Gunns LIMITED

Bell Bay Pulp Mill
2009/2010 Hydrodynamic Modelling Project

Final Report on Commonwealth Requirements

Prepared for the
Commonwealth Minister for Sustainability, Environment, Water, Population and Communities in accordance with approval EPBC 2007/3385

31st January 2011

Revision Status

Revision	Date	Revision Description	Prepared	Reviewed	Approved
A	23 November 2010	Draft submission to DSEWPC for review	LH	IW/NS	LB
B	31 January 2011	Final submission	LH	IW/CF	TP

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Executive Summary

A complex and rigorous Hydrodynamic Modelling Project (the Project) has been completed to meet the requirements of the Commonwealth's Approval Decision 2007/3385 for the Bell Bay pulp mill. The results of the Project are described in a series of technical reports that have been submitted to the Commonwealth and which accompany this report as appendices. The present report is an overarching description of the work and its findings.

The Project's studies are also relevant to State requirements and their findings will also be reported in due course to the State in accordance with the State's reporting and interpretation requirements.

The detailed basic methodology for the Project was provided by the Commonwealth to Gunns in the form of an 'initial scoping brief'. This was followed by an iterative review process by the Commonwealth, State and Gunns' representatives during which more detailed project specifications of common elements were established. Additional studies, required only by the Commonwealth, relating to equivalent or overseas sourced effluent samples were undertaken in concert with the joint State-Commonwealth modelling requirements. This was necessary as the effluent studies informed and facilitated interpretation of the model's outputs.

Expertise from a broad range of engineering and scientific disciplines was assembled and coordinated to address the Commonwealth's tightly specified requirements.

The Project was segregated into three components, with individual sub-components allocated to organisations that possessed expertise in those areas of the Project. Overall coordination was undertaken by Gunns Limited's pulp mill project team.

The Project also facilitates a review of potential or actual sampling locations for the various environmental monitoring activities planned for the Bell Bay pulp mill.

The Project has delivered a wide range of findings, which provide multiple lines of evidence regarding the potential marine environmental impact of a Bleached Eucalypt Kraft (BEK) pulp mill's effluent release as proposed for the Bell Bay pulp mill.

The key findings of the project are:

1. There is no credible risk of significant accumulation of 'dioxins and furans' in sediment in Commonwealth waters or other areas;
2. There is no likelihood of long term accumulation of soluble contaminants anywhere in the Bass Strait region;
3. The key toxicant parameter, chlorate, will readily meet its dilution targets and poses very low ecological risk to Commonwealth marine areas and elsewhere;
4. Thorough and extensive analysis of effluent from a similar overseas mill has shown that only minimal dilution in the receiving environment is required to deliver a very high level of ecological protection to sensitive local marine life. The dilution requirements will be readily met within the defined Mixing Zone;
5. Because of an immediate adoption of 100% plantation mill furnish at the commencement of operations (rather than it being phased in over several years as originally proposed) an 'ECF light' bleaching sequence has been committed to (see EIMP Module L for details). This will allow an even greater level of protection by the proposal to reduce the chlorate compliance limit to a substantially lower long term average level (after an allowance for commissioning).

6. None of the physico-chemical (non-toxicant) parameters regulated by the Commonwealth under Approval Decision 2007/3385 Condition 32 present a credible risk to Matters of National Environmental Significance (or the receiving environment generally) and there is no necessity for the Commonwealth limits for these parameters to be lower than the existing State limits.

With the completion of the Project studies, there are now no remaining significant uncertainties on Matters of National Environmental Significance relating to the release of effluent from the proposed Bell Bay pulp mill.

Preamble

Gunns Limited proposes to construct and operate a bleached kraft pulp mill at Bell Bay (near George Town, Tasmania) near the mouth of the Tamar estuary. The proposed mill will discharge some 64 megalitres per day of treated effluent through a diffuser located 2.7 km offshore from Five Mile Bluff, to the east of Low Head on Tasmania's north coast. In support of the environmental approvals for the proposed mill, particularly in relation to the fate of the pulp mill effluent discharged into Bass Strait, the Commonwealth and the Tasmanian State Governments have requested very detailed hydrodynamic modelling as described in the Scope of Works (RPS MetOcean, 2008). The main purpose of the modelling is to demonstrate that the Water Quality Objectives (WQOs) and Sediment Concentration Limit (SCL) developed specifically for the pulp mill by the Commonwealth and the Tasmanian State Governments will be met.

1 Introduction

This report presents a summary overview of the findings of the Hydrodynamic Modelling Project ("the Project") undertaken to address specific requirements of the Commonwealth Government's Approval Decision EPBC 2007/3385 for the Bell Bay pulp mill. The Project also addresses some of the conditions of the Tasmanian State Pulp Mill Permit and relevant findings will be reported separately to the State.

The Project comprised detailed hydrodynamic modelling and measurement studies and supporting effluent studies, all of which were undertaken for Gunns Ltd (Gunns) by eminent and experienced scientists and engineers. A specific approval requirement was that "*the modelling to be commissioned and the organisation responsible for performing the modelling must be approved by the Department*". In accordance with this requirement, the Department (then Department of the Environment Water, Heritage and the Arts, DEWHA) approved[1] the consultant firms engaged by Gunns and also the methodologies used by them to undertake the studies[2].

The fundamental design for this Project was provided to Gunns by the Commonwealth.

This was consistent with the Chief Scientist's Report[3] which clearly recommended that the detailed design of the Project should be provided to Gunns in the form of a 'detailing brief' stating such matters as the level of 3-dimensionality within the model, the level of vertical resolution and forcing requirements etc.

In response to a request by Gunns, an "initial scoping brief"[4] guidance document was provided. The document was authored in the main by Dr Michael Herzfeld of the CSIRO, through his membership of the Independent Expert Group (IEG) as an expert in hydrodynamic modelling. Dr Herzfeld was a member of the original Chief Scientist's Independent Expert Panel, which assisted the Commonwealth Minister in his assessment and approval of the pulp mill project under the *Environment Protection and Biodiversity*

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[1] Letter from R. Webb of DEWHA to C. Frame of Gunns Ltd dated 28th May 2009.
[2] Letter from R. Webb of DEWHA to C. Frame of Gunns Ltd dated 14th July 2009.
[3] http://www.environment.gov.au/epbc/notices/assessments/2007/3385/pubs/report-chief-scientist.pdf
[4] Letter from N. Matthew of DEWR to C. Frame Gunns Ltd dated 27th November 2007.

Conservation Act 1999. Subsequent to the approval, Dr Herzfeld was also appointed to the IEG, which assumed the post-approval advisory role for the Minister.

The guidance document was then developed further for Gunns by RPS MetOcean which had been engaged by Gunns for this task. The guidance document was then iteratively reviewed and expanded by further extensive consultation with both the Commonwealth (including the IEG) and State regulators over several months. Suggested amendments identified by these agencies and the IEG were incorporated and the guidance document then became the Project Scope of Works (SoW). This was then submitted to and approved by each jurisdiction[5].

The objective of developing a detailed SoW was to specify the finer technical and reporting specifications for a series of related tasks which drew together all Commonwealth and State regulatory requirements, including the addressing of the remaining areas of concern from prior studies, so that a clear, detailed and unambiguous project specification could be put to tender by Gunns.

Gunns also committed to provide regular progress reports and updates to the Department and IEG during the implementation phase of the studies so that emergent concerns or uncertainties could be identified and addressed as early as possible. The approved SoW was appended to the Environmental Impact Management Plan (EIMP) Module L, which was submitted to the Minister in December 2008 and subsequently made public by Gunns[7].

The approved SoW therefore described the agreed methodology for the required multidisciplinary scientific studies required under both State and Commonwealth jurisdictions.

An additional suite of tasks centred on 'effluent studies' was required by the Commonwealth only. These effluent studies were developed under a separate process, with initial drafts being prepared by Gunns' consultants as a series of Sampling and Analyses Plans (SAPs). The SAPs were reviewed by the IEG, modified in response to their comments, and subsequently formally submitted to and approved by the Department in September 2009.

The draft EIMP Module L submitted to the Minister in December 2008 included a timeline for the Project, which covered the planned construction period of 26 months commencing on the date when a "Notice to Proceed" would be announced by Gunns. The Minister took this 26 month period into account in his 5 January 2009 decision, when he required the Project and finalisation of the EIMP Modules L, M and N to be completed in time to allow him to make an approval decision for those components within 26 months of his 5th of January 2009 decision, namely by 3rd of March 2011.

Following the Minister's January 2009 decision, the SoW was put to tender by Gunns in early 2009 and several organisations submitted detailed technical proposals to undertake all or part of the works.

After commercial principles were established with tenderers, Gunns and the leading tenderers worked to further develop and integrate the overall program so that a well

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5 Letter from R. Webb of DEWHA to C. Frame of Gunns Ltd of 14th July 2009.

7 http://www.gunnspulpmill.com.au/permits/epbc/L/Appendix%20D%20-%20Hydrodynamic%20Modelling%20and%20Measurement%20Scope%20and%20Plan.pdf

resourced and highly credentialed project team could be established, comprising a number of organisations which possessed particular expertise in one or more aspects of the overall Project's scope. A further review of the same detailed methodology documents by DEWHA/IEG was facilitated by Gunns, including a joint technical forum attended by key practitioners from the key contractors Worley Parsons and RPS MetOcean with IEG members to discuss aspects of the proposals (May 2009). The formal approval of organisations to carry out the works was granted by DEWHA in late May 2009.

During this period the key contractors' detailed technical methodology documents were further refined by the relevant organisations and the resulting documents were again submitted to the (then) DEWHA and the (then) State Director of Environmental Management for final review and approval (July 2009). Upon receipt of the final DEWHA and State approvals for the methodology, contracts for the work as approved were issued by Gunns and the project tasks themselves commenced immediately thereafter.

Gunns committed to provide DEWHA (and the IEG) with a series of 'milestone reports' and detailed technical briefings during the implementation phase of the Project, and these commitments have been fulfilled. Technical briefings to outline progress were also given to the technical officers assisting the State Environment Protection Authority (EPA) during the implementation phase of the Project. Some of the milestone reports and technical discussion resulted in alteration(s) to the methodologies(s) as the Project progressed. These alterations were all extensions of the SoW or approved methodologies and were implemented to respond to progressive study findings so as to maximise the strength of the study outputs.

This *Final Report on Commonwealth Requirements* collates all the component and key interim milestone reports (as a series of appendices) for the project and provides an overarching interpretation and integration of the Project's key findings.

Some milestone reports that became redundant at the close of the Project or were superseded by subsequent reports are not presented here but are available for inspection on Gunns Limited's website.

1.1 Project Structure and Organisation

Overall project management was undertaken by Gunns' pulp mill Project staff (Les Baker & Lawson Harding), with assistance from Pitt & Sherry (Dr Ian Woodward). The Project was divided into three logically discrete items, all with associated sub-component tasks.

The three Project items are:

Item 1) Field measurement activities;
Item 2) Effluent studies, utilising effluent from an existing overseas mill;
Item 3) Computer modelling, comprising 'near field', 'far field' & 'sediment transport' sub-components.

Key consultants and technical contributors for the three items are:

Item 1) RPS MetOcean & Gunns' pulp mill project team;
Item 2) The University of New South Wales - Water Research Laboratory (WRL), Ecotox Services Australasia Pty Ltd (ESA), Toxikos Pty Ltd and the National Measurement Institute (NMI) with support from other specialist analytical organisations;
Item 3) RPS MetOcean & Worley Parsons.

A major factor in the selection process for the participating organisations (RPS MetOcean, Worley Parsons & WRL in particular) was the expertise of key staff members who would be allocated to work on the Project. The key Project participants include:

- From RPS MetOcean
  - Dr Chris Fandry

    Dr Fandry has had a long association with the science of oceanography and the application of this science in the context of pulp mill marine outfalls. These include co-authoring a major report for the Commonwealth (Fandry, C. B, Johannes R.B. and Nelson P.J. (1989) *Pulp Mills: Modern Technology and Environmental Protection*. Report to Senator the Hon. John Button, Minister for Industry, Technology and Commerce, Commonwealth of Australia, 77 pp., and the first Commonwealth Government guidelines for bleached Kraft pulp mills: *Environmental Guidelines for New Bleached Eucalypt Kraft Pulp Mills (1995*).

    Dr Fandry was also a member and head of the *National Pulp Mills Research Program* and co-authored several reports on using hydrodynamic models to predict pulp mill effluent dispersion (Fandry, C. B, Walker S. J. and Andrewartha J. R. (1996) *Modelling effluent dispersion in Australian coastal waters*. National Pulp Mills Research Program, Technical Report Ser., 16, 93pp, and Walker, S. J, Craig P. D., Andrewartha J. R. and Fandry C. B. (1996) *Numerical modelling of currents off Western Australia,* National Pulp Mills Research Program, Technical Report Ser., 22, 32pp.

    Dr Fandry has had a distinguished career associated with oceanography within Universities in Australia and overseas, and CSIRO during the period 1971-2006, including (amongst others) the roles of *Chief*, CSIRO Division of Oceanography and *Senior Principal Research Scientist*, CSIRO Marine and Atmospheric

Research. In 1990, Dr Fandry was awarded the CSIRO Medal for contributions to the national debate on pulp mills.

Dr Fandry is a pioneer of hydrodynamic modelling in Australia, with the first model of Bass Strait published in 1981, and numerous further publications on the oceanography of Bass Strait including the discovery and naming of the Zeehan Current published in 1983. He is the author of some 60 peer reviewed publications in the fields of mathematics, fluid dynamics, oceanography, meteorology and environmental management. In summary, Dr Fandry is impeccably credentialed to undertake a key role in the Project.

- Mr Martin Holbrook.

  Mr Holbrook holds numerous engineering qualifications including a Bachelor of Engineering (electronics) from Adelaide University. Mr Holbrook is a specialist in the development and implementation of oceanographic and other technical measurement systems. Mr Holbrook's career developed from his initial engineering training within the defence industries and for over twenty years he has applied his technical skills to oceanography and meteorology for his current employer, including managing major measurement campaigns for the Australian Hydrographic Office and various major off-shore petroleum industry clients.

- From Worley Parsons
  - Mr David McConnell

    Mr McConnell is a civil engineer with a specialised background in coastal, maritime, river and hydraulic engineering. His technical expertise lies in analytical and field investigations of physical processes, conceptual and detail design and physical and computer modelling. Project experience has included shoreline stabilisation and development, environmental impact and protection studies, fisheries habitat mitigation, coastal and river sediment studies, marine structures, breakwaters and revetments, and river training and crossings.

    Mr McConnell was formally a Principal with the company Patterson Britton & Partners Pty Ltd and contributed to the review commissioned by the then Department of Water Resources (DEWR) for the Bell Bay pulp mill project's original hydrodynamic modelling studies. Mr McConnell was also consulted by the Chief Scientist during his review of scientific aspects of the same studies, prior to the Chief Scientist finalising his report to the Minister for the Environment and Water Resources.

  - Mr Greg Britton

    Mr Britton is the Manager – Marine & Coastal (Southern Operation) at Worley Parsons and has over thirty years experience in the investigation, design, planning, environmental assessment and project management of coastal, estuary and maritime projects.

    Mr Britton's experience includes the investigation of coastal and estuary processes; numerical and physical modelling, determination of coastline hazards, including those associated with climate change; the design of a wide range of coastline structures including outfalls, seawalls, breakwaters, groynes, jetties and wharves, marinas, and boat ramps; dredging and beach nourishment;

water quality and sediment quality studies; submarine cables; environmental assessment including EAs, EISs, REFs and SEEs; coastal and estuary management studies and plans, preparation of tender documents; and construction supervision and administration.

Mr Britton has provided expert advice on coastal, estuary, maritime and environmental engineering to the NSW Land and Environment Court, NSW Supreme Court, Federal Court of Australia and several Commissions of Inquiry. He has fulfilled the role of a Court Appointed Expert (CAE) to the NSW Land and Environment Court. Mr Britton was formally a Principal with the company Patterson Britton & Partners Pty Ltd and provided the review commissioned by the then Department of Water Resources (DEWR) for the Bell Bay pulp mill project's original hydrodynamic modelling works.

- From UNSW Water Research Laboratories
    - Dr William Glamore

      Dr Glamore is a Senior Project Engineer at WRL and has extensive experience in coastal investigations/effluent discharge studies. Dr Glamore has a PhD in Environmental Engineering and a BSc (Honours) in Environmental Science. Dr Glamore is a Churchill Fellow, a committee member of the Sydney Water Panel, a recognised 'Expert of International Standing' by the Australian Research Council and the recent recipient of the 2008 International Willems-DePaepe Award. He has also been awarded the 2007 Kevin Stark Award and the 2007 PIANC Authors Award for excellence in Coastal Engineering. Dr Glamore has provided and continues to provide independent expert advice to a range of Federal and State Authorities including DEWHA, NSW DECC, NSW DWE and NSW DPI.

- From Ecotox Services Australasia Pty Ltd
    - Dr Rick Krassoi

      Dr Rick Krassoi is the Director of Ecotox Services Australasia and has over 20 years experience in ecotoxicological and environmental assessment. Dr Krassoi established the Ecotox Services Australasia laboratory in Lane Cove NSW in 2001, attaining NATA accreditation for the laboratory within its first year of operation. Dr Krassoi has published several scientific papers on the toxicity of chemicals and effluents using a range of local test species and was instrumental in the adaptation of a number of Australasian test species for use with USEPA Whole Effluent Toxicity (WET) testing methodologies. These tests include the doughboy scallop and rock oyster larval development tests, acute juvenile tiger prawn test, sediment amphipod test, and the freshwater crustacean *Ceriodaphnia dubia*, all of which are now commonly used throughout Australia.

      Dr Krassoi has presented numerous papers in Ecotoxicology using Australasian species, and is one of the most experienced ecotoxicologists working with marine WET testing and Toxicity Identification Evaluation studies in the Australasian region.

- From Toxikos Pty Ltd
    - Mr John Frangos

Mr Frangos is a consultant toxicologist with ecotoxicology skills and experience in air, land and water human health and ecological risk assessment. Firstly as a corporate advisor to Hoechst Australia and ICI Australia and later as a consultant to the chemical industry, Mr Frangos has acted as an expert in toxicology, risk assessment and chemical control laws in Australia and New Zealand.

Mr Frangos specializes in identifying, reviewing and critically evaluating complex toxicological data using the latest scientific methods to pragmatically advise risk managers. Mr Frangos has worked on numerous contaminated site risk assessments in Australia and New Zealand and has experience in establishing risk criteria, preparing toxicity profiles and communicating results to key shareholders.

- Dr Roger Drew

Dr Drew is a recognised national and international expert in toxicology and health based risk assessments. Dr Drew is the only consultant toxicologist in Australia who has certification with the American Board of Toxicology. He has over 30 years experience in toxicological research, interpretation of toxicological data and health based risk assessment. He has been a toxicology consultant to Federal and State Health Authorities, was appointed to several standing chemical expert committees constituted for regulatory assessment of chemicals and an invited member of many expert task groups of the WHO for the International Programme on Chemical Safety. Dr Drew is Adjunct Professor in Biochemical Toxicology at RMIT.

The interrelation of Project Items 1-3 are described by Figure 1 below. Items 1 and 2 are substantial programs in their own right but their primary purpose is to provide field or laboratory measured inputs for various components of the computer modelling (Item 3) and/or to validate a range of model outputs.

A more detailed description of the activities carried out under Items 1-3 are provided below under the sub-heading "*Summary of Project Components*".

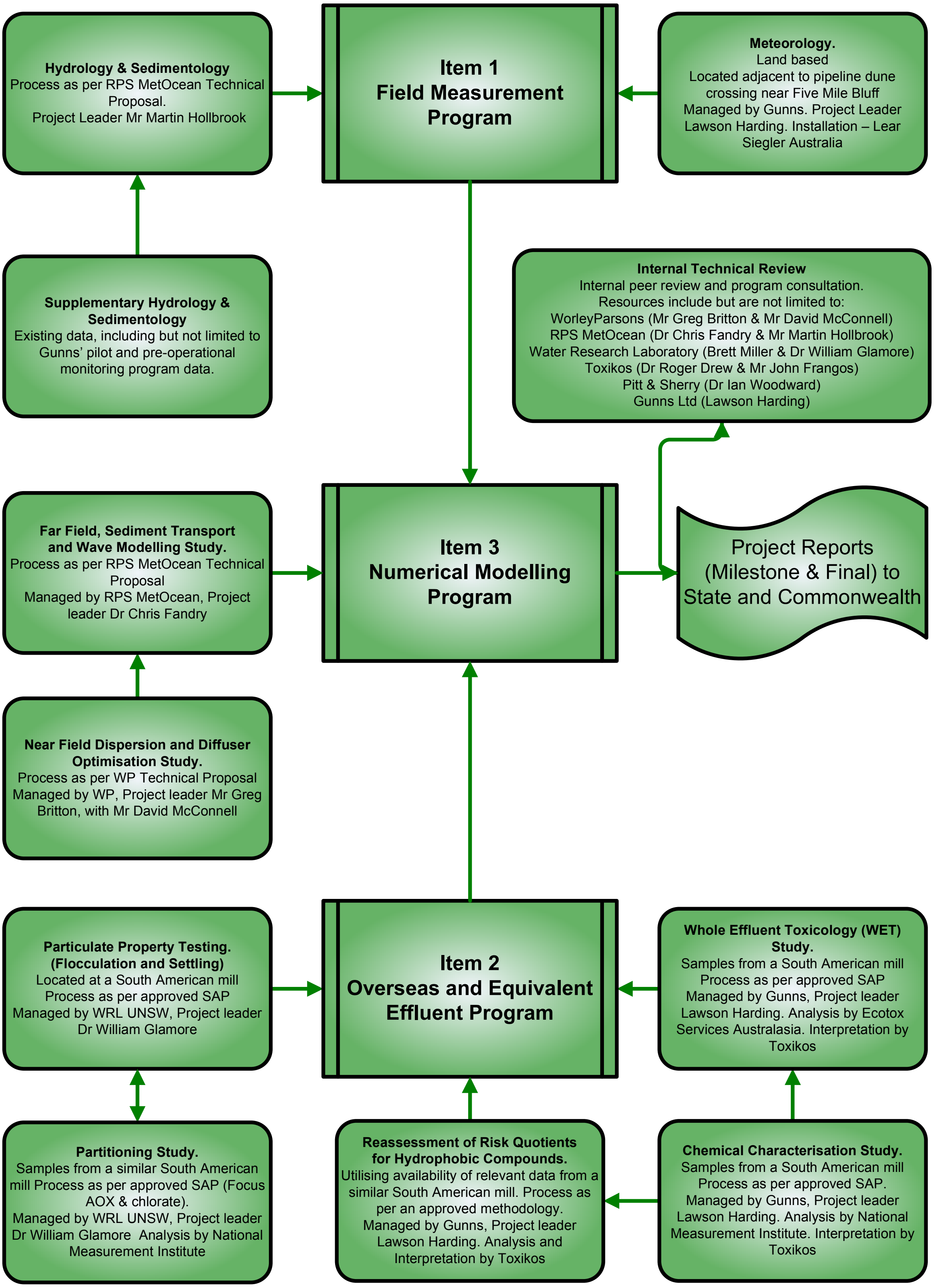

Figure 2 Hydrodynamic Modelling Project structure, description and relationships.

