be in the effluent will only be diluted 46 times. Such an outcome is patently wrong because:
    - The diffuser at the end of the effluent pipeline will be made to achieve a 1 in 100 dilution within a short distance (approximately 100 m) of effluent release.
    - The hydrodynamic modelling, which takes into account long term effluent discharge, shows dilutions of more than 1000 fold will occur within at least 1 km of the outfall.
    - The claimed water concentration is markedly higher (by 25 times) than that measured in water of the Baltic Sea, which has much lower water fluxes than Bass Strait and for decades has received far higher dioxin environmental loads than will occur in Bass Strait from 30 years operation of the Bell Bay mill.
    - The calculations in the submission do not include all factors influencing the water concentration and utilise low values for other parameter values. An apparent high concentration of dioxin in the water occurs because a very low ‘flushing’ rate for Bass Strait was assumed, not all water flows through the receiving water were included in the calculations, and a critical removal mechanism for dioxin was not included.
- Dr Wadsley has undertaken calculations for dioxin fish concentrations assuming environmental concentrations were at steady state with a 1 in 100 dilution of effluent. Unfortunately the analysis does not consider other dilutions of effluent nevertheless the 1 in 100 dilution calculation results have been extrapolated in the submission to imply all biota throughout the 5 Mile Bluff Region and Tamar Estuary will be the same. This cannot be so and is misleading because:
    - Field measurements from around the world show the amount of dioxin taken up by organisms is proportional to the amount that is in their environment, and
    - Common sense, as well as the hydrodynamic modelling dictates that at greater distances from the effluent outfall steady state dilutions of effluent will be much greater than 1 in 100, hence environmental levels of dioxins at greater dilutions are much lower and the concentrations in biota will be correspondingly lower.

- Based on calculations above, the submission claims the 1 in 100 dilution area is much larger than shown by the hydrodynamic modelling. For the reasons articulated above this assertion is considered to be incorrect.
- The submission applies Monte Carlo techniques when calculating the uptake of dioxins by fish. The submission does not provide sufficient information to allow evaluation by a third party.
    - It is noted however that the probability distribution functions for background sediment dioxin concentrations and organic carbon content of sediment and suspended solids are inappropriate for the site.
    - It appears that the calculations have been done for only a 1 in 100 dilution of effluent, i.e. a point estimate, and other dilutions have not been addressed.
    - Therefore, as already noted from the reality checks, the Monte Carlo analysis is not predictive of what may happen at the site.

Conclusions

Overseas regulatory authorities are no longer concerned about the dioxins in ECF mill effluents because they are formed in very limited amounts and cannot be measured with sensitive analytical techniques and previously high concentrations of dioxins in biota near pulp mill outfalls have fallen to levels below standards set for environmental/human health protection and are now the same as, or near concentrations in biota collected from control locations. The collective experience from around the world with dioxins in effluent from modern ECF mills is that they present negligible environmental threats to the aquatic environments receiving the discharged effluent.

In the Draft IIS and marine impact assessment, the quantitative risk assessments concluded there would be negligible impact from dioxins in the effluent of the proposed Bell Bay mill. These conclusions are consistent with field experience for ECF mills and are unaltered whether or not some of the suggestions of Dr Wadsley are included in the calculations.

Dr Wadsley's calculations and conclusions of catastrophic environmental impacts, adverse human health effects, adverse effects on fauna, and closure of fisheries due to dioxins in the Bell Bay mill effluent are not consistent with the observations and measurements for modern ECF mills. They are also incompatible with the detailed hydrodynamic modelling that has been undertaken for the effluent discharge. His conclusions are heavily biased by inappropriate assumptions and use of background dioxin concentrations, use of default values (instead of site specific values) for parameters in equations, by assumptions regarding dioxin removal from the receiving waters, and by not considering effluent dilutions greater than 100 fold.

1. Overview

The impact of the very low amounts of dioxins that may be present in the Bell Bay effluent has been evaluated in the Draft IIS and supplementary material in two ways:

1. *Practical and common sense:*
    - Comparison with international standards which require that dioxin concentrations in the effluent are not measurable using appropriately sensitive analytical methods nominated by the competent regulatory authorities.
    - The fact that these 'non-measurable' levels of dioxins in pulp mill effluent do not have environmental impacts, even after long term discharges, is demonstrated by removal of fishing bans in waters that had been receiving very high levels of dioxins and by decline of levels in wildlife that no longer endanger their population viabilities.
    - The reality is that dioxins, like most other chemicals, have a level of exposure that is without significant risk of harm and it is the dose that makes the poison. This is the basis of setting standards for the protection of humans and animals from hazardous chemicals (natural and man made) in the environment. Low concentrations in the environment mean low levels in organisms, even if the organism is able to take up the chemical and store it in its fat.

2. *Conceptual, hypothetical and prospective:*
    - If the mill has not been built and there is no effluent to be sampled it is necessary to model the movement of effluent and make mathematical predictions if the fate and impact of any small amount of dioxin that may be in the effluent is to be forecasted. This approach necessarily requires assumptions to be made. In the Draft IIS, the impact of substances in the effluent, including dioxins, has been facilitated by creating a conceptual scenario where the effluent in the water body was only diluted 100 times and was kept at this concentration for the entire operational life of the mill. It was reasoned that if impacts were negligible within this hypothetical water body then at higher dilutions, which occur further away from the outfall, impact would also be negligible, and indeed smaller.

Unfortunately all the comments regarding the assessment of dioxins relate to the second of the above evaluation methods. The fact that dioxin concentrations in the effluent will be less than the limits imposed by Australia, Canada and the USA has been overlooked. In evaluating the impact of dioxins in the effluent more attention should be given to compliance with the regulatory requirements than to calculations, based on assumptions, predicting fish dioxin concentrations.

Notwithstanding the above comments, the methodology used to predict dioxin concentrations in fish becomes more relevant as site specific data, rather than assumptions, are used for parameter values in the equations. Site specific data has now become available (Table 1) and has been incorporated in the information below. Nevertheless care still needs to be exercised when interpreting and/or extrapolating the results. However it is important to note the large difference between the calculated predictions of dioxin concentrations (including background) in sediment and biota at steady state environmental levels (i.e. after the mill has been operating for some years) when compared with the appropriate guidelines. This large margin of safety is present with or without some of the calculation suggestions of Dr Wadsley, and provides confidence in the overall conclusions.

The conclusions in the Draft IIS and Supplementary material of no environmental impact due to dioxins in discharged effluent remain valid.

2. General response to Submission 214 of Dr Wadsley

Dr Wadsley in his submission has performed calculations as if the dioxin concentration in the effluent was at the regulatory limit. He is claiming that at this concentration there will be distressing impacts on the environment, human health and economic viability of fishing industries in the greater area around the proposed outfall. By making this allegation he is in fact challenging the competent agencies in all the above jurisdictions that their regulatory limits for the allowed amount of dioxins in pulp mill effluent are wrong. It is difficult to believe that the Australian, Canadian and American Federal and State/Provincial authorities are all incorrect.

In this document we provide supporting information, additional to that in the Draft IIS for:

- The fact that in modern bleaching technology, chemical conditions are not conducive to dioxin formation.
- The fact that since the introduction of chlorine dioxide, dioxin concentrations in pulp mill effluents have decreased to non-measurable levels.
- The fact that since the introduction of chlorine dioxide and the lowering of environmental dioxin loads to the receiving environment, past adverse environmental impacts have

been reversed to the point that in most cases there is no longer any impact from present discharges of dioxins in effluent.

With regard to the second method used for evaluating the impact of dioxins, Dr Wadlsey makes a number of criticisms regarding the dioxin impact assessments in the Draft IIS. Among these are the assertions that a sub-calculation is missing in the estimations of dioxin uptake by fish (the so called 'missing factor'), wrong assumptions were made for some of the parameter values in the equations, and existing background levels of dioxins have been ignored.

In criticising the Draft IIS, Dr Wadsley has produced an alternative set of calculations and predictions of dioxin fish concentrations following to the proposed outfall becoming operational. In doing this he has included various numerical versions of the 'missing factor', substituted alternative values for equation parameters, has made assumptions regarding background concentrations of dioxins and dioxin-like substances in sediment in the receiving water body and incorporated these sediment backgrounds when calculating the overall uptake of dioxin by fish from sediment. In addition he has introduced the additional mathematical technique of Monte Carlo modelling for the numerical values of some of the equation parameters. All these changes have brought compounded conservatism to his calculations that have resulted in quite unrealistic predictions of fish dioxin concentrations. This is demonstrated below (Section 6.2) with some reality checks of dioxin environmental loads to various coastal water bodies around the world and the associated measured fish concentrations. On the other hand the predictions in the Draft IIS are broadly in line with what global experience indicates should be expected from the very low amounts of dioxins in the Bell Bay effluent.

Perhaps the largest influence on Dr Wadsley's calculations and unrealistic predictions is the assumption(s) about existing background dioxin levels in sediment and how these have been applied in the calculations predicting fish dioxin concentrations. Both his assumed background levels in sediment and their use in calculating the fish dioxin concentrations are inappropriate. Dr Wadsley has used concentrations of both dioxins plus PCBs for marine waters around Australia, these include sediments from areas polluted by industry and clearly do not represent (they markedly over estimate) the background dioxin sediment concentrations for the area in Bass Strait which is of interest. In addition, PCBs make up a significant portion of the assumed background sediment concentrations, these substances behave differently to dioxins in the environment and they are handled differently by organisms than are dioxins. They should not be included in equations tailored for calculating fish uptake of dioxins. The proper place for the accounting of background dioxins and dioxin-like substances is in the exposure stage of the risk assessments, i.e. the existing measured background concentrations in fish should be added to the incremental amount calculated to occur due to dioxin in the effluent. This is how background dioxin and dioxin-like substances have been incorporated into the assessments of the Draft IIS and Supplementary material. Background concentrations have not been ignored as claimed by Dr Wadsley.

The question of choice of values for some of the factors in the equations has been largely resolved. Site specific measurements have been obtained for some of the critical parameters influencing the calculations of dioxin uptake into biota. These are presented in Table 1 and, unless otherwise stated, have been integrated into the information provided in the rest of this commentary.

Table 1: Site specific values for various parameters used to calculate dioxin uptake by fish.

Parameter description	Equation symbol	Parameter Value	Range
Sediment organic carbon (mg/kg)	$f_{oc,bs}$	1249 ± 402 (n = 10) (i.e. 0.12%)	890 - 2200
Organic carbon of suspended solids (mg/L)	$f_{oc,\ sw}$	4 ± 2 (n = 28) (i.e. 0.0004%)	<1 - 8
% Lipid in fish	f_{lipid}	0.5 ± 0.1(flathead) 0.4 ± 0.1(other fish [e])	0.4 – 0.6 0.3 – 0.5
Measured PCDD/F + PCB sediment concentration (pg TEQ /kg sed)	$C_{sb\ bckgrd}$	3.8[d] ± 2.6 (n = 8)	0 – 6.6
Measured PCDD/F + PCB fish concentration (pg TEQ /kg wet weight)	$C_{F\ bckgrd}$	25.2[c] ± 0.02 (flathead n = 6[d]) 11 ± (other fish)	12 - 39

[a] Data (mean ± SD) was provided by Gunns and, with the exception of organic carbon in suspended solids, was primarily obtained from two rounds of background monitoring around the outfall site undertaken in October and December 2006. Monitoring of these parameters is ongoing and will likely include scallops and Australian salmon.

[c] TEQ from PCBs were below detection limits.

[c] 75% of the mean total TEQ comes from PCBs.

[d] One of the 6 samples was a composite of 3 fish.

[e] Australian salmon have not been measured at the time of writing.

Concerning the ‘missing factor’, it is debatable whether or not this should or should not be included in some of the assessments undertaken in the Draft IIS. However rather than quarrel over the minute details of what is potentially mathematically right and wrong for the calculations we have rerun the calculations with and without the ‘missing factor’ of Dr Wadlsey and find *it makes no material difference to the outcome or conclusions of the assessments*. This information is presented below in Section 6 (Table 2 and Figures 11 to 14).

3. Dioxin formation and concentrations in effluent

It is apparent there is a general misunderstanding amongst submitters regarding the relative amounts of dioxin in the effluent of modern bleached Kraft mills versus older mills that did not use best practice bleaching processes and/or effluent treatments. In historic bleached Kraft mills using elemental chlorine (i.e. chlorine gas, Cl_2) there was an excess of reactive chlorine relative to the carbon in aromatic portions of the wood lignin molecules. This resulted in historically high amounts of dioxins and furans being formed. This does not happen in a modern pulp mill using high purity chlorine dioxide (ClO_2). There is simply not enough chlorine from the ClO_2 to react with lignin to make dioxins [1]. Dioxins concentrations in modern mill effluents are negligible and are a concern of the past [2]. Since the Bell Bay mill will use BAT it will be able to minimally achieve equivalent performance to the best operating mills overseas.

Pöyry, the Finnish designers of the proposed Bell Bay mill, have provided comment on the dioxin and furan content of effluent from the mill in the Response to Submissions document. They present the evidence from the experience of Swedish mills that polychlorinated dioxins are not formed in modern mills using chlorine dioxide. The empirical data is consistent with the chemistry stoichiometric discussion above.

Reality checks

Figures 1 and 2 below illustrate the decline of dioxin levels in pulp effluent following the introduction of chlorine dioxide and other mill engineering/process improvements.

