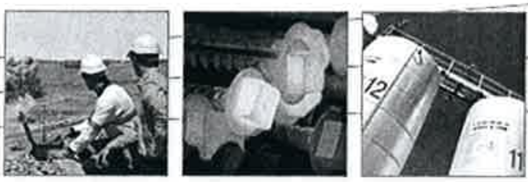
ORICA



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Board Members

Selection and Appointment of Directors

Board and Executive Performance Evaluation

Terms of Reference - The Board, Chairman & Chief Executive Officer

Peter JB Duncan

BChE (Hons) GradDip (Bus)

Chairman, Non-Executive Director since June 2001, appointed Chairman on 16 December 2009. Chairman of the Board's Corporate Governance and Nominations Committee.

Chairman of Cranlana Programme Foundation and Scania Australia. Former director of National Australia Bank Limited, GasNet Australia Limited and CSIRO and former member of Siemens Australia Advisory Board. Former Chief Executive Officer of the Shell Group of Companies in Australia.

Graeme R Liebelt

BEc (Hons)

Managing Director and Chief Executive Officer (CEO) since September 2005. Executive Director since July 1997. Member of the Corporate Governance and Nominations Committee.

Director of Melbourne Business School Limited. Board member of The Global Foundation. Former CEO of Orica Mining Services, Chairman and Director of Incitec Limited, General Manager of Plastics and Managing Director of Dulux.

Noel Meehan

B Sc (Hons), CPA

Executive Director Finance since September 2005. Member of the Corporate Governance and Nominations Committee. Former Chief Financial Officer for Orica Chemicals, Orica Group Investor Relations Manager and Corporate Reporting Manager.

Prior to joining Orica, he held a variety of finance roles both within Qantas Airways Limited and Australian Airlines Limited.

Michael E Beckett
BSc, FIMM, FRSA

Non-Executive Director since July 2002. Member of the Corporate Governance and Nominations Committee and the Safety, Health & Environment Committee.

Chairman of Thomas Cook Group plc and Endeavour Financial Corporation. Director of Northam Platinum Limited (South Africa), Mvelaphanda Resources Limited

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52 Week High
$26.38
52 Week Low
$20.47

(South Africa), Egypt Trust Limited, Endeavour Mining Capital Corp and Banro Corporation.

Russell R Caplan

LLB
FAICD

Non-Executive Director since October 2007. Chairman of the Human Resources and Compensation Committee. Member of the Corporate Governance and Nominations Committee.

Chairman of the Shell Group of Companies in Australia and the Melbourne and Olympic Parks Trust. Director of the Australian Institute of Petroleum. Former Director of Woodside Petroleum Limited.

Garry Hounsell

BBus (Accounting)
FCA, CPA, FAICD

Non-Executive Director since September 2004. Member of the Audit and Risk Committee, Human Resources and Compensation Committee and the Corporate Governance and Nominations Committee.

Chairman of PanAust Limited and Deputy Chairman of Mitchell Communication Group Limited. Director of Qantas Airways Limited, Nufarm Limited and Ingeus Limited. He is also Chairman of Investec Global Aircraft Fund. Board Member of law firm Freehills. Former Chief Executive Officer and Country Managing Partner of Arthur Andersen and former Senior Partner of Ernst & Young.

Nora Scheinkestel

Ph D, LLB (Hons),
FAICD,
Centenary Medal

Non-Executive Director since August 2006. Chairman of the Audit and Risk Committee. Member of the Corporate Governance and Nominations Committee and the Human Resources and Compensation Committee.

Director of AMP Limited and Pacific Brands Limited. Associate Professor Melbourne Business School. Former director of Newcrest Mining Limited, Mayne Group Ltd, Mayne Pharma Limited, North Ltd, PaperlinX Limited, MBF Health Fund, Docklands Authority, IOOF Funds Management and a number of utilities across the gas, water and electricity sector. Also former Chairman of South East Water Limited and the Energy 21 and Stratus Group.

Michael Tilley

GradDip, BA

Non-Executive Director since November 2003. Member of the Audit and Risk Committee, the Safety, Health & Environment Committee and the Corporate Governance and Nominations Committee.

Former Managing Director and Chief Executive Officer of Challenger Financial Services Group Limited. Former member of the Takeovers Panel. Former Non-Executive Director of Incitec Ltd and former Chairman and Chief Executive Officer of Merrill Lynch Australasia.

Non-Executive Director since July 2010. Member of

Lim Chee-Onn

BSc (Hons), MPA (Edward Mason Fellow, Harvard), D.Eng (h.c)

the Corporate Governance and Nominations Committee.

Chairman of Singbridge International Singapore Pte Ltd. Former Executive Chairman and current Senior Adviser for Keppel Corporation Ltd. Also sits on the Board of the Monetary Authority of Singapore and is Alternate Member, Council of Presidential Advisers, Singapore.

Ian Cockerill

BSc (Hons) Geology, MSc (Mining) MDP, AMP

Non-Executive Director since July 2010. Member of the Corporate Governance and Nominations Committee.

Chairman of Petmin Limited and Leadership for Conservation Africa. Former Chief Executive of Anglo Coal and Gold Fields Limited. Also held former executive positions with AngloGold Ashanti and Anglo American Group.

Annette Cook

Dip Bus (Accounting), Dip Bus (Data Processing), CPA

Company Secretary of Orica Limited since 16 February 2005 and prior to that was assistant Company Secretary from August 2002. Joined Orica in July 1987 and has had a variety of roles in Business Services, IT and Finance.

Group Executive

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ORICA

Mining Services

Minova

Chemicals

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Group Executive Team

Graeme R Liebelt

BEc (Hons)

Managing Director and Chief Executive Officer

Graeme has held a variety of key positions within the Orica group since joining in 1989 including Chief Executive of ICI Paints Pacific, General Manager Plastics and Advanced Sciences Groups and Chief Executive Officer, Orica Mining Services.

Prior to joining Orica Graeme held a number of senior positions including Marketing Director, Repco (Australia), Marketing Director, Philip Morris (Australia) and Consultant for Pappas Carter (now Boston Consulting Group).

Noel Meehan

BSc (Hons), CPA

Executive Director Finance

Noel joined Orica in April 1999 as Corporate Reporting Manager. Since then, he has held a number of other senior finance roles within the Group, including CFO for Chemicals and Orica Group Investor Relations Manager. Noel was appointed to the role of Chief Financial Officer in May 2005 and Executive Director Finance in September 2005.

Prior to joining Orica, Noel held a variety of finance roles both within Qantas Airways Limited and Australian Airlines Limited.

John Beevers

BEng (Mining) M.Bus.

Chief Executive Officer, Orica Mining Services

John joined Orica in 1985 in the Operations Division of Mining Services (Australia).

Since then he has held a variety of positions in Mining Services with leadership roles in Technology, Operations and Business. In 2005 he became General Manager, Chemical Services, before being appointed General Manager, Orica Mining Services Australia/Asia in September 2006.

John was appointed to this role in November, 2008.

Craig Elkington

BBus (Acc) CPA

President Orica Mining Services, North America

Craig joined Orica in 1994 initially with corporate accounting responsibilities before moving into several senior finance roles acoss the Group's business platforms. In 1998 he moved to Denver,

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52 Week Low $20.47

Colorado to join the North American Mining Services business following the acquisition of ICI's explosives operations.

In recent years he has held the CFO positions of the Company's former subsidiary Incitec Ltd, Chemicals Division and most recently as CFO of the global Mining Services Group. Craig was appointed to the role of President Orica Mining Services North America in December 2007.

Prior to joining Orica, Craig held a number of positions with Qantas Airways Limited, Australian Airlines Limited and Touche Ross International.

Michael Reich

B Mining Eng

Chief Executive Officer Minova International

Michael was appointed to the role of Chief Executive Officer Minova International in December 2007.

He has been with Minova for the past fifteen years having held the position of CEO of Minova's German business for the last five.

Michael has extensive experience in the mining industry particularly in the area of underground coal mining operations. Throughout his career he has as held a number of positions including sales and operations management.

Greg Witcombe

BSc

General Manager Orica Chemicals

Greg joined Orica in 1977 as a research chemist with the Agricultural Products business before moving into a series of commercial roles in the Chemicals business, including a secondment to the United Kingdom where he had responsibility for chemical exports to Asia.

His senior management positions have included General Manager of Trading (now Chemnet) and Mining Chemicals, General Manager of Polyethylene Group, Manager Director of Incitec Ltd and Managing Director of Incitec Pivot Limited.

Prior to this appointment, Greg was General Manager People and Community with responsibility for Human Resources, Safety Health and Environment, Corporate Affairs, Six Sigma and Group Procurement.

Andrew Larke

LLB
BComm
Grad Dip
(Corporations & Securities Law)

General Manager, Mergers and Acquisitions, Strategy and Technology

Andrew has spent over 15 years in mergers, acquisitions, divestments and corporate advisory. He joined Orica in April 2002 as General Manager, Mergers and Acquisitions and has been responsible for leading Orica's M&A activities since that time, including the merger of Incitec and Pivot in 2003, the subsequent divestment of Orica's shareholding in the merged Incitec Pivot entity in 2006 and the acquisition of Dyno Nobel in 2005.

Before joining Orica, Andrew was principal in SLM Corporate Advisory and prior to that held the role of General Manager Mergers, Acquisitions and Strategy at resources company North Limited where he also held a number of senior commercial and legal roles.

Trisha McEwan Dip Bus (Admin)

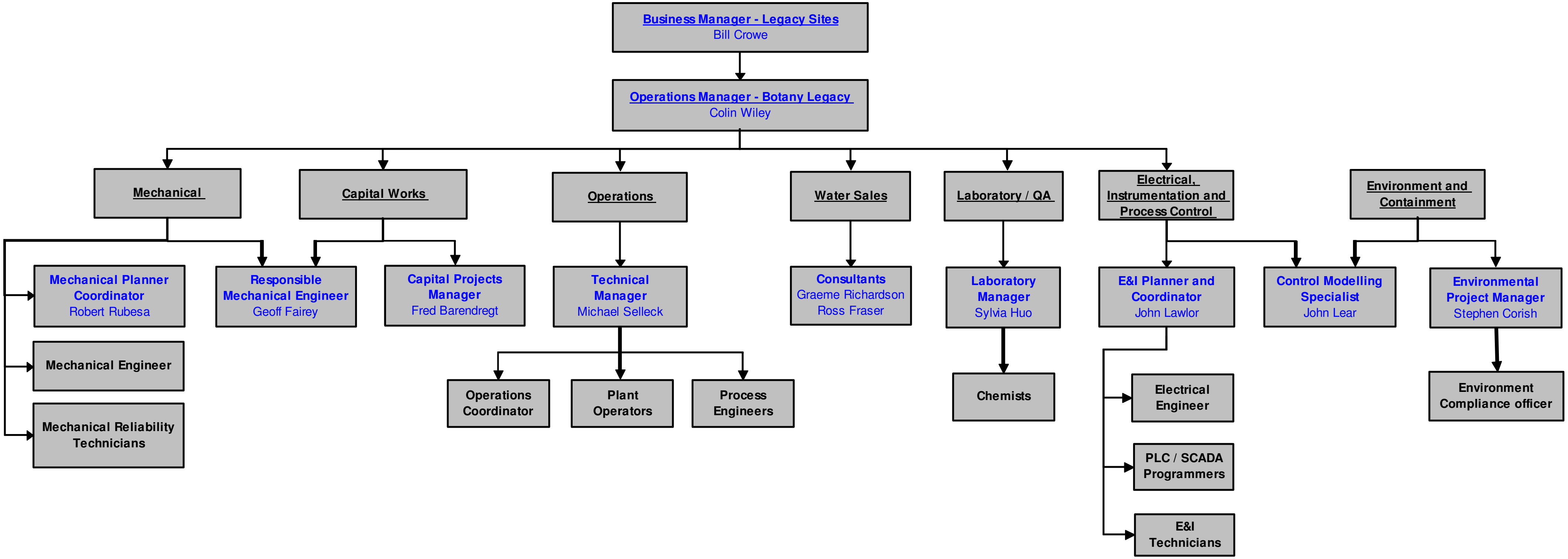
General Manager Human Resources and Communications

Trisha joined Orica in June 2009 and has had a broad career spanning roles within a number of industry sectors, mainly within New Zealand. Trisha recently spent over seven years as Group Director Human Resources with Telecom NZ, helping build people and organisation capability as the business went through a period of major change.