1.2 Project Objectives

Key objectives were established by the Project team prior to commencing. These were:

- Meet or exceed the State and Commonwealth's permit and approval requirements pertaining to hydrodynamic modelling of the proposed pulp mill outfall.
- Demonstrate to stakeholders the likely fate and key effect(s), if any, that the emission of mill effluent parameters as predicted by the mill designers (based on confirmation by scientific analysis) would have on the local and regional ecosystem and other environmental values of Bass Strait.
- Demonstrate to regulators (State and Commonwealth) the likely fate and key effect(s), if any, that the emission of key mill effluent parameters when released at the maximum loading allowed under the permit and approval conditions would likely have on the local and regional ecosystem and other environmental values of Bass Strait.
- Demonstrate the level of conservatism built into the above assessment for as many key study parameters as practicable.
- Provide information to validate or refine the selected marine sampling locations and/or program design established for the Bell Bay pulp mill project's Baseline and Operational Monitoring Program (P-BOMP)[8].
- Provide a sound yet conservative estimate for the probability of a range of water and sediment quality objectives set by the Commonwealth (or in their absence, suitable State values) being compromised by the pulp mill's discharge.

In order to accommodate the different interests of the Commonwealth and the State, separate final project reports are being submitted. Although there are many commonalities and overlaps between State and Commonwealth interests, the detailed environmental matters of concern, their relative priority or even the interpretive mechanisms do not always align.

This current report addresses the specific needs and concerns of the Commonwealth and is submitted on a schedule suitable for the Commonwealth under the terms of the relevant Approval Decision (EPBC 2007/3385). Some subsidiary reports provided herein do include reference to State matters; however, these references are not relevant to the assessment of the modelling from the Commonwealth's perspective and are not considered within the scope of this report in drawing any conclusions on matters related to the Commonwealth's jurisdiction.

A report to the State addressing its issues will be provided prior to mill commissioning in accordance with reporting provisions.

[8] Site selection and program design will also consider other factors in addition to the modelling in line with best practice monitoring protocols.

1.3 Comparison of Methodologies – Current and Prior Modelling

The Project arose from concerns with previous studies identified during the State and Commonwealth's assessment processes for the Bell Bay pulp mill project, in particular those expressed by the Chief Scientist and his Independent Expert Panel in advice to the Minister under the Commonwealth's assessment process.

The outcome of the State and Commonwealth conditional approvals for the Bell Bay pulp mill project included prescriptive requirements for a revised series of linked studies relating directly or indirectly to the release and dispersion of treated pulp mill effluent in Bass Strait. The primary requirements were Conditions 34, 35, 36(c) & 38 of the Commonwealth's Approval Decision (2007/3385). The specifications for the modelling works, which are central to this Project, are prescribed by Condition 38 of the Approval:

38) Additional modelling must be carried out in relation to the fate of effluent, as part of the EIMP, prior to the commencement of commissioning of the mill. The details of the modelling to be commissioned and the organisation responsible for performing the modelling must be approved by the Department. The modelling to be commissioned must include, but not be limited to:

- *a) The inclusion of a sediment transport component.*
- *b) The use of three-dimensional models for all levels of spatial resolution.*
- *c) Increased vertical resolution for the high resolution model used in the water quality analysis.*
- *d) Forcing from all mechanisms that may potentially influence residual or diurnal dynamics, including background sea level gradients, low frequency sea level oscillations, surface heat flux, sea level, temperature and salinity open boundary and initial conditions which capture mesoscale variability and wave enhanced bottom friction.*
- *e) The execution of long term simulations that capture seasonal variability, and evidence of the model achieving pseudo-steady state in the regional (Bass Strait) field.*
- *f) The calibration of model tracers (e.g. temperature or salinity) and velocity to data derived from moored instruments (for temporal comparisons) and measured profiles (for spatial comparisons) over the period the model is simulated. This will involve a supplementary field program designed specifically for model calibration (i.e. implemented over an annual cycle). Detailed evidence of satisfactory calibration must be supplied, including correlation between phase and amplitude of calibration variables.*
- *g) Sensitivity analysis for key model parameters, particularly horizontal diffusion.*
- *h) The use of appropriate simulation lengths for generating plume statistics.*
- *i) The use of data (modelled or measured) that captures the three-dimensional nature of the water column and seasonal variability for use in the near-field model.*

A detailed comparison of the modelling conducted in response to Condition 38 of the Approval Decision with the prior hydrodynamic modelling undertaken for the original project assessment is provided in Table 1. The comparison shows how the detailed prescriptive requirements of the approved methodology vary from the original series of studies and that substantial improvements have been introduced.

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
Model and modelling organisations	The details of modelling and the organisation responsible for carrying out the modelling must be approved by the Department.	Gunns Ltd commissioned GHD. Components as follows: ○ Modelling – As described by a series of GHD reports authored 2006-2007. Models used: ○ Far-field - Flow Module of Delft3D ○ Near-field - Visual Plumes USEPA.	Project subdivided to components, managed and coordinated by Gunns Ltd. Components as follows: ○ Modelling – Near-field allocated to Worley Parsons ○ Modelling - Far-field allocated to RPS MetOcean ○ Modelling - Sediment Transport allocated to RPS MetOcean. Models used as follows: ○ Near-field: Flow-3D Computational Fluid Dynamics model validated against the JETLAG (University of Hong Kong) empirical Lagrangian model. ○ Far-field and Sediment Transport: Sparse Hydrodynamic Ocean Code (SHOC) CSIRO.

[9] Key reference is *Addendum for Bell Bay Pulp mill IIS Additional modelling Works Report 2 January 2007. GHD Doc. No. 41/16384/349858*

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
Nested modelling domains - horizontal resolution	Cell spacing progressively decreases and thus resolution progressively increases nearer the outfall location.	Three levels: ○ B Model at 1000 m cell spacing ○ C Model at 250 m cell spacing ○ D Model Variable cell spacing from 50 m near the outfall to 250 m at greater distance.	Four levels: ○ Regional grid at 2500 m cell spacing ○ Intermediate grid at 1000 m cell spacing ○ Fine grid at 250 m cell spacing ○ Very Fine grid at 50 m cell spacing
Nested modelling domains - vertical resolution	Vertical resolution is to be increased to provide 3-dimensional configuration in all domains	○ Models B & C were 2-dimensional depth averaged. ○ Model D was 3-dimensional with 8 layers and layer thicknesses all equal to 12.5% of total water depth.	Four domains all multi-layered: ○ Regional - 17 layers ○ Intermediate - 24 layers ○ Fine - 24 layers ○ Very Fine - 24 layers (bottoms at 0.2, 0.5, 1, 2, 4, 6, 8, 10, 13,…66 m)
Surface layer thickness	Increased resolution is required at the surface, particularly for the high resolution model used for water quality analysis.	○ Models B & C - not applicable ○ Model D 5 m	○ Regional grid 1 m ○ Intermediate grid 1 m ○ Fine grid 0.5 m ○ Very Fine grid 0.2 m
Model run lengths	Model run lengths are to be adequate to demonstrate long term simulations that capture seasonal variability and provide evidence of the model achieving pseudo-steady state in the regional field.	30 day period, commencing April 2005.	○ Regional, Intermediate and Fine grids. 12 months committed to and provided. ○ Very Fine grid 4 months, with at least 1 month from each season committed to; 9 months, with at least 1 month from each season, actually provided. ○ Simulations correspond with 12

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
	Plume statistics must be generated over appropriate simulation periods.		month measurement program commencing September 2009.
Model forcing summary	A comprehensive array of forcing mechanisms is required of the revised modelling including: Background sea level gradients, low frequency sea level oscillations, surface heat flux, sea level, temperature and salinity (open boundary and initial conditions).	○ Wind data - Bureau of Meteorology Research Centre (BMRC) MESOLAPS data (5 km resolution across Bass Strait, 6 hr time intervals), supplemented by 3 hr wind records from the BoM Low Head Met Station applied in the D Model only. ○ Tides - BMRC data ○ Temperature and salinity along open boundaries – World Ocean Atlas 2001 (National Oceanographic Data Center (NODC). ○ Time varying fresh water inflows from the Tamar	○ Wind data, atmospheric pressure and surface heat flux - MetOcean's database of National Centre for Environmental Protection (NCEP) from various resolution sources as follows: ○ Global Data Assimilation System (GDAS) at 0.3° x 0.3° and 3-hourly intervals. ○ Tides - Barotropic tides, via a global tidal model that is inbuilt in SHOC ○ Low frequency sea level - (BlueLink) ○ Temperature and salinity along open boundaries and for initial conditions -(BlueLink) ○ Time varying fresh water inflows from the Tamar (Sediment Transport component only)

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
Sediment transport model	A sediment transport component was required within the revised project.	Sedimentation was dismissed as being insignificant in the original studies due to an expectation that whatever particulates were emitted would 'behave like plankton' and not settle.	○ Sediment Transport Module within the SHOC suite of models. ○ Wave modelling - WAVEWATCHIII (NCEP/NOAA)
Measurement program period and organisation(s) conducting the works	The details of the field program and the organisation responsible for carrying out the measurements must be approved by the Department.	November - December 2005 field campaign and other existing data from various sources.	September 2009 to August 2010 field campaign. ○ Marine - RPS MetOcean. ○ Meteorology - Gunns Ltd. ○ Effluent Studies - Particulate Properties - UNSW Water Research Laboratories
Measurement program design summary	As above and in addition the model's outputs must be calibrated to tracers (temperature and salinity) and velocity, with evidence of satisfactory calibration to be provided.	Single instrument - Acoustic Doppler Current Profiler (ADCP) deployment. Outfall location	Three mooring clusters (multiple instruments at different levels within the water column) deployed at three locations: 1. Outfall 2. Offshore (deepwater) 3. River Tamar mouth. Supplemented by conductivity (i.e. salinity), temperature and depth (CTD) profiles and extractive water quality samples taken during instrument service visits.

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
Measurement parameters for deployed marine instruments	As above and the measured data must capture the 3-dimensional nature of the water column and seasonal variability.	○ Waves - ADCP (period, direction etc) ○ Currents – ADCP (speed, direction through the water column) ○ Tide level - ADCP ○ Bottom temperature - ADCP All logged at 1 hour intervals	○ Waves - AWAC (period, direction etc) ○ Currents - AWAC and CM04 (speed, direction through the water column taken by 2 instruments) ○ Tide level - AWAC ○ Temperature - AWAC, CT, Seastar,CM04, SONDE, LISSTat multiple levels of the water column ○ Salinity - CT, SONDE ○ Suspended sediment and particle settling speeds - LISST_110X, LISST_ST ○ Turbidity - SONDE All logged at 10 min intervals.
Model parameterisation (far-field) horizontal diffusivity scheme	Sensitivity of the model must be analysed for key model parameters, particularly the horizontal diffusion parameter.	Constant related to model domain/grid size as follows: ○ Model B 100 m^2/s ○ Model C 50 m^2/s ○ Model D 10 m^2/s with sensitivity analysis at 5 m^2/s	Smagorinsky (0.2) for all domains with sensitivity analysis in the *Very Fine* grid at a constant 0.2, 0.4 and 4m^2/s.
Model parameterisation (far-field) vertical mixing scheme		k - ε	k - ε

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
Diffuser configuration	An opportunity to 'optimise' the diffuser's performance by altering the configuration has been integrated into the project by Gunns.	○ 200 m total length. ○ 20 diffuser ports at 10 m c-c ○ Round ports (no valves) ○ Port orientation - 75° alternating	○ 250 m total length ○ 51 diffuser ports at 5 m c-c ○ 'Duckbill' valves on each port ○ Port orientation - 1/riser vertical (Option 1) or 2/riser x horizontally opposed (Option 2)
Coupling of near and far field models	The near-field and far-field models are not computationally 'linked' for each time step. Therefore a robust and conservative mechanism must be established. A *simple* coupling mechanism would be where the effluent is loaded into the far-field model at a conservative calculated dilution level and/or strata constantly for each model time step. A *complex* coupling mechanism would be to alter the grid location and/or other parameters at each	Align information from near-field model and map this to the far-field's model grid. Release into the surface layer (i.e. the top 5 m layer) directly over the diffuser as a *simple* coupling mechanism. Detailed as follows: The near-field model determined the dimensions of the interfacing area to be 150 m x 300 m. The interfacing area was then mapped to 18 x 50 m far-field cells in a 3 wide x 6 high matrix, with greater mass weighting to the central cells. Method III from Zhang 1995	Align information from near-field model and map this to the far-field's model grid. Release into the surface layer(s) (i.e. the nominated depth, see below) directly over the diffuser as a *simple* and therefore conservative coupling mechanism. Detailed as follows: The near-field model determined the dimensions of the interfacing area to be 70 m wide and 9 m deep (Diffuser Option 1) or 52 m wide and 17 deep (Diffuser Option 2), both over the 250 m diffuser length[10]. Thus, the raw coupling surface area for Option 1 was determined to be 70 m x 250 m. To couple the 70 m width to the 50 m grid size of the far-field model, the width was reduced to

[10] Option 2 was selected as it is expected that the Option 2 diffuser configuration would exhibit superior performance under low current flow conditions.

Table 1 Comparison of key modelling project configurations and parameterisations

Approval condition requirement	Description	Original (DIIS) configuration[9]	Current configuration
	time step (e.g. increase dilution, with increased current velocity and decrease dilution again as current velocity drops). Computationally, complex coupling would be significantly more difficult. Worley Parsons report a complex coupling for this Project would be likely to predict on average 25% lower concentrations within the receiving environment and deliver a more realistic (but less conservative) simulation.		50 m and the initial depth was correspondingly increased to 9.9 m (to maintain the same volume). The interfacing area was then mapped to 5 x 50 m far-field grid cells, being the length of the diffuser. A sensitivity analysis was also undertaken to compare the adopted depth of 9.9 m with a 'rule of thumb' depth of 8.1 m (30% of water depth), which had been suggested by the IEG. Method III from Zhang 1995
Effluent characteristics		○ Salinity 2.0 PSU ○ Temperature - 15 °C ○ Volume flow rate 64 ML day^{-1} (initially 0.81 reduced to 0.74 m^3/s) ○ Density 1001 kg/m^3	○ Salinity - 3 PSU ○ Temperature - 30 °C ○ Volume flow rate - 64 ML day^{-1} (0.74m^3/s) ○ Density 997 kg/m^3

2 Summary of Project Components and Methodologies

Detailed reports for the three Project Items are provided in Appendices 1 A to 3 B, authored by the participating organisations. The appended reports by necessity are very detailed technical documents, written for expert technical review. Therefore, the information presented here provides a summary overview and an interpretation, including an explanation of the linkages between the project components.

2.1 Item 1 Field Measurement

2.1.1 Context

The field measurement program addressed condition 38 (f) of the Commonwealth's approval decision and supported the modelling work, with specific focus on model calibration.

A key factor in the design of the measurement program arose from the comments by several reviewers (eg. Herzfeld (2007); Godfrey (2007)) of prior modelling that thermal stratification needed to be more thoroughly examined in any revised modelling as it was thought by them to have significant implications for plume rise and subsequent dispersal.

Thermal characterisation of the receiving environment was therefore a major focus in the design of the measurement program. The initial scoping brief of the measurement program was provided to Gunns by the IEG, as described in the *Introduction* section above. The iterative review process that followed expanded the program design. For example, in initial proposals, two measurement locations (moorings) were planned; the State Government, as part of its review, recommended that three current meters (moorings) be deployed, including one located at the mouth of the Tamar, and this recommendation was adopted.

2.1.2 Field Measurement Objectives

The project team identified the following objectives, specific to Item 1 of the Project:

- To represent the seasonal variability in (1) oceanic conditions at two near-shore and one offshore site and (2) meteorology at a terrestrial site nearby to the proposed outfall;
- To provide characterisation of the receiving environment (temperature, salinity, sediments);
- To validate and calibrate hydrodynamic models (sea-levels, currents, waves and sediment transport) over the range of conditions typically experienced in any one year;
- To provide evidence by local comparison of measured data to meteorological forcing data (NCEP) used to drive the model(s).

2.1.3 Field Measurement Design

The field program covered a full annual cycle and collated detailed water, sediment and meteorological data. These data provided some inputs into the hydrodynamic computer model and were also used to calibrate or validate the model's predictions as described in Figure 3.

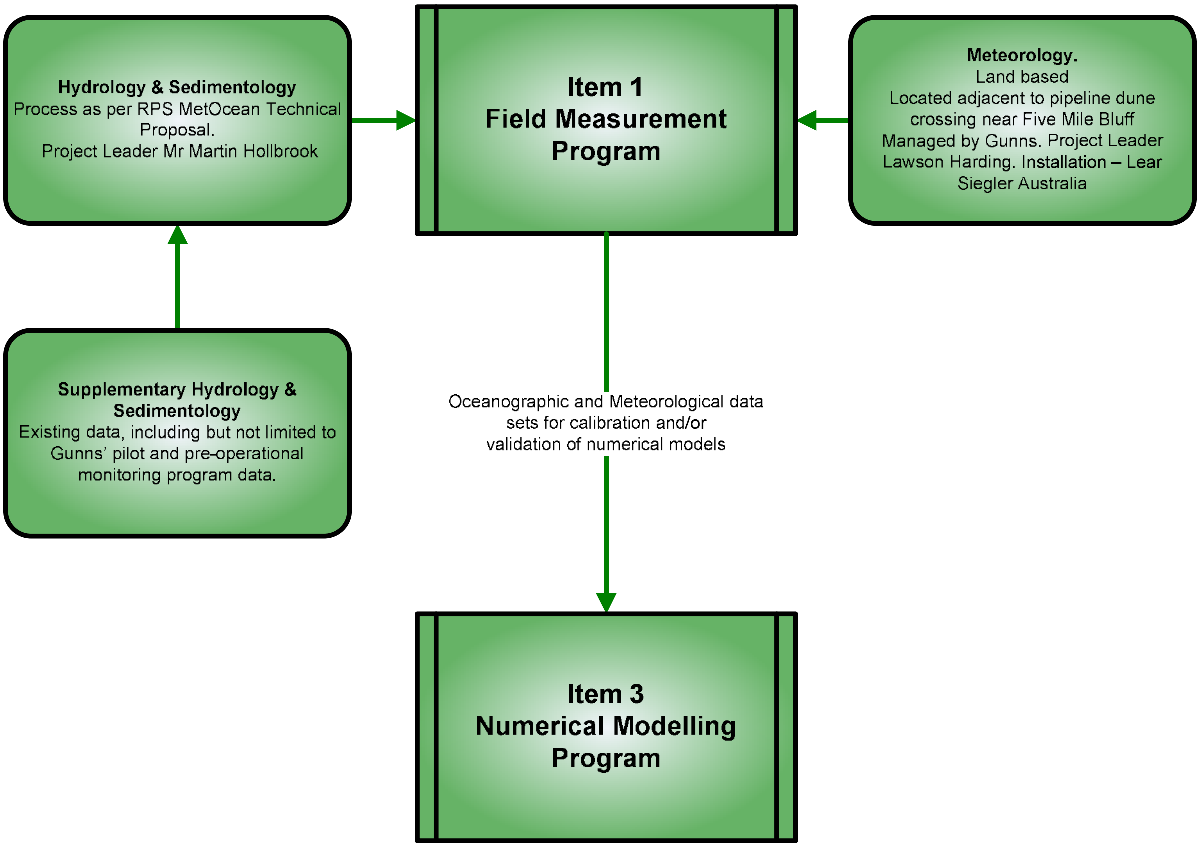

Figure 3: Schematic of Field Measurement Program (Item 1 of the overall Project) showing Program structure, brief description and relationship to Numerical Modelling Program.

A meteorological station deployed on shore near Five Mile Bluff was a minor component of the field measurement program and this sub-component was implemented and managed by Gunns' pulp mill project team, with quarterly meteorological database reports provided to RPS MetOcean.

Figure 4 Photograph of meteorological station deployed near Five Mile Bluff

The marine based components of the measurement program were undertaken by RPS MetOcean. The deployment program required several service visits during the year for retrieval of instruments, downloading instrument data on shore and subsequent redeployment of the instruments after cleaning, re-calibration etc. Supplementary oceanographic measurements and extractive sampling for laboratory analyses were also conducted during the service visits at and between mooring locations.

Three complete mooring bundles were deployed for the duration of the program. One mooring was deployed at the mouth of the Tamar Estuary "Tamar"; one was located within the defined Mixing Zone i.e. where the mill's outfall is proposed to be located "Outfall"; and a third was located in Commonwealth waters (and was relocated once during the program), north west of Five Mile Bluff "Offshore" & subsequently "New Offshore".

Figure 5 shows the approximate locations of the moorings as deployed and Figure 6 demonstrates a typical mooring configuration. Note that each mooring was configured slightly differently on account of the different water depths.

The Project also utilised existing oceanographic measurements obtained by Gunns or on behalf of Gunns prior to commencement. These data were mostly used to provide modellers with an initial indication of oceanographic conditions. This information included measured temperatures, salinity, currents, sediment grain size etc. These pre-existing data allowed the modellers to make an early start to 'fine tuning' the models prior to the accessing of detailed oceanographic data obtained during the Project.

The only pre-existing (i.e. supplementary, as described in Figure 3) data used by the modellers as an actual input parameter to any model were sediment quality parameters reported previously to the State as part of *Gunns' Environmental Performance Report Number 1*[11], covering baseline monitoring undertaken up to November 2008. Otherwise, these supplementary data sets were not utilised for detailed final validation or calibration processes and are therefore not presented within this *Final Report on Commonwealth Requirements*.