Figure 1 shows the decrease in environmental discharges of dioxins from pulp mills in Canada over the years 1988 to 1998. The cumulative dioxins and furan discharges from the mills decreased from 450 g TEQ/yr in 1988 to 3.3 g TEQ/yr in 1997. Figure 2 shows the change in average discharge level from British Columbia pulp mills and the corresponding decrease in the hepatopancreas of the Dungeness crab. Note the Dungeness crab is used as a sentinel species for monitoring dioxins in biota because it is relatively sedentary and is in close contact with

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[1] In old, elemental chlorine based mills of the 1980's the stochiometric ratio of Cl per lignin molecule was 8.2 – 10 (Personal communication from Pöyry). For the Bell Bay mill the overall mass balance of chlorine (70% becomes salt and 20% becomes chlorate) leaves just 1.3 Cl atoms per lignin molecule of 100 carbons (Personal communication Hannu Jappinen of Pöyry Excel mass balance sheet emailed 15/06/07). This is practically the same as the ratio of 1.2 observed in bleach plant effluent from a Swedish mill of similar operations as the proposed Bell bay (Dahlman et al. 1995).
[2] Personal communication to Toxikos from Environment Canada.
Personal communication to Pöyry from the Finnish environment agency.

sediments. The hepatopancreas is the organ of choice for biomonitoring studies because it has high fat content and accumulates lipid soluble compounds. For example, for crabs in San Francisco Bay the dioxin TEQ content in hepatopancreas was 100 times that of crab muscle, the fat content of the hepatopancreas was 4.3% compared to 0.2% for muscle (Greenfield et al. 2003).

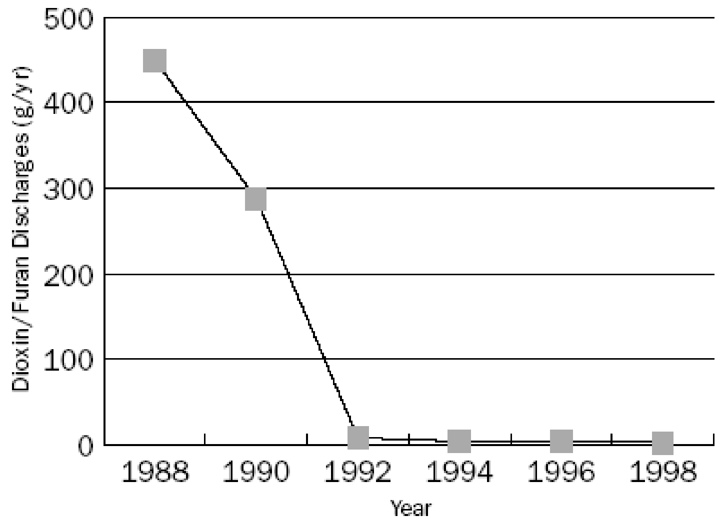

Figure 1: Changes in cumulative discharges of dioxins from Canadian pulp mills (Sourced from Environment Canada 2005 and Halliburton & Maddison 2004).

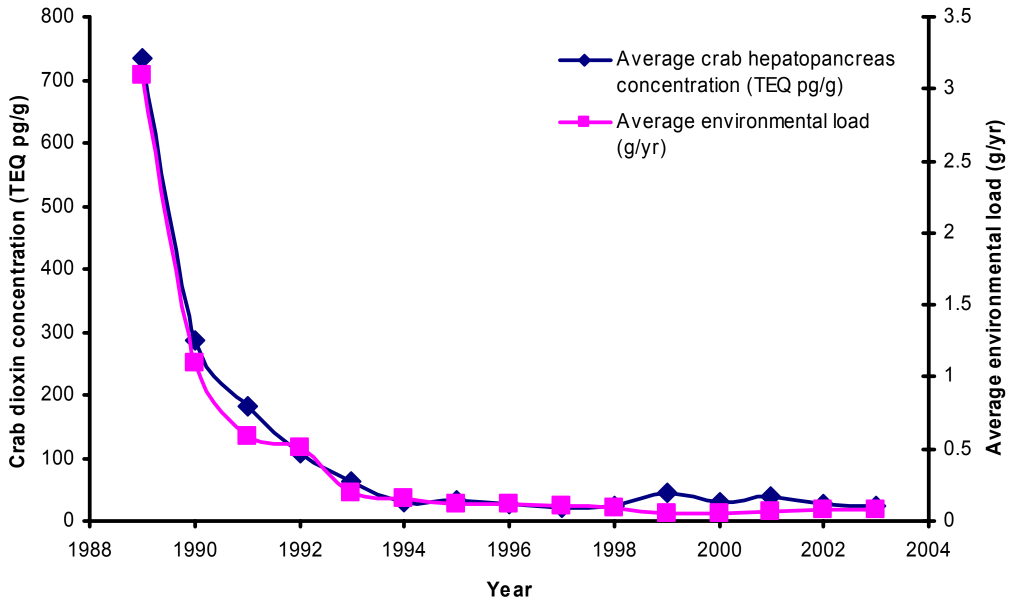

Figure 2: Concomitant decreases in the average effluent discharge load from British Columbia pulp mills (pink line) and dioxin content of fatty tissue of crabs (blue line). (Sourced from Government of British Columbia, BCOME 2005).

4. No regulatory concern for dioxins in modern mills

It is a fact that in modern mills using BAT process technology and chlorine dioxide as the bleaching agent, that dioxins, specifically 2,3,7,8 –TCDD, are not measurable with routine analytical procedures. Regulatory limits around the world stipulate that dioxin levels should not be measurable and the limit values have been set to reflect the analytical quantification limits (See Text box 1). An appreciation of how low the limits have been set is provided in Text Box 2.

Text Box 1: Regulatory limits for dioxins and furans in pulp mill effluent

RPDC = 10 pg/L for 2,3,7,8-TCDD & 30 pg/L for 2,3,7,8-TCDF
(Equivalent to 13 pg TEQ/L)

Canada = non-measurable levels of 15 pg TCDD/L, Furans 50 pg/L
(Equivalent to < 20 pg TEQ/L)

US EPA = TCDD non-measurable at QL of 10 pg/L, TCDF QL of 50 pg/L
(Equivalent to < 13.1 pg/L as total TEQ)

Text Box 2: Contextual information on the chemical analytical quantification limits of dioxins in effluent.

The regulatory analytical quantification level of TCDD in pulp mill effluent recommended by the U SEPA and the RPDC is 10 pg TCDD/L of effluent. This is a concentration of 10 parts per quadrillion (10 ppq).

ppq is a unit of concentration used to measure vanishingly small levels of a substance in a fluid.

It is the equivalent of attempting to measure the concentration of salt after one salt grain has been put in the volume of 24 Olympic sized swimming pools [a].

It is very difficult, and expensive, to reliably measure at or below these concentrations.

[a] A grain of salt weighs approximately 60 µg (i.e. 6×10^{-5} g) and the volume of an Olympic swimming pool (50m x 25m x2m) is 2.5×10^{6} L. Hence the number of Olympic swimming pools for a concentration of 10 pg/L (10^{-12} g/L) is $[6 \times 10^{-5} \div 10^{-12}] / 2.5 \times 10^{6} = 24$.

In a personal communication to Pöyry (the Bell Bay mill designers) in June 2007, Finnish Environment [3] advised it is no longer concerned about dioxins in effluent from bleached Kraft pulp mills. The agency no longer has a regulatory requirement for mills to monitor dioxin levels in their effluent because modern bleaching processes result in non-measurable dioxin levels.

The following statements from a number of organisations and researchers relate to the amounts of dioxin in the effluent of modern mills. They also reflect the lack of concern that these organisations now have for dioxins in bleached Kraft mill effluent, the statements support the advice received from the Finnish authorities.

UNEP (2005):

"Replacement of Cl_2 in the first bleaching stage by ClO_2 will dramatically reduce the formation of 2,3,7,8-Cl4DD and 2,3,7,8-Cl4DF (below detection limits of 0.3-0.9 pg/L). Data generated and published by NCASI (National Council (of the Paper Industry) for Air and Steam Improvement, Inc.) (1998) in the USA from 20 bleach lines at 14 U.S. Kraft mills that use complete chlorine dioxide substitution for chlorine gave 119 data pairs for 2,3,7,8- Cl4DD and 2,3,7,8-Cl4DF in pulp mill effluents. The results showed that 2,3,7,8-Cl4DD was not detected in any sample above the proposed guideline concentration of 10 pg/L. 2,3,7,8-Cl4DF was detected in two samples from the acid stage at concentrations in the range of 15-18 pg/L and in the alkaline stage at concentrations in the range 11-18 pg/L."

European Commission (EC 2001):

The European Commission Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Pulp and Paper Industry does not include emission limits for dioxins in waste waters because such compounds have been virtually eliminated:

"…mills [have] *virtually stopped the use of molecular chlorine for bleaching of pulp. This means that the formation of chlorinated dioxins and dibenzofurans has virtually ceased and the degree of chlorination of the remaining chlorinated substances has declined."*

Environment Canada (2004)

Under the *Fisheries Act* 1992 the Pulp and Paper Effluent Regulations (PPER) an environmental effects monitoring (EEM) program was established. Among other things, the EEM required mills using, or had at some used Cl_2 their bleaching processes to monitor dioxin concentrations in edible portions of fish downstream from their effluent discharges. However

"Few mills are required to conduct fish tissue studies because dioxins and furans have been virtually eliminated from mill effluents."

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[3] Finnish Environment is the agency responsible for health of the environment in Finland.

Servos et al. (2003)
"Reductions in the discharge of 2,3,7,8-TCDD/TCDF-TEQs (Parsons and Luthe 1995) are reflected in the dramatically reduced contamination in fish. By the first cycle of the EEM monitoring program no freshwater fish muscle tissue exceeded Health Canada consumption limit of 15 pg/g TEQ and in most cases were approaching reference values….The EEM data collected between 1993 and 1995 demonstrates a dramatic decrease in body burdens in fish across the entire country over a relatively short period of time".

NCASI (2006)
The National Council for Air and Stream Improvement (NCASI) is a research institute that focuses on environmental topics of interest to the forest products industry. NCASI (2006) recently conducted a review of contemporary topics on the subject of dioxin that may be of interest to pulp and paper mills.

"Efforts to reduce or eliminate TCDD and TCDF at mills have been remarkably successful. Data generated in 2004 from bleached papergrade kraft mills show no instances of TCDD or TCDF above analytical minimum levels in treated final effluents and no TCDD in bleach plant effluents. TCDF was observed only rarely and at just four mills at very low levels. Median TCDD and TCDF levels in wastewater residuals have decreased 98% and 96%, respectively, since 1988 and do not now differ significantly from municipal biosolids with respect to TCDD and TCDF concentrations. Other PCDDs and PCDFs were sometimes found in effluents and wastewater residuals with octachlordibenzodioxin (OCDD) being the most commonly detected congener, likely owing to its widespread distribution in the environment as a common combustion by-product. Since 1990 there has been a 90% decrease in the number of fish consumption advisories downstream of pulp and paper mills. The number of dioxin-related ecotoxicology studies has increased greatly over the last 15 years relative to the prior period and toxicity benchmarks have generally decreased as scientists find more sensitive species and end points to evaluate. However, risk assessments conducted near pulp and paper mills did not find or predict impacts on aquatic wildlife or three Threatened or Endangered species due to PCDD and PCDF."

Hatfield Consultants Ltd (2006)
Hatfield Consultants were reporting for an expert panel on the review they undertook of the final Cumulative Impact Study (CIS) for two proposed ECF bleached kraft pulp mills proposed to be built near each other on the Uruguay River. The mills are colloquially referenced as the Botnia and ENCE mills after the proponents intending to build them. The CIS review was prepared for the International Finance Corporation World Bank Group.

"The panel considered that these mills will probably perform to a standard of the top five in the world if operated to design specifications, discharging lower quantities of pollutants than most of the older, smaller mills in Latin America, USA and Canada".

Furthermore the review stated -

"There has been considerable concern expressed by many stakeholders regarding dioxin discharges from the mills. We believe such concern to be unnecessary, given that the dioxin discharges from the two proposed mills will be trivial, and at a concentration well below US

drinking water standards. Perhaps the concerned stakeholders have been misled by the extensive body of older literature that simply refers to "pulp mills" and in reading it do not realize the dramatic difference between the discharges from modern ECF mills and the several older ones using chlorine without any chlorine dioxide, that are currently operating in Argentina and Uruguay.

The CIS indicates (Table 4.1-4 and elsewhere) that dioxin discharges from the Botnia mill will be less than 2.5 x 10^{-10} kg/ADt pulp This is equivalent to 0.25 µg/ADt pulp, equivalent to 10 picograms/litre (pg/L), which in turn is equal to 10 parts per quadrillion (ppq) in practice. The predicted dioxin discharge is stated as being under 2.9 x 10^{-10} kg/ADt pulp for the ENCE mill, equivalent to 0.29 µg/ADt pulp. The above values of concentrations apply also to ENCE, the only difference between the two sets of data being the predicted effluent discharge flows, 25 m^3/t and 29 m^3/t, respectively.

UNEP estimates that dioxin discharges from the average ECF mill are 0.06 µg/ADt pulp, TEQ basis. This is under 25% of the "less than" value stated in the CIS. Since the Botnia and ENCE mills will bleach with relatively low quantities of chlorine dioxide, we would expect their dioxin discharges to be somewhat lower than those estimated by UNEP. Thus, the concentration of dioxins in the Botnia and ENCE mills will probably be less than 2 pg/L.