Board

Top

Organisation Chart - Orica Groundwater Treatment Plant



ORICA
WATERCARE

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F 303-268-5250

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F 44-1257-256-149

Asia Pacific
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MIEX®

Visit our website at www.miexresin.com or contact your nearest Orica Watercare office for more information or to inquire about a specific application.

ORICA
WATERCARE

Corporate Profile

MIEX®

Worldwide Headquarters
Melbourne, Australia

About Orica

Orica is a leading publicly owned Australian company with operations in 50 countries and customers in twice that many.

Orica turns science into the solutions that satisfy basic human needs. Our products, brands and services can be trusted for their reliability, range and quality. Each of our businesses – Orica Mining Services, Orica Consumer Products, Chemnet, and Chemical Services – is the leader in its chosen market and enjoys a world-class reputation.

At Orica, we care about people and the environment. We recognize the impact our products and services have on the communities in which we work. That's why we are committed to conducting our business in a sustainable manner that best serves our customers and the environment.

Orica Watercare

Orica Watercare, a division of Chemical Services, supplies a range of water and wastewater treatment products and services for municipal and industrial applications in Australia, North America, Europe, Africa, and the Asia-Pacific region.

The MIEX® Business Platform, within Orica Watercare, devotes itself to the development and support of ion exchange solutions for water, wastewater, and industrial processing applications. Our international team is focused primarily on the sale, manufacture, and distribution of the MIEX® Technology – an advanced ion exchange process that uses MIEX® Resins for the removal or recovery of targeted species from waters.

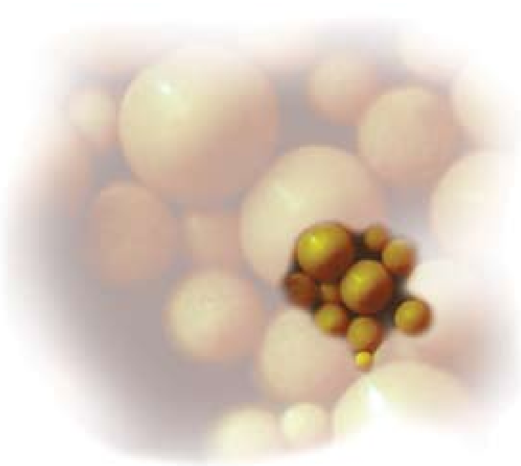
We take pride in creating cost-effective and value adding treatment solutions that are environmentally friendly and designed with the future in mind. Whether the objectives are for health, environmental, or aesthetic purposes or for improved plant efficiencies, Orica Watercare can help.

MIEX® Technology

The name MIEX® is derived from 'Magnetic Ion Exchange' as the MIEX® Resin beads have a unique magnetic property. This magnetic property enables the ion exchange process to occur in either continuous or batch processes. This provides a distinct advantage over conventional ion exchange processes, where continuous operation is not typically available.

The MIEX® Technology is utilized as a continuous process where capacities are large and consistent treatment quality is required. This process involves the continuous treatment of a liquid stream and the removal of targeted species. The ion exchange process is maintained in a steady state by the withdrawal and regeneration of loaded resin, and the return of this resin to the process.

The MIEX® Technology can also be applied by utilizing MIEX® Resin in a batch process. Often, existing infrastructure can be used with minimal capital investment. This application involves the simple mixing of resin with the liquid to be treated, loading this resin with the target species and then capturing and removing the loaded resin from the process stream.



Magnified MIEX® Resin beads

Regeneration of the loaded resin then takes place in a separate process, or the resin is simply disposed of in its loaded form. This treatment approach can be used specifically for the separation and disposal of hazardous materials from waste streams.

MIEX® Process Benefits

The MIEX® Process offers a number of benefits over alternative technologies.

- The ability to apply it in a continuous or batch process.
- High up-flow rates in continuous operation of up to 10 gpm/ft^2.
- High ion exchange surface areas allowing for rapid kinetics in both the ion exchange and regeneration processes.
- Minimal impact from suspended solids allowing the technology to be used in various locations within a treatment process.
- Small treatment footprint and low resin inventories.
- Enhanced downstream treatment efficiencies due to a reduced contaminant load.
- Significant reductions in coagulant and chemical doses with reduced operating costs.
- Very low waste volumes of less than 0.1% of flow.
- No contaminant breakthrough.

Potable Water Treatment

The MIEX® Process has a number of applications in potable/drinking water treatment. One key application is the removal of dissolved organic carbon (DOC). The benefits of efficient DOC removal include reductions in disinfection by-products, color, taste and odor as well as reduced coagulant and chlorine demand, improved downstream process efficiencies (i.e. reduced membrane fouling) and reduced sludge volumes. In addition to the removal of DOC, MIEX® Resins can also be used in the removal of nitrate, bromide, arsenic, and chromate, and in water softening applications.

Wastewater Treatment

The MIEX® Process is also suited for the treatment of both municipal and industrial wastewater. The MIEX® Technology finds application where water quality improvements are sought prior to discharge to sewer or further waste treatment and where water reclaim or recycle is a priority. The ability of the MIEX® Technology to remove DOC provides significant benefits in municipal wastewater treatment and in a range of industrial processes including pulp and paper, food and dairy, textiles, and power generation. In addition, the removal of a range of inorganic materials provides benefits in mining, mixed acid waste treatment and numerous other applications.

Industrial Processing

The unique continuous ion exchange process that the MIEX® Technology offers also allows ion exchange to be used in industrial processes more efficiently than conventional ion exchange systems. To this end, MIEX® Resins can be used to treat process streams in industrial applications, such as ultrapure water, in order to improve treatment efficiency and throughput capacity.

Treatment Systems

MIEX® Systems are available as packaged units (MAGNAPAK® Systems) up to 2 Million Gallons per Day (2 MGD) and as custom-designed systems for all capacities greater than 2 MGD. Open tank gravity flow systems and enclosed pressurized systems are available.

MIEX® Treatment Systems are modular, allowing simple delivery, installation, and equipment addition should additional capacity be required.

Services

Orica Watercare performs laboratory and pilot evaluations to determine the optimum performance of the MIEX® Technology on water and wastewater streams. A design package and budget estimate can be provided based on these feasibility studies. Orica Watercare is also fully equipped to supply equipment and perform system commissioning and optimization upon installation.

Process Flow Description and Diagram

Process description

The Groundwater Treatment Plant can be broadly divided into three sections known as:

1. Groundwater Handling System
2. Off-gas Oxidiser Package (OGOP)
3. Stripped Water Treatment Plant (SWTP)

A description of each section is given below. Unit operations written below in italics are shown in the process flow diagram.

1. Groundwater Handling System

Groundwater extraction

Groundwater is pumped out of the Botany aquifer from 113 extraction wells located in areas designated as the Primary Containment Area (PCA), the Secondary Containment area (SCA) and the Botany Industrial Park (BIP). Water is transferred from the containment areas via pipelines and enters the *Feed Tank*, the headspace of which is padded with *Nitrogen* (N_2).

Feed Tank, Air Stripping and Chlorine Dioxide (ClO_2)

The *Groundwater* is contaminated with volatile organic compounds (VOC) and the VOC are effectively removed by the *Air Stripping* units. The *Air Stripping* operation involves the use of large *Blowers* to draw air up through a falling column of groundwater. Eleven trays within two air stripper cabinets connected in series provide the stages sufficient to remove VOCs in groundwater from several hundred parts per million (ppm) down to single digit parts per billion (ppb). The GTP has twenty pairs of *Air Stripper* cabinets.

The pH of feedwater affects the rate of inorganic and biological fouling within the *Air Strippers* as well as the performance of the SWTP. The pH of the *Feed Tank* is controlled by dosing hydrochloric acid (HCl) into a feedwater side stream that recirculates around the *Feed Tank*. Typically HCl is dosed to achieve pH 4.2 – 4.9. In the event the downstream *Acid Absorber* recovers more HCl than the feedwater demand, the excess HCl is added to the *Feed Tank* and is neutralised by addition of *Caustic Soda (NaOH)*.

The groundwater contains volatile fatty acids (VFA) and ammonia, and the *Air Stripping* action promotes biofouling. From the earliest days of commissioning until recently, the non-pathogenic fungus *Trichoderma asperellum* has fouled the *Air Strippers*, requiring regular offline periods for cleaning. Raising the feedwater to pH 4.9 slowed the growth of the gelatinous fungus, but it was not until *Chlorine Dioxide* dosing was implemented that biofouling was brought under control. *Chlorine Dioxide* is produced on site by reacting sodium chlorite with HCl recovered from the process.

2. Off-gas Oxidiser Package (OGOP)

Thermal Oxidation and Waste heat recovery

The off-gas stream containing the VOCs exits the *Air Strippers* and is blown through a series of *Heat Exchangers* before entering the *Thermal Oxidiser* in two air streams known as the primary and secondary air streams. Steam is directly injected into the primary air before it enters the burner nozzle where it mixes with *Natural Gas* to fuel the flame. The secondary air stream flows as an annulus around the combustion chamber before then mixing with the hot combustion gases in the main chamber of the *Thermal Oxidiser*. The off-gas is subjected to $900^{o}C$ for approximately 3 seconds, and the chlorinated VOCs are oxidised to carbon dioxide, water and HCl vapour. The injection of steam into the primary air serves to limit the amount of nitrous oxides (NO_x) formed.

A *Waste Heat Boiler* recovers heat from the combustion gases to produce steam. Steam is used at the GTP in the O*ff-gas Pre-heater*, in the primary air stream to suppress NO_x formation, and to suppress plume formation as the saturated gases are discharged into the atmosphere. Excess steam leaves the GTP via *Steam Export* to the site grid or by safe *venting* to atmosphere.

The combustion gases leave the *Waste Heat Boiler* and flow to the *Off-gas / Effluent Heat Exchanger.* In this unit operation the hot combustion gases indirectly heat the incoming off-gas before it enters the oxidiser. This second heat recovery step cools the combustion gases to $400^{o}C$ before they enter the *Quencher.* The combustion gases enter the top of the *Quencher* and flow down through a spray zone of recirculating 5% HCl, which rapidly cools the gases to $80^{o}C$.

Acid recovery, Caustic scrubbing and Plume Suppression

The *Acid Absorber* is a column containing plastic tellerette packing that provides high surface area for HCl vapour to be absorbed into a recirculating stream of dilute hydrochloric acid. *Treated Water* produced by the process is added to the recirculating stream to replace evaporative losses and a small flow of HCl liquor that overflows from the *Absorber* sump into the *Quencher* sump. A small flow of *Quencher* recirculating liquor is transferred to the *HCl acid tank* for subsequent use in the formation of *Chlorine Dioxide* and to acidify *Feedwater.*

The *Caustic Scrubber* is a column containing plastic tellerette packing that provides high surface area for residual HCl vapour to be absorbed and neutralised by a recirculating alkaline stream. *Treated Water* produced by the process is added to the recirculating stream to replace evaporative losses and a small flow of scrubber liquor that is bled off and fed to the *Actiflo®* units. *Caustic Soda* is dosed into the recirculating stream to maintain the alkaline pH needed to neutralise HCl vapour and to convert absorbed carbon dioxide into bicarbonate/carbonate species.