[11] http://www.gunnspulpmill.com.au/permits/Environmental%20Performance%20Report%20No.%201.pdf

Figure 5 Approximate locations of measurement stations (moorings) while deployed August 2009 to September 2010.

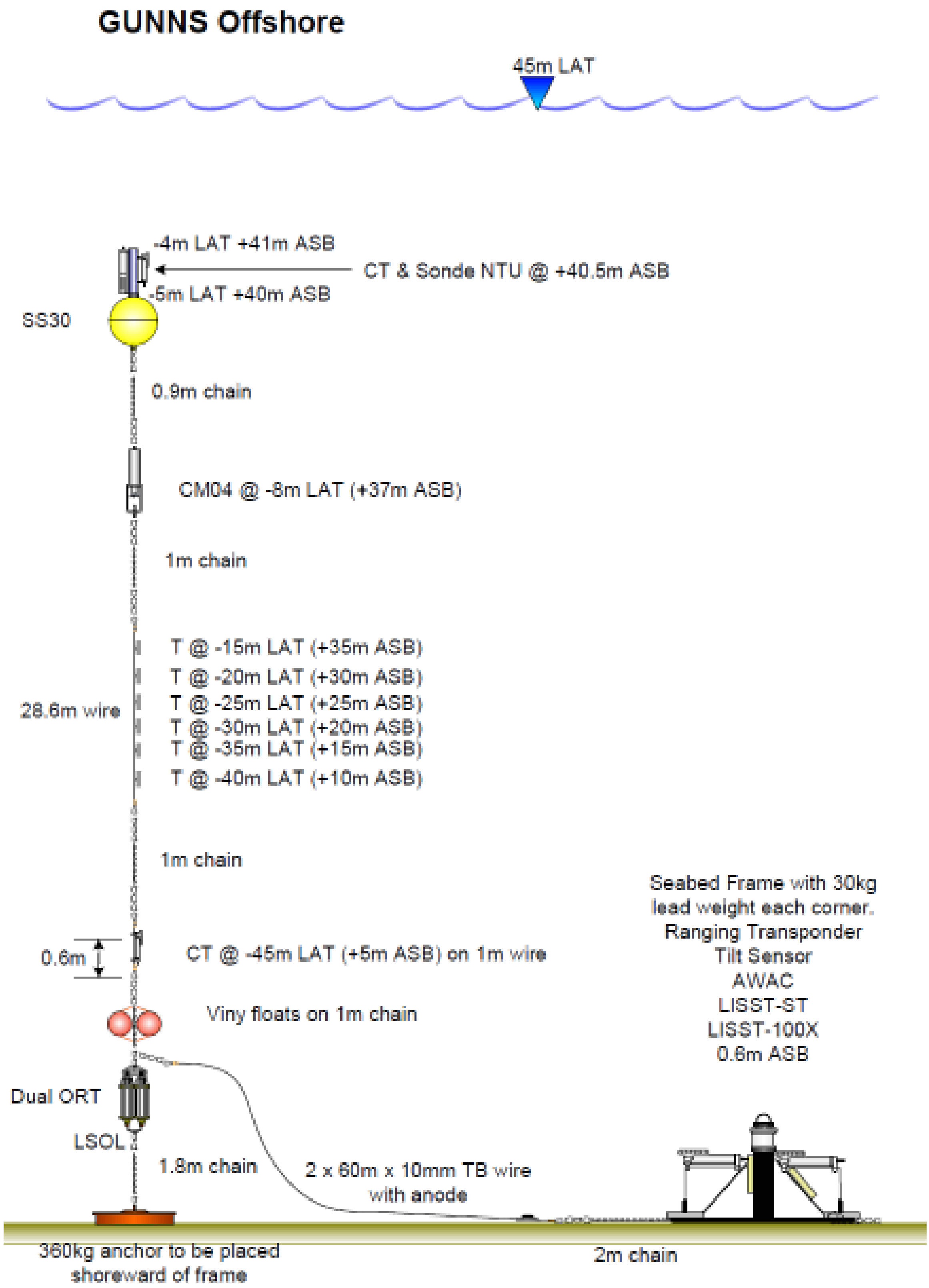

Figure 6 Offshore mooring showing typical configuration of oceanographic instruments.

The marine program included instrument(s) to measure waves, currents throughout the water column, temperature, salinity, suspended sediment particle size and particle settling velocity. The sediment settling and particle size measurements utilised two state of the art devices (LISST-100X & LISST-STX) that have not been a component of prior or similar studies of this scale and are an example of the comprehensive and innovative nature of this measurement program. The LISST devices were selected to satisfy a requirement of the SoW that ‘state of the art sediment sampling instrumentation be used’.

(a) (b)

Figure 7: Photographs of second deployment of moorings in Bass Strait. (a) is a sea bed frame containing a current and wave meter, battery packs and LISST sediment analysers. (b) is a sub-surface buoy with a temperature and turbidity sensor mounted above. The two components shown are connected with a chain equipped with an anchor, multiple temperature sensors and an additional CM-04 current meter. Retrieval was achieved by the use of an auto-release mechanism whereby the main uplift buoy rises to the surface when the main anchor is jettisoned.

2.1.4 Field Measurement Reporting

The second ‘milestone’ report submitted to the Commonwealth during the Project’s implementation phase - *Field Measurement Program: Interim Oceanographic Data Report 2 September to 3 December 2009* submitted to the Commonwealth in March 2010 - only covered the first two six weekly deployments (i.e. a total of three months) and is therefore not included in this *Final Report on Commonwealth Requirements* package as it is superseded by the subsequent full year report.

The full year report of oceanographic observations made during entire measurement program has been provided to the Commonwealth under separate cover. Due to its very large size (several thousand pages) the full report is not appended to this document. A partial report detailing measurement protocols, equipment etc is appended to this document as *Report No. 6: Field Measurement Program* (Appendix 1 A); however, no actual measurement data is presented.

The salient oceanographic measurements from the program are presented along side appropriate model predictions within MetOcean’s *Report No.4: Calibration and Validation of Hydrodynamic Model* (Appendix 3 B Document 4 discussed below) and a full series of linked pdf files comprising RPS MetOcean’s *Report No. 6: Field Measurement Program* is available on Gunns’ web site. A brief summary of information obtained by the measurement program is provided in the *Final Report Interpretive Summary* section of this document below.

2.2 Item 2 Overseas Effluent Studies

2.2.1 Context

The Commonwealth's Approval Decision included two specific tasks that were required to inform and/or assist with interpretation of the hydrodynamic model. They were:

(1) Particulate property testing (settling and flocculation) by laboratory tests (Condition 35), and

(2) Effluent (physico) chemistry and toxicity analysis (Condition 34).

Both are based on the approval requirement to use an 'equivalent effluent' or to be conducted on 'samples obtained from a similar overseas mill'. In addition to effluent chemistry and toxicity analyses, Gunns was also required to report on the temporal variability in both contaminant concentration(s) and toxicity.

On the recommendation of the IEG, additional studies to examine the potential partitioning of key effluent quality parameters (AOX & chlorate) between water and sediment were undertaken. Partitioning could potentially be influenced by a change in ionic strength (salinity) such as would be experienced when the low salinity effluent is released in the marine receiving water body.

The results of the Effluent Studies provide some of the inputs into the computer hydrodynamic model(s) as described in Figure 8 and they also assist with interpretation of the model outputs. As Stated in the *Introduction*, the Effluent Studies component of the Project was required by the Commonwealth only. Nevertheless, State officers provided valuable advice in the planning stages which was adopted and implemented during the studies.

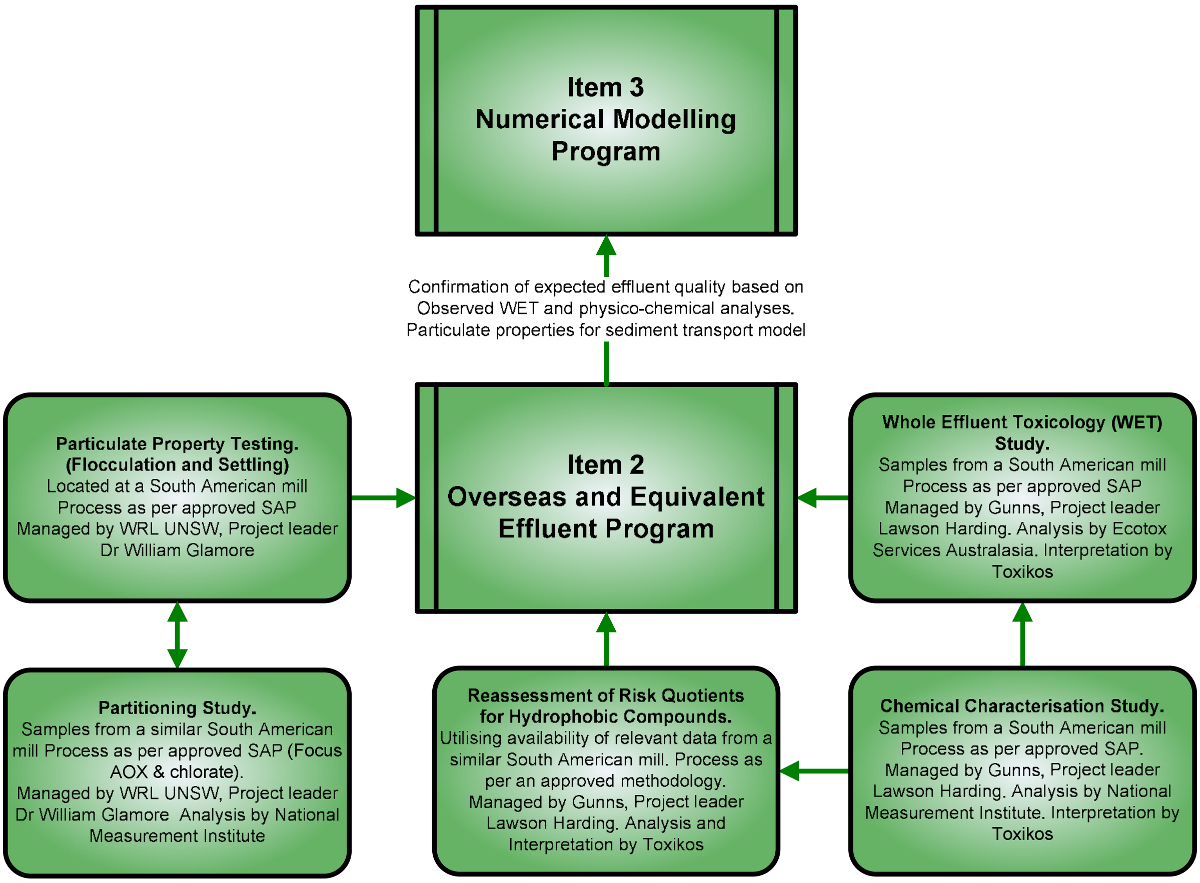

Figure 8 Overseas and Equivalent Effluent Program (Item 2 of the overall Project) showing Program structure, brief description and relationship to Numerical Modelling Program.

2.2.2 Segregation of tasks to Phase 1 & Phase 2

The effluent studies component of the Project was managed directly by Gunns and undertaken primarily by Water Research Laboratory (WRL) and Ecotox Services Australasia Pty Ltd (ESA), with interpretive and other support from Toxikos Pty Ltd. Analytical services were mainly provided by the National Measurement Institute (NMI), with assistance from CSIRO Materials Science & Engineering and Levay & Co Environmental Services. A minor suite of physico-chemical analyses was also conducted by Cetrel S.A. of Brazil.

In order to undertake the studies, a suitably similar source of effluent first had to be obtained. The choice of modern candidate mills of similar scale, process and furnish (*Eucalyptus spp.*) etc is extremely limited world wide. While no two Kraft mills are ever identical in this context, the most similar mills to the Bell Bay project, as advised by its designers, are in South America. After correspondence with a number of candidate mill owners, the owners of the Veracel S.A. facility in the State of Bahia, Brazil kindly agreed to allow Gunns access to their facility, including for the study to be undertaken on their effluent and/or on their site if necessary. The Commonwealth and the IEG were notified of the identity of the mill and confirmed it was fit for purpose.

A preliminary visit to Brazil in late 2009 was undertaken by Dr William Glamore of WRL and Lawson Harding of Gunns to ascertain what local resources would be available at the Veracel mill. The preliminary visit confirmed that the tasks were technically achievable but that there was an elevated risk of failure due mainly to export/import provisions of some key technical equipment into and out of Brazil and potential airline delays for retrieved samples.

At the close of the initial visit, the laboratory settling studies, which required large volumes of effluent that could not practically be transported to Australia, were scheduled for a subsequent visit by Dr Glamore on-site at Veracel (reported to the Commonwealth as Phase 2 of the Effluent Studies). Physico-chemical and Whole Effluent Toxicity (WET) analyses, which required less material, were conducted on samples retrieved on the initial visit and couriered immediately to Australian laboratories. An acceptable holding time during transit and robust sample Quality Assurance (QA) and Quality Control (QC) protocols were considered achievable provided there were no flight or unanticipated regulatory delays and these requirements were indeed were achieved. These analyses were subsequently reported to the Commonwealth as Phase 1 of the Effluent Studies.

2.2.3 Phase 1. Whole Effluent Testing and Physico-chemical Analysis

Samples from the outlet of the Veracel mill's effluent treatment plant were collected at the close of the initial visit and returned to Australia for detailed ecotoxicological and physico-chemical analysis. A number of reports have been prepared and are attached as appendices, covering the first and second phase of these studies. The first phase reports comprised:

- A Sampling Report by Gunns Limited, detailing the sampling protocols, including timing and transport details, of the effluent samples retrieved from Brazil (Appendix 2 A).
- Two Toxicity Assessment Reports of WET tests undertaken by Ecotox Services Australasia Pty Ltd using the retrieved samples (Appendix 2 B, Document 1 & Document 2).
- Two interpretive reports on the above, prepared by Toxikos Pty Ltd (Appendix 2 C, Document 1 & Document 2).
- A schedule of physico-chemical test data developed from a suite of analyses undertaken by NMI on retrieved samples. This schedule also included analytical results of samples for a limited suite of key analytes undertaken by a local Brazilian laboratory (Cetrel S.A.) where the transit time to Australia would have been excessive to deliver a valid result for a particular analytical protocol (Appendix 2 D).
- A report on a Partitioning Study developed and reported by WRL to investigate the effect that a change in ionic strength (salt water mixing) may have upon key dissolved contaminants (Appendix 2 E).

A summary of the first phase methodology is provided below.

2.2.3.1 Whole Effluent Toxicity Analysis

The approved Whole Effluent Toxicity (WET) Sampling and Analytical Plan (SAP) for the overseas effluent included the following assays:

- Microtox assay using the marine bacterium *Vibrio fischeri*
- 72-h micro-algal growth inhibition test using *Nitzschia closterium*
- 72-h macro-algal germination assay using *Hormosira banksii*
- Sea urchin fertilisation success using *Heliocidaris tuberculate*
- 72-h larval development using the sea urchin *Heliocidaris tuberculat*
- 48-h larval development using the doughboy scallop *Mimachlamys asperrima*
- 96-h survival of the juvenile amphipod *Allorchestes compressa*
- 96-h larval fish imbalance test using the striped trumpeter *Latris lineata*[12].

In addition to the approved schedule of tests, Gunns included a number of other tests on the analytical schedule to be undertaken if sufficient sample material were available, in order to provide further objective evidence of the effluent's nature beyond that required to comply with the approved SAP. The additional tests, which were undertaken, are:

- 1-hr sea urchin fertilisation success using *Heliocidaris tuberculate*
- 72-hr macro-algal germination assay using *Ecklonia radiata*
- 14-d macro-algal gametophyte growth assay using *Ecklonia radiata*
- 48-hr acute *Ceriodaphnia dubia* immobilisation test.

Of particular note, the *Ecklonia radiata* tests were commissioned to provide further information to support an assessment of the potential effect that pulp mill effluent may have on brown algae, in this case a local sub-tidal species in addition to the local, but mostly intertidal, *Hormosira banksii*.

An interpretation report examining the results of the above assessments and all prior rounds of WET testing was prepared by consulting toxicologists, Toxikos Pty Ltd. This is the same organisation that authored the original *Marine Impact Assessment* (Drew & Frangos, 2007) for the Bell Bay pulp mill project. The Toxikos report is provided as Appendix 2 B Document 1 and discussed further in the *Final Report Interpretive Summary* section of this document below. The interpretive summary also draws on available information to further examine the temporal variability in the various qualities of Kraft pulp mill effluent, focussing on those with a *Eucalyptus spp* furnish.

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[12] Due to sampling occurring out of season to the *L.lineata* species, *Pagrus aurata* (golden snapper) was substituted for *L. lineata* (striped trumpeter).

2.2.3.2 *Physico-chemical Analysis*

The approved suite of physico-chemical analyses of the retrieved effluent samples was very extensive and included the key parameters described in the *Marine Impact Assessment* referred to above. A minor suite of analyses was also conducted by a local Brazilian laboratory for those analytes that would otherwise have exceeded their recommended holding time before analysis, if transported for the expected 48 hour (approximately) journey to Australia.

A report of the results of the physico-chemical analyses of the Veracel effluent samples is provided as a summary table in Appendix 2 D. The relevant supporting analytical certificates given in the summary table are also provided. The table also provides a reference to expected effluent concentrations utilised by the abovementioned *Marine Impact Assessment* for the Bell Bay pulp mill project. A brief interpretive summary of information obtained by the physico-chemical analysis is provided in the *Final Report Interpretive Summary* section of this document below.

2.2.3.3 *Partitioning Study*

The objective of the partitioning study was to examine the fate of a limited suite of dissolved contaminants upon initial mixing with seawater. Specifically, this study was undertaken to seek evidence of whether additional attenuation (beyond physical dilution) occurs in the dissolved concentration of chlorate and adsorbable organic halides (AOX) in pulp mill effluent when mixed with seawater. The study was designed to be run as an initial pilot trial with a small number of samples and then reviewed to determine the efficacy of further studies, with a statistically derived sampling design being one potential outcome of the initial trial. The partitioning study report is provided as Appendix 2 E.

The two effluent parameters, chlorate and AOX, were selected on the basis of:

- Chlorate requiring the greatest level of dilution of all the effluent parameters in the receiving environment from its maximum permitted concentration in raw effluent to achieve the prescribed water quality objective.

- AOX (adsorbable organic halides), are commonly associated with ECF Kraft pulp mill effluents and have a propensity to adhere to carbon. They are therefore a convenient and easily measurable ‘tracer’ of effluent contaminants that may accumulate in sediment. Note, however, that AOX in itself is not an environmentally relevant parameter for inferring actual ecological impact.

Prior to undertaking the initial trial study, it was thought that information derived from this exercise could be utilised for further interpretation of hydrodynamic modelling outputs. The expectation was that partitioning of these parameters between dissolved and sedimentary phases would allow commensurate adjustments to final concentrations in each of these phases. However, the initial trial did not produce any robust evidence to suggest that additional attenuation was occurring and the investigation was therefore not taken any further. The findings of the initial trial are provided within this final report document for completeness but because this initial investigation indicated partitioning was unlikely and, in any event, was not a permit requirement, it was suspended and it is not discussed any further.

2.2.3.4 Reassessment of Risk Quotients

The primary objective of the Reassessment of Risk Quotients study, in accordance with Condition 37 (b) of Approval Decision 2007/3385 was to confirm the scope of hydrophobic contaminants required by the effluent monitoring program described under Module L. A methodology document has been prepared and submitted to the Commonwealth for review/approval. Due to a delay in the review/approval process, and also because the study itself not being a significant factor to the outcome of the Project, this component of the Project will be submitted under separate cover in accordance with Module M and not discussed any further in this *Final Report on Commonwealth Requirements*.

2.2.4 Phase 2. Particulate Property Testing (Flocculation and Settling)

This component of the Overseas Effluent Program solely focuses on providing information to support the sediment transport modelling tasks (Item 3). A return visit to Brazil was made in early 2010 by Dr William Glamore and his assistant, Mr Alessio Mariani, of WRL to undertake the second series of tests at the Veracel mill site. Effluent volume requirements for the tests dictated that these tasks be conducted as close as practicable to the effluent source.

This Project component's objective was to simulate the processes of sedimentation and re-suspension by ambient hydrodynamic forcing of any fine organic particulates suspended within the effluent upon discharge. A major requirement of this task was measuring the physical properties of the fine particulate (or flocs) in the effluent, including particle size distribution, settling rates, and re-suspension rates. These properties needed to be determined by physical modelling processes using representative samples of effluent from a similar (overseas) operating mill.

The study examined the physical properties of flocs within the pulp mill effluent using a series of physical model experiments. Overall, this investigation aimed to track, by physical simulation, the suspended floc throughout its dynamic transport cycle from the end of the production process, through the discharge pipe, and in the marine receiving environment within the near-field zone, including settling and re-suspension dynamics. Figure 9 illustrates the various phases of the floc transport cycle analysed in this study and the related WRL investigations.

Processes Affecting Particle Transport and Settling

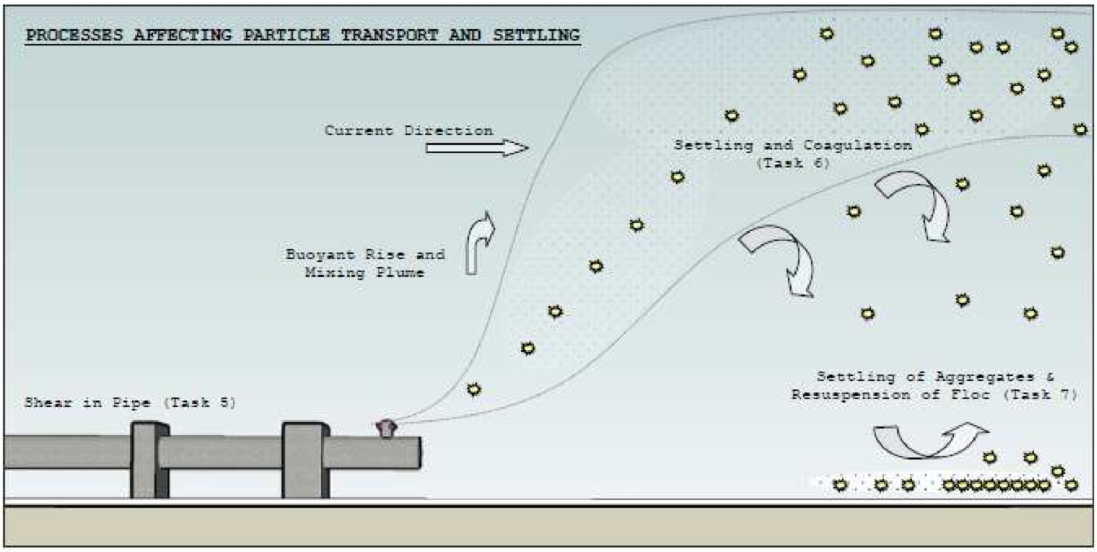

Figure 9 Diagrammatic representation of the key processes studied by WRL to determine settling and resuspension properties of particles within a Kraft pulp mill's effluent.