We are aware that all the ECF mills in Quebec, Canada, are normally unable to detect 2,3,7,8-TCDD in their monthly effluent tests at detection levels of approximately 1 pg/L[1], despite using 2 to 5 times as much chlorine dioxide as the Botnia and ENCE mills. (Other N. American mills simply report that they comply with regulations, without publishing actual discharge concentrations.)

To put concentrations of dioxins expected in the mill effluents in perspective, the new US EPA drinking water standard [2] for dioxin is 30 pg/L; therefore, the mill effluents will carry under 10% of the concentration permitted in US drinking water. Notice that the US EPA standard is for the 2,3,7,8-TCDD congener only, further increasing the margin of safety in the above discussion." [4]

[1] Detailed data for two years operations provided to Neil McCubbin by Ministère de Développement Durable, Environnement et Parcs, Québec, QC, Canada in 2006. The data are public, but are not published so must be requested from the Ministère.

[2] Technical Factsheet on: DIOXIN (2,3,7,8-TCDD) EPA http://www.epa.gov/OGWDW/dwh/t-soc/dioxin.html updated 28th February 2006.

5. Impact on the environment

Beca Amec (2006) has independently compiled case studies supportive of the principle that elimination of dioxins at ECF plants has resulted in reductions in the levels of dioxins in biota present near pulp and paper mill effluent discharges. After the conversion of elemental chorine kraft mills to ECF or TCF bleaching, a rapid decrease in the concentration of dioxins/furans is notable in biota at several pulp mill locations. Case studies identified by Beca Amec (2006) included evidence from both riverine and marine environments, and locations in North America and Sweden. Overall dioxin concentrations have markedly decreased in a range of biota

[4] The primary reference for the US drinking water limit of 30 pg/L is US EPA (2006).

(including fish, crabs, oysters, prawns and shrimps) sampled from waters at pulp and paper mill outfall areas.

There have been many investigations demonstrating reduced environmental impacts of dioxins in mill effluents after mills converted to elemental chlorine free bleaching and upgraded effluent treatments. The improvement in environmental impact has been such that at in the mid to late 1990s the concentrations of dioxin in biota were beneath guideline levels and at/or approaching the concentrations observed in biota at reference sites.

Conclusion

Given the improvements in environmental quality and lowering of dioxin concentrations in a range of organisms down stream of where bleached kraft mill effluents are discharged into water it is logical that dioxins in the effluent of a new mill using chlorine dioxide and BAT, and with none of the legacy of past high dioxin pollution, will have negligible impact on the waters of the receiving environment. This is even after many years of operation.

Evidence and reality checks

The Maryvale pulp mill discharges into Bass Strait 1.2 km offshore at a depth of 15 m at 90 Mile Beach. Investigations have been undertaken for dioxin accumulation in sediment down current from the outfall. In addition mussels have been hung at various distances down current from the outfall as well as a reference site. The studies found no evidence of dioxin deposition into sediments of the seafloor nor of uptake by mussels (Haynes et al. 1995, 1996). At the time these studies were conducted the Maryvale mill used elemental chlorine for bleaching.

A collection of some of the evidence for the above conclusion is presented below, it includes:

- Lifting of fishing bans in US waterways (Figure 3).
- Decreases in dioxin TEQ levels of oyster, prawn and shrimp near selected bleached kraft outfalls from British Columbia coastal pulp mills (Figure 4).
- Decreases in crab hepatopancreas and muscle dioxin TEQ concentrations in animals collected near pulp mill outfalls (Figures 2 & 5 and Figure 6 respectively).
- Decreases in dioxin TEQ in fish liver in the Mattagami River (north-western Ontario) to levels similar to the background levels measured in fish upstream (Figure 7).
- Decreases in fish liver TEQ in Jackfish Bay and Sawmill Creek (Lake Superior) to levels akin to control fish (Figure 8).

- Decreases in fish TCDD concentrations in the Wapiti River (Alberta, Canada) down stream of bleached kraft mill effluent discharge (Figure 9).
- A steady decline in TCDD concentrations from 1983 to 2000 in Herring Gull eggs from an island in Lake Michigan impacted by effluent from many pulp mills (Figure 10).

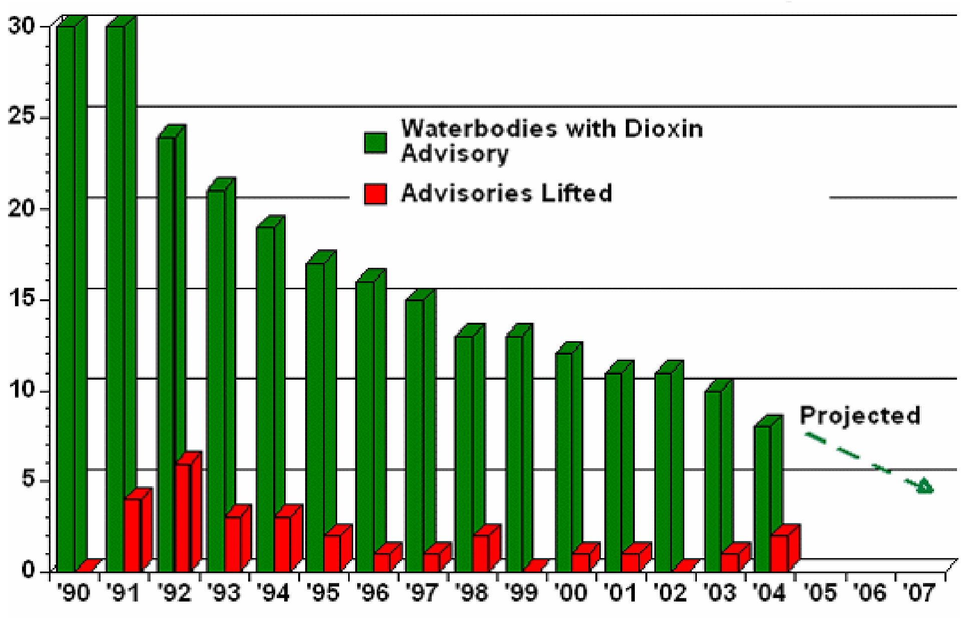

Figure 3: Number of U.S. *fish* advisories downstream of US pulp and paper mills.

The graph shows that for each year there has been a steady decrease in the number of advisories (effectively bans on fishing in the water body) since 1990. This corresponds with the phase out of Cl_2 for bleaching and process engineering improvements at the mills. [Reproduced from AET (2005)].

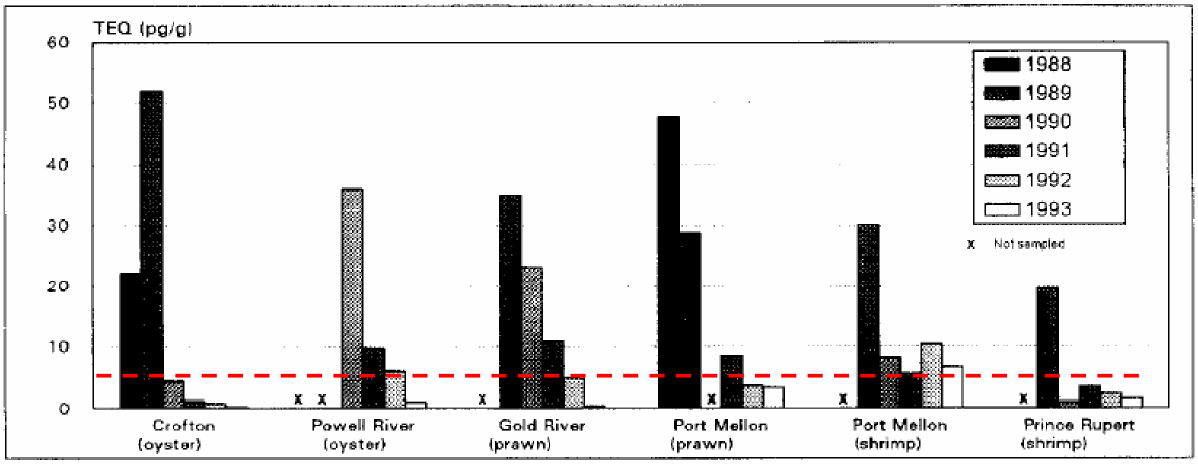

Figure 4: *Oyster, prawn, and shrimp* dioxin TEQs near a number of bleached kraft pulp mill outfalls in Canada.
For each pulp mill the graph shows the concentration of PCDD/F TEQs in the nominated biota (oyster, prawn or shrimp) for the years 1988 through to 1993. At each mill there is a progressive decrease in the organisms TEQ concentration. [Reproduced from Hagen et al. (1997)]. The dashed red line depicts the EU limit for PCDD/F TEQ in seafood.

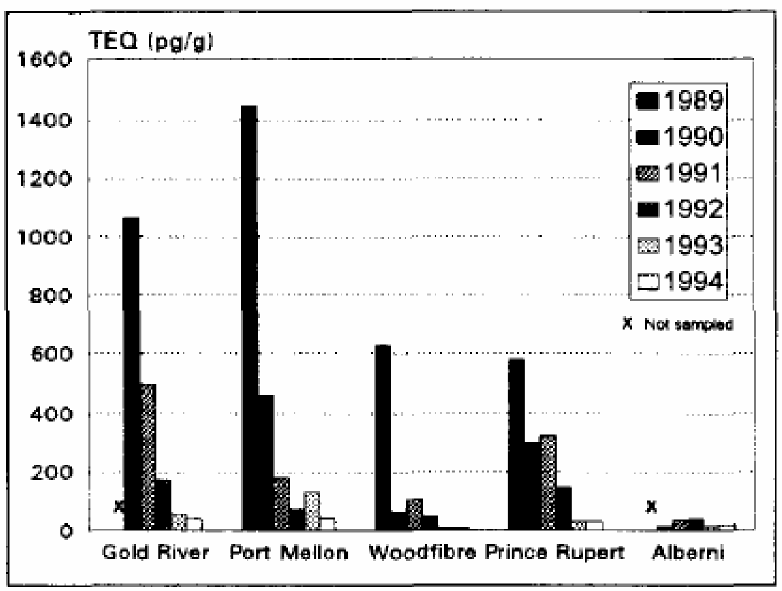

Figure 5: Dioxin and furan TEQs in Dungeness *crab hepatopancreas* at pulp mill outfall sites in the channel at Prince Rupert, Canada.
The graphs show a rapid decline in the levels of dioxin TEQ over the 5 year period 1989 to 1994. [Reproduced from Hagen et al. (1997)].

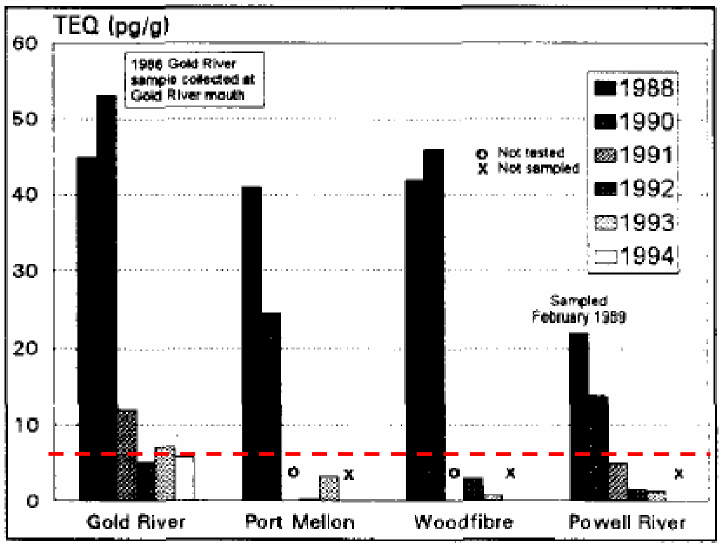

Figure 6: ***Crab muscle*** **dioxin TEQs in animals collected near outfalls of four bleached kraft pulp mills in Canada.** At each mill there is a progressive decrease in the organisms TEQ concentration. [Reproduced from Hagen et al. (1997)]. The dashed red line depicts the EU limit for PCDD/F TEQ in seafood. [Reproduced from Hagen et al. (1997)].

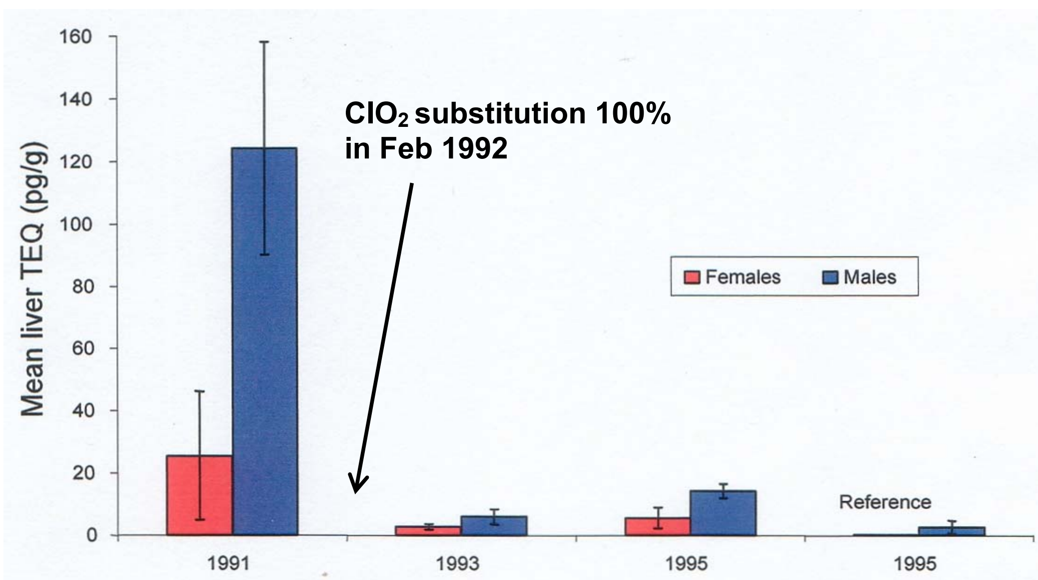

Figure 7: The PCDD/PCDF concentration in white sucker *fish liver* collected from the Mattagami River down stream of a a pulp mill effluent outfall.

