

18 April 2007

Gunns Limited  
PO Box 572  
Launceston Tasmania 7250

Our ref: 41/16384/00/356677  
Your ref:

Attn: Calton Frame

Dear Calton,

## **Pulp Mill IIS Response to Review of Hydrodynamic Reports**

We have reviewed the comments made in Patterson Britton's letter to the Department of Environment and Water Resources (dated 30<sup>th</sup> March 2007). We welcome this third party review, and offer our response to each item, focussing on where specific queries have been raised.

We note that over half of the letter provides either a generic overview of relevant principles, or provides a level of support for what GHD has undertaken to date. In particular, the support for the following three items is of significance:

- ▶ Use of Plumes software for near field model assessment (support for software and technique)
- ▶ Method of distributing near field plume into far field model (over 18 "cells")
- ▶ Validation of model against non-concurrent datasets.

Our responses are based on reference to a range of documents, including:

- ▶ Our reports and work to date,
- ▶ existing literature;
- ▶ previously completed but unreported model runs; and
- ▶ similar work undertaken for projects unrelated to the proposed pulp mill.

All responses are arranged in accordance with Patterson Britton's (PB) letter of 30<sup>th</sup> March 2007.

### **1 Description of Model**

#### **1.1 Near Field Model**

We note supporting comments by PB. No response is required.

#### **1.2 Interfacing of Near and Far Field Models**

As for Section 1.1.

#### **1.3 Far Field Model**

Supporting comments with respect to grid size are noted.



### **1.3.1 Simulation of Bass Strait Hydrodynamics**

No response is required in relation to the comparison of model results to data, and the ability of the model to reproduce / simulate the movement of water in Bass Strait.

However, a query has been raised as to whether East Coast Lows should have been specifically modelled. The following comments are therefore offered in relation to:

- ▶ the capability of the model to represent low-frequency sea-level motion, and
- ▶ the need to model East Coast Lows for this part of Bass Strait.

#### **Response**

Using both a numerical model and collected data, Middleton and Viera (*The Forcing of Low Frequency Motions within Bass Strait*, Journal of Physical Oceanography, Vol. 21, pp. 695-708, 1991) found that low-frequency motion within the Strait is the product of both local wind forcing and the incidence of coastally trapped waves from the Great Australian Bight. Their analysis showed that:

- ▶ at the south-west corner of the Strait, wind stress is the larger contributor to sea-level variability except for very low-frequencies where interference from the effects of coastally trapped waves along the Victorian coast may have an impact; and
- ▶ low-frequency sea-level variability should essentially vanish at the south-east corner of the Strait.

This evidence was interpreted by GHD as indicating that:

- ▶ the effects of low-frequency sea-level variability are more pronounced along the northern coast of the Strait;
- ▶ modelling of low-frequencies may be excluded from a reasonable first-order approximation of forces governing the hydrodynamics along the Tasmanian coast without necessarily excluding the possibility of undertaking additional hydrodynamic simulations including low-frequency motion during design stages of the project;
- ▶ ensuring conservatism in the process of assessment of the extent of the mixing zone (by potentially reducing the energy levels in the receiving waters).

It is also noted that:

- ▶ The effects of low-frequency sea-level variability are best integrated in the investigation when applied to the entire Bass Strait covered by the parent B grid model at 1 km spatial resolution;
- ▶ The B grid model used for the Gunn's project has been run for a separate, unrelated project with the inclusion of these low frequency effects (the project focussed on hydrodynamics and transport investigations along the Victorian coast);
- ▶ Results from a run focussing on the Victorian coastline (i.e. completed for another project) and inclusive of low frequency sea-level variability have been extracted at a location near Devonport (depth of approximately 19 m with respect to MSL). These results have then been compared to tide-only results (refer Figure 1). The effect of winds on hydrodynamics is not part of this comparison.
- ▶ No attempt has previously been made (by GHD) to quantify the impact of the low frequency sea-level change on the numerical results for these sets of runs. However, the results (i.e. from the unrelated project) have provided justification of the approach adopted for the Pulp Mill IIS study.