The *Plume Suppression* system involves heating ambient air to 100°C and mixing it with the saturated scrubber gas at the point of release into the environment. The hot air and mixing system serve to lower the dew point and disperse the gas.

3. Stripped Water Treatment Plant (SWTP)

Iron removal by Actiflo®, wastewater recovery and filtration

Stripped Water that exits the *Air Strippers* is pumped into *Actiflo®* units. The units can be operated in parallel or one unit can receive the full flow for 7.5 ML/day of *Groundwater* extraction. *Caustic Soda* and *bicarbonate* solution from the scrubber overflow are added to the first chamber to achieve pH 8.0, the pH at which iron is least stable and coagulates. In the second chamber anionic polyelectrolyte (*Polymer)* and microsand are added. The *Polymer* forms a bridge between the heavy microsand and coagulated iron and aluminium. In the third chamber, gentle mixing and residence time facilitates growth and maturation of flocs. The last chamber is the settling chamber. Here the water flows upward through a lamella pack and the heavy flocculated solids descend towards a hopper, leaving clarified liquor to flow over into the *1st Stage Relift Tank*. The settled solids are continuously pumped through hydrocyclones and the heavy microsand re-enters the *Actiflo®*, whilst the lighter iron flocs are carried over to the *Wastewater Buffer Tank*.

The *Wastewater Buffer Tank* receives *filter backwash water* and iron flocs from the *Actiflo®. Polymer* is added to the wastewater as it is pumped into the *Sludge Thickener.* Thickener underflow containing the iron sludge is periodically pumped away to *Sewer*. Some of the clarified thickener overflow is recovered by flowing back into the *1st Stage Relift Tank* and the remaining fraction flows to the *Effluent Pit* for subsequent disposal via the BIP site effluent system.

The water in 1st *Stage Relift Tank* is pumped through *Multimedia Filters Train 1,* which contains riversand and anthracite (filter coal) layers. The filtration serves to remove small residual iron flocs.

Nutrient removal by Biological Aerated Filters (BAFs)

Stripped water itself contains insufficient phosphorus for effective biological treatment and so *phosphoric acid* is dosed into outlet water from the *Multimedia Filters Train 1*. The water enters the *BAFs* at the base and flows up through an aerated bed of zeolite media. The zeolite provides a high surface area for microbes to proliferate and consume carbon, nitrogen and phosphorus nutrients. The primary role of the *BAFs* is to remove the readily biodegradable total organic carbon, which is principally in the form of acetic and butyric acids.

Sodium Hypochlorite (NaOCl) is added to the *BAF* outlet water to kill microbes that otherwise would colonise the *Granular Activated Carbon* (*GAC*) filters downstream. Under anoxic conditions such microbes have been observed to reduce sulphate to undesirable hydrogen sulphide.

Chlorinated phenol removal by GACs

The chlorinated *BAF* product water is pumped from the *2nd Stage Relift Tank* and into the *GAC filters.* Under anoxic conditions microbes resident on the carbon degrade the non-volatile chlorinated phenols. The feedwater to the *GACs* is dosed with *Calcium Nitrate* $Ca(NO_3)_2$. The resident microbes reduce nitrate in preference to sulphate, with nitrogen gas as the by-product.

Chloramination, filtration and reverse osmosis (RO)

Monochloramine (NH_2Cl) - generated by reacting ammonia with *Sodium Hypochlorite* in a *Treated Water* carrier stream - is dosed into GAC outlet water to provide a bacteriostatic environment in the downstream unit operations and in *Treated Water* produced. The *Multimedia Filters Train 2* provides contact time for the *monochloramine* as well as some coarse filtration prior to the *RO Cartridge Filters* and *ROs*.

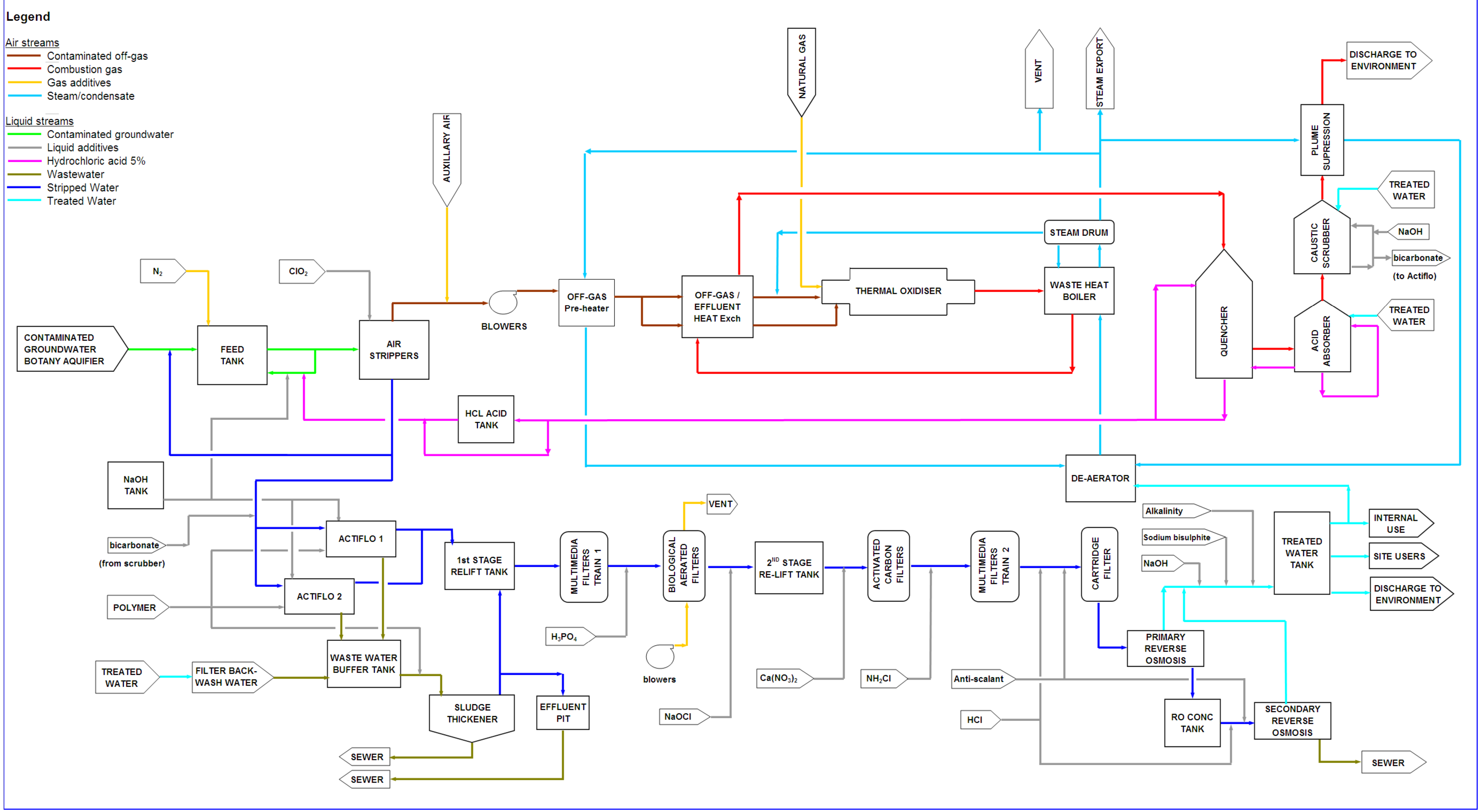
The *Primary RO* consists of two stages and the unit recovers 65 – 70% of the RO feedwater as permeate. *Anti-scalant* is dosed into the feedwater to mitigate inorganic scaling in the *ROs.* The plant has provision for dosing of hydrochloric acid into the RO feedwater, which can also benefit against scaling.

Concentrate from the *Primary RO* flows to the *RO Concentrate Tank*, which then feeds the high pressure pumps for the *Secondary ROs.* The *Secondary ROs* consist of two stages and the unit recovers 65 – 70% of the feedwater as permeate. The RO reject from the *Secondary ROs* joins the *thickener underflow* and is directed to *Sewer*.

The combined permeate produced by the *ROs* is acidic and a small amount of *Caustic Soda* is added to achieve *Treated Water* pH within pH 6 – 9. Depending on the relative requirements of site users *Alkalinity* agents can be added to the *Treated* Water. Depending on the sensitivity of site users to chloramination; sodium bisulphite to the *Treated Water* to reduce the Total Residual chlorine in the water.

Treated Water has multiple uses within the GTP including tank level control, boiler feedwater, absorber and scrubber make up water, cooling boiler blowdown, filter backwashing and cleaning of RO filters. Under normal operation the vast majority of *Treated Water* produced is sold to site users. In the event a site user is offline and/or there is *Treated Water* excess, the excess is discharged to Bunnerong Canal, which flows into Botany Bay. Before *Treated Water* is discharged, it is first dosed with sodium bisulphite in stoichiometric excess. This reduces the chloramines and thus reduces the potential for adverse effects on the environment.

PROCESS FLOW DIAGRAM - GROUNDWATER TREATMENT PLANT



WATER BUSINESS RISK ANALYSIS
Prepared for Water Industry Competition Licence Application
June 2009

Introduction

The Orica Water Business is unusual in that it is a benefit of statutory requirements to treat contaminated groundwater. As a consequence the principal risk is compliance with statutory obligations and not a financial business risk.

Financial risk is further mitigated because the capital infrastructure is currently in place.

It is also noted that the POEO Act Licence for Orica's Botany Site (Environment Protection Licence 2148), where the Water business operations are based (Condition E 5.1.2) requires Orica to "… to maximize the reuse of treated water from the groundwater treatment plant …"

A further factor is that this is an established Water Recycling Business serving industrial customers. It is not intended that this business will supply any domestic users.

As such the business risk analysis is qualitative and not quantitative.

Background

The Botany Groundwater Treatment Plant (GTP) was constructed and commissioned in 2005. Since then stable operation of the GTP and compliance with statutory, quality and supply, and commercial requirements has been demonstrated.

Because of this history it is not proposed to present a detailed risk assessment. A number of hazard studies and other risk management processes have been utilised during the construction, commissioning and operational phase of the GTP.