At this mill ClO_2 substitution was increased to 100% in February 1992. White sucker fish are bottom feeders eating insects and molluscs. Their average size is about 24 cm and are used as a sentinal fish in the Environmental Effects Monitoring programme of the Canadian EPA. [Reproduced from Servos et al. (2003)].

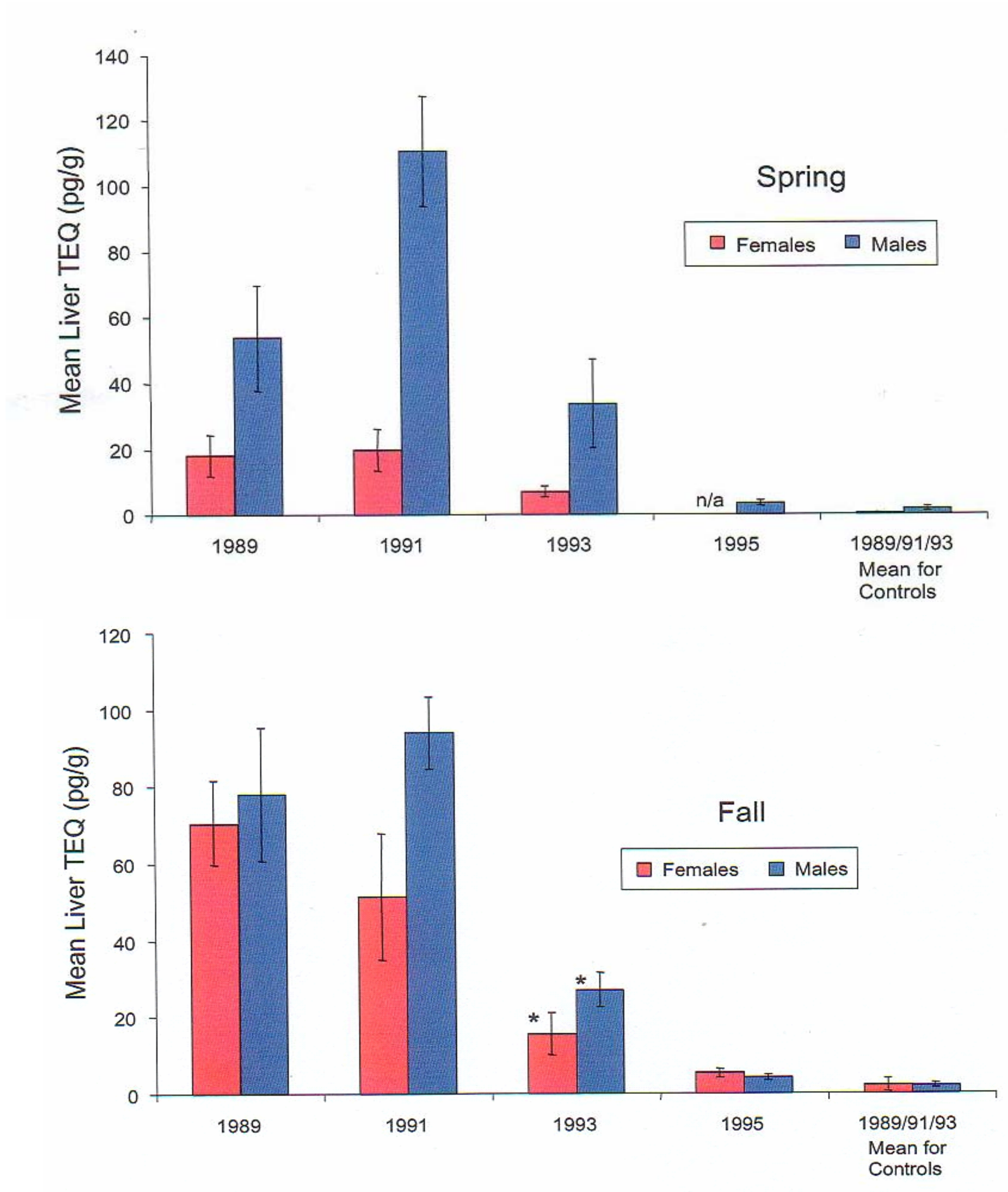

Figure 8: The PCDD/PCDF TEQ concentration in white sucker fish liver collected from Jackson Bay during the fall and Sawmill Creek (Lake Superior) during the spring spawning runs. [Reproduced from Servos et al. (2003)].

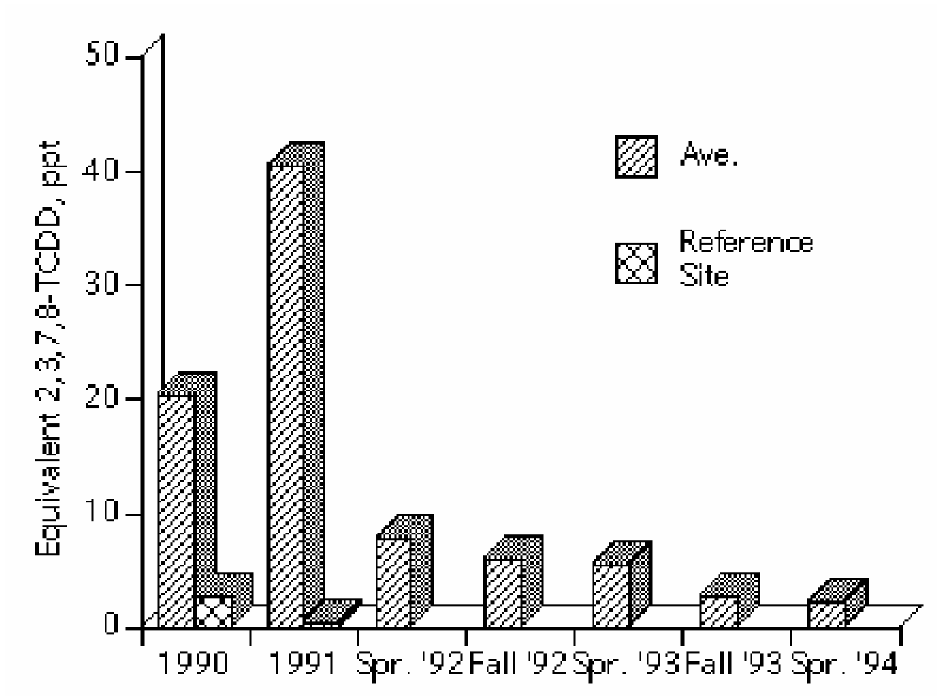

Figure 9: Dioxin concentrations from 1990-1994 in mountain whitefish from the Wapiti River (Alberta).

Fish were collected down stream from bleached kraft mill effluent outfall. The reference site was up stream. [Reproduced from Beca Amec (2006)].

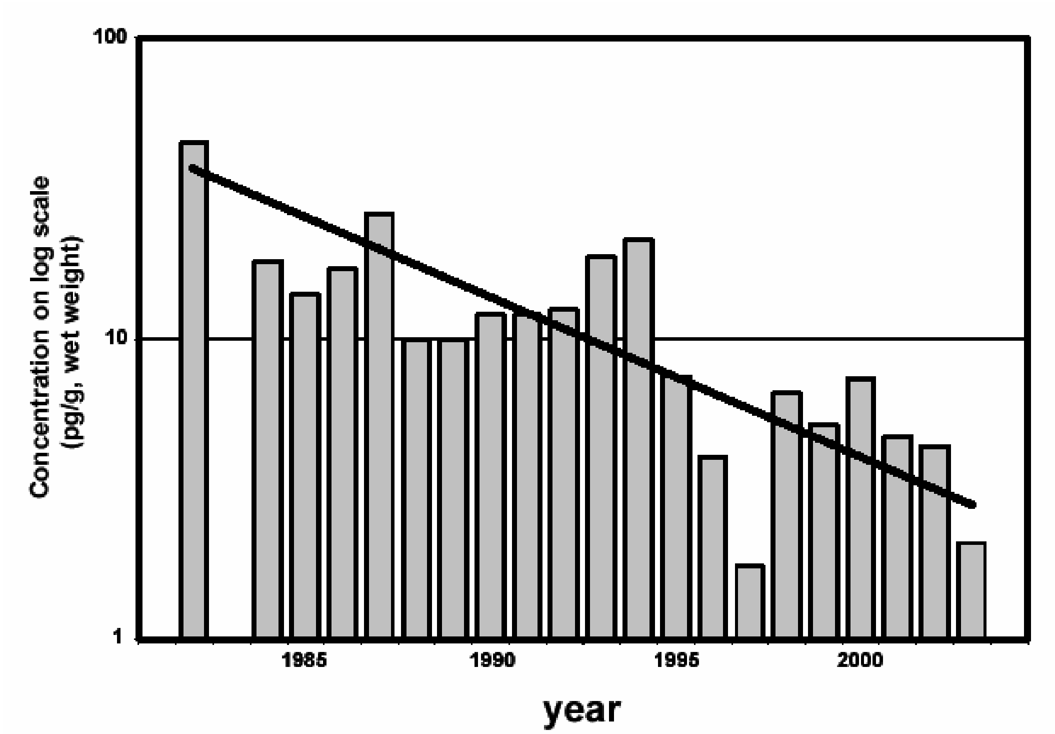

Figure 10: Amount of TCDD in Herring Gull Eggs on Big Sister Island in Lake Michigan. [Reproduced from US EPA (2007)].

Note the data in this graph is for mass of TCDD in eggs. Since TCDD has a toxicity equivalent factor (TEF) of 1.0 the data is equivalent to dioxin TEQ.

According to Weseloh et al. (2006) the major source dioxins at Big Sister Island is Green Bay. This receives the waters of the Fox River which for approximately 60 km upstream of Green Bay has the greatest concentration of paper mills in the world (Imamoglu and Christensen 2002).

6. Influence of the 'missing factor'

6.1 Calculations

Dr Wadsley has put forward the notion that there is an equation missing from the calculations undertaken for the Draft IIS and marine impact assessment. He has calculated a variety of 'missing factors' by which the computation of dioxin uptake by fish are claimed to be underestimated. One could enter into a lengthy technical debate on whether the claim of the missing factors is legitimate for all or part of the dioxin assessments undertaken in the Draft IIS and Supplementary material. However a technical argument such as this will do little to inform stakeholders of the benefits and/or uncertainties associated with the calculations. Instead, using the site specific information in Table 1 and applying background dioxin concentrations at the proper place, we have redone the calculations with and without the so called 'missing equation'. The calculations have been performed for the fish type chosen in the Draft IIS and also for the fish (Australian salmon) that Dr Wadsley has used in his calculations. The comparisons set out in this section enable easy appreciation of the impact that the missing equation would have (*if* it was legitimately missing) on the calculated dioxin levels in fish and on the conclusions of the risk assessments undertaken.

The recalculations (with and without the 'missing equation') in Table 2 are compared with the European Union and NSW action guidelines for the amount of total dioxin-like TEQ in seafood. Also in the table are the concentrations that Dr Wadsley purports will be in fish. Contrary to Dr Wadsley's assertions the data in Table 2, and in Figures 11 – 14, clearly demonstrate that incorporation of the so called 'missing equation' is of no material consequence to the calculated values in the Draft IIS and MIA.

Therefore the conclusions of the Draft IIS and marine impact assessment that the very low amounts of dioxins in the effluent will have negligible impact remain unaltered.

Effect of dilution

In Table 2 the calculations have been performed for 100, 1000 and 5000 fold effluent dilutions. This is an important consideration because both in the Draft IIS and MIA it was assumed there would only be a 100 times dilution. In fact, the hydrodynamic modelling shows far greater effluent dilutions than this.

It should be noted that Dr Wadsley also assumes a 100 fold dilution in his calculations *but extrapolates the result* to imply that fish in the entire area around Five Mile Bluff and the Tamar Estuary will take up the dioxins to the same extent as if they were in the body of water with 1 in 100 dilution. This obviously is not the case. Because uptake of dioxins by marine organisms is directly related to the amount of dioxin in their environment (e.g. see Figure 15) it is manifestly obvious that in areas with lower steady state environmental concentrations, such as at higher dilutions than 1 in 100, biota will take up dioxin to a proportionally lower extent. Indeed at effluent dilutions higher than 1 in 100, the concentration of dioxins in biota is dominated by existing background levels.