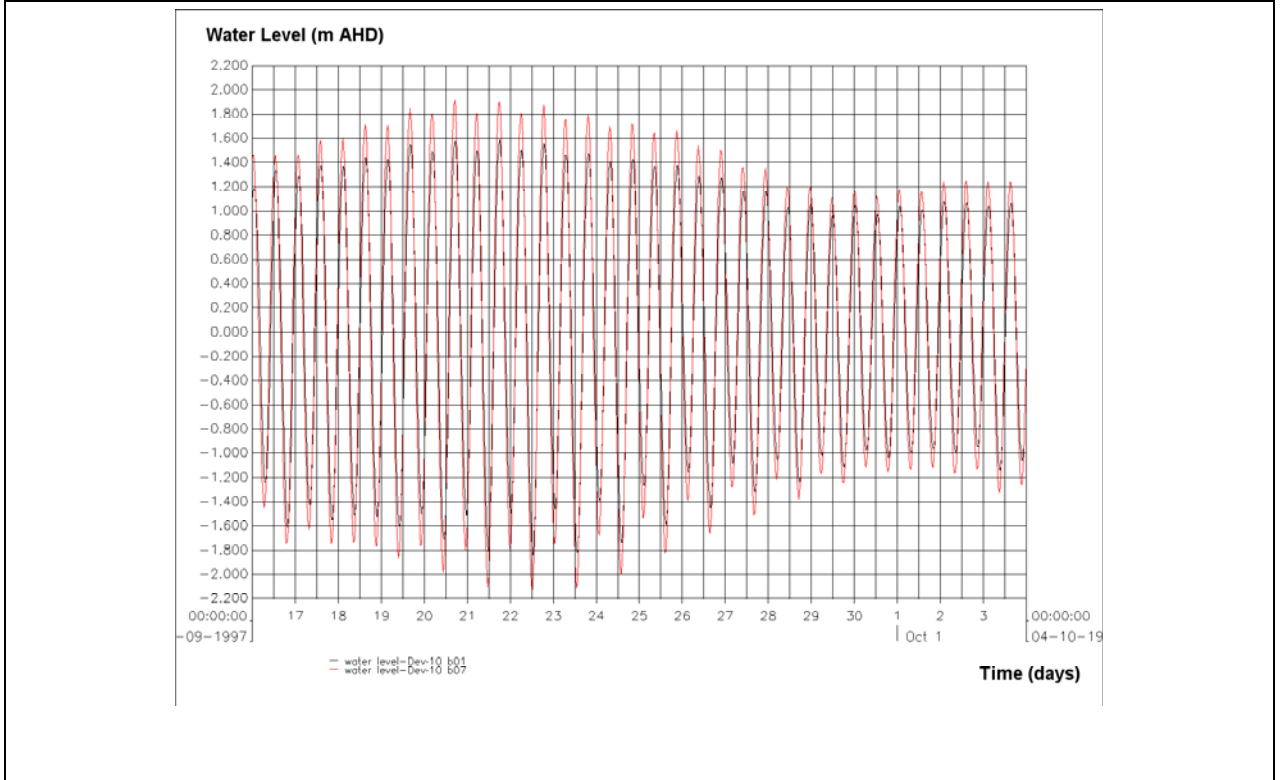


Figure 1(a) Water Level Comparison

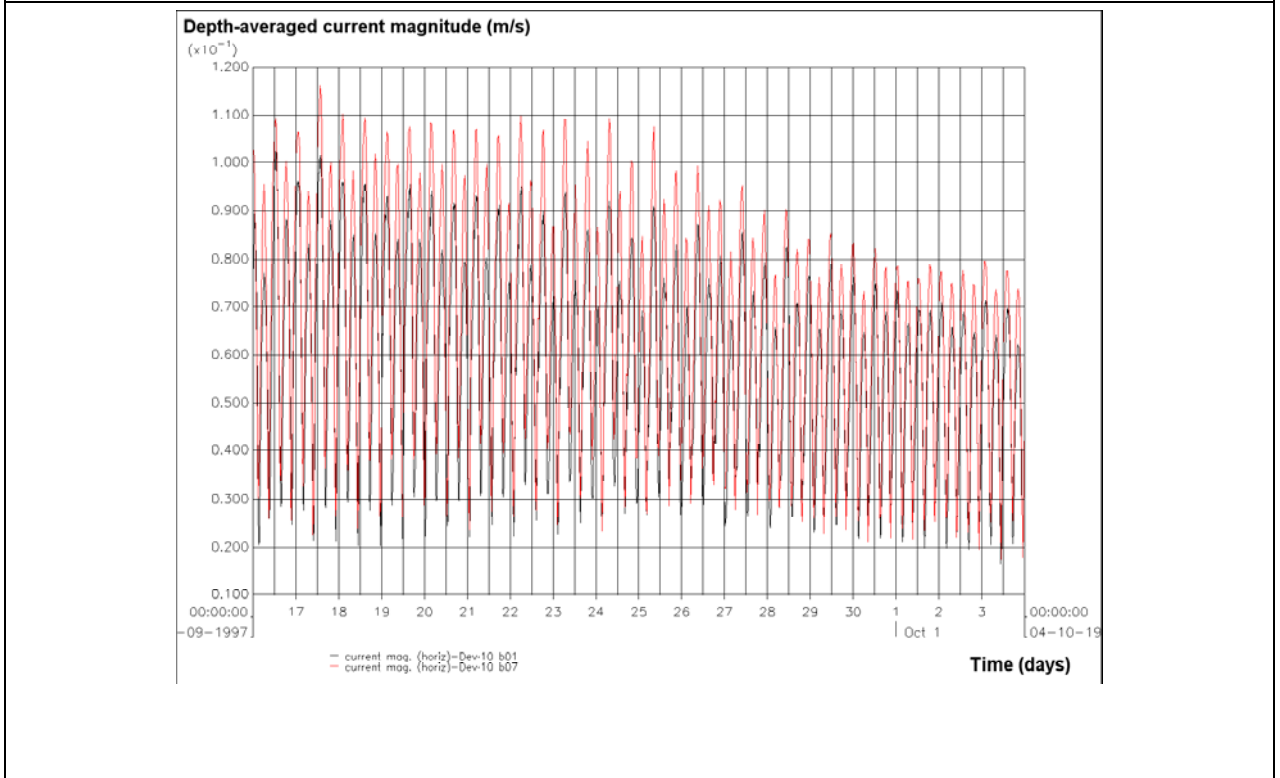


Figure 1(b) Comparison of Depth-Averaged Current Magnitude

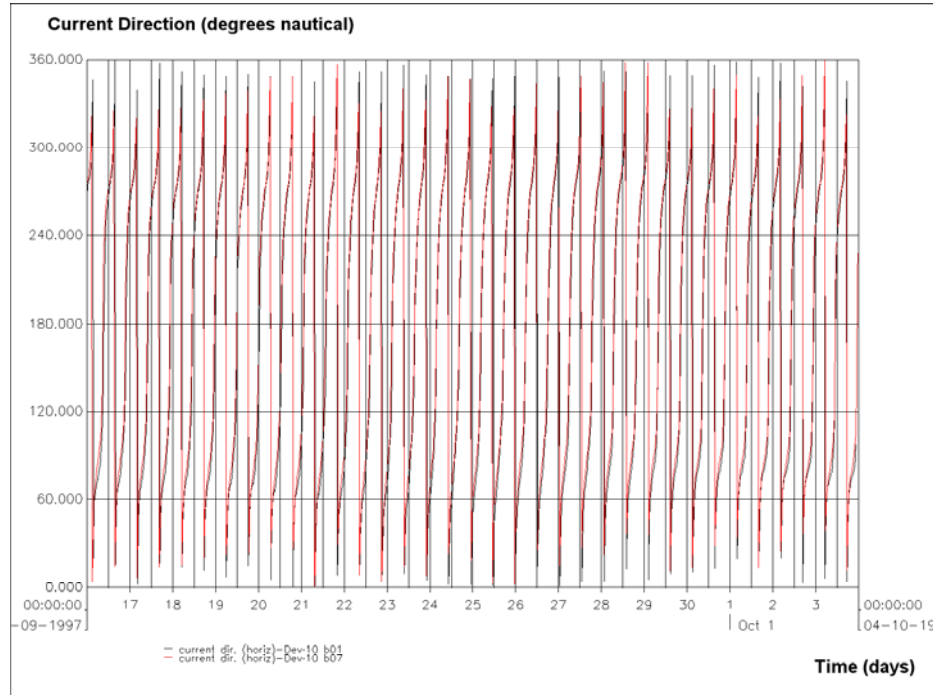


Figure 1(c) Current Direction

**Figure 1: Comparison of results generated near Devonport along the Tasmanian coast by combined action of tide and low-frequency sea-level motion (red) versus tide only (black):**

The comparison suggests that:

- ▶ Under the effect of low frequency sea-level variations, tidal amplitude peak and current magnitude may increase by as much as 0.6 m and 0.02 m/s, respectively;
- ▶ Inclusion of low frequency sea-level variations in the analysis has led to a relatively uniform, steady **increase** in predicted tidal amplitudes and peak currents along the Tasmanian coast;
- ▶ No significant change in current magnitude and direction is observed which is attributed to the fact that the numerical monitoring station adopted in the comparison is in relatively deep waters (approx. 19 m at MSL).

### 1.3.2 Simulation of Tamar Estuary Hydrodynamics

The Tamar Estuary hydrodynamics were represented using grid C and grid D models, with the coverage as illustrated (for the C grid) in Figure 2.

Additional fine scale 2D models (T1 and N1) are referred to in this section, and were developed with focus on a fine-scale representation of hydrodynamic processes near the proposed wharf facility in Bell Bay. These have been described elsewhere in separate reports (refer “*Proposed Bleached Kraft Pulp*”).

Mill in Northern Tasmania, Hydrodynamic Modelling Associated With A Proposed Wharf Facility in Bell Bay, GHD, March 2006")