Statutory Compliance:

The plant has been subject to three independent compliance audits conducted by KMH Environmental Consulting to confirm compliance with the following:

1. COMPLIANCE WITH EPL[1] LIMIT CONDITIONS
2. COMPLIANCE WITH EPL OPERATING CONDITIONS
3. COMPLIANCE WITH EPL MONITOIRNG AND RECORDING CONDITIONS
4. COMPLIANCE WITH EPL GENERAL CONDITIONS
5. COMPLIANCE WITH EPL VALIDATION AUDIT CONDITIONS
6. COMPLIANCE WITH EPL ENVIROMENTAL REVIEW CONDITIONS
7. COMPLIANCE WITH EPL ENGINEERING AUDIT CONDITIONS
8. COMPLIANCE WITH EPL FINANCIAL ASSURANCE CONDITIONS
9. COMPLIANCE WITH EPL THERMAL OXIDISER AND HEAT EXCHANGER CONDITIONS
10. GROUNDWATER TREATMENT PLANT COMMISSIONING CONDITIONS
11. COMPLIANCE WITH CONDITIONS UNDER PART V OF THE WATER ACT
12. COMPLIANCE WITH CONDITIONS ISSUED BY THE DEPARTMENT OF PLANNING
13. COMPLIANCE WITH CONDITIONS ISSUED BY SYDNEY WATER

14. COMPLIANCE WITH CONDITIONS ISSUED BY SYDNEY PORTS CORPORATION

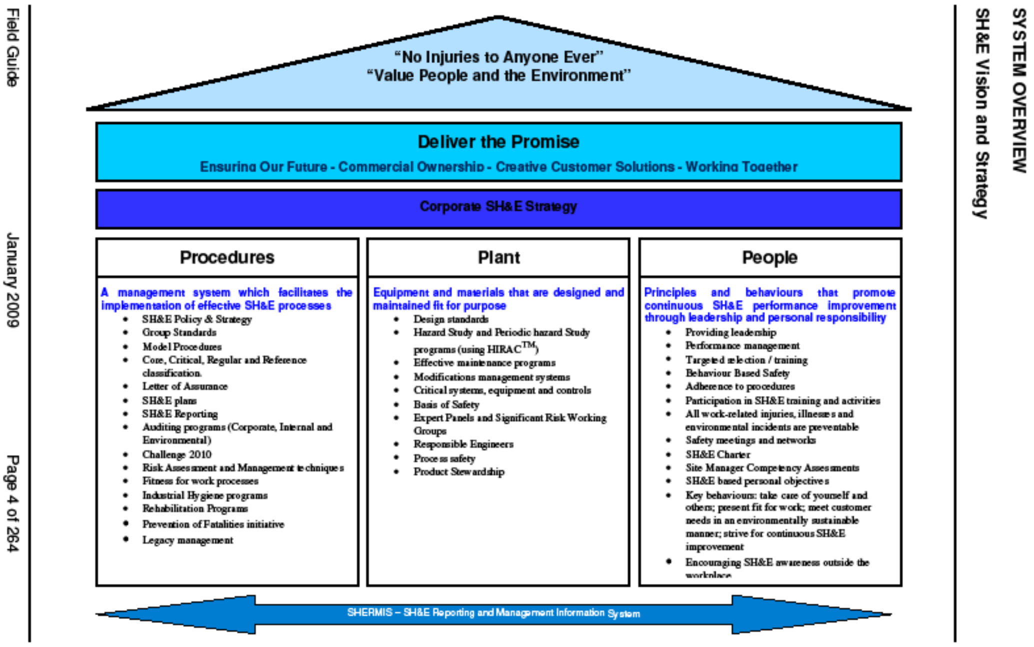
[1] Environmental Protection Licence

Safety, Health and Environmental Management:

It is noted that the GTP is located on an existing industrial site, Botany Industrial Park that has well established security and Emergency Response Plans.

The Orica Safety, Health and Environment Management System (SHEMS), which has been developed over many decades of operation world wide is used to manage safety systems in the operation of the GTP. Compliance with the SHEMS is subject to internal Orica audits.

The key elements of the system are appropriate engineering design and equipment, well trained and competent people and management systems, which are appropriate and fit for effective and safe operations. This is illustrated in the figure below:



Field Guide

January 2009

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SYSTEM OVERVIEW

SH&E Vision and Strategy

"No Injuries to Anyone Ever"
"Value People and the Environment"

Deliver the Promise

Ensuring Our Future - Commercial Ownership - Creative Customer Solutions - Working Together

Corporate SH&E Strategy

Procedures

A management system which facilitates the implementation of effective SH&E processes
- SH&E Policy & Strategy
- Group Standards
- Model Procedures
- Core, Critical, Regular and Reference classification.
- Letter of Assurance
- SH&E plans
- SH&E Reporting
- Auditing programs (Corporate, Internal and Environmental)
- Challenge 2010
- Risk Assessment and Management techniques
- Fitness for work processes
- Industrial Hygiene programs
- Rehabilitation Programs
- Prevention of Fatalities initiative
- Legacy management

Plant

Equipment and materials that are designed and maintained fit for purpose
- Design standards
- Hazard Study and Periodic hazard Study programs (using HIRAC™)
- Effective maintenance programs
- Modifications management systems
- Critical systems, equipment and controls
- Basis of Safety
- Expert Panels and Significant Risk Working Groups
- Responsible Engineers
- Process safety
- Product Stewardship

People

Principles and behaviours that promote continuous SH&E performance improvement through leadership and personal responsibility
- Providing leadership
- Performance management
- Targeted selection / training
- Behaviour Based Safety
- Adherence to procedures
- Participation in SH&E training and activities
- All work-related injuries, illnesses and environmental incidents are preventable
- Safety meetings and networks
- SH&E Charter
- Site Manager Competency Assessments
- SH&E based personal objectives
- Key behaviours: take care of yourself and others; present fit for work; meet customer needs in an environmentally sustainable manner; strive for continuous SH&E improvement
- Encouraging SH&E awareness outside the workplace

SHERMIS – SH&E Reporting and Management Information System

Supporting this approach are the Orica procedures listed in Table 1.

Community

A Community Liaison Committee has been established to provide a mechanism for feedback to the local community on not only environmental compliance and related issues but also the Water Recycling Business. There have been special workshops held with the Community on the Water Recycling business.

This Committee meets four times per annum and has access to an Independent Monitoring Committee for independent technical advice.

For both the local and wider communities comprehensive information is provided on a website. (http://www.oricabotanytransformation.com/index.asp)

Operations and Commercial Sales:

The GTP commenced operation in 2006. The GTP is modern computer controlled plant with its own NATA accredited quality laboratory as well as extensive in line monitoring. Nominal capacity is 7.ML/d and there is provision for additions to increase capacity to in excess of 9.5ML/d.
Sales have been progressively introduced to industrial customers and over 1000 ML of treated water has been sold.

Risk Review

Area	Risk	Controls
Statutory Compliance	Statutory requirements, including licences	• Good track record • Training • Internal and external audits • Quality and discharge point testing regime • Orica SHEMS Procedures • Site and plant operating procedures • On line monitoring and instrumentation • Independent Monitoring Committee • Relationship with authorities
	Reporting requirements	• Proven track record • Established reporting procedures and management systems • Independent Monitoring Committee

Area	Risk	Controls
Health Safety & Environment	Injury or harm to any person or the environment	• Proven track record • Detailed environmental and health assessments conducted at project planning and approval stage • Quality and discharge point testing regime • Training • Internal and external audits • Plant specific SH&E Plan (annual) • Orica SHEMS Procedures, including incident reporting & investigation to prevent any similar incident. • Site and plant operating procedures, including safe work clearances
	Excessive soil settlement due to groundwater extraction resulting in building damage	• Extensive hydraulic modelling to determine allowable groundwater extraction • Settlement plates installed and monitoring has been conducted
Operations	Security	• Restricted access • Site security system, including 24/7 security staff on site • Plant staffing 24/7
	Process Reliability	• Proven track record • Training • Internal and external audits • Quality control testing regime • Site and plant operating procedures • On line monitoring and instrumentation • Process equipment monitoring • Proven supply contracts for process materials
	Mechanical and E&I Reliability	• Proven track record • Training • Site and plant operating procedures • Computerised maintenance management system • Adequate spares • Back up maintenance staff available on site • Statutory Engineering Audit every five years

Area	Risk	Controls
Commercial	Supply contracts	- Contracts are in place with existing customers & letters of intent will be agreed with new customers - Quality control systems - Potable water back up
	Price	- IPART establishes pricing

TABLE 1 – Orica Procedures in use at the GTP

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MP-SF-025 Storage of Dangerous Goods D GS 5 135
MP-SF-027 Driver Safety H GS 10 137
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MP-SF-029 Air Travel Safety A GS 12 141
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FINAL REPORT

Groundwater Treatment Plant EIS Human Health Risk Assessment

Prepared for

Orica Australia Pty Ltd

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This human health risk assessment (HRA) concludes:

Risks to human health associated with emissions from the proposed Groundwater Treatment Plant during both normal operation and the worst-case accidental release scenarios have been evaluated and are considered to be representative of negligible risks.

Human Health Risk Assessment

The objective of the HRA is to identify, characterise and evaluate potential risks to human health associated with the operation of the Groundwater Treatment Plant (GTP) proposed to be located on land owned by Orica Australia Pty Ltd (Orica) at the Botany Industrial Park (BIP), Denison Street, Matraville, NSW.

The HRA has been undertaken after consultation and agreement with the NSW Department of Environment and Conservation (DEC) and the NSW Department of Health (Health).

The methodology adopted is consistent with that adopted for the evaluation of human health risks associated with other activities on the Orica site. The HRA has been undertaken in accordance with the protocols/ guidelines recommended by enHealth (Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2002). These guidelines draw on and are supplemented by those provided by ANZECC and NH&MRC as detailed in the documents:

- "The Health Risk Assessment and Management of Contaminated Sites" (CSMS 1991, 1993, 1996 and 1998 and enHealth 2002);
- ANZECC/NH&MRC (1992); and
- The NEPM (Schedule B(4), Guideline on Health Risk Assessment Methodology, 1999).

ANZECC and NH&MRC provide general guidance and more detailed protocols and guidelines developed by the US EPA (1989 and 2001) have been used to provide supplementary guidance.

Risks may be considered to be unacceptable if they exceed a specified regulatory limit, or if the circumstances are such that the risks cannot be accepted. Negligible risks are those that are so small that there is no cause for concern about them, or so unlikely that there is no reason to take action to reduce them.

The conduct of a health risk assessment (HRA) can be divided into the following four prime tasks;

- ***Issue Identification*** – involving an evaluation of the proposed process and potential for emissions to air, water and soil. The evaluation draws on the assessment of potential impacts to air, water and soils and includes an identification of key chemicals, or chemicals of potential concern (COPC), which may require detailed quantification in the HRA;

- ***Exposure assessment*** – drawing on the evaluation undertaken as part of the "issue identification" stage and involves a detailed evaluation, identification and quantification (where required) of the potential exposure pathways and all significant population groups. Where no measured data is available, modelling is required to estimate concentrations of the key chemicals in air, water or soil (and other media as required) so that risk can be quantified;

- ***Hazard Assessment*** – providing a review of the chemicals which have been identified as COPC and identifies relevant hazards associated with exposure to these chemicals. This includes and evaluation of relevant toxicology for exposure to the chemicals via air, water and/or soil and identifies the toxicity values relevant to the quantification of risk for each chemical; and

- ***Risk characterisation*** – providing quantification and evaluation of potential risks to human health. The characterisation of risk draws on the "exposure assessment" and "hazard assessment" and compares potential risk estimates with commonly accepted measures of acceptable risk with discussion of potential implications.

The HRA has been carried out in accordance with international industry practice and accepted general principles and methodology. However, there are certain features of the HRA methodology that are fundamental to drawing soundly based conclusions regarding the results.

- Risk assessment is a mathematical procedure which addresses potential exposure pathways based on the process selected, the predicted emissions and the current land use. The risk assessment is based on worst-case emissions expected from the facility and is therefore expected to overestimate actual risks.

- Conclusions can only be drawn with respect to the (groundwater treatment) process investigated.

- The HRA reflects the current state of knowledge regarding the potential health effects of identified COPC.

- The HRA does not include an assessment of risk resulting from exposure to chemicals from historical land uses that may no longer exist in the study area e.g. market gardening or industrial water use.

- The HRA does not present an evaluation of the health status of the existing community in the area but aims to evaluate risks to human health associated with emissions from the proposed GTP. Estimate of exposure to these emissions are then compared with regulatory and published estimates of daily intakes that a person may be exposed to over a lifetime without unacceptable risks to their health.

Background

Various residents, workers and visitors might be exposed to emissions from the GTP. The nearest residential areas are located to the east of the plant site along Denison Street. Commercial/ industrial premises, a golf course and areas of public open space occupy the area between the western boundary and Penrhyn Estuary. The public open space at Penrhyn Estuary has been developed as a boat launching facility and recreational fishing takes place in the vicinity. Other recreational activities include bait worm collecting, wading and possibly swimming, general exercising and bird watching.