The second phase reporting comprised only one report being:

- *Particulate Property Testing Report, Gunns Pulp Mill (August 2010)*

The above report[13] (as a prior version) has been submitted previously to the Commonwealth as 'milestone' report and is included again here as Appendix 2 F. A brief interpretive summary of WRL's *Particulate Property Testing Report* is provided in the *Final Report Interpretive Summary* section of this document below.

13 The Particulate Property Testing Report was revised since the April 2010 version as previously submitted to the Commonwealth in order to address formatting errors and other minor matters.

2.3 Item 3 Numeric (Computer) Modelling

2.3.1 Context

The modelling components of the Project were subdivided into two key sub-components: 'near field' and 'far field'. The far field modelling was further subdivided into a water quality component, which examined dissolved parameters and a sediment transport component, which as the name implies examined those parameters which can be classified as sediment or are associated with sediment. The near field modelling component was undertaken by Worley Parsons and the far field modelling, including both the water quality and sediment transport components, was undertaken by RPS MetOcean (RPS MetOcean was also the key contractor for Item 1 of the Project).

The information presented in this section provides supporting contextual information and also describes the interpretive analysis of the key Worley Parsons and MetOcean reports, provided as Appendices 3 A (comprising Worley Parsons documents) and 3 B (comprising RPS MetOcean documents).

The modelling tasks are informed by the Item 1 and 2 studies, as described in Figure 10.

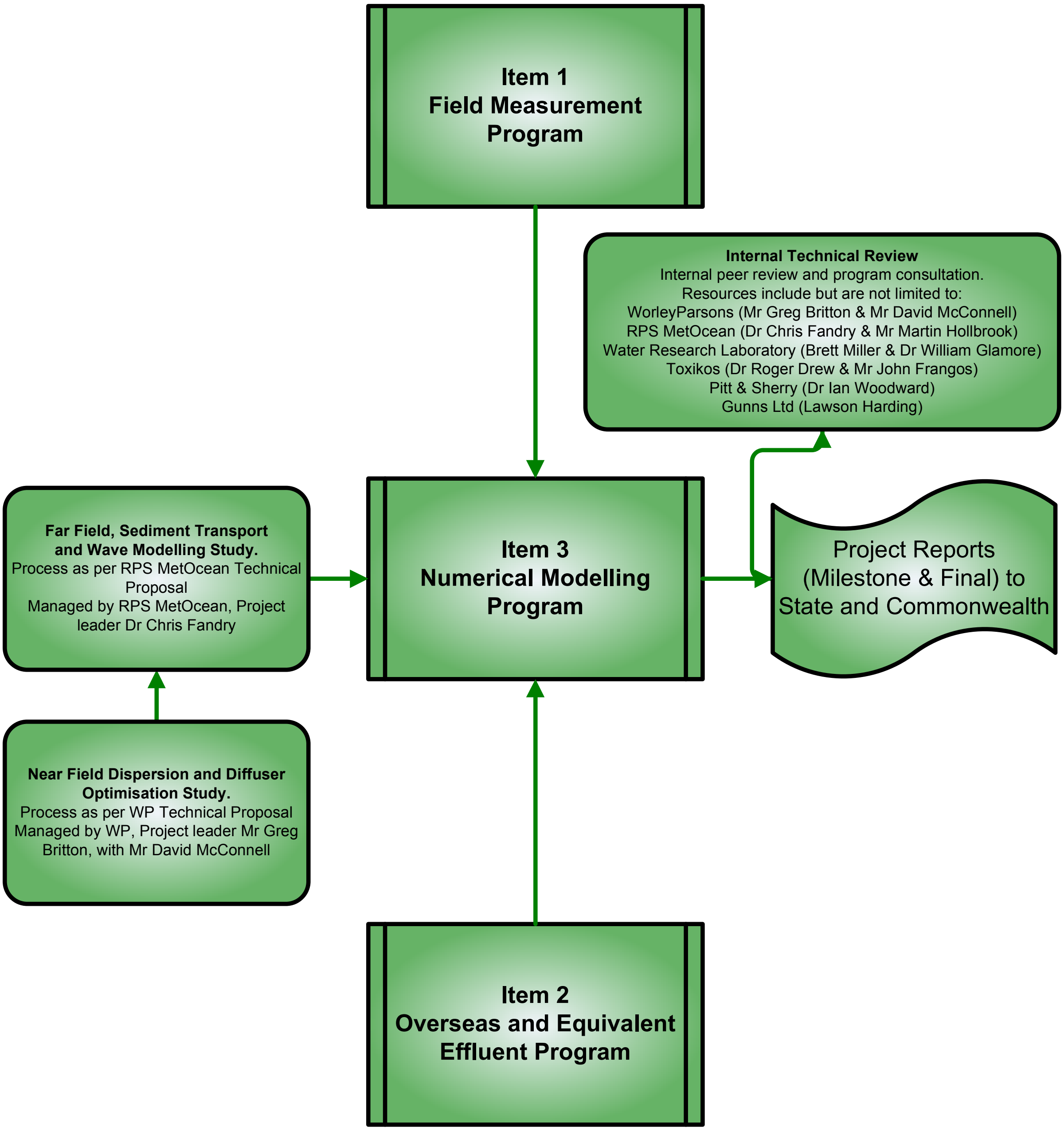

Figure 10 Numerical Modelling Program (Item 3 of the overall Project) showing Program structure, brief description and relationship to Overseas Effluent and Measurement Programs.

2.3.2 Near field modelling

The finest resolution of the modelling used in the Project is the near field element. Near field modelling is used to predict the initial dilution patterns of a specified discharge rate of effluent (0.738 m^3s^{-1}, equivalent to 64 $MLday^{-1}$), in this case from release at the bottom of a circa 26 m deep water column, through its expected rise to the surface and then horizontally with current and buoyancy induced momentum. This is an important part of the overall Project as it provides evidence of the initial plume characteristics, including the number and location of the grid cells that the finest resolution far field model should use to begin its own dispersion simulation.

The initial objective of the near field modelling for the Project was to undertake a review of the design elements of the diffuser itself, including port spacing, alignment and overall diffuser length.

As a result of the initial review, the diffuser design was altered as a conservative management strategy from that used in prior studies, with the design alteration mainly focussing on lengthening the diffuser from 200 m to 250 m. This design review is discussed in more detail in the near field model interpretation section below and in the main Worley Parsons report (Appendix 3 A, Document 1).

In order to be thorough and utilise the best available technology, the near field modelling component used two parallel modelling methods. They were:

(1) a conventional empirical method as used by many similar studies world wide using the *JETLAG* model software; and

(2) a computational fluid dynamics (CFD) approach using the *Flow-3D* software, which is a developing technique for this type of application.

The empirical method provides a validation link to prior field observations and trials of similar existing infrastructure, while the CFD approach uses highly sophisticated detailed computer simulations based on fundamental physical science equations. This combined approach ensures that the detailed design of the diffuser is optimised and fit for purpose from: (1) a good initial dilution performance perspective; (2) optimal performance under any constraining conditions that could be encountered (such as a density stratified environment); and, (3) efficient long term maintenance perspectives.

Near field modelling is also further discussed in the context of coupling the near field model to the far field model within the *Far Field Modelling – water quality* section below. The *Final Report Interpretive Summary* section of this document will also include commentary on the effect of density stratification and Worley Parson's examination of that phenomenon for this Project.

2.3.3 Far field modelling-water quality

The discharge plume concentration outputs as determined by the CFD near field model provide the loading parameters to the grid cells corresponding to the diffuser's location in the far field model. The far field model then simulates propagation of the plume across its nested modelling domains, calculating the dispersion and dilution of discharge plume 'tracers' within and beyond the mixing zone.

2.3.3.1 Coupling of near and far field models

The configuration and detail of the near field modelling is extensively reported in the 'milestone' reports authored by Worley Parsons, which are appended to this report. In order to utilise the near field model outputs, which describe the initial physical extent and characteristics of the effluent plume (i.e. plume depth; plume width etc), the method of transferring this information (sometimes termed 'loading' or 'coupling') into the far field model as a starting point for the far field model needed to be decided and implemented.

Following early technical review by the IEG, it advised that partial loading of far field cells during model coupling should be avoided. In particular, the IEG required that the scale dimensions of the diffuser be the same as the model (or *vice versa*). Because the far field model cell dimensions are 50 m x 50 m (as required by the approved methodology), the diffuser length must therefore be in 50 m length units (200 m, 250 m, 300 m etc).

The earlier modelling by GHD used for the assessment process for the Bell Bay pulp mill project had used partial loading to far field cells. That partial loading strategy was not in itself criticised by technical reviewers at the time and was in fact supported (Patterson Britton 2007). Nevertheless, the IEG advice to avoid partial loading in the current series of model runs was adopted and formed one of the parameters for the diffuser's design review.

To avoid the far field model potentially discounting the impact of the width of the plume (depending on the final coupling methodology), the raw results of the near field model were adjusted where necessary to match the grid size of the far-field model. The adjustment process is described in detail in the Worley Parsons report.

A specific report by MetOcean on the coupling methodology selected for the Project is provided as an appendix. *Report No. 2: Coupling of Near and Far Field Models*. Appendix 3 B, Document 2. This report was also presented to the Commonwealth under separate cover as a 'milestone' report. A conceptual diagram describing coupling of near field to far field models is shown in Figure 11.

MetOcean's *Report No. 2: Coupling of Near and Far-Field Models* describes how the final selected coupling method evenly distributes the 0.738 m^3s^{-1} effluent discharge into the far field model over five 50 x 50 m Very Fine Grid cells (consistent with the length of the diffuser, which is 250 m long) to an initial depth of 9.9 m, measured from the surface.

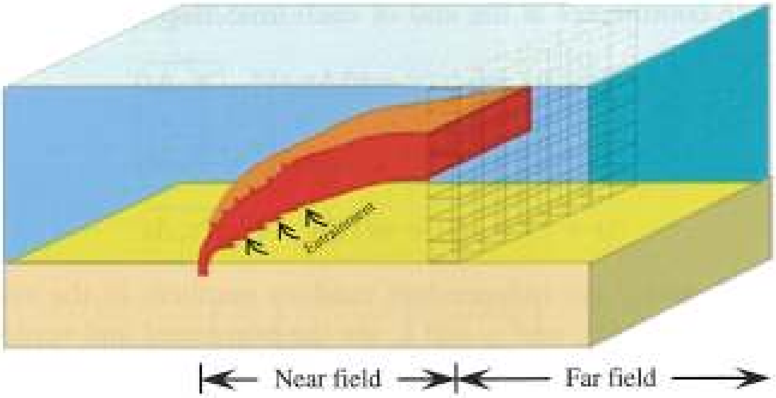

Figure 11 Conceptual diagram of model coupling (from Roberts *et al* 2010).

This configuration corresponds to an initial dilution of 280:1 at the conservative cross current velocity of 0.018m sec^{-1} presented within the Worley Parsons near-field modelling report.

It should be noted that the 280:1 value itself is not a loading parameter to the far-field model; the loading parameters are the 250 m x 9.9 m plume cross-section dimensions, corresponding to the vertical cross sectional area of a line plume exposed to a cross current, and the effluent injection rate of 0.738 m^3s^{-1}.

In early consultation, the IEG suggested a 'rule of thumb' assumption that the plume's initial depth would be 30% of the available water depth. At the diffuser location, this equates to a plume depth of 8.1 m. The Worley Parsons modelling recommendation of 9.9 m for the coupling depth is broadly consistent with this rule of thumb depth. It is also consistent with the empirical formula presented in Roberts *et al* (2010) of 36% of the water depth (for a stationary, homogenous environment), corresponding to 9.8 m for this design scenario.

The initial Worley Parsons modelling examined the 250 m diffuser case by extrapolation from 300, 400 and 500 m configurations. After technical review, the IEG advised Gunns to consider a supplementary near field modelling run to test the veracity of Worley Parsons' extrapolation. The advice was accepted and a supplementary run examining a 250 m diffuser was commissioned and subsequently reported. The Worley Parsons near field modelling report for the 250 m diffuser model run is provided as an addendum to the initial report and is attached as Appendix 3 A, Document 2. The results of the supplementary modelling showed that the 250 m diffuser would perform better than what was anticipated by extrapolation, confirming the conservatism of Worley Parson's original extrapolation. It further identified that the horizontal "T" port configuration would perform noticeably better than the conservatively assumed vertical port model at the low current speed of 0.018 ms^{-1}.

After consideration of the two Worley Parsons modelling runs, the final review by the Project team of the diffuser configuration (horizontal or vertical discharge) and the model coupling design therefore resolved the following:

- The horizontal port configuration would be carried forward through to implementation. In making this decision, it was noted that the horizontal port configuration would be more likely to deliver better dilution during low or zero current periods (eg. turn of tide), although it may have slightly inferior performance in a strongly stratified environment (which is infrequent for periods longer than days at a time, but can be frequent for short (< ½ day) periods in warmer months). The driver for this decision was largely aesthetic for colour-dilution considerations. This strategy provides maximum opportunity for the effluent plume to not be visible (i.e. perceived as an area of slightly different ocean colour to that of the surrounding water body) at the surface at times of maximum potential for that to occur. In considering the strategy further, it must be recognised that aesthetic considerations at or around the outfall are not relevant to the Commonwealth's jurisdiction, but are intended to address specific State regulatory requirements.

- The adjusted depth (9.9 m) value for the vertical discharge as originally estimated by Worley Parsons by extrapolation prior to the specific 250 m model run would be retained as a conservative measure, rather than adopting the values calculated by the supplementary 250m diffuser specific run for horizontal ports.

The far field model's calculated dilution predictions at the surface are therefore proportionally lower than they would have been had the less conservative supplementary value of 17.6 m for a "T" port diffuser been used. Had the 17.6 m value been applied to all conditions, by the coupling protocol described in MetOcean's *Report No. 2: Coupling Near and Far Field Models*, the initial dilution for the Very Fine Grid given in Table 4 of that report would have increased from 338:1 to 596:1. This will in turn drive the far field modelling predictions to be strongly conservative (i.e. underestimating dilution is protective of the environment).

2.3.3.2 Far-field Simulation period

A key objective for the model runs of the far field component was to capture annual seasonal patterns and also allow decadal (10 year) simulation for the overall Bass Strait region.

The computer runs for the far field modelling were undertaken separately for each of the different far field level domains. The two larger (coarser) domains take a few days of computer time to simulate many years of effluent release and water movement and thus temporal coverage was easily achieved for these domains. The finer resolution domains take very much longer to run and the finest resolution model of the far-field domains (termed the Very Fine Grid or 'VFG') could not simulate an entire year within the approved Project schedule. For the VFG, 1 day of computer time is required to simulate 2.5 days of real time.

In recognition of this 2.5 day 'run time ratio' for the VFG, and of the potential for model instabilities to arise (as is a common occurrence with complex models), it was originally planned (with the agreement of the State and Commonwealth) that the VFG model would be run to simulate one representative month from within each quarter over the simulation period of one year (a total of 4 months). However, efficiencies and modelling skill delivered by the modelling firm (RPS MetOcean) allowed the VFG model to complete 10 contiguous months simulation, a substantial increase over that originally anticipated and allowing even more robust conclusions and interpretations.

2.3.3.3 Calibration and Validation.

Model calibration and subsequent validation is described in detail MetOcean's *Report No. 4: Calibration and Validation of Hydrodynamic Model* attached as Appendix 3 B Document 4. The calibration process can be simply summarised as checking the model outputs against known values and if necessary adjusting the model's configuration to reduce as much as practicable the difference(s) between the model's outputs and the known values.

The outcome of the calibration process was that an observed offset in temperature and salinity was necessary. This was not due to the model but by the relatively imprecise model forcing from the externally supplied BlueLink database. This type of calibration was always expected (indeed it is specifically required under the Commonwealth's Approval Decision 2007/3385) as the BlueLink database and others like it are not designed to provide the high resolution coastal data required by the complex modelling approach used in this Project.

The calibration of the model to temperature and salinity was successfully achieved by a process termed 'scaling' using field data collected specifically for this purpose. A portion of the temperature and salinity data obtained at the Offshore mooring location was allocated to this process. As the Fine Grid (the model nest larger than the VFG referred to hereafter as the 'FG') is one-way coupled to the VFG, this calibration was therefore also applied to the VFG via the two grid's normal interaction processes. The residual field data (that part not used for calibration) was therefore available for model validation. In essence, validation is the final 'reality check' of the model's performance and is intended to provide evidence of satisfactory calibration and operation.

As stated under *Simulation Period* above, the Very Fine Grid far-field model was required to simulate at least 4 months under the approved methodology. In fact, 10 months were delivered. This has an enormous flow on effect as to the amount of quality information that is available to demonstrate satisfactory calibration.

Validation of the model's output was demonstrated by its ability to meet performance objectives set before the Project commenced under the approved methodology. Model performance is further discussed in the *Final Report Interpretive Summary* section below.

2.3.3.4 Loading Scenarios.

The far field hydrodynamic model has been used to present various outfall scenarios in the final MetOcean results document, *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall.* (Appendix 3 B Document 5). For each scenario, the model predicted contaminant concentrations across the entire modelling domain (i.e. in each cell of each grid).

The outfall scenarios include (among other factors) different outfall discharge rates, relevant to discrete pollutants. The 'worst case' scenario is where an individual effluent pollutant is assumed to be discharging continuously at its maximum permitted limit. Although this would not occur continuously in the real world, the worst case scenario is used to examine whether the concentration (or loading) limits are appropriately protective of the receiving environment.

For example, the Commonwealth Approval Decision 2007/3385 sets the concentration limit for chlorate (ClO_3^-) to be 3.7 mg L^{-1} as a monthly average (Condition 32) and the maximum volume of wastewater discharge as 64 ML day^{-1} on an average monthly basis (Condition 31). The combination of these two limits provide an assumed maximum loading rate for chlorate into the receiving environment allowed under the Commonwealth's approval (concentration multiplied by volume per period time = mass load per period time).

A number of presentation scenarios were discussed and developed with both State and Commonwealth Departments during the implantation phase of the Project. The State and Commonwealth scenarios do not always align because the two jurisdictions in some cases set limits based on different sampling periods, such as daily maximum versus monthly average and overall mass loading rates. Nevertheless, the common principle from both jurisdictions was the need to answer the question: 'what would be the result if the mill were emitting a pollutant(s) constantly at the jurisdiction's maximum allowed rate?' It is this principle that underpins the vast majority of scenarios presented herein.

2.3.3.5 Presentation Methods

All of the discharge scenarios are subject to the influence of the dynamic nature of the receiving waters, which have varying conditions such as tidal and wind driven currents. These conditions cause the discharge plume to behave dynamically in the model, as it will in the real world. Prior modelling had been criticised by reviewers as the statistical dilution contours presented previously did not show a plume leading towards shore, which some expected. This revised round of work extends the presentation methods to depict the outfall dynamically. Some of these dynamic presentation techniques were not possible in the prior work. The key presentations for an appropriate environmental assessment, however, remain as statistical presentations similar to those presented previously.

The modelling predicts that most of the time the plume is analogous to an expanding and contracting ribbon trending north east or south west away from the outfall (parallel to the coast), which gradually dissipates as the plume mixes by diffusion and turbulence. Under some conditions, particularly around the turn of tides, the plume can be relatively small, with little horizontal movement. In other circumstances it may move away, partially dissipate and then move back over the diffuser and re-concentrate, before moving away again. The plume is also shown by the model to be occasionally carried toward the north coast of Tasmania for relatively short times.

Instantaneous Data Presentations

The dynamic nature of the plume can be presented in a number of ways. The first and simplest is to depict the plume as a 'snapshot', which is analogous to an aerial photograph capturing the plume at a single point in time. Figure 12 shows a typical instantaneous model 'snapshot' of the plume's path. It is important to recognise that the colours depicted in this image and others within this report represent an effluent tracer as a numerical value. They do not represent actual colour as would be perceived by eye.

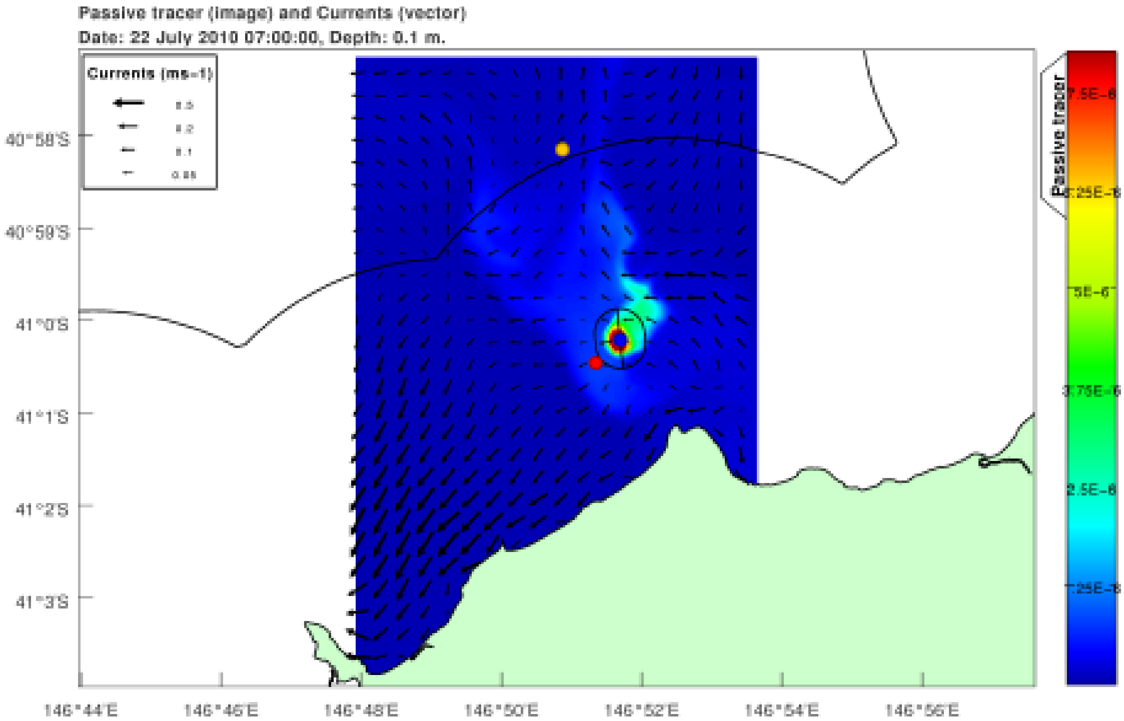

Figure 12 Snapshot of the plume's typical path trajectory. Note the legend colours are set to provide high resolution for demonstration purposes and are not set to represent what would be the observable nature of the plume.