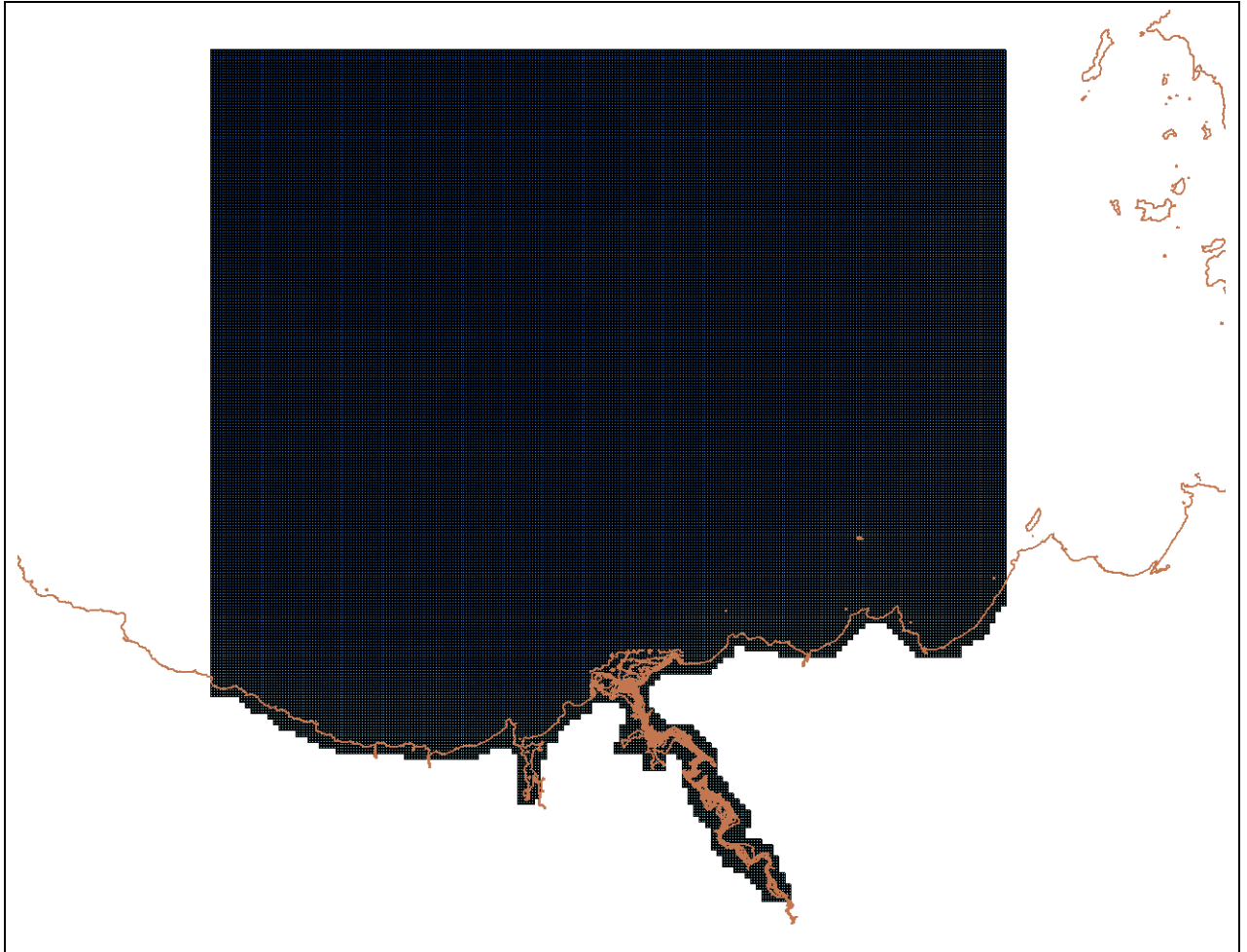


Figure 2: Extent of the C grid model showing coverage of the Tamar River

### 1.3.3 Advection and Dispersion of Pollutants

With respect to the statement:

*It would be expected in this type of model, for the effective eddy viscosity and eddy diffusivity to decrease with decreasing grid size and model refinement...*

it is noted that GHD have used different values of horizontal eddy viscosity and horizontal eddy diffusivity for different grids. The adopted values were:

- ▶ Horizontal eddy viscosity  $E_h=100 \text{ m}^2/\text{s}$  and horizontal eddy diffusivity  $D_h=100 \text{ m}^2/\text{s}$  for the B grid model;
- ▶  $E_h=5 \text{ m}^2/\text{s}$  and  $D_h=50 \text{ m}^2/\text{s}$  for the C grid model;
- ▶  $E_h=1 \text{ m}^2/\text{s}$  and  $D_h=10 \text{ m}^2/\text{s}$  for the D grid model;



Further responses are provided in Section 1.5 of this letter.

#### **1.4 Mass Balance Considerations**

We agree that there will be a gradual build-up of the total mass of any given pollutant within a defined area.

We also agree that with pollutants having been treated as conservative (ie no allowance for decay), and that the background level could build up to higher than may actually occur (i.e. . *an effective background concentration which could feed back into the area of high concentration gradients.*”). This is part of the conservative approach to the assessment of pollutant concentrations that GHD has adopted.