A number of environmental investigations have been conducted within and around the BIP over the past 10 years. These investigations have indicated and delineated the presence of volatile chlorinated hydrocarbons within groundwater beneath the site. Other areas investigated include the HCB Waste Encapsulation located beneath the car park located at the northern end of the BIP. Risk assessments of these issues have concluded that potential human exposures on-site and off-site (including occupational, recreational and residential areas) to target chemicals derived from the Orica site do not present unacceptable risks to human health.

Groundwater Treatment Plant

The GTP involves the extraction, transfer and treatment of up to 15 ML/day of groundwater. The objective is to hydraulically contain an identified contaminant plume currently moving towards Botany Bay. The transfer and treatment of contaminated groundwater will occur generally within a closed system. Treatment will involve air stripping to remove volatile hydrocarbons, thermal oxidation and subsequent purification of the air flow, iron precipitation and filtration of the stripped water flow followed by purification by carbon absorption of all treated water to meet relevant guidelines. Approximately 10 ML/day of treated water will be further treated by reverse osmosis to meet Australian Drinking Waster Guidelines.

Issue Identification

The HRA has drawn on information and assessments undertaken as part of the Environmental Impact Statement (EIS) process, evaluated and identified the following:

Potential Issues	Potential exposures and management measures	Key Issues and Chemicals of Potential Concern
Construction of GTP		
Exposure to chemicals in soil and groundwater on site	Any exposure to chemicals identified in groundwater managed under health and safety plan for the site	None identified
Emissions to air	Products of fuel combustion and dust emissions. All these are to be managed and controlled on site	None identified

Potential Issues	Potential exposures and management measures	Key Issues and Chemicals of Potential Concern
Normal Operation of GTP		
Extraction and handling of contaminated groundwater	Sealed system with fugitive emissions to be managed and expected to be low	None identified
Storage, handling as use of process chemicals	Compliance with relevant Australian Standards and on-site health and safety plans	None identified
Impacts to stormwater drainage system	Control using bunding and on-site stormwater management system to minimise impacts	None identified
Impacts to wastewater and other process wastes.	Discharges to sewer in accordance with trade waste agreement. Other waste discharges to meet EPA guidelines	None identified
Treated water reuse within the BIP or discharge via Bunnerong Canal to Brotherson Dock and Botany Bay	Quality of treated water to meet Australian Drinking Water Guidelines and ANZECC Water Quality Guidelines for the protection of marine waters. In addition expected quality of water screened against human health based screening levels. No exceedances of human health based levels expected.	None identified
Emissions to air from thermal oxidiser	Air Quality Impact Assessment indicated compliance with regulatory requirements.	None identified
	Air dispersion modelling used to predict maximum ground level concentrations in areas on and off the site. Predicted emissions and concentrations compared with relevant human health risk based screening levels in air. Chemicals which exceeded either the 1-hr average or annual average screening level identified as COPC.	**Potential for inhalation of:** ○ **Chloroform** ○ **Carbon tetrachloride** ○ **EDC** ○ **Vinyl chloride** ○ **TCE** ○ **PCE** ○ **Dioxins**
	Chemicals identified as persistent and bioaccumulative identified for further assessment in off-site areas (multiple exposure pathway assessment).	**Potential for exposure via non-inhalation routes for:** ○ **HCBD** ○ **Dioxins** ○ **Mercury**
Accidental Releases		
Identification and evaluation of hazards and failure scenarios	Preliminary hazard assessment provided review in accordance with DIPNR guidance. Indicated risks comply with relevant guidance.	
Worst case scenarios for emissions to air (frequency of failure for both scenarios estimated to be once per 50,000 years)	**Increased emission of dioxin** associated with subtle failure in oxidiser, temperature controls and other indicators. This may go un-noticed between dioxin measurements which may be up to 12 months	**Potential for exposure via non-inhalation routes for:** **Dioxins**

Potential Issues	Potential exposures and management measures	Key Issues and Chemicals of Potential Concern
	No destruction of chemicals in the thermal oxidiser resulting in emissions to air which are equal to that in the air stream from the strippers. Significant failure event which may occur for up to 12 hours. Increasd emissions modelled with maximum ground level concentrations compared with relevant acute exposure criteria. Potential increased emission of persistent and bioaccumulative chemicals identified.	**No COPC identified for exposure via inhalation** **Potential for exposure via non-inhalation routes for:** ○ **HCBD** ○ **Dioxins** ○ **Mercury**

Exposure Assessment

The key exposure issues identified are:

- Inhalation exposure to chemicals identified in air following normal emissions from the thermal oxidiser;
- Multiple pathway exposure to persistent and bioaccumulative chemicals which may be emitted to air during normal operation of the thermal oxidiser;
- Inhalation and multiple pathway exposure associated with the potential upset to operating conditions that may give rise to increased dioxin emissions for up to 12 months; and
- Multiple pathway exposure to persistent and bioaccumulative chemicals which may be emitted to air following a worst-case accidental release where no destruction occurs in the thermal oxidiser for up to 12 hours.

The key exposure pathways for off-site populations to emissions to air associated with the proposed GTP are:

- Inhalation of chemicals in air by all groups in the area surrounding the site (residents, workers and recreational groups);
- Direct contact (ingestion and dermal contact) by residents with soils that may have accumulated levels of persistent and bioaccumulative chemicals;
- Ingestion of home-grown produce by residents which may have been grown in soils which have accumulated levels of persistent and bioaccumulative chemicals; and
- Ingestion of persistent organic chemicals by infants during breastfeeding.

When quantifying exposure or chemical intake in areas on or off the site, the risk assessment process focuses on chronic exposure occurring over years and possibly a lifetime. The quantification of exposure requires a number of inputs and assumptions. These are:

- Values that describe physical and activity-specific variables for residents (adults, children and infants), workers and recreational users in the area (adults playing golf or athletics and children participating in athletics or other physical activity). These are values such as body weight, inhalation rate at home or exercising, how much soil may be eaten (ingested), how much of the body gets dirty, how much fruit and vegetable products are grown and eaten from home gardens, how many hours are spent at home (or in the area) and for how many years. The values selected are representative of maximum exposures and have been reviewed and agreed with the DEC and NSW Health prior to use.

- Concentrations of chemicals in air. This has been obtained from the air dispersion modelling undertaken in the Air Quality Assessment. As discussed in the Air Quality Assessment the concentration of chemicals in air derived from the GTP will decrease with distance from the site due to natural processes of mixing or dispersion with the atmosphere. To provide a conservative assessment of potential exposure, the maximum predicted concentration at ground level (known as the maximum ground level, or MGL, concentration) has been used in the health risk assessment. This concentration would occur on the BIP (not in residential areas), however, as conservative approach, this concentration has also been used in the assessment of maximum exposure by residents and recreational users in the area. This is expected to overestimate risk. Further detailed assessment of exposure at specific locations (discrete receptors as modelled in the Air Quality Section) has also been undertaken.

- Concentration of persistent and bioaccumulative chemicals in soil. This has been estimated using a soil accumulation model (Stevens, 1991) that predicts the concentration in soil based on the deposition rate and chemical-specific parameters such as the half-life of the chemical in soils. The deposition rate used in the assessment has been obtained from air dispersion modelling with the maximum deposition value from the model used in the assessment. The maximum deposition rate occurs on the BIP, however to be conservative, the assessment of maximum exposure by residents has also used this value. This is expected to overestimate risk. Further detailed assessment of exposure at specific locations (residential and schools identified as discrete receptors as modelled in the Air Quality Section) has also been undertaken.

- Concentration of persistent and bioaccumulative chemicals in fruit and vegetables. This has been estimated using a plant model (Stevens, 1991) that predicts the concentration in edible fruit and vegetables on the basis of deposition onto leaves of the plant (and absorption) as well as uptake by roots from chemicals accumulated in soils from deposition of GTP atmospheric emissions. This has been undertaken using the maximum deposition rate and soil concentrations estimated as above.

- Concentration of persistent and bioaccumulative chemicals in breast milk. This has been undertaken using a model (USEPA 1998) that is based on maternal (mother's) intake of chemicals from all sources (inhalation, soils, fruit and vegetables and other background intakes) and accumulation of the chemical in milk fat. The milk is then ingested by the infant. This assessment has utilised the maximum concentrations and maternal intakes estimated for inhalation of chemicals in air, soil concentrations and fruit and vegetable consumption and is therefore expected to conservatively overestimate risk.

Using exposure variables and concentrations in air, soil, plant and breast milk, the amount of each chemical which enters the body each day, referred to as a ***daily chemical intake***, associated with emissions from the GTP by residents, workers or recreational users in the area has been estimated. This is the maximum intake associated with emissions from the GTP that may occur every day for a lifetime (or for up to a year for worst case 1 in 50,000 year worst-case scenario).

The daily chemical intake calculated for each chemical (for all pathways of exposure) for each group is then compared with the relevant toxicity value for the chemical to determine a risk.

Hazard/Toxicity Assessment

The objective of the toxicity assessment is to identify toxicity values for the COPC that can be used to quantify potential risks to human health associated with calculated intake. Toxicity can be defined as *"the quality or degree of being poisonous or harmful to plant, animal or human life"* (NEPM, 1999).

Non-Threshold Response

Non-threshold toxicity values assume that increasing exposure to the chemical has the potential to result in an increased risk. These chemicals are typically carcinogens with their toxicity values referred to as cancer risk slope factors. The WHO assigns slope factors to chemicals identified as genotoxic carcinogens with other carcinogens evaluated generally identified as exhibiting a threshold relationship (refer below). A slope factor is an upper bound estimate of the probability of a response occurring following the intake of a chemical over a lifetime via a specific exposure pathway (such as ingestion or inhalation). Therefore the higher the slope factor the higher the risk that may be associated with a given exposure.

Threshold Response

Non-threshold toxicity values assume that there is a level of exposure below which there is no appreciable risk of an adverse health effect. The WHO identifies non-threshold chemicals as those which are not suspected of exhibiting carcinogenic effects (non-carcinogens) or those which exhibit non-genotoxic carcinogenicity. Toxicity factors for these chemicals are referred to as an acceptable daily intake (ADI, by the WHO) or reference dose (RfD, by the USEPA) for oral exposures and a tolerable concentration (TC, by WHO) or reference concentration (RfC, by USEPA) for inhalation exposures. The lower the ADI, RfD, TC or RfC, the more toxic the chemical and the lower the concentration above which there exists a potential for an adverse health effect.

The identification of toxicity values undertaken in this HRA has followed enHealth (2002) guidance, which is in accordance with the NEPC (1999) policy. Toxicity profiles have been prepared for the chemicals identified with the exception of dioxins. These profiles provide a review of potential health effects associated with exposure and identification of relevant toxicity values for the quantification of risk associated with oral, dermal and inhalation exposures. The Department of the Environment and Heritage (DEH, 2004) has undertaken an extensive review of dioxins in Australia and have published a summary document "*National Dioxins Program, Dioxins in Australia: A Summary of the Findings of Studies conducted from 2001 to 2004*". This document provides a summary of key exposures and health effects associated with dioxins.

The following Table presents a summary of the toxicity evaluation and data identified for use in this HRA. The toxicity values have been reviewed by the DEC and NSW Health prior to use in this HRA.

The toxicological data presented are considered to be appropriate for the assessment of risks to human health associated with the potential exposure to the chemicals identified. Whilst it is accepted that toxicological data has some uncertainties, the approaches adopted by the different regulatory bodies in determining the relevant toxicological values are considered to be conservative and likely to overestimate the risks.