- Figure 11 compares the recalculated sediment concentrations of dioxin like substances with US EPA and Canadian guidelines.
- Figure 12 summarises the recalculations and outcome of the risk assessment for seals.
- Figure 13 shows the influence of the new data and recalculations for the little penguin.
- Figure 14 outlines the risk assessment for sea eagles.

In Figures 12 to14 the risk to marine organisms has been characterised in two ways. Firstly by comparison of the average dioxin level in the prey of seals or birds with the mammalian and bird tissue residue guidelines of Canada for prey (CCME 2001). Secondly, by comparing the average daily total TEQ intake of seals and birds with the toxicity reference value of the US EPA (US EPA 1993).

Table 2: Comparison and influence of suggested changes to fish dioxin calculations at different dilutions of effluent.

Assumptions for calculating fish dioxin concentrations	Fish concentration [a] (total pg TEQ/kg)		
Guidelines			
EU action limit for TEQ (PCDD/F + PCB) in seafood (EU 2006)	**8,000**		
Limit recommended by NSW Food Authority for total TEQ in seafood (PCDD/F + PCB) (NSWFA 2006)	**6,000**		
Influence of site specific parameters and suggestion for C_{wtot} calculation	**Effluent dilution**		
	100x	**1,000x**	**5,000x**
For 1 in 100 dilution the estimated value is as per the existing methodology in the Draft IIS, HHRA and MIA [b] reports. In the absence of site specific data; default assumptions were made in these reports regarding OC content of sediment & suspended solids, fish lipid levels & background TEQ concentration in fish.	68	61	60
As per existing Toxikos methodology above but with site specific data for sediment and water OC, and *flathead* lipid content [c].	30	27	26
Site specific parameters for sediment and water OC and *flathead* lipid content but inclusion of Dr Wadsley's suggestion for calculation (i.e. the so called 'missing factor').	56	29	27
As per existing Toxikos methodology but with site specific data for sediment and water OC. *Salmon* lipid [d] was taken as 1.1% and default BSAF of 0.2	72 [d]	31	27
As per existing Toxikos methodology but with site specific data for sediment and water OC and Dr Wadsley's suggestion for calculation (i.e. the so called 'missing factor'). Australian *salmon* lipid [d] was taken as 1.1% and a default BSAF of 0.2 used.	317 [d]	55	32
Dr Wadsley estimations for ave TEQ uptake by Australian salmon.	11,330 [e1] 22,750 [e2]	-	-

[a] The calculated fish concentration includes the calculated incremental increase plus the total PCDD/F + PCB background. Values are rounded to the nearest whole number. Since background concentrations for salmon at Five Mile Bluff were not available the site specific background TEQ content for flathead (i.e. 26 pg TEQ/kg) has been used. Prior to the availability of site specific background TEQ in fish the default background fish TEQ was taken to be 60 pg/kg, this was the mean for marine fish reported by Gatehouse 92004) but not including those from Port Jackson. *It should be noted that at effluent dilutions greater than 1000x, the predicted concentrations of TEQ in all fish is dominated by the existing background fish TEQ levels.*

[b] MIA = Marine impact assessment, HHRA = Human Health Risk Assessment, OC = organic carbon.

[c] Background site specific data obtained from two rounds of sampling in October and December 2006. See Table 1 for values.

[d] Only juvenile (< 2yr old) Eastern Australian salmon are found in coastal waters of Tasmania. Since fish tissue lipid increases with age, the lower end of the measured lipid content reported for Australian salmon (1.1, 1.3, 6.2%, see Appendix 1 on salmon) is adopted for estimating potential for TEQ uptake. The upper value is for adult salmon caught within the Derwent River; juvenile fish in Bass Strait are unlikely to have such high lipid levels. Furthermore the BSAF of 0.2 associated with the Derwent River salmon is unlikely to be realised by juvenile salmon visiting Five Mile Bluff. In addition, in the waters where these fish will be found effluent will be diluted more than 1,000 times.

[e1] Wadsley main submission 5 June 2007, p18 (para 96).

[e2] Wadsley review of June 2007, p10.

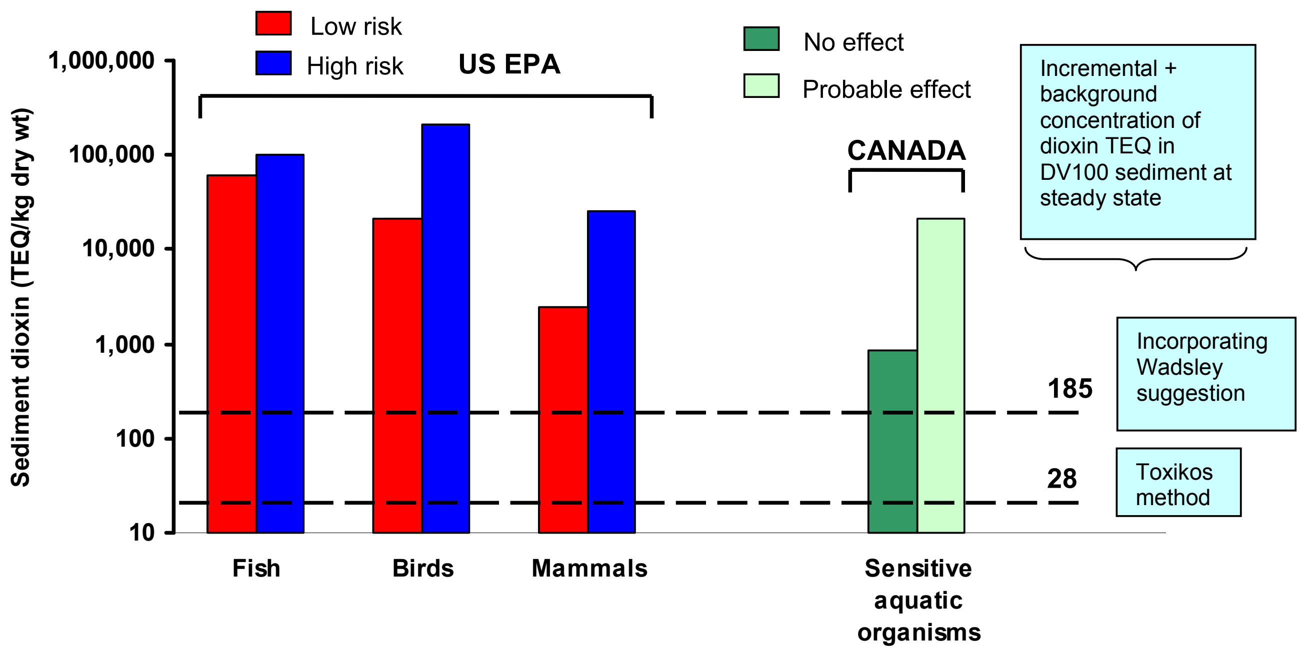

Figure 11: Comparison of predicted dioxin concentration in DV_{100} sediment (incremental + background) with sediment guidelines established for protection of aquatic animals.

Note the logarithmic scale for sediment concentrations. The predicted dioxin concentration (incremental) was calculated with the Toxikos method as per the IIS and MIA using the site specific data in Table 1. It was also calculated by incorporating the suggestions of Dr Wadsley for the missing equation. To both these values was added the site specific existing background concentrations for sediment TEQ. With respect to the sediment guideline values the change makes no difference to the conclusion that based on comparison with guideline values for sediment dioxins in discharged effluent will have negligible impact on the receiving environment.

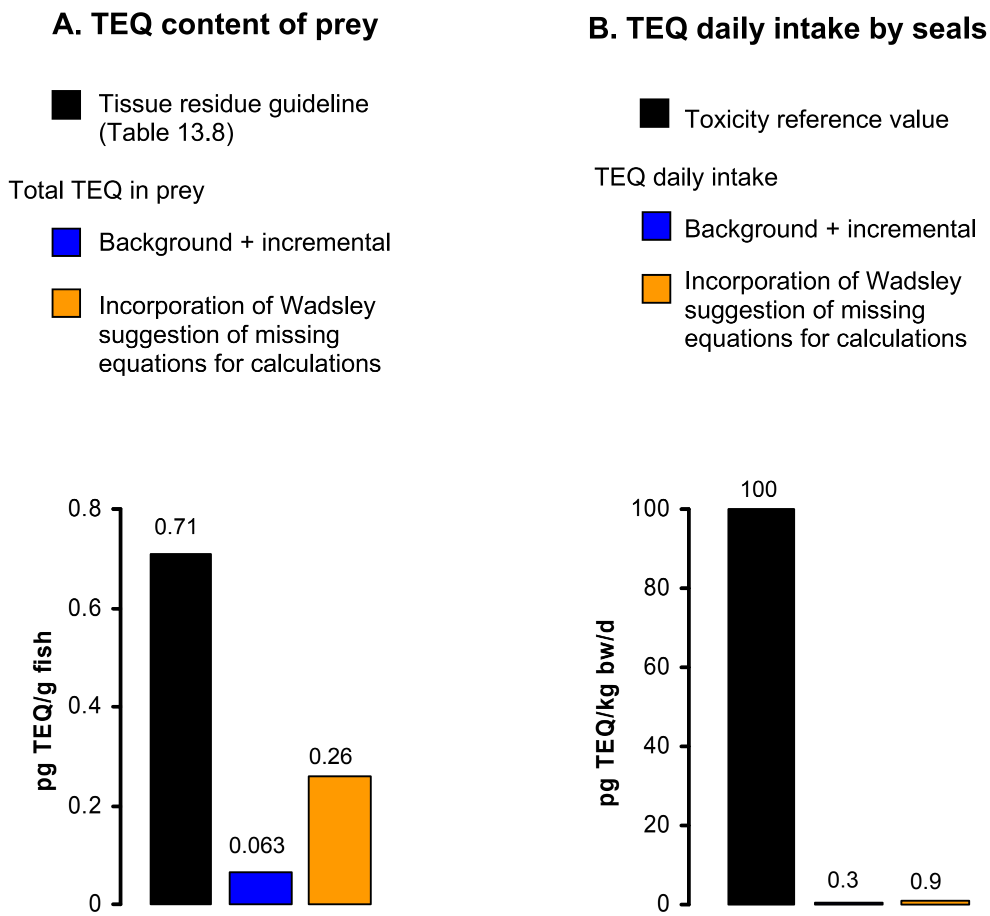

Figure 12: Summary of risk characterisation for dioxin exposures by seals.

A. Comparison of recalculated total TEQ in prey with tissue residue guidelines for prey of mammals (Canada CCME 2001). The total TEQ for prey in water at 1 in 100 effluent dilution includes background TEQ (dioxin + PCB) plus incremental dioxin TEQ from mill effluent.

B. Comparison of calculated total TEQ intake by seals with US EPA (1993) toxicity reference value for protection of aquatic mammals.

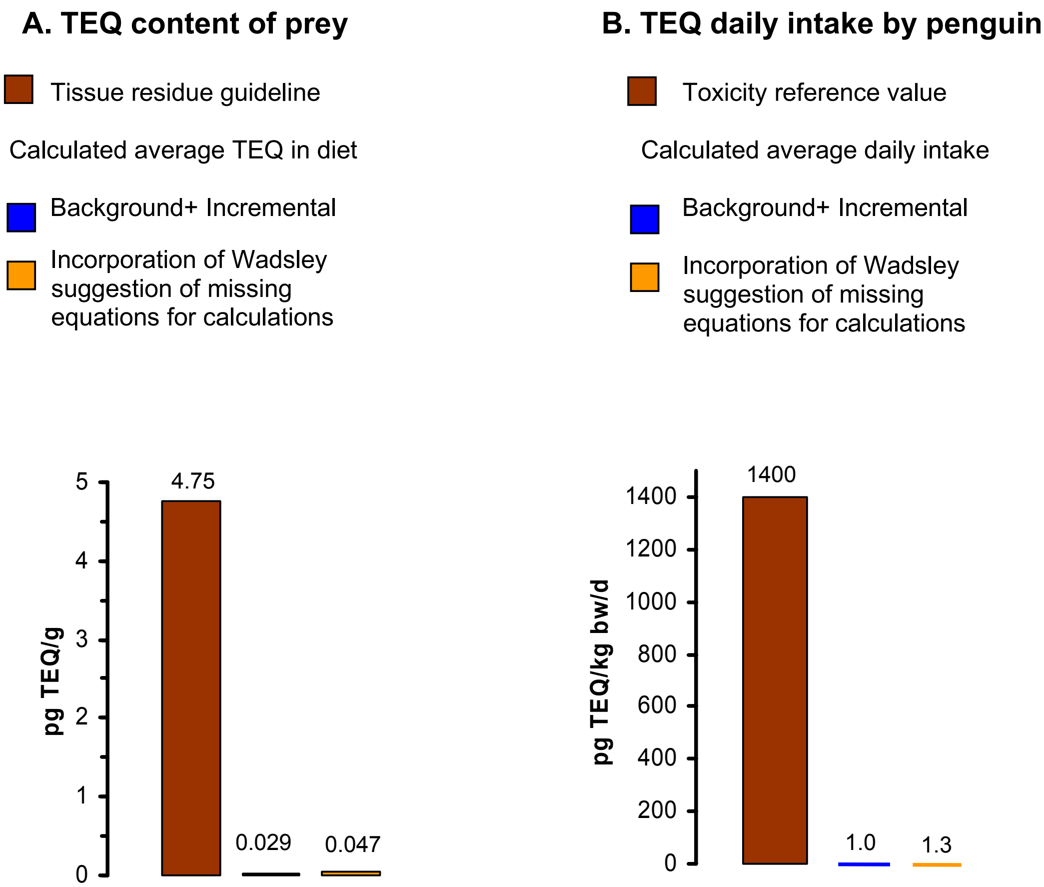

Figure 13: Summary of risk characterisation for penguins.