However, we are not in agreeance with the example calculation method discussed at the end of Section 1.4. Whilst the calculation is offered as an example only, the selection of control volume is arbitrary, and has a significant influence on results. If a larger volume were selected, the concentrations would reduce. Similarly, if a higher flushing rate (e.g. 3%) were assumed for the arbitrary control volume, the concentration would decrease. Hence, the example offers no real value.

This issue is discussed further in the following section.

Finally, we note in relation to the last paragraph of Section 1.4 (top of page 5), reference is made to a time to develop mass balance as being large than 100 days.

This is true for Bass Strait as a whole, but does not mean that the modelling of the outfall has to be run for 4 to 6 months in order to demonstrate equilibrium. Never-the-less, some additional model runs undertaken over the longer time frame were previously completed. These supported the earlier findings, namely that equilibrium is effectively reached over the shorter (30 day) timeframe.

#### **1.5 Examination of Mass Balance in the GHD Model**

There are a number of items requiring a response.

##### ***Paragraph #1***

*Although the figures do not represent an instantaneous snapshot of the plume, because they do represent equilibrium conditions in the model, they can be used as a pretty good guide to characterise the distribution of pollutant mass within the plume.*

We note that:

- ▶ the reviewer has applied spatial statistics results to a mass balance analysis - in this particular case, the envelop of maximum concentrations;
- ▶ we do not believe this is relevant, as supported by some of the results obtained from the analysis;
- ▶ the spatial statistics presented in the GHD report were solely conceived for the purpose of evaluating the extent of the mixing zone;
- ▶ the distributions of effluent concentrations based on spatial statistics, despite their uncontested value in various engineering and decision-making processes, do not exist in the material world. They pertain to the realm of probabilistic concepts. Mass balance desktop analysis results based on such concepts will therefore be misleading.



### ***Use of a tidal prism method to estimate flushing***

With respect to use of the tidal prism method to estimate the highest possible flushing of the control volume (defined by the reviewer as the plan shape of the 5000 dilution contour extending to the ocean floor at a depth of 25 m), we note that:

- ▶ Flushing time using the tidal prism method is defined as:

$$T_f = \frac{VT}{(1-b)P},$$

where

$T_f$  - flushing time (hours);

$P$  - tidal prism estimated as the tidal range  $R$  multiplied by the surface area at mean sea level ( $m^3$ );

$T$  - tidal period (hours);

$V$  - mean control volume ( $m^3$ );

$b$  - return flow factor, the fraction (0.0-1.0) of effluent water returning to the domain during each tidal cycle;

- ▶ The approach is applicable to relatively small, simple tidal embayments, generic square-shaped tidal basins, and other semi-enclosed water-bodies. We do not believe the approach should be used as a formulation for sanity-checks of sophisticated numerical models operating within an open sea environment.
- ▶ The approach assumes that:
  - tides are the exclusive factor contributing to the process of flushing;
  - the tidal range is constant; and
  - the return flow factor is a known and constant value.
- ▶ We believe that the assumptions stated above do not apply. Spatially- and time- varying winds and freshwater inflows in addition to real-life tides have been used in the simulations precluding the steady state for which the tidal prism method is valid. Engineering practice (mostly river and lake based) shows that a 50% and larger discrepancies between scenarios involving steady and unsteady currents even for the most simplistic geometrical configurations are common. When these discrepancies are compounded with those due to the effects of winds, one should beware of misleading results.
- ▶ The return flow factor cannot be readily estimated owing to the complexity of the modelled (receiving water) environment (refer Sanford, L. P., W. C. Boicourt, and S. R. Rives. Model for estimating tidal flushing of small embayments. *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol. 118, No. 6, November/December 1992, pp. 635-654)
- ▶ The results obtained using the above method are highly sensitive to the return flow factor even when simple geometrical configurations and a constant tidal range are being used.