Summary of Toxicity for COPC

Chemical	Non-Cancer Toxicity Endpoint	Animal Carcinogen and Mechanism	Genotoxic	Oral Slope Factor (mg/kg/day)$^{-1}$	Oral TDI (mg/kg/day)	Inhalation Unit Risk (µg/m^{3})$^{-1}$	Inhalation TC (or equivalent) (mg/m^{3})	Occupational Inhalation Standard TWA $^{(6)}$ (mg/m^{3})	Potential for background intake
Hexachlorobutadiene (HCBD)	Kidney	Yes, M,C	Equivocal	T	0.0002$^{(3)}$	T	O	0.21	Refer to Section 6.3
1,2-Dichloroethane (EDC)	Liver	Yes, M,G	Yes	0.012$^{(1),(3)}$	NT	(0.5 to 2.8)x10^{-6} $^{(2)}$ **2.8x10^{-6} proposed**	NT	40	---
Vinyl Chloride	Liver	Yes, G	Yes	2.3$^{(1)}$	NT	4.4x10^{-6} adulthood **8.8x10^{-6} lifetime** $^{(4)}$	NT	13	---
Chloroform	Liver, kidney, CNS	Yes, P, C	No	T	0.013$^{(1)}$	4.2x10^{-7} $^{(2)*}$	0.14$^{(2)}$	10	Yes (50%)
Carbon Tetrachloride	Liver, kidney	Yes, P, C	No	T	0.00142$^{(1)}$	T	0.0061$^{(2)}$	0.63	Yes (65%)
Trichloroethene (TCE)	CNS, liver	Yes, P, C, MG	Equivocal	T	0.0238$^{(1)}$	4.3x10^{-7} $^{(2)}$	NT	54 (proposed)	Yes, low
Tetrachloroethene (PCE)	Liver, kidney, CNS	Yes, P, C, MG	No	T	0.014$^{(3)}$	T	0.25$^{(2)}$	335	Yes (34%)
Mercury	Elemental: CNS Inorganic: Kidney Methyl: CNS	No Equivocal Yes	--- No No	T	0.00071$^{(1)}$ for total mercury and **0.00023 for methylmercury$^{(1)*}$**	T	0.001$^{(2)}$ total mercury	Elemental:0.255 Divalent Inorganic:0.025 Monavalent Inorganic 0.1 Alkyl: 0.01	Yes (80%)
Dioxin (TEQ)	Hormonal, reproductive and developmental	Yes	No	T	1 to 4 pg/kg/day$^{(2))}$ **2.3 pg/kg/day$^{(8)}$**	T	1 to 4 pg/kg/day $^{(2))}$ **2.3 pg/kg/day$^{(8)}$**	NA	1.25 pg/kg/day based on data for young children $^{(9)}$

(1) Derived from WHO Drinking Water Guidelines (1993, 1996, 1998 and 2004)

(1)* Derived from revision to PTWI for methylmercury provided by JECFA 2003

(2) Derived from WHO Air Quality Guidelines (2000, 2000b or CICAD 58 (2004) for chloroform).

Where a range is presented, the most conservative value (higher unit risk and lower ADI) has been adopted.

(3) Derived from NHMRC Australian Drinking Water Guidelines (1996 and draft 2002)

(4) Derived by USEPA (IRIS evaluations, current 2004)

(6) Occupational data available from NOHSC except where noted, TWA values based on 8-hour average

(8) Dioxin evaluation presented by NHMRC as presented by Therapeutic Goods Administration (TGA), endorsed 2002. Value recommended for use in risk assessment.

(9) Background intake derived from upper bound estimates from Australian data of 22% for adults and 54% for young children, National Dioxins Program, DEH 2004.

O Inhalation exposure evaluated using oral data as no relevant chronic inhalation data available

T Threshold approach adopted, hence no oral slope factor or inhalation unit risk considered relevant.

NT Non-threshold approach adopted

NA Not available

NG = Non-genotoxicC = Cytotoxic P = Peroxisome proliferation G = Genotoxic

M = metabolite mediated with questionable relevance to humans

MG = species specific α2-microglobulin mechanism

TEQ = Toxicity Equivalence

Risk Characterisation

Risk characterisation is the final step in a quantitative risk assessment. It involves the combination of the exposure assessment and the toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold health effects.

Risk for Non-Threshold Effects

The potential for unacceptable non-threshold carcinogenic risks associated with exposure to COPC has been evaluated using US EPA methodology.

Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows:

$$\textit{Carcinogenic Risk} = \textit{Daily Chemical Intake} \bullet \textit{Cancer Slope Factor}$$

The total non-threshold carcinogenic risk is the sum of the risk for each chemical for each pathway.

Deciding whether the calculated cancer risk is of concern or not requires identification of an acceptable cancer risk value. The calculation of a cancer risk implies that any exposure to these chemicals may result in an increased risk or probability of contracting cancer over a lifetime. The cancer risk value is expressed as a probability such as 1 in 10,000 ($1\text{x}10^{-4}$) or 1 in 1,000,000 ($1\text{x}10^{-6}$). An incremental lifetime cancer risk of $1\text{x}10^{-6}$ means that in a population of 1 million people which has been exposed to the chemical for their lifetime one additional cancer is predicted over and above the background incidence of cancer in that population.

These values are extremely low when compared to the background incidence of cancer in our society. The background incidence is in the order of 1 in 4 to 1 in 3. This means that for a population of 1,000,000 around 250,000 individuals are expected to contract cancer over a lifetime. An additional $1\text{x}10^{-6}$, risk predicts 1 additional individual may develop cancer.

Specific Australian guidance related to the significance of cancer risk estimates is not available. Current US EPA policy states that: *"Where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4},..action is generally not warranted unless there are adverse environmental impacts"* (US EPA, 1991).

The application of cancer risk values in Australia and elsewhere is generally consistent with the US EPA policy. That is, the 10^{-6} risk value is commonly identified as the point of departure from negligible risk and the 10^{-4} risk value is commonly adopted as being indicative of unacceptable risks.

Adopted Risk Targets

Based on the above discussion, URS considers that the following is representative of current practice in NSW with respect to incremental lifetime cancer risks:

- Calculated incremental risks below 1 x 10^{-6} would be considered to be effectively zero;
- Calculated incremental risks between 1 x 10^{-6} and 1 x 10^{-5} would be considered acceptable; and
- Calculated risks greater than 1x 10^{-4} would be considered to warrant some form of action or management to reduce the risk.

Hazard Index for Threshold Effects

The potential for adverse threshold effects, resulting from exposure to a COPC, has been evaluated by comparing an exposure level, expressed as a daily chemical intake, with the adjusted acceptable daily intake (ADI) or equivalent threshold value (tolerable daily intake (TDI), reference dose (RfD) or TWA). The resulting ratio is referred to by the USEPA as the hazard quotient (USEPA, 1989) and is derived in the following manner:

$$Hazard\ Quotient = \frac{(Daily\ Chemical\ Intake\ from\ GTP)}{(ADI) - (Background\ Intake)}$$

The evaluation of risk associated with threshold chemicals involves a comparison of the total daily intake with the adjusted ADI. The adjusted ADI is that which has been adjusted for background intake from all other sources so that the hazard quotient calculated compares the chemical intake derived from the proposed GTP with the ADI allowable from sources other than background. If the hazard quotient exceeds one, then this would indicate potentially unacceptable chemical intakes. The hazard quotient does not represent a statistical probability of an effect occurring.

To assess the overall potential for adverse health effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway have been summed. The resulting sum is referred to by the USEPA as the hazard index (HI) (USEPA, 1989). The HI approach assumes that multiple sub-threshold exposures to several chemicals could result in a cumulative adverse health effect, and exposures are summed over all intake routes.

If the Hazard Index is less than one, cumulative exposure to the chemicals is judged unlikely to result in an adverse effect. If the index is greater than one, a more detailed and critical evaluation of the risks (including consideration of specific target organs affected and mechanisms of toxic action of the chemicals of concern) would be required to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

Background Intake of Threshold COPC

The calculation of risk associated with threshold chemicals (using a hazard index) presented above requires the assessment of background intake. These are intakes associated with exposures to background chemical concentrations in food, water, soils and urban air. Background exposure to chemicals in air has been accounted for in the initial stage of screening. In addition background intakes of threshold chemicals has been reviewed and estimated for industrial areas.

Assessment

Non-threshold risks and threshold hazard indices have been estimated for potential exposure (reasonable maximum exposures and maximum emissions) associated with normal operation of the GTP and for the worst-case accidental release scenarios evaluated. Further evaluation of risk has also been undertaken for the normal operations of the GTP for a range of specific locations surrounding the BIP site.

Recreational areas such as the golf course, reserves, athletics fields and the Girl Guide hall have been evaluated on the basis of recreational inhalation exposure scenarios. Other areas, which include residential areas and schools, have been evaluated on the basis of residential type exposure scenarios which include inhalation and multiple pathway assessment. The assessment presented for a young child is expected to overestimate the risk for an older child.

Conclusions

The characterisation of risk associated with the operation of the proposed GTP has identified the following for key receptors and exposure pathways:

- Normal operation of the GTP:
  - The evaluation has focused on potential inhalation exposure to chemicals identified in air following normal operation of the thermal oxidiser and multiple pathway exposure (inhalation, ingestion and dermal contact with chemicals in soils, ingestion of home-grown fruit and vegetable crops and accumulation of chemicals in breast milk and subsequent exposure by infants).
  - Relevant receptors have been identified as residents (inhalation and multiple pathway exposure), recreational groups (inhalation only) and workers (inhalation only).
  - The total hazard index value for all receptor groups evaluated for all threshold chemicals fall below 1. This indicates that the estimated intake associated with reasonable maximum exposures by all receptor groups plus background intakes, falls below the acceptable intake for the chemicals as defined by the ADI (or equivalent including background intakes).
  - The total incremental lifetime risk for all receptor groups evaluated for all non-threshold chemicals identified fall below the incremental risk level of 10^{-6} adopted as representative of negligible or effectively zero risk.

  - The evaluation of risk to human health associated with emissions during normal operation of the proposed GTP is therefore considered to be low and representative of negligible risks.

- Accidental releases from the GTP:
  - The evaluation has focused on potential inhalation and multiple pathway exposure to chemicals identified in air following two worst-case accidental release scenarios identified for the thermal oxidiser.
  - Receptors have been identified as residents (inhalation and multiple pathway exposure), as these are the most sensitive population group in the area. Risks associated with exposures by other groups (workers recreational or visitors) are expected to be lower than evaluated for the resident.
  - The total hazard index value for all receptor groups evaluated for all threshold chemicals fall below 1. This indicates that the estimated intake associated with reasonable maximum exposures by all receptor groups plus background intakes, fall below the acceptable intake for the COPC as defined by the ADI (or equivalent including background intakes).
  - The total incremental lifetime risk for all receptor groups evaluated for all non-threshold chemicals fall below the incremental risk level of 10^{-6} adopted as representative of negligible or effectively zero risk.
  - The evaluation of risk to human health associated with emissions during the worst-case accidental release scenarios evaluated is therefore considered to be low and representative of negligible risks.

Because of the low to very low concentrations of other chemical emissions predicted from the GTP (normal operations and accidental releases), the cumulative impact of such chemicals on the estimated reasonable maximum risk for all receptor groups is expected to be negligible.

These calculated levels of risk are indicative of acceptable levels of risk for potential exposures to emissions from the proposed GTP.

The results from the HRA are considered to be inherently conservative because:

- Exposure concentrations used in the assessment of maximum risk for all receptors (including residents) are the maximum ground level concentrations (which occur on the BIP);
- Deposition rates used to estimate soil concentrations and fruit and vegetable concentrations for the calculation of maximum risk for all receptors (including residents) are the maximum rates (which occur on the BIP);
- The models used to estimate concentrations of persistent chemicals in soil, plants and milk are simple and over-estimate actual concentrations;
- Activity parameters are based on the worst-case (most conservative) exposure scenarios; and

- Toxicity values used are primarily based on animal studies with a number of safety factors applied to provide a conservative value for the use in human health risk assessment.