The colour bar at the right of the image presents an unscaled tracer concentration in units of kg m^{-3}. As the standard model loading equates to 1 mg L^{-1} (equivalent to 1.0×10^{-3} kg m^{-3}), the passive tracer scale colour bar can be interpreted for dilution levels using the following example; the green band of the colour bar in Figure 12 is "3.75 E-6", which itself is a 'shorthand' representation for the scientific notation value for 3.75×10^{-6} kg m^{-3}. The dilution level is simply the ratio of passive tracer loading concentration to passive concentration tracer level in the receiving environment (1.0×10^{-3} kg m^{-3} / $3.75\ 10^{-6}$ kg m^{-3} = 266:1 dilution).

The above instantaneous presentation is consistent with model interpretation in prior studies submitted during the original assessment and approval processes, which noted that *the direction and duration of the diluting and dispersing effluent plume will vary on a daily basis and affect different coastal water areas and offshore waters* (Envirogulf Consulting, 2007).

Presentations Developed from Continuous Data.

An instantaneous snapshot is informative but it alone does not provide sufficient alone. Thorough interpretation of the effluent discharge requires information on:

- The highest concentrations of effluent encountered in the different areas of interest within the modelling domain through a representative period.
- The maximum continuous levels of exposure encountered in the different areas of interest within the modelling domain through a representative period.

The relative importance of the two points should be related to the nature of the parameter being considered. In the context of a toxicant in BEK mill effluent, such as chlorate, it is important to understand whether that toxicant has a known impact 'signature' from an acute (short term) exposure or a chronic (mid to longer term) perspective and, if so, at what concentration levels.

To meet the dual interpretation objectives above, two approaches can be employed. In order to determine the level and location of the highest concentration values that are likely to be observed throughout the modelling domain it is common to produce n^{th}-percentile statistic plots.

For toxicants these could be 95^{th}, or even 99^{th} or 100^{th} percentiles (n^{th} %ile). For non-toxicants they should be 50^{th} or sometimes 80^{th} percentiles.

Percentile plots were the main presentation method in prior modelling works, as they are a useful initial screening tool for an ecological interpretation.

The second and ecologically linked method is to produce time averaged exposure plots over a suitable exposure period. Examples of these may be a 1 hour average concentration isopleths (for an acute toxicant) or 4 day average concentration isopleths (for a chronic toxicant).

The rationale for examining time averaged values for toxicants is detailed within the *USEPA Technical Support Document for Water Quality Based Toxics Control (USEPA 1991)*. As the title implies, this document provides guidance on the interpretation of toxicants in receiving water bodies based on their known acute and chronic effects. The USEPA recommends a 1 hour averaging period for the assessment of exceedences by acute (fast acting) toxicants and 4 day average concentration for the assessment of exceedences by chronic (slower acting) toxicants.

The USEPA document defines the CMC (Criteria Maximum Concentration) to protect aquatic ecosystem from acute and lethal effects; the CCC (Criteria Continuous Concentration) similarly is for protection from chronic effects. Roberts *et al* (2010) discuss this point and state: "*The CCC is like a regular water quality standard and must be met at the edge of the mixing zone. 'It is …intended to be the highest concentration that could be maintained indefinitely in receiving water without causing an unacceptable effect on the aquatic ecosystem or its uses'. The CCC limits may sometimes be exceeded, as organisms can tolerate higher concentrations for shorter periods so long as peak concentrations are limited*".

In the case of chlorate, which is the key toxicant for examination by this Project, the State Government and the Commonwealth have advised Gunns that a 3 day (72 hour) rolling average should be used to determine exceedences of the relevant receiving water quality criteria for chlorate. This 3 day rolling average (which is more conservative than the USEPA's 4 day average) is considered appropriate based on the chronic toxicity signature for chlorate reported and analysed in detail in the original *Marine Impact Assessment* (MIA) and other supporting documentation (Drew & Frangos 2007, Envirogulf Consulting 2007).

Statistical Presentations

The conventional representation of a modelled plume is to examine statistical contours of parameter concentrations (or the inverse, as dilution contours). As the plume is extremely dynamic, and progressively diluted with distance from the outfall, the percentile plots logically would be expected to be concentrated around the point of origin (i.e. adjacent or above the diffuser and within or surrounding the Mixing Zone). This is because the proportions of time the fluctuating plume will be present in any given model cell will nearly always diminish with distance from the plume origin in a relatively unconstrained environment such as a near shore oceanic site.

A series of static figures depicting statistical (eg. 99th %ile) concentration contours (isopleths) has been presented in the *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall* by RPS MetOcean, an example of which is also presented below in Figure 13.

Care must be taken when interpreting percentile isopleth plots to not wrongly interpret the isopleths as being a depiction of the plume itself such as shown in Figure 13. Rather, the isopleths are a statistical depiction of concentrations experienced over time at any given point, based on a known time base. For example, the 95th %ile isopleth surrounds all points where a nominated concentration is exceeded 5% of the time; the 99th %ile isopleth surrounds all points where the nominated concentration is exceeded 1% of the time; and the 100th %ile isopleth surrounds all points where the nominated concentration is never exceeded (i.e. the maximum concentration experienced).

The isopleths are not intended to depict simultaneous concentrations (or dilutions) at all points within the bounds of a given isopleth but they do provide evidence of how concentration levels decay (or dilutions increase) along any axis, from their point of origin. Unless otherwise stated, the time base in all statistical presentations is the raw 15 minute value determined and recorded by the VFG far-field model.

As described earlier, the key toxicant scenario examined by the modelling is that of chlorate because chlorate requires the greatest dilution to achieve its water quality objective concentration, assuming the emission rate is at the maximum allowable rate. The Commonwealth has set a site specific water quality objective (WQO) of 0.03 mg L^{-1} in the Commonwealth's receiving environment[14]. Brown algae has been shown in some studies to be sensitive to chlorate when exposed to it for extended periods of days to months, rather than hours. Other organisms, such as fish and crustacea, are generally more tolerant to higher concentrations of chlorate but once again when exposed over days, rather than hours.

Due to their mostly sessile nature, brown algal species are more likely to be attached to the benthos or reside in shallow inshore to lower littoral zones, rather than being free floating. For chlorate, the plume behaviour of most interest is therefore when a relatively undiluted plume remains over or in contact with a given area of seabed for extended periods, such as at the bottom of the water column in shallow embayment areas, or along rocky shores.

In the case of chlorate, therefore, a statistical interpretation of raw 15 minute modelled data could be somewhat limited, unless the levels predicted by the model are always well below a threshold level such as a 'trigger level' or WQO. In such a case, if the maximal levels (as indicated by the 95th or 99th percentile concentrations) are below the nominated criteria trigger level, then there is little point considering the period mean exposures (such as a 72 hour rolling average) as the average concentration (the 50th %ile for a normal

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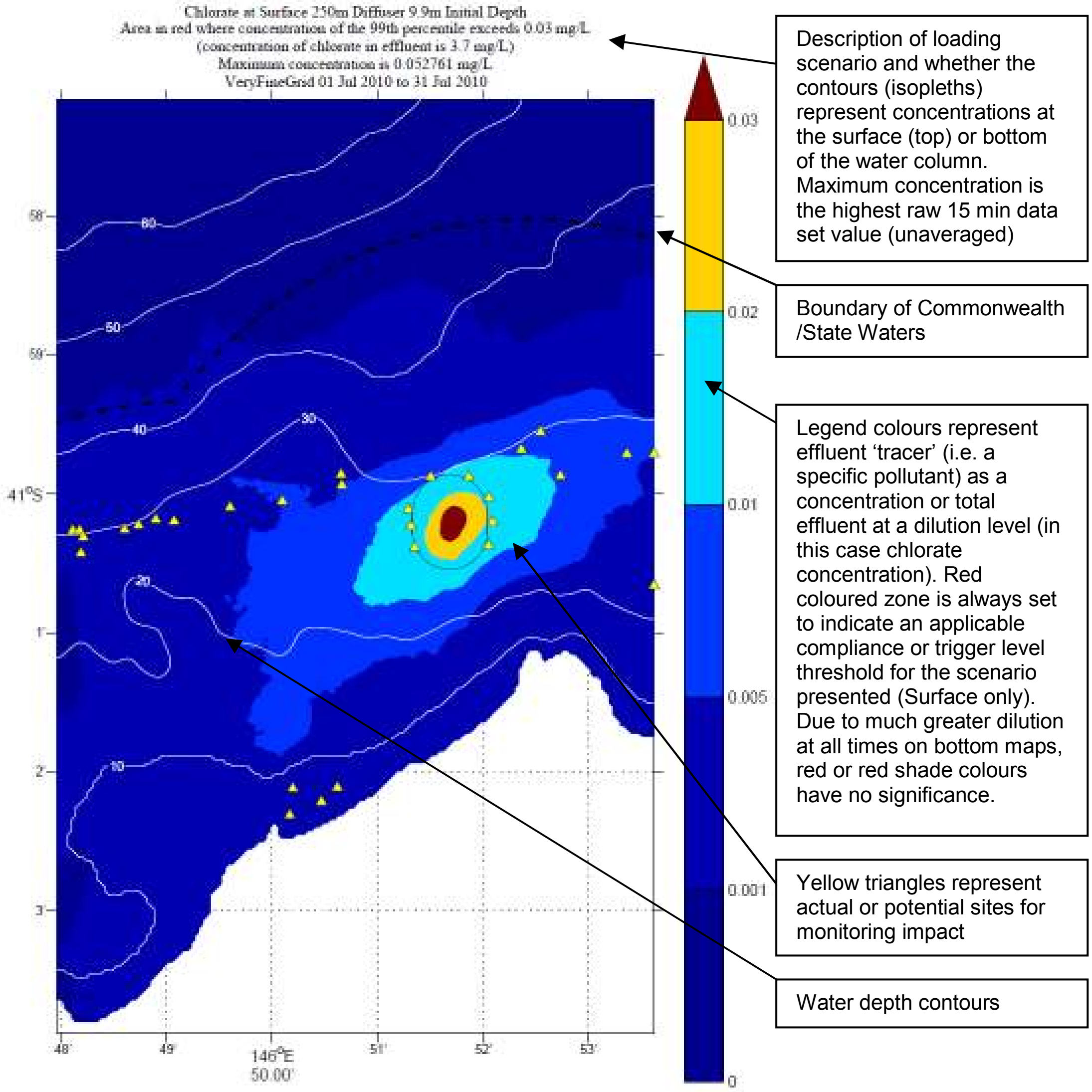
[14] Note: the Commonwealth approval uses the equivalent term "trigger level" but the more descriptive term "WQO" is used for convenience here (the State Permit uses WQO)

distribution) will always be below the maxima. Figure 13 below is used to demonstrate the salient points of a typical statistical presentation as provided in the final MetOcean Report. A summary and how this presentation can be interpreted are also presented below the image.



Summary:
This map demonstrates for the month simulated (June 2010) that if effluent always contained 3.7 mg L^{-1} of chlorate (i.e. the Commonwealth's effluent limit), 1% of the time the chlorate concentration in the receiving environment would be above the Commonwealth's chlorate WQO (0.03 mg L^{-1}) inside the red zone. Similarly, the other coloured isopleths indicate inside of which for no greater than 1% of the time the concentration would be above 0.02 but less than 0.03 mg L^{-1} (yellow), and no greater than 1% of the time above 0.01 but less than 0.02 mg L^{-1} (light blue). The highest concentration at any time anywhere is calculated to be 0.052761 mg L^{-1}, which logically must occur within the red zone.

Conclusion for this illustrative example only:
The Commonwealth's interest would be well protected under this scenario at the top of the water column because:

(1) The red zone does not occur in Commonwealth waters
(2) There is a wide 'margin' between the (red) WQO isopleth and the lowest (mid blue) isopleth which enters Commonwealth waters indicating that 99% of the time the concentration of chlorate in Commonwealth waters would be below 0.001 mg L^{-1} apart from a small area to the North West where 99% of the time it would be below 0.005 mg L^{-1}.
(3) The red zone does not incur over known brown algal beds that may be assumed to be sensitive to chlorate, such as along a rocky area of coast
(4) The simulation period encompasses a full tidal cycle (28d) and thus would be representative of a range of forcing conditions.
(5) There is no need to consider a more ecologically relevant (3 day average) exposure profile for this scenario as the maximum red isopleth is located fully within the mixing zone allowed for under the State Permit.

Figure 13. Example of a statistical representation of a model scenario using concentration isopleths, with a suitable interpretation.

A toxicant scenario is demonstrated by Figure 13 above. Non-toxicants require a different consideration. The impact of the entire suite of non-toxicants of interest can be interpreted against a series of dilution isopleths on a single map presentation as demonstrated below.

Two examples of non-toxicant parameters are:

- Biological Oxygen Demand (BOD)
- Colour

Firstly, the BOD loading is set equivalent to the maximum monthly average effluent concentration limit in the Commonwealth's Approval Decision 2007/3385 at 11 mg L^{-1}. The Commonwealth has not set a site specific water quality objective for this parameter but the State has. The State has set a BOD WQO at 2 mg L^{-1} and thus the State's WQO is used as a surrogate in this assessment. The intent of this parameter trigger level is to ensure that oxygen levels in the receiving waters are such that respiration by all relevant biota is not unduly compromised in the region of the Mixing Zone. Other relevant information for interpretation includes the following:

- The ANZGFMWQ[15] have a default 'trigger value' dissolved oxygen concentration for South-east Australia for protection of aquatic ecosystems. The lower limit trigger is 90% saturation and the upper limit trigger is 110% saturation.
- Baseline monitoring published by Gunns has recorded oxygen concentrations as low as circa 7.5 mg L^{-1} in warmer months to circa 10.0 mg L^{-1} in colder months (as would be expected), with these levels equivalent to circa 96% to 102% saturation[16].
- BOD is an important parameter in managing the environmental impact of effluents with a high organic loading in a river or lake environment. However, BOD (like suspended solids) is classified as a wastewater constituent of low importance in the context of a coastal marine discharge (Roberts *et al* 2010). This is because high initial dilution and the large surface area available for re-aeration generally results in negligible depletion of dissolved oxygen. The lower importance of BOD in a marine context is also demonstrated by the Tasmanian *Emission Limit Guidelines for Sewage Treatment Plants that Discharge Pollutants into Fresh and Marine Waters* (DPIWE, 2001). In these guidelines, median BOD limits for Accepted Modern Technology (AMT) sewage treatment facilities are 50% higher in the context of a marine outfall than is the case for an equivalent freshwater scenario.

In order to examine the likely impact that an 11 mg L^{-1} BOD discharge at 64 ML day^{-1} would have on the oxygen levels at the outfall a *dilution* contour map (as apposed to *concentration* as per Figure 13) can be assessed. As can be determined from the effluent limit of 11 mg L^{-1} and WQO of 2 mg L^{-1}, the mean dilution level required to meet the WQO is a simple ratio of 11mg L^{-1} (effluent) divided by 2 mg L^{-1} (WQO) = 5.5 parts seawater to 1 part effluent, assuming nil background levels.

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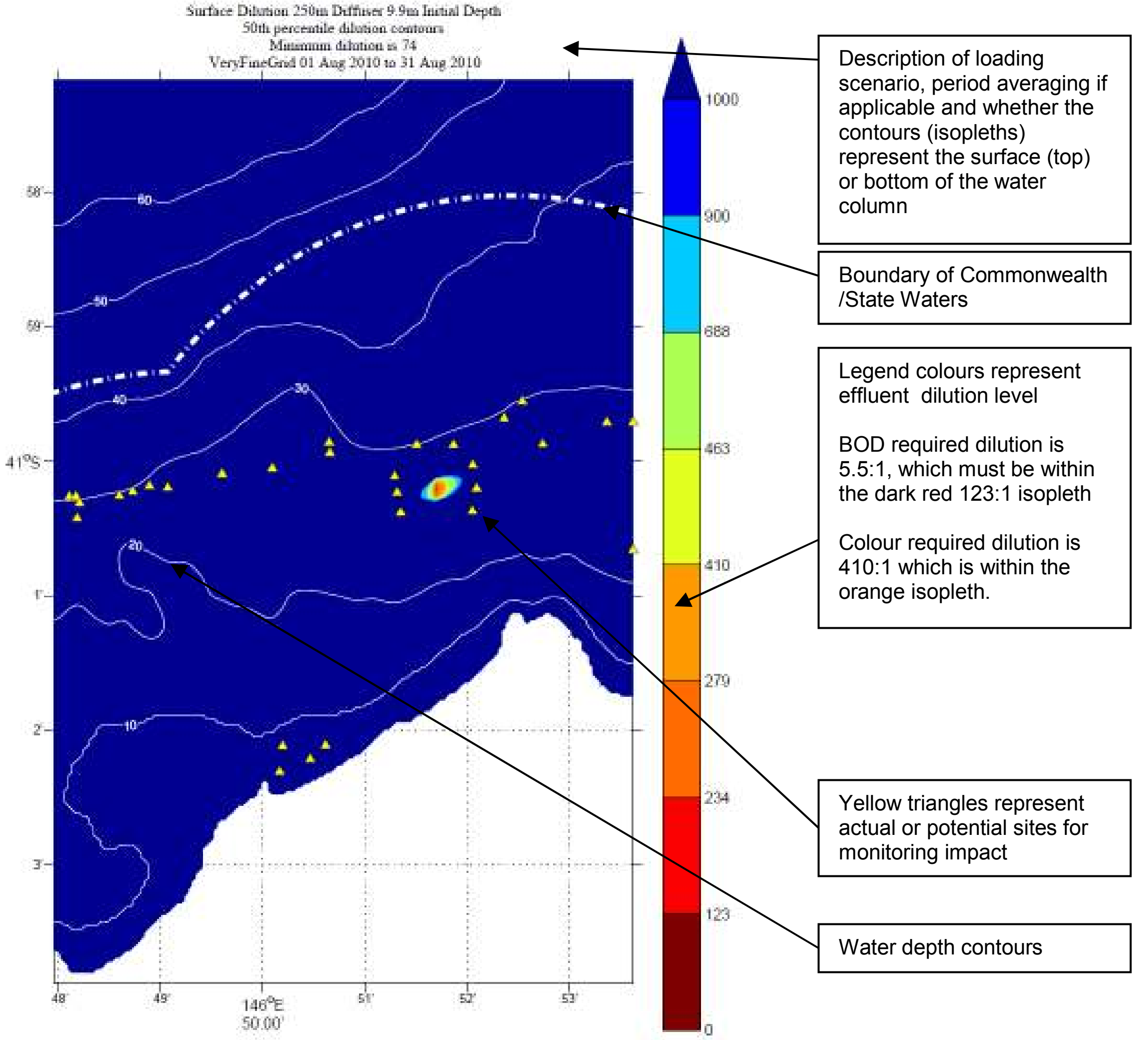
[15] Detailed under the Australian and New Zealand Environment and Conservation Council's (ANZECC) **A**ustralian and **N**ew Zealand **G**uidelines for **F**resh and **M**arine **W**ater **Q**uality 2000.
[16] http://www.gunnspulpmill.com.au/permits/Environmental%20Performance%20Report%20No.%201.pdf

Secondly, when considering effluent Colour, the Commonwealth has not assigned an effluent limit in Approval Decision 2007/3385, although a Colour limit is required to be developed under the framework of the Environmental Impact Management Plan (EIMP).

Module L of the EIMP presents a potential limit for Colour equivalent to the States' 30 day rolling average loading limit, but expressed as a mean concentration. That concentration level is 819 mg L^{-1}. As with BOD, the Commonwealth has not set a site specific WQO but the State has. The State has set a Colour WQO of 2 mg PtCo/L. As can be determined from the effluent limit of 819 mg L^{-1} and WQO of 2 mg L^{-1}, the mean dilution level required to meet the WQO is a simple ratio of 819 mg L^{-1} (effluent) divided by 2 mg L^{-1} (WQO) = 410 parts seawater to 1 part effluent, assuming nil background.

A series of static figures depicting statistical (eg. 95^{th} %ile or 50^{th} %ile) dilution contours (isopleths) has been presented in the *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall* by RPS MetOcean, an example of which is also presented here as Figure 14. A summary and how this presentation can be interpreted for both Colour and BOD is also presented below the image.



Summary:
This map demonstrates for the month simulated (April 2010) that if effluent quality was always 11 mg L^{-1} of BOD (i.e. the Commonwealth's effluent limit), 50% of the time, the BOD level in the receiving environment would be below the State's BOD WQO (2 mg L^{-1}) inside the dark red zone. Similarly, if effluent quality was always 819 mg L^{-1} of Colour (i.e. the Commonwealth's effluent limit subject to approval of EIMP Module L), 50% of the time, the Colour level in the receiving environment would be below the State's Colour WQO (2 mg L^{-1}) inside the orange zone.