In summary, open-sea conditions violate the validity assumptions of the approach. Hence, references in section 1.5 of the review document (to a theoretical maximum of flushing based on the tidal prism method) are likely to be misleading as the theory behind the approach is not applicable to the open sea environment.

Finally, and perhaps most importantly, flushing has been determined using a mathematical model, developed with world recognised software, and reproducing tidal levels and currents to an acceptable standard (refer reviewer comments in Sections 1.2 and 1.3). The model has been driven by boundaries placed at the edge of Bass Strait. Hence, if currents are well represented at the outfall site, but are being driven by information at the edge of Bass Strait, there should be comfort that the physical processes are well represented, and that flushing is also well represented.

### ***Turbulent Diffusion (Paragraph 6)***

We refer to the following statement with respect to diffusion:

*It would appear that the GHD model is over-estimating the contribution of turbulent diffusion towards the mixing and net transport of pollutants. The reason for this may lie in the use of inappropriate eddy viscosity and eddy diffusivity values in the fine scale 3D model, Grid D.*

It is noted that:

- ▶ GHD are aware of the fact that the values of the horizontal eddy viscosity and the horizontal eddy diffusivity adopted for numerical modelling purposes, depend on the flow and the grid size used in the simulation. For detailed models where much of the details of the flow are resolved by the grid, grid sizes typically tens of meters or less, the values for the horizontal eddy viscosity and the horizontal eddy diffusivity are typically in the range of 1 to 10 m<sup>2</sup>/s. For large areas with coarser grids, grid sizes of the order of hundred meters and more, the values range from 10 to 100 m<sup>2</sup>/s. Both coefficients are calibration parameters and must be determined in the calibration process (Delft3D-Flow, User Manual).
- ▶ The process of model calibration is subject to availability of field data. When field data is sparse, values lying within the default ranges quoted above are usually adopted.
- ▶ In addition to the above-mentioned general guidelines, we typically supplement the selection of horizontal eddy viscosity and horizontal eddy diffusivity values with various formulations obtained from the literature. Traditionally, the latter provide a range of values and hence great caution is exercised in the selection process. Once adequate values are selected for a given model (see below), they are kept constant for the rest of the study for consistency reasons. The values may be revised, should field data for calibration purposes become available during the project.
- ▶ The D grid model operates on a telescopic grid that ensures a resolution of 50 m within a distance of 1 km from the diffuser of the outfall. The resolution gradually increases to a grid size of 125 m beyond that distance.
- ▶ For grid sizes in the 50 m to 125 m range, we estimated that the horizontal eddy diffusivity should lie in the range of 5 m<sup>2</sup>/s to 12.5 m<sup>2</sup>/s. A value of 10 m<sup>2</sup>/s was adopted, as reported in Section 1.3.3.
- ▶ The adopted computational time step was constant at a value of 15 seconds.



In summary, the following values were originally adopted for the assessment of the extent of the mixing zone using the fine scale 3D model (i.e. these values applied to the D grid):

- Horizontal eddy viscosity  $E_h=1 \text{ m}^2/\text{s}$ ;
- Horizontal eddy diffusivity  $D_h=10 \text{ m}^2/\text{s}$ ;

We believe these values are appropriate in the absence of specific data.

### **Sensitivity Testing of Diffusivity Parameters**

With respect to the suggestion that *...sensitivity testing of the impact of different parameter settings on the solution with a view to optimising the settings* should be conducted, we note that:

- ▶ Vertical eddy viscosity and vertical eddy diffusivity (time- and space-varying) were calculated internally using a second-order turbulence closure model ( $k-\varepsilon$ ). The process is standard. First, the kinetic energy  $k$  and the energy dissipation  $\varepsilon$  are used to determine the vertical eddy viscosity, then the vertical eddy diffusivity is scaled from the vertical eddy viscosity by means of the Prandtl-Schmidt number.
- ▶ Optimising of horizontal eddy viscosity and horizontal eddy diffusivity values adopted in the modelling process was not undertaken owing to lack of sufficient field data associated with mass transport and dispersion;
- ▶ A sensitivity analysis was previously carried out by rerunning one selected scenario using a value of  $D_h=5 \text{ m}^2/\text{s}$  (as compared to the adopted value of  $D_h=10 \text{ m}^2/\text{s}$ ) whilst retaining a constant value of  $E_h=1 \text{ m}^2/\text{s}$ .
- ▶ A 45-day period of hydrodynamics starting on 01 January 2005 was adopted for the analysis. Tides and NW January winds with a constant wind speed of 9.37 m/s and constant wind direction (nautical convention) of 284 degrees were used to drive the sensitivity model run. Model results were generated for the last 10 days of the modelled period only. Spatial statistics were obtained from the results and used to plot the area covered by the 1:670 dilution contour. This contour is relevant in terms of representing the dilution required to reduce chlorate concentrations to the desired levels.

Whilst a detailed analysis of results was not completed, the sensitivity analysis indicated that:

- ▶ the coefficient of eddy diffusivity and the predicted effluent concentration are in inverse proportion, i.e., the lower the value of the coefficient of eddy diffusivity, the higher the predicted **peak** value of effluent concentration in the immediate vicinity of the outfall; and
- ▶ the lower the value of the coefficient of eddy diffusivity, the larger the area enclosed within the 1: 670 dilution contour. In this case, the area of interest would increase in size from an approximate 500 by 500m to something closer to 900 by 700m.

It must be noted that the above results are offered merely to indicate the sensitivity of the diffusivity parameter for one model scenario.

### **Summary**

Whilst the coefficient of eddy diffusivity would ideally be verified against field data associated with mass transport and dispersion, there are other means and references available to allow estimation of an appropriate value. A range of values has been adopted in keeping with grid size. In this case, values ranged from 10 for the D grid to 100 for the B grid. Adopting a lower value of diffusivity would potentially increase the concentration of modelled parameters in the vicinity of the outfall, but given the values



adopted for the current analysis lie within the acceptable range and are supported by the existing literature, no change is proposed.

## **1.6 Sedimentary Processes**

### **1.6.1 Effluent Particulate Matter**

A separate report relating to benthic accumulation was prepared by Roger Drew. Reference should be made to this report if required.

### **1.6.2 Turbid Discharges from the Tamar Estuary**

Again, we defer to the report by the Eco-toxicologist (Roger Drew).

## **1.7 Uncertainty of Trigger Values**

No response required.

## **2 Conclusions**

Points made in the conclusions repeat those made earlier, and hence have largely already been responded to. In summary, we note that:

- (a) OK - no further response required.
- (b) OK - no further response required.
- (c) OK - no further response required.
- (d) Reference to previous work, literature and other projects undertaken by GHD where East Coast Lows have been considered support the approach adopted for the Pulp Mill IIS.
- (e) Calibration data for mass transport was not available, hence the adoption of parameters associated with grid size.
- (f) We do not believe the far field model produces unrealistically high daily flushing and dispersion, and suggest that some of the desk-top techniques used are not valid for an open ocean scenario.
- (g) Our work has supported that of third parties in terms of the flushing characteristics of Bass Strait. Longer model times would not lead to a change in conclusions, and are therefore not supported.
- (h) The presentation of additional results is possible. Results can be presented in additional spatial and time history formats, should this be required. However, we note that the responses provided in this document should have clarified some issues in terms of how well flushing characteristics have been represented, and with respect to parameter selection. Hence, additional result presentation may not be required.
- (i) The potential for long-term benthic accumulation has been considered by others (i.e. project toxicologist), with separate reports prepared.
- (j) Refer above.



We trust that this letter clarifies the extent of analysis undertaken for the project, and satisfactorily addresses the issues raised by the Patterson Britton review. We await any further instruction you may have.

Yours faithfully  
GHD Pty Ltd

**Ross Fryar**  
Manager Waterways and Coastal  
07 3316 3619