Further evaluation of risk associated with the GTP has been undertaken to illustrate the low level of risk calculated for the proposed GTP. Figures ES-1, ES-2 and ES-33 (following) provide an indication of calculated risks associated with operation of the GTP relative to background risk levels (associated with multiple pathway exposure to persistent chemicals), incremental risks for non-threshold chemicals and the hazard index for threshold chemicals for all areas evaluated (maximum as well as select areas off-site).

Figure ES-1 - Intake of Persistent and Bioaccumulative Chemicals by Residents During Normal Operation of GTP

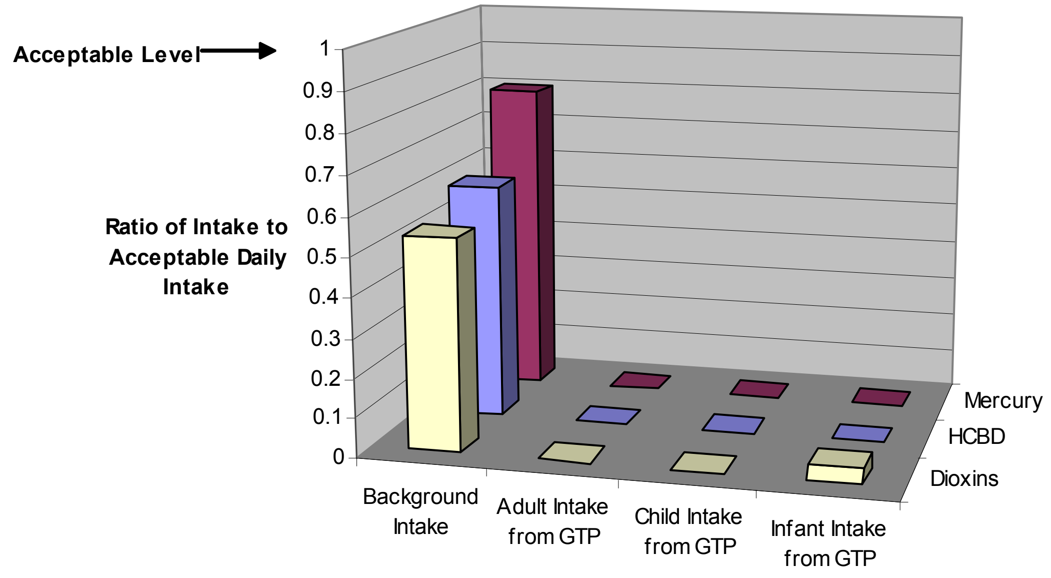
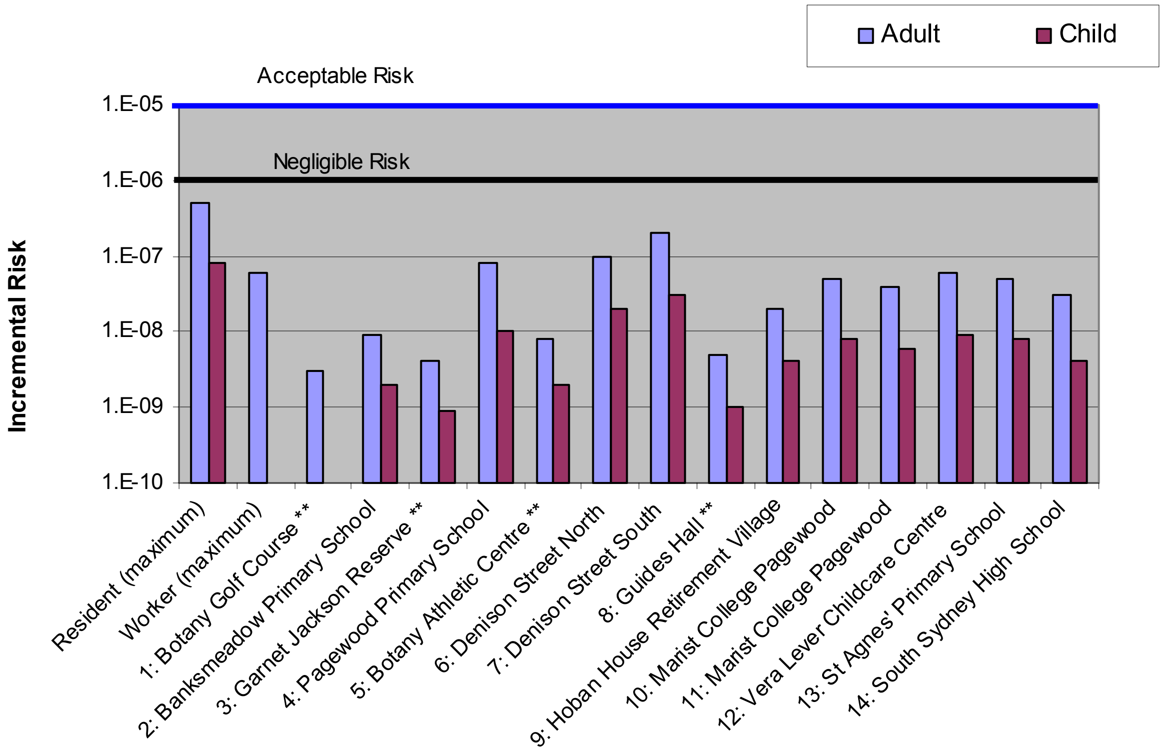
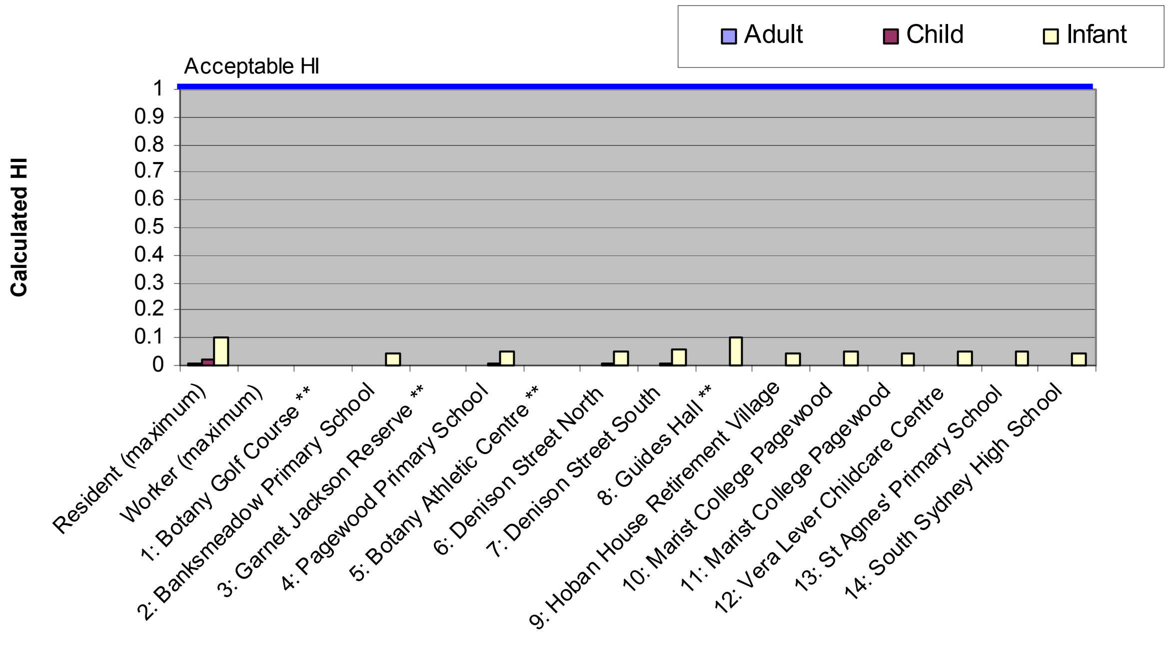


Diagram ES-2 - Calculated Total Non-Threshold Risk Associated with Normal Operation of GTP



** Areas assessed on the basis of recreational exposure. Other areas assessed on the basis of residential exposure

Diagram ES-3 - Calculated Threshold HI Associated with Normal Operation of GTP



** Areas assessed on the basis of recreational exposure. Other areas assessed on the basis of residential exposure

1.1 General

This report presents the methodology and findings of the human health risk assessment completed for the preparation of an Environmental Impact Statement (EIS) for the proposed Groundwater Treatment Plant (GTP) undertaken by URS Australia Pty Limited (URS), on behalf of Orica Engineering Pty Limited (Orica). The proposed facility site is located within Orica land at the Botany Industrial Park (BIP) on Denison Street, Matraville, NSW.

The overall objective of the health risk assessment is to identify, characterise and evaluate potential risks to human health associated with the operation of the proposed GTP. The focus of the health risk assessment is off-site[1] long-term risks, however where relevant, short-term risks have also been addressed.

The health risk assessment presented is not an epidemiological study (which is a study of the distribution and causes of existing health related issues in the community), nor does this assessment provide a statistical analysis of the existing health status of the community. The assessment evaluates the potential impact of the proposed GTP on risks to human health using guidance recommended and endorsed by Australian regulators in particular the NSW Department of Environment and Conservation (DEC) and the NSW Department of Health (Health).

The assessment of human health risk associated with the proposed GTP has drawn on information and assessments undertaken as part of the Environmental Impact Statement (EIS) process. In addition, the methodology adopted for the evaluation of risks to human health follows guidance from enHealth (2002) and is consistent with methodology adopted for the evaluation of human health risks associated with other aspects of the Orica site.

1.2 What is Risk Assessment?

1.2.1 Risk

Risk assessment is used extensively in Australia and overseas to assist in decision making on the acceptability of projects that present possible risks to the public. Risk is commonly defined as the chance of injury, damage, or loss. Therefore, to put oneself or the environment "at risk" means to participate either voluntarily or involuntarily in an activity or activities that could lead to injury, damage, or loss.

Voluntary risks are those associated with activities that we decide to undertake (e.g. driving a car, riding a motorcycle, smoking cigarettes).

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[1] Off-site as used in the health risk assessment refers to areas which are not on the site used for the proposed GTP. Hence off-site implies assessment of workers within or surrounding the BIP and residential or recreational areas surrounding the BIP.

Involuntary risks are those associated with activities that happen without prior consent or knowledge. Acts of nature such as being struck by lightning, fires, floods, tornados, etc., and exposures to environmental contaminants are examples of involuntary risks.

1.2.2 Defining Risk

Risks to the public and the environment are determined by direct observation or by applying mathematical models and a series of assumptions to infer risk to humans or the environment. No matter how risks are defined or quantified, they are usually expressed as a probability of adverse effects associated with a particular activity. Risk is typically expressed as a likelihood of occurrence and/or consequence (such a negligible, low or significant) or quantified as a fraction or a numeric probability of an event occurring.

Risks from hazardous facilities are usually assessed through qualitative or quantitative risk-assessment techniques. In general, risk assessments seek to identify all relevant hazards, assess or quantify the likelihood of occurrence and consequences, and estimate risk levels for people who may be exposed (such as those beyond the perimeter boundary of a facility).

1.2.3 Acceptability of Risk

Risks can be considered to be ‘acceptable’ or tolerable if the exposed public could be expected to bear them without undue concern. Risks may be considered to be unacceptable if they exceed a specified regulatory limit, or if the circumstances of the proposal are such that the risks cannot be accepted. Negligible risks are those that are so small that there is no cause for concern about them, or so unlikely that there is no reason to take action to reduce them.