A. Comparison of recalculated total TEQ in prey with tissue residue guidelines for prey of birds (Canada CCME 2001). The total TEQ for prey in water at 1 in 100 effluent dilution includes background TEQ (dioxin + PCB) plus incremental dioxin TEQ from mill effluent.

B. Comparison of calculated total TEQ intake by penguins with US EPA (1993) toxicity reference value for protection of birds.

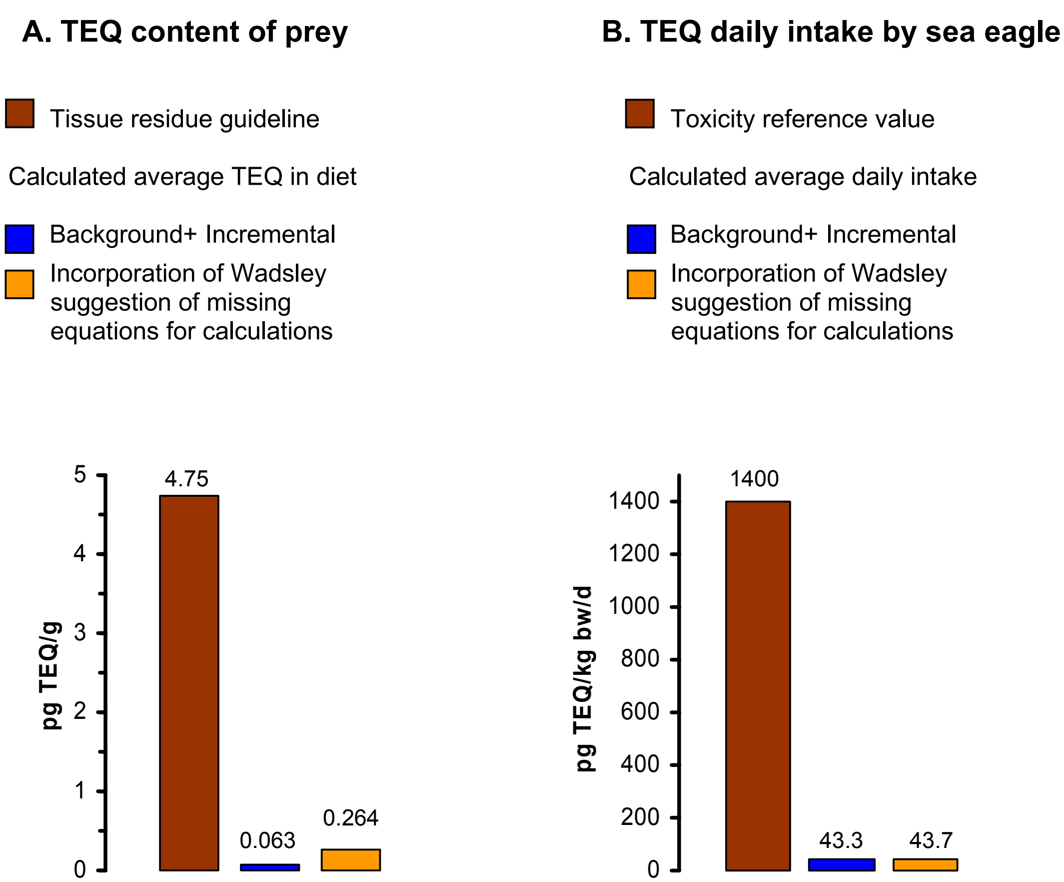

Figure 14: Summary of risk characterisation for White bellied sea-eagle.

A. Comparison of recalculated total TEQ in prey with tissue residue guidelines for prey of birds (Canada CCME 2001). The total TEQ for prey in water at 1 in 100 effluent dilution includes background TEQ (dioxin + PCB) plus incremental dioxin TEQ from mill effluent.

B. Comparison of calculated total TEQ intake by sea eagle with US EPA (1993) toxicity reference value for protection of birds.

6.2 Reality checks

Not withstanding the above we remind the reader that most emphasis in making a judgement on the impact of dioxins in effluent should be through appreciation of real world experiences, some of which have already been discussed in Sections 3, 4 and 5 above.

Dr Wadsley conducted his calculations assuming the effluent dioxin concentration would be at the allowed discharge limit. He claims the ensuing dioxin concentrations in fish would be far in excess of the limits set for human consumption. As previously pointed out, this assertion says the regulatory authorities have got the limits wrong. We do not believe this is the case.

To further place the fish dioxin concentrations that Dr Wadsley declares will occur into context we have compared his calculated concentrations with the measured dioxin concentrations in fish that occur after various dioxin loads have been discharged into different water bodies around the world. Although the comparison in Figure 16 is somewhat coarse, it nonetheless provides a reality check for the calculations undertaken by Toxikos and in the submission of Dr Wadsley. The comparison in Figure 16 illustrates that Dr Wadsley's calculations do not reflect reality.

The logarithmic scale of Figure 16 tends to obscure the actual difference between the observations of fish dioxin concentrations and the predictions of Dr Wadsley. To further facilitate evaluation of the case studies in Figure 16 with the predictions for fish around the Bell Bay mill outfall, the ratio of fish concentration to environmental load has been calculated for each scenario. This ratio on its own is not especially meaningful, nevertheless the comparison of the observed ratios in the case studies with the ratio of predicted dioxin outcomes by Dr Wadsley for fish near the Bell Bay outfall provides compelling evidence that the calculations undertaken in the submission of Dr Wadsley are not reflective of reality, or of what is likely to occur at the outfall.

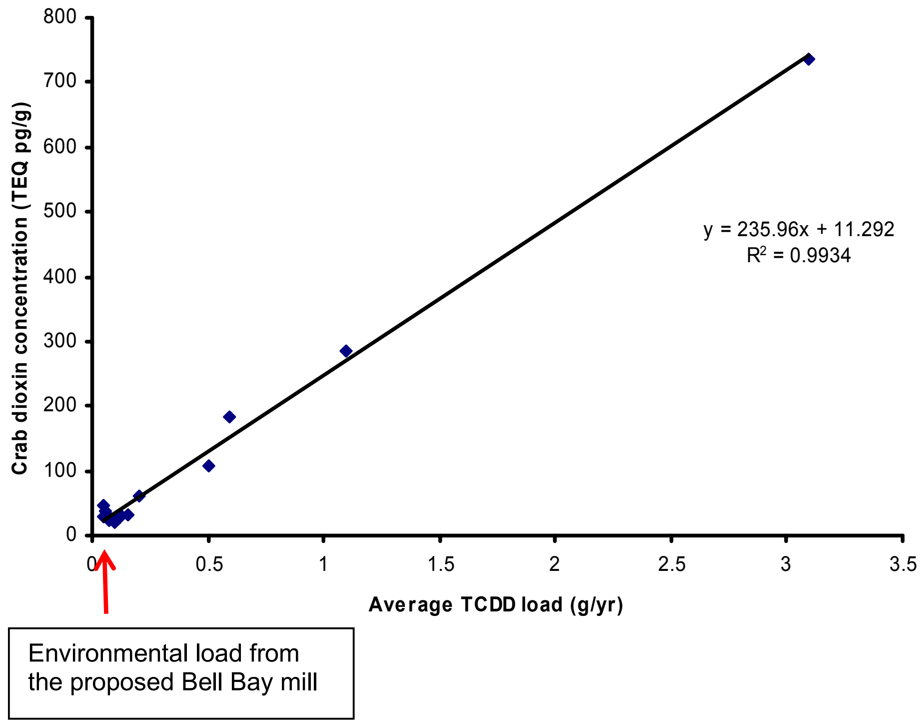

Figure 15: The relationship between the dioxin concentration in the hepatopancreas of Dungeness crabs and *dioxin effluent loadings* from coastal British Columbia pulp and paper mills.
Data is taken from the British Columbia Coast and Marine Environment Project (BCMOE 2005) and shows a strong correlation between the environmental dioxin load and the amount of dioxin in the animals.

The data indicates high environmental loads result in high concentrations in biota.
Low environmental loads are associated with low dioxin concentrations in biota.

Similar relationships have been observed for other aquatic animals.

For comparison the yearly environmental load from the proposed Bell Bay mill is 0.074 g/yr (indicated by the red arrow).

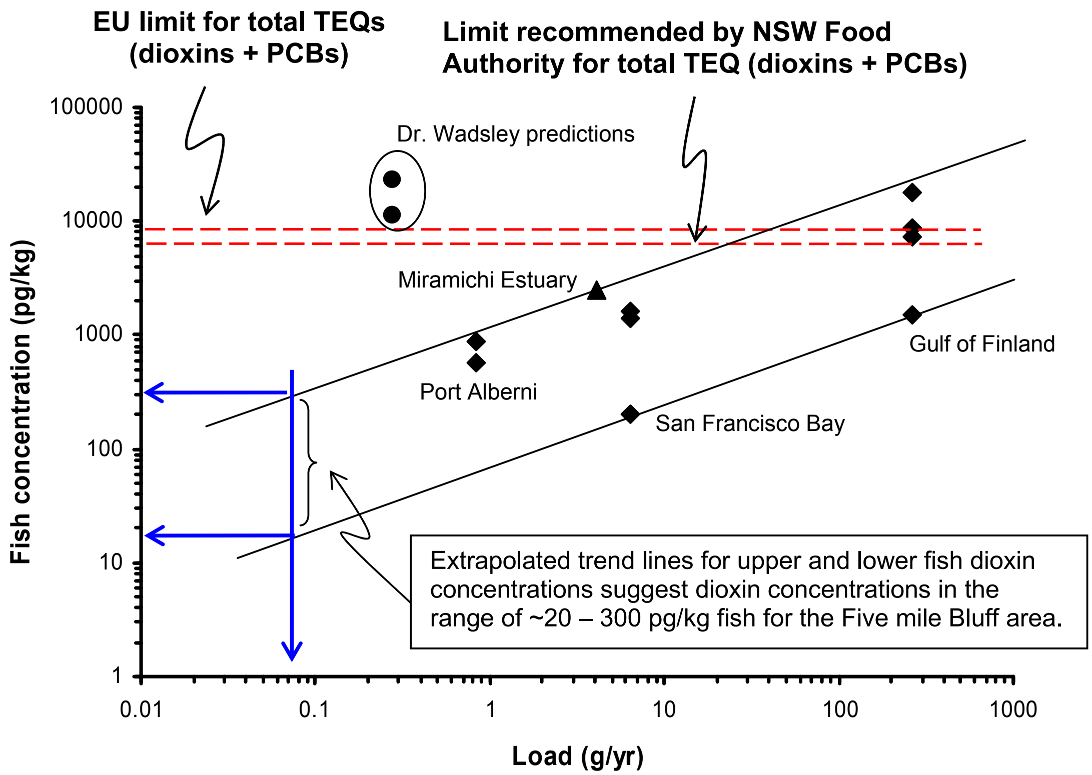

Figure 16: The relationship between the range of fish concentrations and environmental loads observed at various locations around the world.

A linear relationship between biota concentration and environmental load, as seen with the crab tissue in Figure 15, occurs for both the lower and upper measured fish concentrations. Extrapolation of these trend lines to intersect the dioxin load from the Bell Bay mill gives indicative expected concentrations in fish of approximately 20 – 300 pg TEQ/kg fish.

These rough predictions are consistent with the estimations of Toxikos in Table 2 and are 20 – 300 times less than the limit recommended by NSW.

In comparison the predictions of Dr Wadsley are far higher than would be expected from the trend lines and in fact are about 2 – 4 times higher than the NSW limit.

It is concluded Dr Wadsley is significantly over predicting dioxin concentrations in fish.

The data represented in this figure is provided in the technical appendix attached.

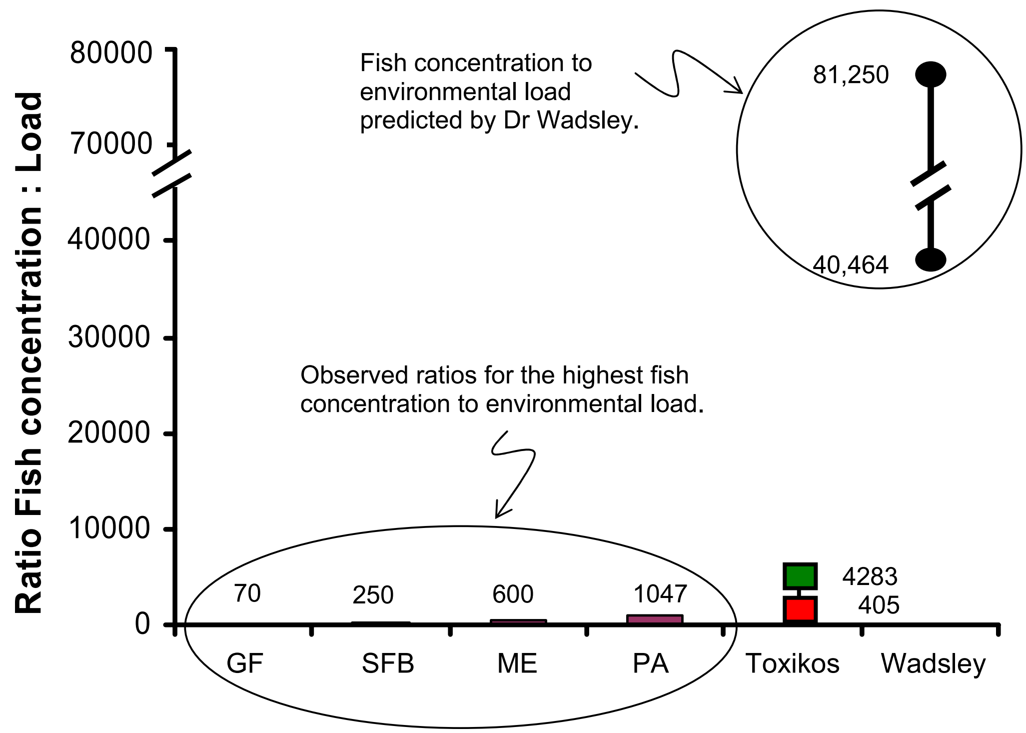

Figure 17: Comparison of the ratio of the highest measured mean fish concentration in Figure 16 to the environmental load with the predictions of Toxikos and Dr Wadsley.