Conclusion (for this illustrative example only):
The Commonwealth's interest would be well protected under this scenario at the top of the water column because:

(1) The red or orange zones do not occur in Commonwealth waters,
(2) There is a wide 'margin' between the (red & orange) dilution isopleths and the lowest (blue) isopleth which itself does not enter Commonwealth waters.
(3) The simulation period encompasses a full tidal cycle (28d) and thus would be representative of a range of forcing conditions.
(4) It is demonstrated that the Commonwealth's BOD effluent quality limit in particular is enormously overly protective of matters of National Environmental Significance. (as would be the State's, but less so).
(5) The potential impact of Colour emission at the State's longer term loading limit which is depicted by the 50^{th} %ile 410 dilution contour will be protective of Matters of National Environmental Significance.

Figure 14 Example of a statistical representation of a model scenario using dilution isopleths, with a suitable interpretation for BOD.

In summary, the key model outputs in the final MetOcean results report are a series of statistical (percentile) dilution and or concentration contour maps focusing on the immediate area of the outfall (VFG) for numerous parameters of environmental and ecological interest. The various presentation techniques are intended for different methods of interpretation or simply to illustrate the plume's movement or path(s), which in cases where there is a demonstrated lack of an acute effect of the plume may have little ecological relevance. The most powerful methods of interpretation are informed by the results of ecotoxicological studies or appropriate application of established water quality criteria.

For areas more remote from the outfall, the key issue is long term accumulation. This issue can be assessed by examining extended time series of effluent tracer concentrations, as the key issue at distance from the outfall is related to the potential long term accumulation of effluent tracers, rather than spatial variability.

Movie graphic presentations

The final method of presentation used by the final MetOcean results report is to animate model outputs as a 'movie'. These movie files provide a time compressed demonstration of the overall behaviour of the plume during a month, where each frame represents one hour. While these graphic presentations may be captivating to watch, they are not the key method of presentation of the Project from an interpretive perspective.

An interpretive summary of all the information determined by the far field modelling activities is provided below under *Final Report Interpretive Summary*.

2.3.4 Sediment Transport

Sediment Transport modelling, by its nature, is a less precise process than water quality modelling as described above. The spatial scales of relevance for sediment transport are also much greater than is appropriate for water quality assessment. Consequently, sediment transport modelling (1) has a much lower requirement for the higher resolution model domains described as the FG and VFG as above and (2) these two higher resolution grids are too small for the sediment transport analysis. The sediment transport modelling for this Project therefore utilised the "Regional" and "Intermediate" Grids only.

A further contrast with the water quality modelling described above is that the sediment transport model does not require 'coupling' to the near field model. The sediment transport model developed for this Project is a discrete process but utilises many of the same larger scale model configurations, forcing mechanisms etc. It also utilises specific algorithms to describe the dispersion, settling re-suspension and transport of non-dissolved parameters.

Two RPS MetOcean reports relating to sediment transport are attached as *Report No.3: Setup and Calibration of Sediment Transport Model* (Appendix 3 B Document 3) and *Report No. 7: Results of Long-term Sediment Transport Modelling* (Appendix 3B Document 6). Report No. 3 was submitted to the Commonwealth as a 'milestone' report. While the outputs of the Report No. 3 are redundant, being superseded by the results of Report No. 7, Report No. 3 is provided here as it more completely details the modelling methodologies, which are not repeated fully within Report No. 7.

A brief interpretive summary of information determined by the sediment transport modelling activities is provided below under *Final Report Interpretive Summary*

3 Final Report Interpretive Summary

3.1 Item 1 Field Measurements

A series of pdf files comprising the *Final Oceanographic Data Report 2 September 2009 to 2 September 2010* is available for download on Gunns Limited's web site[17]. That report is not appended to this *Final Report on Commonwealth Requirements* because it is too voluminous (the data report comprises >6000 pages). The report has been provided to the Commonwealth under separate cover.

The observations of the oceanographic measurement program can be summarised as follows:

3.1.1 Temperature

- The seasonal range of temperatures at all three locations (Outfall, Offshore and Tamar) showed the lowest temperatures in September (eg. approximately 12 ^{0}C at the Outfall) measured throughout the water column and the highest at the top of the water column in February (eg. 21.5^0 C at the Outfall).

- There was very little horizontal variability in temperature when comparing measured values at the same depth between the mooring locations.

- There was little vertical variability in temperature for most of the year at the Outfall and Tamar measurement locations, meaning that there was very little thermal stratification (i.e. temperature differences between depths at the same location). The Offshore location did exhibit some stratification (circa 2-3^{0}C) during the November to February period but these events were generally short-lived and rarely reported a significant magnitude of difference (significant is considered to be >2^{0}C) between upper and lower measured strata. At the Outfall, the water column generally remained vertically well mixed in the relatively shallow area of the Outfall mooring.

Details of all measured temperature data can be viewed in Appendices I & K of the *Final Oceanographic Data Report 2 September 2009 to 2 September 2010* available for download on Gunns Limited's web site.

3.1.2 Salinity

- There were frequent and small variations in salinity between all locations (i.e. horizontal variability) during the measurement period. In summer months, the magnitude of difference between locations near the surface was approximately 0.5 PSU (35.6-35.4 PSU at the Offshore and Outfall locations compared to 35.0-34.8 PSU at the Tamar location). In winter, the

[17] http://www.gunnspulpmill.com.au/permits/epbc.php

difference was often up to about 3 PSU (35.5-35.0 PSU at Outfall and Offshore to 35.5-33.0 PSU at Tamar).

The Tamar location showed the greatest magnitude and frequency of difference when compared to the other locations. This site appears to be heavily influenced by irregular freshwater flux from catchments along the coast, including that of the Tamar. The susceptibility of this site to salinity fluctuations from coastal catchment outflows confirms the design decision to exclude such outflows from the model - it would be impractical to satisfactorily quantify all coastal outflows to an accuracy and resolution required to significantly enhance model validation.

For much of the measurement period (Dec-May), parallel salinity records measured at the Offshore and Outfall location were very similar. For the balance of the measurement period, corresponding with more frequent freshwater fluxes from the Tamar and adjacent catchments, the linkage between the Offshore and Outfall locations was weaker.

- There was modest but dynamic vertical variability in salinity (i.e. stratification, between depths at the same location) over the measurement period but more particularly in winter at all measurement locations. The Outfall location recorded the largest difference between near surface and bottom layers for an extended period in August 2010 at about 1.4 PSU (35.4 PSU at surface and 34.0 PSU near sea bed). The variation between near surface and bottom layers at the Outfall location was typically < 0.5 PSU for the balance of the measurement period.

Details of all measured salinity data can be viewed in Appendices J & K of the *Final Oceanographic Data Report 2 September 2009 to 2 September 2010* available for download on Gunns Limited's web site.

3.1.3 Currents

- In general, currents at all locations exhibited a tidally dominated pattern, which was often modified by strong winds, typically from the west.

- The dominant current patterns measured at the Outfall location occur along a north east – south west axis. For example, approximately 60% of the measured current data at 23.29 m above sea bed (ASB) were vectored towards the NE or NNE. Currents toward the north west by comparison were relatively infrequent and of low magnitude. Currents towards the south east quadrant had a greater magnitude than those towards the north west. The mean current speed for all directions at 23.29 m ASB was 0.21 m s^{-1} during the measurement campaign, with the maximum recorded current being 0.59 m s^{-1}.

- The Offshore locations, by comparison to the Outfall location, generally returned a higher range of current speeds but with a lower overall mean. Directional patterns were similar to the Outfall location.

- Current patterns at the mouth of the Tamar were primarily along a north-west – south-east axis and were obviously dominated by the tidal exchange and other flux from the estuary itself.

Details of all measured current data can be viewed in Appendix E of the *Final Oceanographic Data Report 2 September 2009 to 2 September 2010* available for download on Gunns Limited's web site.

3.1.4 Sediment

- Suspended particle concentration and turbidity are low except under strong waves.

- The particles suspended have relatively large diameter (mean diameter – 100 μm).

- Near-bottom suspended sediment concentration under strong waves corresponds to wave-induced bottom shear stress both in magnitude and timing, and decreases with increasing depth.

- At the Tamar River measurement location the increase of suspended particle concentration due to Tamar River discharge appears to be small compared to that due to local re-suspension.

Details of all measured sediment data can be viewed in Appendix H of the *Final Oceanographic Data Report 2 September 2009 to 2 September 2010* available for download on Gunns' web site.

3.1.5 Summary of Item 1 - Field Measurement Program.

An intensive field measurement program comprising oceanographic field measurements and meteorological measurements has been successfully completed.

To account for seasonal variation the measurement period covered 12 months from September 2009 to September 2010 and was undertaken in Bass Strait focussing on the inshore waters of the central north coast of Tasmania. The program delivered a comprehensive oceanographic database that can used to calibrate or validate a series of hydrodynamic models to simulate an ocean outfall in the region of Five Mile Bluff on the north coast of Tasmania.

3.2 Item 2 Overseas Effluent Studies

The Overseas Effluent Studies were successfully completed in accordance with various technical Sampling and Analysis Plans (SAPs) supplied to the Commonwealth by Gunns Limited. The SAPs were in turn consistent with the detailed requirements of Conditions 34 & 35 of EPBC 2007/3385 and in some cases exceeded those requirements. The studies were undertaken during late 2009 & early 2010 at a similar mill to that proposed by Gunns. The subject mill is a modern Elemental Chlorine Free (ECF) Bleached Eucalypt Kraft (BEK) pulp mill in the State of Bahia, Brazil.

The tasks were integrated as much as possible to minimise impost on the operational staff of the organisation which kindly allowed the study to be undertaken at their site and using their effluent. The study itself involved two visits to the facility by three scientists (Dr William Glamore and Mr Alessio Mariani of WRL & Mr Lawson Harding of Gunns). The reporting has been aligned to the two visits, which are presented here as *Phase One* and *Phase Two*. Analysis and interpretation of the information obtained by the studies was conducted by several leading scientific institutions and consultancies in Australia and Brazil.

3.2.1 Phase One of Overseas Effluent Studies

3.2.1.1 Sampling

Sampling and retrieval from a relatively remote location in the State of Bahia, Brazil, for handover to laboratories in Sydney, Australia, was achieved well within a challenging target time of 48 hours post sampling (at circa 40 hours). Sample condition on arrival was optimised by careful handling, minimising transit time, thorough pre-chilling and by utilising good quality insulated boxes and heat sink packing. The condition of the samples on arrival in Sydney could not have been better given the difficult logistical and thorough regulatory restrictions for moving such material.

3.2.1.2 Whole Effluent Toxicity

Two key assessments of the Whole Effluent Toxicity (WET) tests undertaken on behalf of Gunns by Ecotox Services Australasia Pty Ltd on samples retrieved from the Brazilian pulp mill were undertaken by consulting toxicologists, Toxikos Pty Ltd. Both assessments are provided as appendices to this *Final Report on Commonwealth Requirements*.

The first assessment (Appendix 2 C, Document 1) considered the results of the Brazilian effluent assays against relevant requirements under the *State Policy on Water Quality Management* 1997[18] and found that the Brazilian samples would comply with these requirements.

The assessment noted that the marine invertebrate tests with reproductive endpoints (48-h doughboy scallop larvae and 72-h sea urchin larval development assays) were found to be sensitive to the effects of the Brazilian effluent. This recent observation is again consistent with pre-existing information including the findings of the *National Pulp Mills*

[18] http://www.environment.tas.gov.au/index.aspx?base=118

Research Program (Simon & Laginestra 1997, Stauber et al, 1994) and the *Canadian Pulp & Paper Environmental Effects Monitoring* data (Lowell et al, 2005).

The second assessment by Toxikos (Appendix 2 C Document 2) examined the same 2009 ESA data to determine the required effluent dilutions in the mixing zone. The standard technique in Australia is to apply a statistical analysis of data from a range of toxicity assays, termed the species sensitivity distribution (SSD) technique. The assessment by Toxikos outlines in detail how the SSD technique has and can be applied to the Brazilian effluent WET data. A variety of scenarios are presented by Toxikos for key parameters used in the statistical analysis and for different 'levels of protection'. The outcome of these analyses suggests a required dilution range of between 33:1 and 17:1 for a conservative 99% level of protection or 12:1 or 8:1 for a less conservative 95% level of protection. This dilution analysis is discussed further in the far-field modelling summary section below.

The first Toxikos assessment above, when considered with the results of prior WET tests undertaken on a Thai (Eucalypt furnish) and Chilean (Pine furnish) mills submitted by Gunns and discussed in detail in the MIA (Drew & Frangos, 2007) during the Bell Bay pulp mill project's assessment process all show a similar pattern. A comparison of Thai and Brazilian (both Eucalypt furnish) effluents shows that Thai effluent elicited a response (NOEC 10, LOEC 30)[19] in the 48-h scallop larval development assay but the Brazilian effluent did not (NOEC 100, LOEC >100). By contrast, the Brazilian effluent elicited a response in the 72h sea urchin larval development assay (NOEC 50[20], LOEC >100) but the Thai effluent did not (NOEC 100, LOEC >100).

In summary, while there may be slight variation between different mill effluents taken some years apart, with detailed analytical protocols, mill furnish etc, the underlying pattern of relatively mild sub-lethal response in larval development assays at low dilution levels and a statistically significant response at no dilution (100% effluent) is further supported by these recent data.

A further line of evidence regarding the temporal variation in WET of a modern BEK pulp mill effluent is available by:

- Examination of a series of three reports concerning the "Orion Project" pulp mill, near the city of Fray Bentos in Uruguay prepared by Ecometrix Incorporated of Ontario Canada.
- Comparison of a series of WET assay reports of the same Brazilian pulp mill's effluent carried out by that mill's operators.

In both the above cases, the assays were designed for local application by those mills (eg. in the context of a fresh water receiving environment) and were not designed for application to the Bell Bay pulp mill project. Nevertheless, the information from those overseas mills contributes to the understanding of the temporal variation in whole effluent toxicity in modern BEK mill effluents.

[19] All NOECs & LOECs reported as % effluent
[20] Note the dilution series differed between Thai and Brazilian assays, thus the dilution series may have an influence on the reported metrics.

Variability of Orion Project WET data

The Orion mill is a new pulp mill in Fray Bentos, Uruguay. It has a similar design to the Bell Bay mill and uses *Eucalyptus*. The reports covering the Orion project are published by the International Finance Corporation (IFC) under an agreement between the Orion project's developer's (Botnia S.A.) and the IFC. A primary purpose of the reports is to provide independent review and analysis of environmental performance monitoring measures required of the Orion mill. The three performance reports cover:

- The first full six months of operation (Dec 2007- May 2008)
- The first full calendar year of operation (2008).
- The second full calendar year of operation (2009).

All of the Orion Project reports are available for inspection via the web address: http://www.ifc.org/ifcext/disclosure.nsf/content/Uruguay_Pulp_Mills

The Orion Project reports include reference to suite of WET assays, including a 15 min assay using the luminescent bacteria *Vibrio fisheri*, a 48-h assay using the microcrustacean 'water-flea' *Daphnia magna* and a 96-h assay using the fresh water fish species *Pimephales promelas*.

The 15 minute bacterial assay appears to be the only assay consistent with the recent suite of assays conducted by ESA for the Bell Bay pulp mill project on the Brazilian mills' effluent. The 48-h *D. magna* assay is widely used as an assay suitable for assessment of xenobiotic compounds, such as pesticide trials, whereas the *C. dubia* protocol as applied by ESA for the Brazilian samples is an assay more suited to whole effluent trials (R Krassoi, pers comm.).

The reported data presents the IC_{50} metric for the luminescent bacteria assay and the LC_{50} metric for the invertebrate and fish assay. In summary, the published Orion toxicity data has shown no variability, with all LC_{50} and IC_{50} metrics reporting ">100% (non-toxic)" from commissioning of the Orion mill in December 2007 to the end of the second calendar year's operation (Dec 2009). The Brazilian effluent tested by ESA for Gunns reported an IC_{50} of >90% for the luminescent bacteria assay. As the Brazilian effluent analysed by ESA had a salinity correction applied[21] for marine conditions, the results reported by the Orion project are consistent with those from the Brazilian samples.

Variability of Brazilin WET data

Two reports on a series of WET analyses taken over a four day period for the Brazilian mill, which supplied effluent for retrieval to Australia, are provided as Appendix 2 G. The analyses were conducted by the respected Brazilian consulting firm Aplysia[22]. The sampling regime utilised 24-h composite samples, taken from the mill's effluent outlet sampling location during January 2010, as used by Gunns for samples transported to Australia in November 2009. Note, the Aplysia reports are presented 'as supplied' to Gunns and are in the Portuguese language.

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[21] Except for the *C. dubia* assay.
[22] http://www.aplysia.com.br/site/pt/

The Aplysia reports present data obtained by acute (48-h) survival assays for three samples collected over 4 days using the microcrustacean *Daphnia similis*. No toxicity (and thus no toxicity variation) was observed in any of the samples.

The Aplysia reports also present data obtained by chronic exposure (7-d) partial life cycle assays for the same three samples as above, using the microcrustacean *Ceriodaphnia dubia*. The final Conclusion section of *C. dubia* report is translated as "The samples LET04/01/10, LET 05/01/10 and LET 07/01/10 do not present chronic toxicity for the microcrustacean *C. dubia* in the condition tested". In summary, the Aplysia documents provide a further line of evidence for the very limited day-to-day variability of a modern BEK mill's effluent toxicity signature.

In summary, the similar mill design and Eucalypt feedstock of the overseas reference mills in South America (the Veracel S.A. facility in Brazil and the Orion project in Uruguay) mean that the findings of Whole Effluent Toxicity on effluent from those mills are also applicable to the Bell Bay pulp mill effluent. These and prior studies provide multiple lines of evidence to support a conclusion that the Bell Bay pulp mill's effluent will readily satisfy the relevant regulatory discharge requirements for toxicity.

Strong protection of the Bell Bay mill's receiving environment will be further enhanced by the achievement of rapid initial dilution that will be achieved within the defined Mixing Zone. The level of dilution that is required to ameliorate the low toxicity signature will be readily achieved within the Mixing Zone. The receiving environment is therefore well protected. The dilution values determined by WET analysis (circa 33:1 or lower) should also be considered alongside the dilutions required to meet any water quality objectives that are discussed in detail under the far-field modelling section below (Item 3).

3.2.1.3 Physico-chemical and toxicant parameter analyses

The findings of the physico-chemical analyses conducted on the samples retrieved from Brazil are consistent with the predictions and assumptions made in preliminary documentation presented in the Bell Bay pulp mill project's assessment processes, in that observed concentrations were lower than the conservative concentrations assumed by the *Marine Impact Assessment* (Drew & Frangos 2007). A summary table of all results and the laboratory analytical certificates listed in the summary table are presented as Appendix 2 D.

Observations from the suite of analyses include:

- The 'dioxin and furan' analysis showed that no members of the WHO_{05} TEQ dioxin or furan group of congeners were detected. Given the resolution of the analytical techniques, this means that the concentration of the TEQ congeners in the sample was below both the Commonwealth's and the State's regulatory limits (Lower Bound[23] $WHO_{05}TEQ_{DF}$ = 0 pg/kg while the Upper Bound[24] $WHO_{05}TEQ_{DF}$ was 2.1 pg/kg).

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[23] Lower Bound defines that all congener values reported below the Limit of Detection (LOD) are equal to zero.

[24] Upper Bound defines that all congener values reported below the Limit of Detection (LOD) are equal to the LOD.

- Phenol and chlorophenols were detected at trace levels. These species of compounds could be expected to be present at trace levels, as they are known to be present in the feed stock. One species of a chlorophenol that was not expected to be present was detected in one lab sample (NMI) while this same determinand was not detected in a parallel sample analysed by CSIRO. This apparent inconsistency cannot be definitely resolved one way or another and may be an artefact of one of the laboratory's analysis.

- Phyto sterols and fatty acids (some of the natural components of wood, termed 'wood extractives') were detected, as was expected, but at even lower levels than anticipated. Wood extractives are generally considered to be a factor in any residual levels of toxicity or other environmental effect (if any) from modern pulp mill effluents.

- Chloroacetic acids, like the majority of chemicals screened for in this process, were not detected. The potential presence of chloroacetic acids was a matter of specific concern to the Commonwealth.

Variability in physico-chemical parameters.

There is now a significant amount of high quality data available on the variability in modern BEK pulp mill effluent that was not available during the assessment process for approval Decision 2007/3385. In particular, the Orion project's public environmental reports, as discussed above, provides substantial, high quality temporal information on effluent that can be used to describe the likely nature of the Bell Bay Pulp mill project's effluent.

A good example of mill effluent variability is provided by the effluent parameter, 'conductivity'. The parameter itself has little or no ecological significance in the Bell Bay pulp mill project's context. The conductivity parameter simply reflects the ionic strength (i.e. dissolved salts) of the effluent. However, this is related to mill processes including process excursions and their management. The ionic strength of raw effluent, as it reports to the Waste Water Treatment Plant (WWTP), can therefore often be used as a surrogate for loading to the biological treatment processes within the WWTP. It is the health and capacity of these biological processes that controls the attenuation efficiencies for most of the effluent quality parameters of higher environmental relevance to the receiving environment, such as chlorate and colour.

The Orion project presents conductivity values in Figure 3.2 of their annual reports[25]. Gunns was provided an additional descriptive statistic (standard deviation) to those already published for conductivity and colour parameters upon request to this mill's operators. The standard deviation values then allow calculation of the Coefficient of Variation (CoefVar) statistic with the mean statistic already publicly available[26]. These data include information over the same period as that covered by the Ecometrix reports and also more recent statistics covering the Jan-Oct 2010 period. These statistics demonstrate how effluent variability reduces with in-plant process stabilisation over the initial few years of a mill's operation. Further evidence of the steady improvement in

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[25] http://www.ifc.org/ifcext/disclosure.nsf/content/Uruguay_Pulp_Mills
[26] Coefficient of Variation = Standard Deviation/Mean and is expressed as a percentage.

process stability between 2009 and 2010 (part) is provided by routine effluent quality reports published directly by the Orion mill showing how most key effluent physico-chemical parameters have a lower mean in 2010 than in 2009[27].

A brief statistical summary of the conductivity and colour data by year is presented below as Table 2 and Table 3. The reduction in the Coefficient of Variation (CoefVar) is a key indicator of the concomitant reduction in process variability as implied by conductivity and the improvement in an environmentally relevant effluent quality parameter (colour).