It is self evident that the ratios of 40,000 to 80,000 from Dr Wadsley's work are significantly greater than what is observed in the field showing the extent of over prediction embedded in his calculations.

GF = Gulf of Finland   ME = Miramichi Estuary
PA = Port Alberni   SFB = San Francisco Bay

7. Extrapolation of calculations for broad area impacts

Dr Wadsley uses the US EPA Equation 5 -35 to calculate an average water body dioxin concentration (C_{wtot}) for the broader coastal environment [5] by using a dioxin load assumed to be equivalent to the RPDC limit (L_T = dioxin input from the effluent = RPDC limit x effluent flow rate). The equation determines the total water body concentration relative to the dioxin load entering the water body and three removal mechanisms; advection (i.e. the average volumetric flow rate of all water through the water body), volatilisation from the surface of the water, and burial of pollutant into the benthic sediment. The latter two processes are incorporated into an overall dissipation rate constant given the symbol k_{wt}. Essentially the water body concentration (C_{wtot}) is calculated by dividing the load (L_T) by a mathematical function that describes the three removal mechanisms.

These calculations have been undertaken by Dr Wadsley to imply the area of the 1 in 100 dilution is much larger than shown by the hydrodynamic modelling and as assumed by Toxikos (the claim is that it is approximately $100km^2$ with an average depth of 20m). However the calculations in the submission do not take into account removal of dioxin by mechanisms other than “flushing” (i.e. advection), even then there is inconsistency within the submission of Dr Wadsley in how this is done. In the main submission (pages 16 – 17) only the assumed flushing rate for the whole of Bass Strait (more on this later) was used in the calculations, this lead to the claim that the 1 in 100 dilution area was underestimated by a factor of 790 times. In the technical review (presented as an appendix to the main submission of Dr Wadsley) the flow of effluent is added to the assumed Bass Strait water flow. This latter ‘audit’ of the Toxikos risk assessments claimed the 1 in 100 dilution volume was underestimated 370 times. Neither of these calculations by Dr Wadsley took account of removal by volatilisation or benthic burial.

The starting point of Dr Wadsley’s calculation is that the entire effluent plume involves a water body of area of $100km^2$ and average depth 20m. In the US EPA equation 5-35 calculation Dr Wadsley assumes the overall water body dissipation rate (k_{wt}) of dioxin from the water body is zero; this is based on the assumption that volatilisation of dioxin from the surface of the water is negligible. However the overall dissipation rate constant is the sum of dioxin loss through volatilisation plus loss via benthic burial, the latter is not zero. Even a small dissipation rate

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[5] Section I of Wadsley main submission dated 5 June 2007 and Section 4 of Wadsley review dated June 2007.

constant (k_{wt} in US EPA Equation 5-35) will have a reducing impact on the calculated total average concentration in the water body (C_{wtot}) because the environmental load (L_T) is divided by the sum of the volume of water passing through the water body and the product of k_{wt} and the area of the water body, which is assumed by Dr Wadsley to be large (1.1×10^8 m^2).

The calculation of C_{wtot} by Dr Wadsley is further inflated by his assumption of very low flushing of the local receiving water around 5 Mile Bluff, assumed by Dr Wadsley to be only twice per year. Hydrodynamic experts advise that it is incorrect to assume the turnover rate of water in a local small portion of a very large body of water such as Bass Strait, is the same as for the large water body. Flushing of the local water is driven by local conditions as well as the macro factors affecting the whole of Bass Strait (see responses from the GHD on comments from submitters on the hydrodynamic modelling).

For an area of 110 km^2 and depth of 20m Dr Wadsley calculates[6] the average concentration in the water column to be 0.072 pg/L this concentration is larger than a 1 in 100 dilution of the effluent (i.e. the DV_{100} concentration of 0.034 pg/L) and obviously cannot be correct since the hydrodynamic modelling shows greater than 1,000 fold dilutions being achieved within 1 km, and dilutions of tens of thousands at approximately 6 km plus. Common sense also orders that at long distances from the outfall, effluent dilution must be much larger than 100 times, even allowing for build up to achieve steady state conditions (see the reality check below).

It should be noted that the US EPA equations assume a steady state situation and therefore reflect the situation after long term operation of the mill. While it is true that the hydrodynamic modelling did not specifically model dioxins, the dilutions used in the marine impact assessment do take into consideration the build up effects of continuous mill operation.

Reality Check

The fact that Dr Wadsley's calculations are incorrect is illustrated by a reference reality check with the Baltic Sea. The Baltic Sea has a low water exchange; a total exchange is estimated to take 20 – 25 years and for many decades the Baltic Sea has received very high environmental loads of dioxins, of the order of 100's g/yr, from a variety of industrial sources. Jenssen (2003) reports the dioxin water concentration in the Baltic Sea has been measured at 2.8 fg/L (i.e. 0.0028 pg/L). In comparison Dr Wadsley calculates the dioxin concentration in the wider waters (110 km^2) receiving the Bell Bay effluent to be 0.072 pg/L, i.e. higher than in the Baltic Sea; this is despite an assumption for the Bell Bay mill calculations of 2 flushes per year (10 less than the

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[6] p16 of 5 main June 2007 submission.

Baltic Sea) and an assumed load[7] of 0.3 g/yr (some hundreds of times less than the load to the Baltic Sea). Dr Wadlsley's calculations do not reflect reality.

Use of the regulatory limit for the calculations

Dr Wadsely claims that the dioxin concentration used for risk assessment purposes should be at least the environmental guideline limit established by the Tasmanian RPDC (2006) of 13 pgTEQ/L. (about 0.3 g TEQ/yr). The mill engineers conservatively consider the concentration will be about 4 times less than the discharge limit and the information in Section 3 shows it will likely be less than this. To support his position he quotes US EPA guidelines for air quality models used to assist the process of establishing air emission limits (US EPA 2005a). These guidelines are not applicable to site specific health or ecological risk assessment. Dr Wadsley overlooks that the US EPA guidance document used by Toxikos and by Dr Wadsley as the source document for the equations used in the risk assessments states:

*"We encourage you to use existing and site-specific information throughout the risk assessment process in order to properly evaluate actual regulated operations" (US EPA 2005b Ch 1, pg 1-*8).

The use of site specific information is also recommended by both Australian and US EPA risk assessment guidance documents (for example enHealth 2004, USEPA 1997, USEPA 1999). It is neither necessary nor appropriate to conduct the type of risk assessment undertaken in the Draft IIS and MIA using the effluent regulatory limits, such an assessment only tests the regulatory limit. No such advice has been found for other types of emissions or for ecological risk assessments.

8. Monte Carlo analysis

The use of Monte Carlo techniques to address measurement variability and parameter uncertainty are common in exposure estimations of health risk assessments. However it is extremely important that the probability density functions for the chosen parameters are justified as being applicable to the scenario under investigation. The enHealth council of Australia has articulated a series of criteria to ensure the results of Monte Carlo techniques can be evaluated and reproduced (enHealth 2004).

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[7] The load Dr Wadsley assumes is that associated with the RPDC limit for dioxin concentration in effluent.

So as not to obfuscate information and introduce unnecessary complexity into risk assessments, enHealth (2004) advocate use of the Monte Carlo techniques only where exposure pathways are likely to be significant. The work in the Draft IIS and MIA show exposure of humans or wildlife to dioxins in effluent is not significant. This is consistent with the experience of well run modern ECF pulp mills (Sections 3, 4 and 5). Therefore application of Monte Carlo techniques is not warranted.

The principles of good Monte Carlo practice outlined by enHealth (2004) include recording all formulae, detailing sensitivity analyses to identify relevant and important input variables, provision of detailed information about input distributions, and how these distributions capture and represent both variability and uncertainty. Measured data for the scenario should be used to test the relevance of input parameter value distributions, there should also be a description of the methods by which measured data were gathered and used to derive probability distributions for the parameter values. The numerical stability of central moments should be assessed and details provided for statistical quality of the random number generator. When interpreting the results detail of the limitation(s) of the methodology for the application at hand should be provided. These requirements are recommended to ensure adequate information is provided to enable review of the assessment, enHealth (2004) note this may require the provision of the software (and underlying formulae) and data. The work done by Dr Wadsley does not meet these criteria.

In relation to the Bell Bay effluent outfall perhaps the most import requirement of enHealth (2004) is demonstration of the relevance of the probability density function data to the site. Commentary has already been provided showing the background sediment dioxin data and organic carbon values used by Dr Wadsley are not applicable to the site. Dr Wadsley does not apply the Monte Carlo technique to fish lipid and or BSAF but rather uses point values [8] (as was done in the Draft IIS and MIA).

It is unclear how the Monte Carlo simulations in the submission that gave the average concentrations in salmon accounted for the progression of effluent dilution as the plume leaves the immediate area of discharge. It seems the calculations were performed for a 1 in 100 dilution and do not address other concentrations of dioxins in the water body. However Dr

[8] On page 14 of the main submission Dr Wadsley implies a BSAF of 0.433 would be a suitable alternative for calculating dioxin uptake by fish. This is an average BSAF derived from a database prepared by a US Army research division and contains 97 BSAF values (Clarke et al. 2004). Most of these BSAFs are for invertebrates from freshwater environments and not for fish in marine environments. In fact there are only 4 values for fish, none of which are marine species.

Wadsley extrapolates the calculations to cover the entire volume of receiving water even though at its outer edges effluent dilutions are 10,000 to 16,000 fold. At steady state conditions in areas outside of the 1 in 100 zone, dioxin concentrations in sediment and fish cannot be as high as supposed by Dr Wadsley.

9. Risk to wildlife and human health

Wadsley claims that because of the issues he raises in relation to the calculations of dioxin uptake by fish in the Draft IIS and MIA, the conclusions of the risk assessments for seals, little penguins and sea eagles, and the conclusions of other consultants that rely on this information are in error. These allegations are incorrect. Relative to the appropriate guidelines the information in Section 6, derived using site specific information and incorporating the calculation suggestions of Dr Wadsley, clearly shows there is negligible impact on these species. Furthermore there is a large gap between the estimated dioxin exposures of each of the species and the relevant guideline. These large 'margins of exposure' provide additional assurance that the very low amounts of dioxin in the effluent will have no impact on the viability of these species.

Based on effluent only being diluted 100 fold and using site specific data (refer Table 1) as well as the suggestions of Dr Wadsley, ingesting fish caught at the outfall does not present an unacceptable health risk. The maximum total monthly dioxin intake for adults and children is not altered by the new calculations from that previously calculated. The conclusions of the Draft IIS that most of the calculated exposure is associated with background intakes and that the dioxin concentrations in discharged mill effluent do not pose a health risk to people consuming fish caught in the vicinity of the outfall still stand. These conclusions are based on an assumption that the person only consumes fish from the outfall, that the person is someone eating fish at the highest rate reported for Tasmanians, and is an individual who already has a background intake of dioxins at the highest level estimated for Australians.

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Appendix 1: Technical background information.

Background information for case studies on the relationship of environmental dioxin load and fish concentrations.

Information has been sought from the scientific and regulatory literature for determining the relationship between the load of dioxins (g TEQ/year) released into coastal environments and amounts of dioxins (PCDD/Fs) measured in fish caught in the same environments. No information was located that described fish TEQ concentrations associated with low environmental releases of dioxins into coastal waters such as will occur with the proposed Bell Bay mill. This is probably because low environmental loads of dioxins are not regarded as being of concern (see Section 4). The data described below relates to water bodies that were receiving large quantities of PCDD/Fs prior to fish sampling and measuring PCDD/F TEQ concentrations in the fish.

Care has been taken to match estimates of coastal water body dioxin TEQ loads to both the timing of fish sampling and the age of the fish sampled, i.e. estimates of water body TEQ load are for periods just preceding, and during, the years that fish resided in the affected water body. Dioxin fish concentrations are as TEQ for PCDD/Fs only; PCB TEQs are not included as these substances are not emitted in the effluent of pulp mills but are pollutants arising from other industrial activities.