Table 2 Descriptive statistics 2007 to 2010 (part) of effluent parameter Conductivity mS m^{-1}. Orion project

Year	N (number of samples)	Mean	CoefVar	Minimum	Median	Maximum
2007	61	162.0	%39.87	25.4	185.9	232.2
2008	362	303.8	%17.61	175.7	299.5	593.5
2009	364	353.1	%18.52	2.8	345.1	780.0
2010 (part)	273	369.1	%6.50	310.8	366.4	450.6

Table 3 Descriptive statistics 2007 to 2010 (part) of effluent parameter Colour mg L^{-1}. Orion project

Year	N (number of samples)	Mean	CoefVar	Minimum	Median	Maximum
2007	61	509.3	%50.24	140	400	1400
2008	366	608.5	%46.41	200	500	1750
2009	365	679.0	%39.88	250	625	2000
2010 (part)	273	494.1	%15.12	300	500	1000

Time series plots of the two metrics are provided for 2008 in Figure 15 below, implying a likely relationship between the two variables.

[27] http://www.upmuruguay.com.uy/upm/internet/upm_fray_bentos.nsf/images/Efluente-ene-jun2010.pdf/$FILE/Efluente-ene-jun2010.pdf

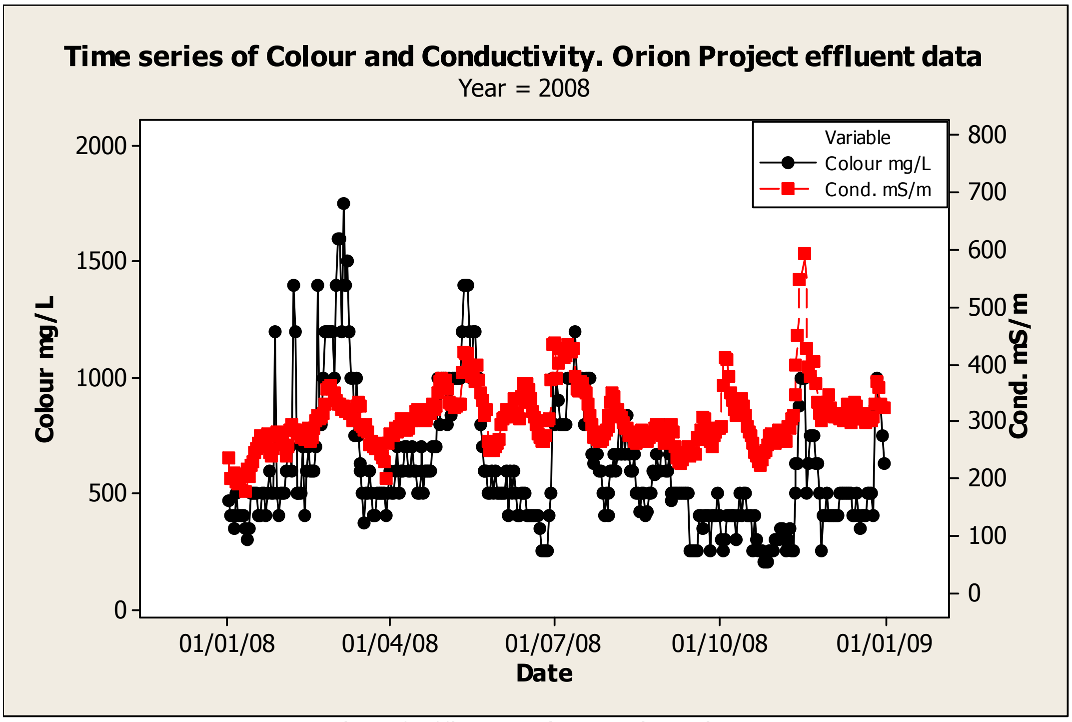

Figure 15 Time series over-plot of effluent colour and conductivity 2008. Orion Project effluent data.

From the above, mill process stability is implied by the low or reducing variability in the conductivity parameter. In turn, process stability results in lower effluent parameter variability, particularly by reducing the magnitude and/or frequency of 'spikes'.

Variability in toxicant parameters.

The variability in effluent quality parameters that are recognised as toxicants in the Orion project data is more difficult to determine as the vast majority of toxicant parameter data (for example chlorate) are consistently 'non-detects', as is expected for the Bell Bay mill. This generally low level of observed toxicants in the Orion data is consistent with their Whole Effluent Toxicity data which consistently reports routine assays as 'non-toxic' as discussed above.

A pattern may be evident in the Orion chlorate data from years 2008 and 2009 that is presented below using Figures 2.1 and 3.2 from the Orion project's public report which are re-presented here as Figure 16 and Figure 17 . These figures have been marked and aligned in order to postulate a likely relationship between stable mill performance and low effluent parameter variability.

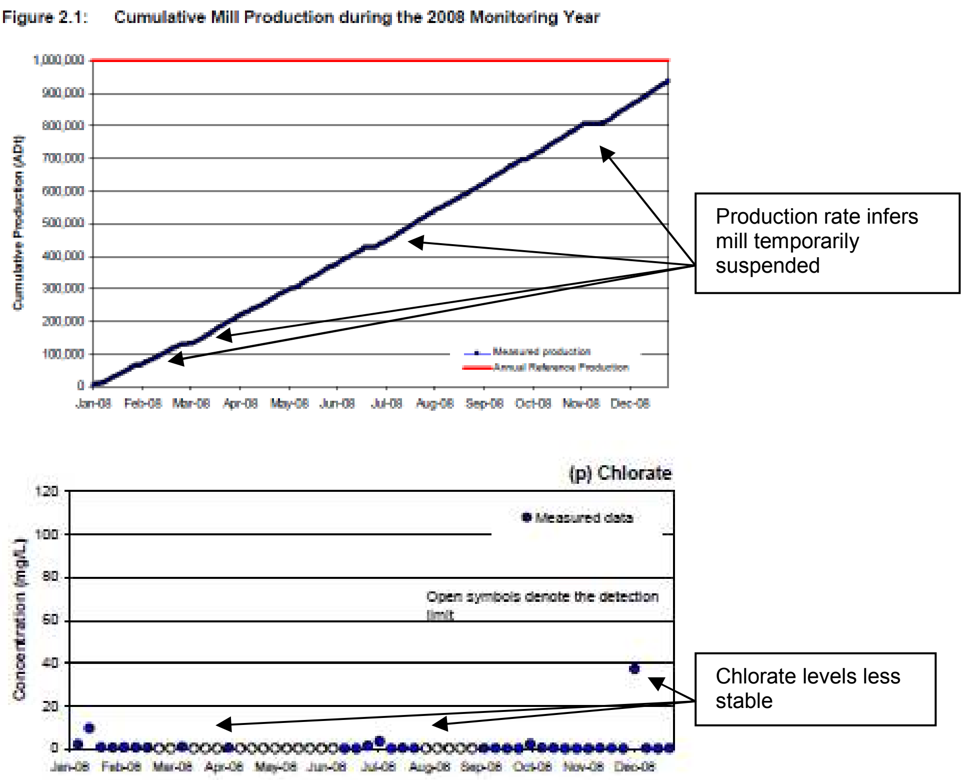

Figure 16 Orion Project effluent quality and production data (Figures 2.1 and 3.2) from *Phase 3: Environmental Performance Review 2008 Monitoring Year* (Ecometrix, 2009)

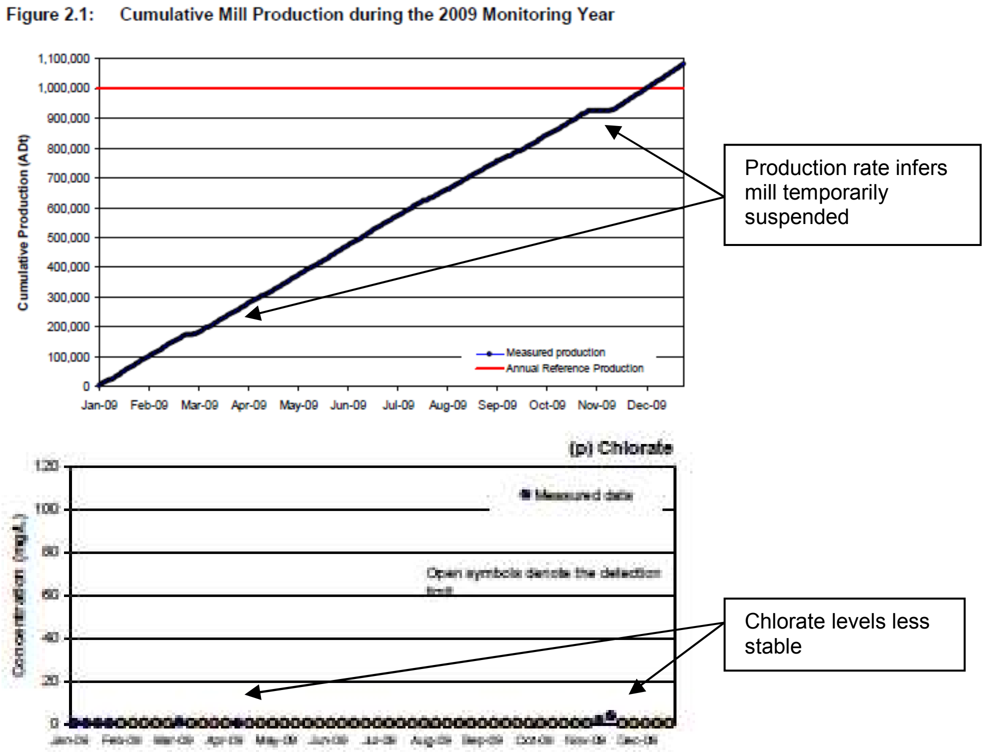

Figure 17 Orion Project effluent quality and production data (Figures 2.1 and 3.2 from *Environmental Performance Review 2009 Monitoring Year* (Ecometrix, 2010)

The above figures support a hypothesis that mill ‘stop/start’ processes are a major contributing factor in variability in effluent chlorate concentration and similarly for the physico-chemical parameter, colour. This is hardly surprising (particularly for chlorate) for an effluent treatment system that utilises a range of balanced microbial metabolic and respiratory pathways (e.g. Activated Sludge combined with Anoxic Chlorate Reduction) to treat the effluent, as any disruption reduces the effectiveness of the microbes.

Module L of the EIMP discusses this point further and demonstrates that for optimal environmental protection, mill stops should be limited to emergency breakdowns and necessary periodic maintenance and should not be a routine response measure to limit exceedences. Forcing a mill to stop, particularly for a non-toxicant and/or for a single exceedence, is likely to result in a worse environmental outcome than resolving the problem while continuing to operate.

Figure 16 and Figure 17 also demonstrate that the long term average chlorate concentration for a mill of very similar design and feedstock to that proposed for Bell Bay will likely perform better (i.e. lower concentrations) that the conservative assessment of 3.7 mg L^{-1} originally made by mill designers Pöyry, some years previously and subsequently adopted by the Commonwealth as a compliance limit.

The chlorate concentration of effluent is not a key environmental performance metric for the Orion mill and the mill is therefore under no regulatory imperative to achieve such low chlorate levels but even without this imperative the Orion mill would achieve the Bell Bay mill’s limits.

Although the Bell Bay mill's chlorate limit is environmentally conservative, Gunns' recent adoption of the ECF Light bleaching sequence, made possible by the company's adoption of 100% plantation feedstock from day one, has lead Gunns to suggest that the regulatory limit for chlorate be lowered for normal operations (i.e. outside the commissioning period) from 3.7 mgL^{-1} to 2 mgL^{-1}. This is discussed further in Module L.

3.2.1.4 Effluent Variability Summary

In summary, effluent quality variability can be expected to be greater in the first years of operation, with the variation reducing thereafter. A Coefficient of Variation can be as high as 50% (daily data points) in ionic parameters, but this magnitude of variability is expected to decrease steadily after commissioning as process variability also drops. The key toxicant of concern to the Commonwealth, chlorate, is generally likely to be not detected (assuming LOR of 0.02 mg L^{-1}) but operational variability may lead to detections, particularly at times of mill commissioning and/or following a maintenance shutdown.

3.2.2 Phase Two of Overseas Effluent Studies

The second phase of the overseas effluent studies was undertaken on site in the State of Bahia, Brazil. Sample condition was therefore ideal due to no transport time lag concerns and the study was completed as planned. Dr Glamore's conclusions from the appended report include the following:

"Based on these results, it is expected that upon discharge in the ocean, when subject to the shear in the outfall pipeline and in the diffusers, the floc dynamics will be dominated by breakage mechanisms. Once discharged into the ocean, in the absence of highly turbulent hydrodynamic conditions, the floc may aggregate and form slightly larger flocs. Settling column experiments provided estimate of the floc settling velocity. Flocs of 20 to 200 μm settled at velocities ranging from approximately 1 to 3 mm/s. Based on these rates and current measurements made by MetOcean, it is unlikely that floc will settle on the seabed. "

From the above, the assertions made by the mill designers Pöyry during the assessment processes for the Bell Bay pulp mill project, suggesting that residual particles discharged from the outfall would 'behave like plankton' and not settle have been supported by this effluent trial. The final conclusions on the matter of the fate of fine particulate matter are examined further by the sediment transport modelling component (Item 3) of the Project.

3.2.3 Conclusions from Item 2 - Overseas Effluent Studies

We therefore conclude from the information presented above that:

- The works undertaken by WRL, ESA, NMI and others on Gunns Limited's behalf and reported as a series of Effluent Studies fully address the requirements of Conditions 34 and 35 of the Commonwealth's Approval Decision 2007/3385.

- The effluent studies have:

    - Provided robust input parameters to the sediment transport model required under Condition 38 (a).

    - Reported on expected variability in contaminant concentration(s) and whole effluent toxicity demonstrated with multiple lines of evidence.

    - Demonstrated that mill effluent, when produced under normal operating conditions and treated with a functioning and well managed biological effluent treatment system similar to that proposed for the Bell Bay mill, only requires dilution in the order of 16-33 parts seawater to 1 part effluent in the receiving environment. These dilution targets are readily achieved, will ensure a very high level of protection of the receiving environment.

The extent and frequency of predicted dilutions likely to be delivered by the Bell Bay pulp mill infrastructure is presented within Item 3 section of this document.

3.3 Item 3 Numeric (Computer) Modelling

3.3.1 Near field modelling

The near field modelling component of the Project has been successfully completed by Worley Parsons and an optimal diffuser configuration has been identified to maximise initial dilutions under the most testing receiving environment conditions.

In response to the findings of the study, the diffuser configuration has been altered in order to improve performance from that presented in the Integrated Impact Statement (IIS) by lengthening the barrel of the diffuser from 200 to 250 m and by specifying “T” ports with ‘duckbill’ valves and an optimal port spacing regime.

To facilitate the key change from 200 to 250 m, an in-principle agreement has been reached with the State regulators to allow a change in diffuser length if it were required, without changing the overall dimension of the Mixing Zone, which is defined in the State Permit relative to the length of the diffuser as presented in the IIS (i.e. 500 m from the ‘original’ 200 m diffuser along its length). This means that the diffuser length can be increased without increasing the size of the prescribed Mixing Zone.

A number of near-field to far-field coupling methodologies were examined by Worley Parsons. The conventional and conservative one-way coupling was carried forward to implementation by the far-field modelling exercises. A number of plume dimension configurations were identified for varying diffuser design and current regimes. A conservative value of 9.9 m initial depth (resulting in a corresponding reduction in dilution) was carried forward to the far field modelling exercises.

The implications of density stratification of the receiving environment was examined. The Worley Parsons study identified that a density change of 0.39 kg/m^3 starting 15 m above the diffuser (i.e. approximately 10 m below the sea surface) would not trap the plume and prevent it from rising to the surface.

Density differences between the top and surface layers > 0.39kg/m^3 did occur at the Outfall location during the field measurement period, as detected by moored Conductivity/Temperature (CT) instruments. The strongest stratification event (maximum 15 min Δ of 1.2 kg/m^3) occurred at the close of the measurement program period, corresponding to a winter flood event from the Tamar and other coastal catchments. One ‘summer’ extended (>12hr duration, at Δ circa 0.6 kg/m^3) stratification event was observed at the end of March 2010.

From the above it can be concluded that the plume should consistently rise to the surface under the majority of circumstances, corresponding to Δ density levels < 0.4 kg/m^3. The exceptions to this may be during infrequent short term events intermittent over a number of days and associated with dissipating flood events from coastal catchments, including the Tamar. Instances such as these were measured over the closing weeks of the measurement program, where density differences between depths (Δ) varied between 0.1 to 1.2 kg/m^3 over a time scale of minutes and hours. Further analysis of measured stratification events was undertaken by MetOcean and is discussed in MetOceans’ *Report*

No. 4: Calibration and Validation of Hydrodynamic Model which reported that density Δ of < 0.5 kg m^{3-1} occurs for 99% of the time.

These observations of density stratification made from field measurements contrasted with expectations of reviewers of prior works (Herzfeld 2007, Godfrey 2007), who suggested that thermal stratification could be a dominant factor in determining initial effluent dispersion.

3.3.2 Far-field Modelling

The Far-field modelling component of the Project has been successfully completed.

The modelling outputs can be used to compare the performance of the model itself against reality to gauge what level of confidence can be placed on its various predictions. It must be recognised that no model can be expected to be 100% correct and that some residual uncertainty is always sensibly expected of a modelling exercise. In order to minimise residual uncertainty emanating from prior modelling works, the configuration and forcing details etc for the modelling were tightly and precisely specified by the regulators through an approved methodology and approved organisation(s) to undertake the works.

3.3.2.1 Model Performance - Validation

The extent to which the model meets the key performance objectives set under the approved methodology are given in Table 4 of MetOcean's calibration and validation report (*Report No 4)* and this table is reproduced here as Figure 18.

Variable	Required Minimum Accuracy (rms error)	Model rms error at Outfall Site	Model rms error at Offshore Site	Model rms error at Tamar Site
Sea-Level Amplitude (M2)	5%	17%	17%	17%
Sea-level Phase (M2)	"A little larger than 5%"	6%	6%	6%
Temperature	10%	4%	4-5%	4%
Salinity	10%	2%	2%	n/a
Tidal Currents	10%	5%	5%	10%
Residual Currents	20-30%	10%	6%	10%

Figure 18 (Figure 4 form MetOcean Report No. 4. Summary of model performance against performance objectives set under the approved methodology

It can be seen from Figure 18 that the most important model grid (the Very Fine Grid or VFG), which is used to determine dilution performance at the edge of the Mixing Zone and in Commonwealth Waters, met all performance objectives except sea-level amplitude.

Modelling tidal sea-level changes in Bass Strait is problematic because the tidal wave moves into the eastern end of Bass Strait and also moves right around the Tasmanian coast to also move in from the western end slightly less than an hour later. To model this complexity would require the modelling domain to encompass the entire island of Tasmania, something that is not practical. MetOcean note that tidal amplitude has little bearing on effluent transport and diffusion and the lower predictive fidelity of this metric is not significant.

Mere achievement of the set performance objectives is not the sole criteria of model performance, although it is a major factor. The model reproduced the temperature field to a high standard in both the FG and VFG. The salinity signal was less than ideal in both FG and VFG, but this is an artefact of the scope of forcing mechanisms selected for the Project under the approved methodology and could reasonably be expected. Currents were reproduced to a high standard, particularly near the surface. Validated predictions of the current field (in other words, where the water goes) is essential for reliable predictions of impact.

The validation of the critically important VFG was enhanced by the care taken to ensure that the FG was itself well calibrated and validated. The VFG could not be expected to produce reliable solutions if the FG, which forces the VFG via open boundaries, is itself not demonstrating reasonable performance. The approach of first focussing calibration processes on the FG and then switching focus to providing multi-point data for validation of the VFG in the final weeks of the simulation period has allowed a better examination of the VFG's performance than would have otherwise been the case.

In summary, the model clearly performed well within both of the important modelling domains: the Fine Grid and the critically important Very Fine Grid that is used to indicate potential environmental effects.

3.3.2.2 Model Outputs

The model outputs are extensively reported in MetOcean's *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall*. In order to minimise the number of reported scenarios required under the approved methodology, the report provided both concentration equivalent outputs for key contaminants and dilution outputs for others. This allows application to any constant contaminant scenario.

The model output first focussed on determining the extent (if any) of long term accumulation in the Bass Strait region. In this regard, the far field modelling simulations by RPS MetOcean have demonstrated:

- Longer term accumulation is not apparent from these simulations within the overall Bass Strait region. The time series of tracer levels (Figures 3.1.1a to 3.1.10) of *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall* near the outfall and at more remote locations show:

(1) No increasing trend after the second year of simulation, noting that it is inappropriate to compare year one to later years for this analysis[28].

(2) Low levels of effluent tracer are apparent in eastern Bass Strait during winter months and these reduce to a very low base level during summer. Conversely, western Bass Strait observes low levels of effluent tracer in summer months that similarly reduce to a very low base level during winter.

Due to the high level of dilution and a lack of accumulation within the Bass Strait region, Matters of National Environmental Significance (MNES) are highly unlikely to be prejudiced by long term operation of the outfall under maximum loading scenarios.

The second aspect of the model simulations examined the potential for a key toxicant, chlorate, to impact on Matters of National Environmental Significance. This is achieved by examining the 99th%ile and 95th %ile chlorate concentration plots and the 3 day rolling average dilution plots.

In this regard the far field modelling simulations by RPS MetOcean have demonstrated:

- Chlorate will readily meet its dilution targets for Commonwealth waters under its implied maximum loading rate scenario and WQO (123:1). Maximum predicted levels are approximately one third the 'trigger level' on an instantaneous basis and lower still when considering an ecologically relevant 3 rolling day average exposure profile.

- While dilution targets are readily met, the area of regular maximal exposure to effluent contaminants for benthic organisms such as brown algae is from near shore shallow areas out to the 20m depth contour region between Two Mile Reef, Bell Buoy Beach and Five Mile Bluff. (Appendices B, D, F, H & J of *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall*)

There is very low risk to Matters of National Environmental Significance under the maximum allowable loading rate for chlorate. The inshore region near Two Mile Reef, Bell Buoy Beach and Five Mile Bluff above the 20 m depth contour would be a logical location to monitor for effect(s) of soluble contaminants such as chlorate as further confirmation that the effluent is not having an adverse impact.

The third aspect of the modelling simulations is to consider the potential for certain physico-chemical parameters nominated in the Commonwealth's Approval Decision 2007/3385 and/or the approved methodology to impact on Matters of National Environmental Significance under the Commonwealth's implied maximum loading rates.

The parameters regulated by the Commonwealth under Condition 32 of Approval Decision 2007/3385 are:

- Total Nitrogen (TN)
- Total Phosphorus (TP)

[28] The more appropriate method to compare long-term accumulation is to compare year two or later with subsequent years. This is necessary to reasonably account for the change in initial condition from no release in year zero to release in year one.

- Total Suspended Solids (TSS)
- Biological Oxygen Demand (BOD).

It is noted that the Commonwealth has not set site specific WQOs for these parameters as it has for chlorate, but the State has for State Waters. These State WQOs are detailed in Schedule EM1, Annex W1 of the State Permit. Further, it is expected that the results of any baseline monitoring will trigger a review of these State WQOs in line with the ANZGFMWQ[29].

Information obtained by Gunns to date indicates that a revision will be required of all current State WQOs for the above parameters except BOD. The 80th percentile of baseline data will be proposed as the site specific value to be adopted, and these values are shown in Table 2 of MetOcean's *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall*. (Indicated with"#"). These new (but provisional) WQOs are therefore the most appropriate levels for assessment here.

From MetOcean's Table 2, it can be seen that of the four physico-chemical parameters above, the highest required dilution level required to meet the relevant WQO from the Commonwealth's maximum loading scenario under Approval Decision 2007/3385 is 35:1 (for TN) and the lowest is 3:1 (TSS) assuming an appropriate background concentration[30] for each parameter.

The potential and mode of environmental impact for the above physico-chemical contaminants are not the same as for a toxicant such as chlorate, and the environmental modelling outputs are interpreted in a different manner. The appropriate consideration for these physico-chemical parameters is to examine the 50th percentile plots for dilutions <35:1.

The extent of a plume with a dilution of circa 35:1 (through examining the lowest dilution isopleth of 123:1 as a surrogate) can be observed by examining the 50th %ile plots in Appendices K and L of MetOcean's *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall*. The required dilutions are met above the diffuser, well within the Mixing Zone.

The effluent concentration limits for BOD, TSS, Total Nitrogen and Total Phosphorus set by the Commonwealth are therefore highly conservative for Matters of National Environmental Significance (MNES). The values set by the State Government for the same parameters are also conservative for protecting MNES and the nominated Protected Environmental Values (PEVs) set for State waters under State legislation. Both Commonwealth and State interests could therefore be protected by the Commonwealth adopting the State's values for these parameters.

The residual physico-chemical parameters required to be examined under the approved methodology are: Colour, Adsorbable Organic Halides (AOX) and Chemical Oxygen Demand (COD).

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[29] Detailed under the Australian and New Zealand Environment and Conservation Council's (ANZECC) **A**ustralian and **N**ew Zealand **G**uidelines for **F**resh and **M**arine **W**ater **Q**uality 2000.
[30] 50th percentile of baseline data is assumed as background concentration.

Of these, Colour can be interpreted against Matters of National Environmental Significance. The potential effect of a coloured effluent in the receiving environment is based on the plume's ability to absorb Photosynthetically Active Radiation (PAR) and limit ecosystem primary productivity. Considerations such as aesthetics are not relevant to the Commonwealth as these are clearly State responsibilities in State Waters.

The Commonwealth has not set a site specific WQO nor can a loading limit be drawn from Approval Decision 2007/3385. In this case, State equivalents will be used as a surrogate. In regard to Colour the far field modelling simulations by RPS MetOcean have demonstrated:

- Colour will meet a suitable dilution target (50^{th} %ile 410:1) within the Mixing Zone based on maximum continuous (30 day rolling average) loading allowed under the State Permit and the State's WQO.

- The plume will undergo frequent changes in location outside the Mixing Zone and this will be protective of benthic productivity because the plume will not consistently reside above one area. This is evidenced by the animations presented by MetOcean in *Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall*.

The State has requested an alternate interpretation scheme for assessment of Colour to that presented here to the Commonwealth. The alternate protocol will include examination of 24 hr average dilutions against maximum loading scenario and this will be presented in the report to the State, which among other factors will assess aesthetic issues in State Waters.

The loading limits set by the State Government for the Colour parameter are conservative and these State limits in addition to protecting the nominated Protected Environmental Values (PEVs) set for State waters under State legislation, will be sufficient to also protect the Commonwealth's Matters of National Environmental Significance.

The parameters of AOX and COD do not have Commonwealth effluent limits set, nor has the Commonwealth set WQOs for these parameters.

While the State has set limits and WQOs for both, WQOs are themselves are under review. Further, it is commonly accepted that AOX is a poor or even a non-indicator of impact in the context of modern bleached Kraft pulp mill effluent. That is, no meaningful or ecologically relevant interpretation can be made using the AOX parameter itself.

The sub-class of compounds that would be expected to be a member of the AOX group of compounds, commonly referred to as 'dioxins and furans' are instead examined in greater detail by the sediment transport model output (below).

Finally, the use of COD as an interpretive measure of organic loading, leading oxygen depletion should in this context be deferred to BOD which, as has been discussed above, is a more appropriate indicator for the ecosystem's ability to accept organic loading.

3.3.3 Sediment Transport Modelling

The long term sediment transport modelling component of the Project has been successfully completed.

The modelling outputs can be used to gauge the performance of the model itself against reality and thus determine what level of confidence can be placed on its various predictions. It must be recognised that no model can be expected to be 100% correct and that some residual uncertainty is always expected of a modelling exercise.

This residual uncertainty ideally should be small but must be considered with other factors, such as the magnitude of difference (i.e. a 'safety margin') between model predictions and relevant environmental criteria.

The criterion for the sediment transport model was to assess whether the provisions of Condition 42 of Approval Decision 2007/3385 (i.e. the maximum limit in benthic sediments in any location in Commonwealth marine waters for 'dioxins and furans' of 850 pg TEQ/kg) is likely to be compromised by an effluent release scenario equivalent to the maximum loading rate for TEQ 'dioxins' and 'furans' implied by Conditions 31 and 32.

Dioxins and furans are a range of 'dioxin like' congeners of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzo furans. In this case, the congeners are expressed in 'Toxicity Equivalents' (TEQ) to the toxicity of the individual congener 2,3,7,8-tetrachlordibenzo-*p*-dioxin. The MetOcean sediment transport reports refers to these compounds collectively as PCDD/Fs, which is a common abbreviation.

The secondary task was to determine the location(s) (if any) of likely deposition zones that may be used in baseline and/or operational surveillance monitoring. This is an important issue as it is expected that if dioxins and furans were in the Bell Bay pulp mill's effluent, they would be at such low concentrations that they would not be detectable even at the vanishingly small detection limit of the analytical techniques for these types of compounds. The most logical media in which to undertake long term surveillance of these compounds is therefore in sediment, where they might, if present, accumulate to at least detectable levels.

3.3.3.1 Model Performance - Validation

Unlike the models which examined dissolved contaminants, no performance objectives were set by the Project's approved methodology for sediment transport. This is appropriate as it is commonly recognised that state-of-the-art sediment transport modelling is far less precise than the hydrodynamic models used in water quality analyses. Nevertheless, the sediment transport model performed well when validated against measured data.

3.3.3.2 Model Outputs

Dioxins and furans and other similar hydrophobic compounds are likely to partition to particles. Several scenarios were examined to consider the propensity for effluent particles to behave independently or in concert with ambient particles when encountered in the receiving environment.

Figures 4.4 and 4.10 of the MetOcean sediment transport report are the key figures for assessment. Figure 4.10 has been presented in part again here as an example for discussion as Figure 19 below.

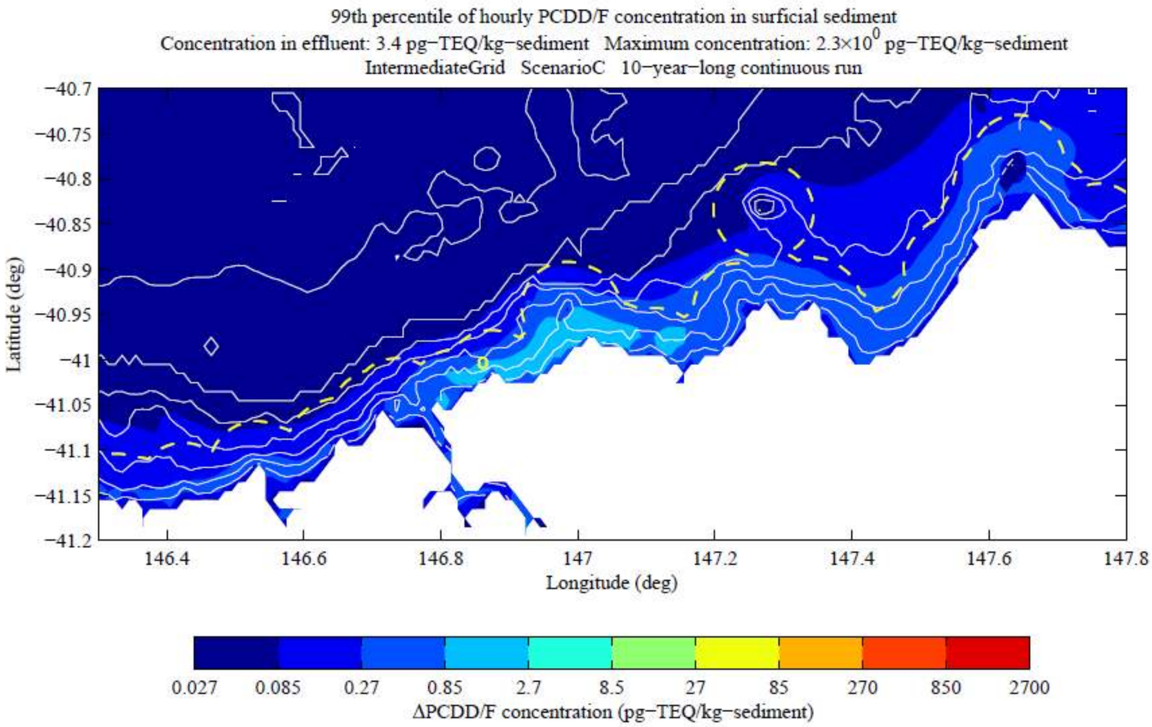

Figure 19 Excerpt from Figure 4.10 of MetOcean's *Report No. 7: Results of Long Term-Term Sediment Transport Modelling*.

It can be seen from Figure 19 that the loading limits set by the Commonwealth for the dioxins and furans parameter are set conservatively and that the effluent limit is more than adequate to protect Matters of National Environmental Significance.

The results of effluent studies reported under Item 2 of this report have supported prior predictions made under State and Commonwealth assessment processes for the Bell Bay pulp mill project which asserted that dioxins and furans measured as TEQ will not be detectable in a modern Bleached Eucalypt Kraft (BEK) Elemental Chlorine Free (ECF) pulp mill effluent. This consistent absence of detecting TEQ dioxins and furans also has implications for interpretation here.

If, as a worst case scenario, TEQ dioxins and furans were present constantly for a decade at the maximum concentration allowed under Approval Decision 2007/3385 (which is above modern detection levels by approximately 70%), the above sediment transport model presents a likely outcome for that scenario.

The scenario shows a predicted increase in TEQ dioxin and furan concentration, beyond what may be the current (i.e. baseline) levels equivalent to approximately 10% of the Sediment Concentration Limit but only in State Waters. The predicted levels in Commonwealth waters in the above scenario are an order of magnitude less than what would be seen in State waters.

In the absence of reliable baseline data[31] for the mid north coast of Tasmania further interpretation of the MetOcean simulation can be placed in context by presenting information on what is currently known in regard to estuarine and marine levels of dioxins and furans in sediments in other Tasmanian waters.

The most authoritative assessment on that topic is likely to be that of *The National Dioxins Program. Technical Report No. 6. Dioxins in Aquatic Environments in Australia.* (Müeller *et al*, 2004). Table 4 below provides a range of values that may be expected for comparison to (1) the predicted 'worst case' outcome under a maximum loading scenario showing an increase in areas generally east of the proposed outfall of up to 8.5 pg-TEQ kg^{-1} sediment (Figure 19) and (2); the Commonwealth's limit for Commonwealth's waters set by Condition 42 at 850 pg-TEQ kg^{-1}, 100 times higher than the conservative predicted worst case.

Table 4 Data from Tables D2a and D3a of *Report No. 6. National Dioxins Program*. Note reported concentration units have been adusted to align closer to those given in Approval Decision 2007/3385 for 'dioxins and furans' in sediment. (pg g^{-1} x 1000 = pg kg^{-1}).

Marine or Estuarine	Location	Lower Bound (exc. LOD values) WHO_{98}-TEQ_{DF} pg kg^{-1} dm	Mid Bound (inc. half LOD values) WHO_{98}-TEQ_{DF} pg kg^{-1} dm
Estuarine	Launceston Region (Lower Tamar)	62	150
Estuarine	Hobart (Derwent R. Estuary)	1600	1600
Estuarine	Hobart (Lower Derwent R.)	4900	4900
Marine	Cape Grim	0	29

While a potential for significant accumulation of dioxins and furans is not predicted by the modelling, the area of regular maximal exposure to effluent sourced contaminants is shown to be from near the Mixing Zone Eastward toward and beyond Five Mile Bluff to near Tenth Island.

Monitoring sites for assessing accumulation in benthic sediments for hydrophobic compounds such as dioxins and furans should be aligned to this axis. However, the highest levels predicted for the Bell Bay pulp mill project after a decadal simulation (< 8.5 pgTEQ kg^{-1}) assuming maximum loading allowed under Approval Decision 2007/3385 may still not be detectable in sediment as evidenced by the band between Lower and Mid Bound values for what is likely a pristine marine site (Cape Grim) reported in Table 4 above. The Lower Bound value indicates that no TEQ congeners were actually detected by the analysis. The Mid Bound value then in this case represents half the Upper Bound value, which is the sum of the detection limits for all TEQ congeners.

[31] Baseline data will be collected before operations commence.

3.3.4 Summary of Item 3 Numeric Modelling Studies

A very complex and extremely thorough series of computer modelling tasks has been completed to meet the requirements of the Commonwealth's Approval Decision 2007/3385 for the Bell Bay pulp mill.

The details of the modelling commissioned and the organisations responsible for performing the modelling were approved by the then Department of the Environment, Water, Heritage and the Arts.

The modelling commissioned included a sediment transport component that was undertaken by RPS MetOcean. The results of the modelling give a clear indication that the requirements of Condition 42 of the Commonwealth's Approval Decision 2007/3385 will not be prejudiced under the maximum loading scenario set by the combination of Conditions 31 and 32.

The following observations are made:

- The spatial resolutions of the models used were three-dimensional for all levels.
- The highest resolution model used (the VFG) had significantly increased resolution than that used in prior studies and reported to the Commonwealth as part of the original assessment process for Approval decision 2007/3385.
- The model(s) were forced with all mechanisms that were specified within the approved methodology.
- Long term simulations that captured seasonal variability were carried out for both the model used for assessing dissolved contaminants and those likely to partition to sediment.
- The model was calibrated to salinity and temperature and velocity data derived from moored instruments. Detailed evidence of calibration has been provided via a validation period.
- Performance targets set by the Department and the IEG in the approved methodology have been met for all apart from one metric, which has little bearing on the outcome of predictions that are necessary for ecological interpretation of the outputs.
- A detailed parameter sensitivity analysis has been undertaken and provided, with particular focus on the horizontal diffusion parameter.
- Simulation lengths required under the approved methodology for determination of plume statistics were met and exceeded by a considerable margin. The approved methodology required four months, one from each season, but ten months were achieved.
- Field data relating to three dimensional nature and seasonal variability of the water column were utilised in the near (and far) field models.

With the completion of the Project studies, there are now no remaining significant uncertainties on Matters of National Environmental Significance relating to the release of effluent from the proposed Bell Bay pulp mill under approval Decision 2007/3385.

The modelling demonstrates that the physico-chemical parameter (non-toxicants) concentration limits, when combined with an expected long term average mass flow limit given under Approval Decision 2007/3385, present no risk to MNES. Indeed, focussing regulatory attention on these parameters may even be counter productive to the overall aim of environmental protection. This point is discussed in Roberts *et al* 2010, as follows:

- *"Realistic Standards for effluent quality should be adopted. They should be flexible in terms of quality and timing, and take into account the assimilation capacity of the receiving water bodies.*

- *The type of treatment must be adjusted to the receiving water body. Wastewater contains many types of pollutants, whose relative impact on the environment depends on the characteristics of the receiving water body. Emphasis should be given to removal of critical pollutants, and unnecessary removal of pollutants that cause insignificant impacts on the environment should be avoided"*

The modelling shows that the loading limits for the physico-chemical parameters BOD, TSS, TN & TP in place under the State Permit are fit for both the State's requirement and MNES.

The required minimum dilution scenario for the key toxicant of ecological concern, chlorate, has been shown to be met by a large margin in Commonwealth Waters.

Nevertheless, the effluent studies required under Condition 34 of Approval Decision have shown that long term average (i.e. monthly to annual) chlorate levels under normal operating scenarios may be even lower than estimated previously, although levels at start-up or re-start after annual maintenance shut-downs may be at or about the current permit level.

With its adoption of the ECF Light bleaching sequence, Gunns is proposing that the chlorate limit be reduced from 3.7 to 2 mgL^{-1}, reducing environmental risk even further.

With a reduced maximum effluent concentration limit of 2 mg L^{-1} long term (eg 30 day rolling) average with assumed flow at 64 ML day^{-1}, the required dilution (66:1) to achieve chlorate's Water Quality Objective would be achieved even closer to the diffuser than it would with 3.7 mg L^{-1} (123:1).

Under that regulatory scenario every value in Table 3 of MetOcean's Report No. 5 would be scaled by 2/3.7 (multiplied by 0.54). Table 4 of the same report provides the same information, but expressed as dilutions which do not require re-scaling. From both of the referenced tables it can be demonstrated that a long term mean concentration/loading limit at 2 mg L^{-1} and 64 ML day^{-1} would achieve its required dilution at almost[32] every model time step inside the Mixing Zone. Accordingly the Commonwealth's WQO would be

[32] Some months the lowest dilution is >66:1 (indicating the dilution level is met 100% of the time), while other months the lowest dilution is just under 66:1 (indicating dilution met circa 99%-100% of the time).

met by a very large 'safety margin' at the benthos dilutions between 22 to 1027 times greater than necessary to achieve the applicable WQO in Commonwealth waters, even on a 15 minute time base.

In regard to Condition 39 of Approval Decision 2007/3385, the hydrodynamic modelling exercise as reported does not 'trigger' any response strategies in relation to approved response strategies, such as redesign of the diffuser, pipeline or effluent treatment plant. These potential strategies were developed prior to the modelling commencing and are described in EIMP Module L. The diffuser reconfiguration already undertaken and described under Item 2 is a conservative, albeit prudent, measure.

The modelling outputs have provided guidance on the location of monitoring locations as required by conditions 40 and 41 of Approval Decision 2007/3385. The final locations can now be established and whenever necessary revised under the relevant Module of the Environmental Impact Management Plan with the aid of the various hydrodynamic modelling scenarios presented in this report.

Acknowledgements

The overseas effluent study component of the Project was facilitated by the management and staff of the Veracel S.A. pulp mill of the Sate of Bahia, Brazil who allowed Gunns Limited and our delegate's access to their site and infrastructure. Gunns Limited is extremely appreciative for this access and wishes to acknowledge the assistance and of all involved with the effluent studies at the Veracel mill.

The modelling Project components substantially benefited from the professionalism and skill of key Project participants. These include Messers McConnell and Britton Worley Parsons and Messers Hollbrook and Buchan and Dr Shimizu from RPS MetOcean. The overseas effluent studies likewise benefited from the professionalism and skills of Dr Glamore and Messers Mariani and Miller of WRL, Dr Krassoi of ESA and a number of members of the staff at Toxikos Pty Ltd and the National Measurement Institute.

A special acknowledgement is made to Dr Chris Fandry of RPS MetOcean. Dr Fandry's expertise in the science of oceanography and modelling oceanic systems including that of Bass Strait in particular and the benefits of his experience gained as a member and head of the Commonwealth's *National Pulp Mills Research Program* through the 1990's allowed Dr Fandry to make an exceptional contribution to this Project.

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Appendices

1.1

Appendix 1 A

Report No. 6: Field Measurment Program October 2010 - excluding data

1.1

Appendix 2 A

Sampling Report – Overseas Effluent Phase 1 November 2010 with attachments 1 & 2

1.1

Appendix 2 B

Document 1

Toxicity assessment of Pulp Mill Effluent for the Proposed Tasmanian Pulp mill – Brazil Pulp Mill Sample. December 2009

Document 2

Toxicity assessment of a Brazilian Pulp mill Sample to Gametophytes of the Kelp Ecklonia radiata. December 2009

1.1

Appendix 2 C

Document 1

Assessment of additional Whole Effluent Testing relevant to Bell Bay Pulp Mill Effluent. February 2010

Document 2

Research notes on possible dilution factors for Bell Bay Pulp Mill based on ecotoxicity results Brazil pulp mill effluent. October 2010

1.1

Appendix 2 D

Schedule of physico-chemical analyses, with Laboratory certificates attached.

1.1

Appendix 2 E

Partitioning Study of Chlorate and AOX from a nominated Brazilian Pulp mill.
Letter Brett Miller, WRL to Lawson Harding, Gunns Ltd. February 2010

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Appendix 2 F

Particulate Property Testing Report, Gunns Pulp Mill. August 2010

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Appendix 2 G

2 x Laboratory Certificates of Analysis.
Aplysia Project No. VRC-TOX-01-10. February 2010.

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Appendix 3 A

Document 1

Bell Bay Pulp Mill. Outfall Near-Field Modelling. August 2010

Document 2

Bell Bay Pulp Mill. Outfall Near-Field Modelling – Addendum. October 2010

1.1

Appendix 3 B

Document 1

Report No 1: Functional Nested Pilot Model. September 2009

Document 2

Report No 2: Coupling of Near and Far-Field Models. May 2010

Document 3

Report No.3: Setup and Calibration of Sediment Transport Model. June 2010

Document 4

Report No.4: Calibration and Validation of Hydrodynamic Model. November 2010

Document 5

Report No. 5: Far-Field Modelling Results of the Transport and Dispersion of Effluent Discharged from the Proposed Ocean Outfall. January 2011

Document 6

Report No. 7: Results of Long-term Sediment Transport Modelling. November 2010