The case studies below illustrate the correlation between dioxin TEQ loads to coastal water bodies and the amount in fish for a range of disparate environmental locations (Figure 16). The fact that these locations are not similar strengthens, rather than weakens, the observed collective association which is similar to that observed for crabs (Figure 15). Since the observed associations span a number of environmental conditions (e.g. different sediment and water organic carbon contents, different fish with differing lipid levels), the associations can be broadly extrapolated to the environmental load and expected fish concentrations at the Bell Bay mill outfall location. This provides a, albeit rough, reality check on the calculations undertaken by Toxikos and others for fish dioxin TEQ concentrations at steady state environmental concentrations around the Bell Bay mill outfall.

CASE STUDY 1

Miramichi Estuary (New Brunswick, Canada)

Couillard and Nellis (1999) investigated the concentrations of dioxins and furans in mummichog fish immediately down stream[9] of a bleached Kraft mill in Miramichi Estuary, New Brunswick, Canada. Between 1988 and 1995 the mill discharged effluent containing 100 ppq TCDD and 1,000 ppq TCDF (total PCDD + PCDF = 200 pg TEQ/L) [10]. In May 1993 the mill partially substituted chlorine with chlorine dioxide and in 1995 TCDD concentrations were 5 ppq (5 pg TEQ/L) and TCDF to 13 pg (i.e. 1.3 TEQ/L).

Mummichog is a small- sized fish that lives for up to 5 years, they feed on benthic insects, crustacean and invertebrates; they also have a sedentary existence with a quite limited range. These characteristics, i.e. reasonable life span, benthic feeding and restricted range, render the mummichog reliable indicators of contamination at their site of capture. Fish (flesh and skin) analysed for PCDD/F were 3 years old and had an average lipid content of 1.1%. Fish were sampled in May – June 1995; hence the period which is of interest for environmental TEQ load is from 1991 through to early 1995.

The PCDD/F TEQ in male and female mummichog was respectively 2.88 ± 0.33 pg/g and 2.01 ± 0.32 pg/g (i.e. 2,880 pg TEQ/kg and 2,010 pg TEQ/kg, average 2,445 ± 320 pg TEQ/kg).

In 1994 the mean flow of effluent discharged into the estuary was 72,923 m^3/d Couillard and Nellis (1999), this is taken to be the average flow rate for the period of interest. Thus the effluent flow rate is approximately 7.3×10^7 L/d which at a concentration of 200 pg TEQ/L is an environmental load of 1.46×10^{10} pg TEQ/d (or 1.46×10^{-2} g TEQ/d). If the mill operates for 365 days per year the environmental load is 5.3 g/yr. This was the situation for 1991 and 1992. In May 1993 dioxin formation decreased with the introduction of chlorine dioxide and was measured in 1995 as 1.3 pg TEQ/L, this is 0.35 g TEQ/yr. Thus over a 2 year period the environmental load decreased from 5.3 g TEQ/yr to 0.35 g TEQ/yr. For the purpose of estimating environmental load from the mill from May 1993 through to June 1995 we have assumed it was the average of the 1992 and 1995 loads, i.e. (5.3 g TEQ/yr + 0.35 g TEQ/yr) ÷ 2

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[9] Site M1 of the collection sites used in Couillard and Nellis (1999).
[10] 100 ppq TCDD/L = 100 pg TEQ/L and because the toxic equivalency factor of TCDF relative to TCDD is 0.1, a concentration of 1,000 ppq TCDF/L = 100 pg TEQ/L. Hence the total TEQ is 200 pg/L.

= 2.8 g/yr. Thus the average yearly load for the period of interest is the average for 1991, 1992, 1993, and 1994, i.e. (5.3 + 5.3 + 2.8 + 2.8) ÷ 4 = 4.1 g TEQ/yr.

Summary:

- Fish = Mummichog:

  Lipid content = 1%

  Age = 3 years (lifespan up to 5 years)

  TCDD/F TEQ in early 1995 = 2,445 ± 320 pg TEQ/kg wet weight
- Average environmental load for 1991 – 1994 (all from a bleached Kraft mill) = 4.1 g TEQ/yr.
- Ratio of fish concentration to environmental load (F:L) = 2445:4.1 ≈ 600

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CASE STUDY 2

San Francisco Bay

San Francisco Bay is an estuary draining 60,000 square miles of hinterland. The Bay is relatively shallow, it is mostly approximately 14 ft deep but at its deepest is 300 ft. As contribution to the San Francisco Estuary Regional Monitoring program for Trace Substances the San Francisco Estuary Institute collected fish from various parts of the Bay and measured the dioxin TEQ content of muscle plus skin (Greenfield et al. 2003).

Table 1 below summarises the results for fish that showed measurable levels of PCDD/F in their flesh.

Table A1: Summary of fish statistics and dioxin TEQ content

Fish	Age at sampling time (yr) [b]	Length of sampled fish (cm)	% Lipid	Median TEQ (pg/kg wet weight) [a]
Jacksmelt	7	27	1.4	200
Shiner Surfperch	2 -3	11	2.6	1,400
Striped Bass	5	52	1.1	200
White Croaker	5 - 6	27	4.3	1,600

[a] TEQ data is for flesh plus skin, except for Striped Bass which is flesh only.
[b] Information determined from fish length as function of age from California Department of Fish & Game (CDFG 2001, 2007 a, b, c).

San Francisco Bay receives dioxins from a number of sources; in order of highest to lowest the contributions are watershed/stormwater, air deposition, refinery effluent, Sacramento River and municipal effluent. In 1998 the total estimated load to San Francisco Bay was 6.4 g TEQ/yr, in 2004 the load was re-estimated at 9.1 g TEQ/yr (Connor et al. 2004). Since fish were sampled in May and June 2000, the timing of the environmental load is from approximately 1990 to 1999. This is taken to be 6.4 g TEQ/yr.

Using the highest fish concentration (1,600 pg TEQ/kg for White Croaker) and an average yearly load of dioxins of 6.4 g TEQ/yr the fish concentration:load ratio is 1600:6.4 ≈ 250.

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CASE STUDY 3

Gulf of Finland (Baltic Sea)

The Gulf of Finland is surrounded by Finland, Russia and Estonia. It is a relatively small water body of 1,110 km^3 but has a catchment area of 30,000 km^2. There are three main rivers discharging into the Gulf. The highest PCDD/F levels in the Baltic Sea have been reported along the Finnish coast, where at least two notable industries have been responsible for releasing large amounts of PCDD/F into the Gulf. Vinyl chloride monomer (VCM) and chlorophenol manufacture. The latter was located on the Kymijoki River and PCDD/F impurities in the chlorophenol products were as high as 860 µg TEQ/kg (Isosaari et al. 2002, Verta et al. 2007).

Kiviranta et al. (2003) have measured PCDD/F in herring caught in the Gulf of Finland in May – June in 1993, 1994, and 1999. Catch locations where along the length of the Finnish coast and for 1993 – 1994 pools of 9 – 17 fish were made according to the age of the fish (i.e. 2, 3, 4, 5, 6, 7, and 8 - >15 yrs). For these age groups mean TEQ concentrations increased from 1,500 to 18,000 pg/kg wet weight. Lipid concentration showed little variation for 2 – 7 year old fish being about 2%, however mean lipid content in the 8 - >15 yrs was 5.6%. Fish caught in 1999 were divided into two groups, small and large fish (these correlated roughly to < 7yrs and ≥ 8 yrs old); the mean lipid content was respectively 2% and 2.4% and the mean TEQ concentration 7,200 pg TEQ/kg and 8,800 pg TEQ/kg.

Using spatial distribution of PCDD/F in sediment cores and modelling of the temporal accumulation of PCDD/F, Isosaari et al. (2002) have estimated the post 1960 loads of PCDD/F to the Gulf of Finland. For the overall area correlating to that from which herring were sampled, the average mass load of PCDD/F in 1986 to1997 was estimated to be 37.4 kg/yr. Since the average ratio of TEQ to PCDD/F total mass in the post 1960 sediment cores was 0.007 ± 0.0016, the average yearly load of PCDD/F as TEQ was 37.4 kg dioxin/yr x 0.007 TEQ/kg dioxin = 262 g TEQ/yr.

Summary:

- Fish = Herring

  1993 – 1994 sampling for 2 – 18+ year old fish:

  Lipid content ≈ 2 – 5.6%

  Mean PCDD/F = 1,500 to 18,000 pg/kg ww.

  1999 sampling for small and large fish:

  Lipid content = 2 – 2.4%

  Mean PCDD/F = 7,200 and 8,800 pg TEQ/kg ww.

- Estimated environmental load for 1986 to1997 = 262 g TEQ/yr.
- Using the highest fish concentration of 18,000 pg TEQ/kg 8 - >15 yrs and an average yearly load of dioxins of 262 g TEQ/yr the fish concentration:load ratio is 18,000:262 ≈ 70.

References:

Isosaari, P., Kankaanpää, H., Mattila, J., Kiviranta, H. Verta, M., Salo, S. And Vartiainen, T. (2002). Spatial distribution and temporal accumulation of polychlorinated dibenzo-*p*-dioxins, dibenzofurans and biphenyls in the Gulf of Finland. Environ. Sci. Technol. 36: 2560 – 2565.

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CASE STUDY 4

Port Alberni (British Columbia, Canada)

Vermeer et al. (1993) measured PCDD/F concentrations in fish of the Somass River Estuary downstream of the Port Alberni Pulp and Paper Mill. Fish (Pacific staghorn sculpins and three spin sticklebacks 3 – 5 cm long for each species) were obtained in April 1991. Both fish are demersal and benthic feeders. Highest concentrations of PCDD/F (880 pg TEQ/kg) were found in stickleback, concentrations in sculpin were 580 TEQ/kg. Specific information on tissue analysis was not provided in Vermeer et al. (1993), however since the study was primarily investigating sources of PCDD/F in local birds it is likely the PCDD/F data relates to whole fish. Sticklebacks have a lifespan of about 3-4 years and grow to a maximum length of 11 cm but are usually around 4 cm, they are a permanent all-the-year resident wherever it is found (Bigelow and Schroeder 1953, MDFW 2003). In contrast sculpin live to about 10 – 15 years with the largest recorded length of 17 inches (43 cm) (MSAP 2003, CDFG 2007).

The effluent loading of 2,3,7,8-TCDD to the receiving water was measured in 1991 to be 0.65 mg/d. Although measurements at Port Alberni for previous years were not available other British Columbian pulp mills achieved an average reduction of 2.3 fold between 1990 and 1991, and 4.6 fold between 1989 and 1991. Assuming the loading for 1988 was the same as for 1989 the average environmental loading for the 3 years prior to fish collection (1988, 1989, and 1990) can be determined by applying the above factors to the 1991 measured load; i.e. the average load for the nominated years is approximately [(4.6 x 0.65 mg/d) + (4.6 x 0.65 mg/d) + (2.3 x 0.65 mg/d)] ÷ 3 = 2.3 mg TEQ/d, this is the same as 0.84 g/yr.

The fish concentration to load ratio is thus 880:0.84 ~ 1050.

Summary:

- Fish = Stickleback, lifespan approximately 3-4 years, sampled early 1991.
- Extrapolated annual average environmental load for 1988 to 1990 is 0.84 g TEQ/yr.
- The fish concentration to load ratio is thus 880:0.84 ~ 1050.

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Eastern Australian Salmon - Summary

Australian salmon inhabit continental shelf waters, including estuaries, bays and inlets. They school in shallow, open coastal waters, and can move over reefs in depths just sufficient to cover their bodies (McNee et al. 1993). Spawning takes place between Lakes Entrance and Bermagui between November and February. Larvae and first year eastern Australian salmon juveniles drift and migrate from the spawning grounds off south-eastern Australia to Tasmanian and Victorian waters during autumn and winter, initially under the influence of the south-flowing East Australian Current (McNee et al. 1993). The juvenile salmon feed on zooplankton and epibenthic species of fish, squid, crustacea and polychaete worms. Adults feed mainly on zooplankton, in particular on small crustacea (euphausiids) (McNee et al. 1993). Juveniles are found in Tasmania over soft substrates in sheltered coastal waters (i.e. river mouths and off beaches). Juveniles move away from Tasmania at age of 2+ years (DPIW 2007) and thus salmon older than 2 years are not found in Tasmanian waters (Stanley 1978). Large (60-90cm) adult Australian salmon are rarely caught in Tasmanian waters (DPIW 2007). Australian salmon mature at 4 years when they are around 40 cm long, they can grow to 90 cm in length and over 4 kg in weight, on reaching this size they are around 10 years old (DPIW 2007, McNee et al. 1993). Reported lipid content for Australian salmon is given as 1.1%, 1.3% and 6.2% (Yearsly et al. 1999, FRDC 2007, Gatehouse 2004). The high value of 6.2% is for a composite of 5 adult fish collected from the Derwent River as part of the National Dioxin Program, the other measurements are the average of 5 – 10 animals obtained from commercial fishermen or seafood markets.

Since the lipid content of fish increases with age (Kiessling et al. 2005), it is appropriate to use the lower end of the above measured lipids when evaluating the potential for uptake of dioxins by salmon visiting the Five Mile Bluff region. It should also be noted that in waters around the Bell Bay mill outfall likely to be visited by salmon, effluent will be diluted at least 1,000 times. In addition it is quite unlikely that the sediment biota accumulation factor (BSAF) of 0.2 reported by Gatehouse (2004) for salmon in the Derwent River and with lipid content of 6.2% will be realised. Nevertheless an alternative BSAF for salmon could not be located and this has been used as a default in the calculations.

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