Perceptions of risk are also important in determining whether risks for hazardous facilities in particular locations can be considered acceptable. The risks that tend to be of greatest concern are those that are involuntary, man-made and perceived as potentially catastrophic in their consequences.

While risk assessments can help to quantify levels of risk, risk is usually an emotive issue and the level of perceived risk acceptable to the community may differ depending on the knowledge and lifestyle expectations of the community involved. With respect to fatality or injury risks arising from accidents, DIPNR (Department of Infrastructure, Planning and Natural Resources) defines levels of acceptable risks.

In the case of human health risk assessments, the potential health effects are not necessarily well defined or measurable and hence some degree of debate arises as to the level of acceptable risk. There is a common expectation that risks should be reduced as low as reasonably practicable or achievable. The process of evaluating risk to human health associated with the proposed GTP has followed accepted methodology (refer to Section 1.3) and accepted methods of defining acceptable risk (refer to Section 6.2) which are considered to be conservative and protective of all individuals.

The process of risk assessment aims to assist risk managers in addressing the potential impact of a proposed development on the surrounding community and the communication of the potential risks.

1.3 Approach to Human Health Risk Assessment

This section presents an outline of the approach utilised in the assessment of both human health and environmental risks associated with development and operation of the proposed GTP facility. The methodology adopted is consistent with that used to evaluate risks to human health associated with other aspects of the Orica site. This includes the evaluation of risk presented in the Stage 2 Risk Assessment (Woodward-Clyde, 1996e), Health Risk Assessment Associated with Western Margin (URS, 2003b), HCB Car Park Waste Health Risk Assessment (URS, 2002b) and the HCB Waste Destruction Plant EIS (proposed facility, URS 2001b and 2002c).

The approach taken to the assessment of human health risks is generally in accordance with the protocols/ guidelines recommended by enHealth (Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2002). These guidelines draw on and are supplemented by those provided by ANZECC and NH&MRC and detailed in the documents:

- "The Health Risk Assessment and Management of Contaminated Sites" (CSMS 1991, 1993, 1996 and 1998 and enHealth 2002b);
- ANZECC/NH&MRC (1992); and
- The NEPM (Schedule B(4), Guideline on Health Risk Assessment Methodology, 1999).

ANZECC and NH&MRC currently provide only general guidance for the completion of these tasks and, as such, the more detailed protocols and guidelines developed by the US EPA (1989 and 2001) have been used to provide supplementary guidance.

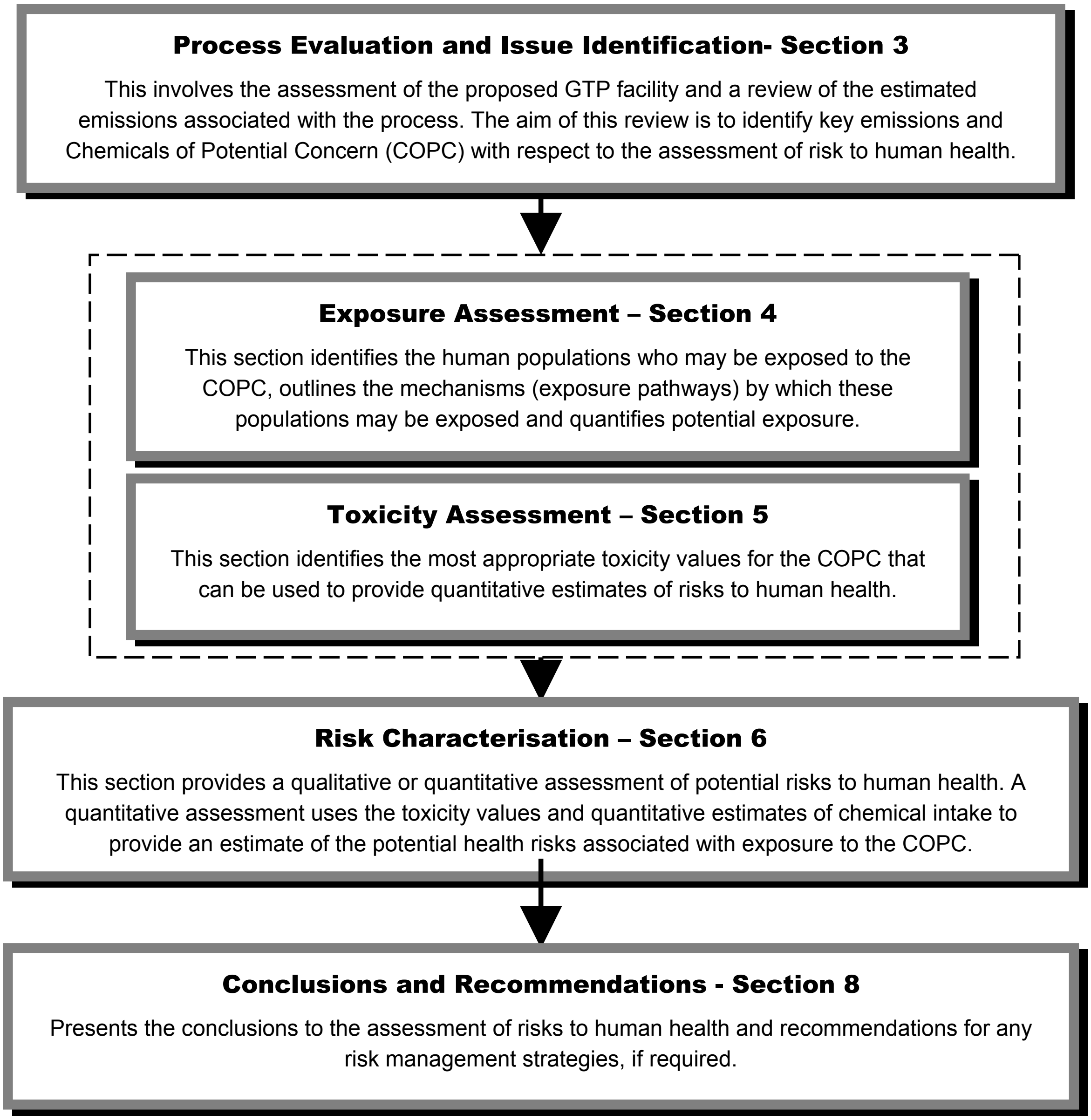
The conduct of a health risk assessment (HRA) can be divided into the following four prime tasks;

- ***Issue Identification*** – This involves an evaluation of the proposed process and potential for emissions to air, water and soil. The evaluation draws on the assessment of potential impacts to air, water and soils and includes an identification of key chemicals, or chemicals of potential concern (COPC), which may require detailed quantification in the HRA;
- ***Exposure assessment*** – This task draws on the evaluation undertaken as part of the "issue identification" stage and involves a detailed evaluation, identification and quantification (where required) of the potential exposure pathways and all significant population groups. In some cases (where no measured data is available), modelling is required to estimate concentrations of the key chemicals in air, water or soil (and other media as required) so that risk can be quantified;
- ***Hazard Assessment*** – This task provides a review of the chemicals which have been identified as COPC (Chemicals of Potential Concern) and identifies relevant hazards associated with exposure to these chemicals. This includes and evaluation of relevant toxicology for the chemicals relevant to air, water and/or soil and identifies (following guidance provided by enHealth) the toxicity values relevant to the quantification of risk for each chemical; and

- ***Risk characterisation*** – This task provides quantification and evaluation of potential risks to human health. The characterisation of risk draws on the "exposure assessment" and "hazard assessment". Comparison of potential risk estimates with commonly accepted measures of acceptable risk is undertaken with discussion on potential implications.

The following diagram illustrates these key activities and how each of these tasks fit into the overall assessment of risks.

Risk Assessment Approach



Process Evaluation and Issue Identification- Section 3

This involves the assessment of the proposed GTP facility and a review of the estimated emissions associated with the process. The aim of this review is to identify key emissions and Chemicals of Potential Concern (COPC) with respect to the assessment of risk to human health.

Exposure Assessment – Section 4

This section identifies the human populations who may be exposed to the COPC, outlines the mechanisms (exposure pathways) by which these populations may be exposed and quantifies potential exposure.

Toxicity Assessment – Section 5

This section identifies the most appropriate toxicity values for the COPC that can be used to provide quantitative estimates of risks to human health.

Risk Characterisation – Section 6

This section provides a qualitative or quantitative assessment of potential risks to human health. A quantitative assessment uses the toxicity values and quantitative estimates of chemical intake to provide an estimate of the potential health risks associated with exposure to the COPC.

Conclusions and Recommendations - Section 8

Presents the conclusions to the assessment of risks to human health and recommendations for any risk management strategies, if required.

Features of the Risk Assessment

The risk assessment has been carried out in accordance with international industry practice and accepted general principles and methodology. However, there are certain features of risk assessment methodology that are fundamental to drawing conclusions on the significance of the results.

These are summarised below:

- The risk assessment is a mathematical procedure which addresses potential exposure pathways based on the process selected, the predicted emissions and the current land use. The risk assessment is based on worst-case emissions expected from the facility and hence is expected to overestimate actual risks from the facility.
- Conclusions can only be drawn with respect to the groundwater treatment process investigated.
- The risk assessment does not include an assessment of risk resulting from exposure to chemicals from historical land uses that may no longer exist in the study area e.g. market gardening or industrial water use.
- The risk assessment does not present an evaluation of the health status of the existing community in the area. Rather, it is a logical process of calculating the amount of potential daily intake of chemicals associated with emission from the proposed GTP. This estimate is then compared to regulatory and published estimates of daily intakes that a person may be exposed to over a lifetime without unacceptable risks to their health.
- The risk assessment reflects the current state of knowledge regarding the potential health effects of COPC identified for the GTP. This knowledge base may change as more insight into biological processes is gained, further studies are undertaken and more detailed and critical review of information is conducted.
- The risk assessment does not provide an evaluation of the general health of workers or residents within the investigation area.

2.1 General

A detailed discussion on the site location and description is provided within the relevant sections of the EIS document. The section presented here provides a summary of the information available which is relevant to the assessment of potential risks to human health.

The BIP is located on the northern side of Botany Bay approximately 11 km south of the Sydney Central Business District. The BIP occupies approximately 77 hectares and is one of the largest chemical complexes of its type in the southern hemisphere.

Manufacturing began at the south end of the Botany site in 1942 under wartime conditions with the range of products increased in the post-war years. The larger manufacturing plants were introduced in the 1960s with developments in the 1970s and early 1980s resulting in the current layout of the site. Manufacturing processes have changed over time with many plants relocated and modernised. Various other manufacturing operations were undertaken in the past and have since been discontinued. Most notable of these are trichloroethene manufacture (1948 to 1977), solvents manufacture which included carbon tetrachloride and tetrachloroethene (1964 to 1991) and PVC/EDC manufacture (1950 to 1998).

The BIP site is an operating industrial site and as such the on-site environment is limited to grassed and small garden areas within the industrial site. The proposed location for the GTP facility is paved and contains no vegetation or areas that could be considered to be habitats for threatened species.

2.2 Topography and Drainage

The BIP is located on an area of former sand dunes and coastal swamps within the Botany Basin. The elevation of the site drops from around 20 m above sea level on the eastern side of the site to less than 5 m above sea level on the western side. An extensive low-lying area (less than 5 m above sea level) which was formerly swampy occurs to the west of the site. Natural drainage on the site is towards two drains, Springvale and Floodvale Drains, which drain the low-lying area southwards to Botany Bay. The drains enter the Bay via Penrhyn Estuary, which was formed by the reclamation of the Port Botany Container Terminal area.

Springvale and Floodvale Drains were excavated prior to the establishment of the ICI Botany Site in the early 1940s to assist in the drainage of Veterans Swamp and surrounding areas. The urban stormwater systems follow the natural fall of the land and discharge mainly into Springvale and Floodvale Drains or the drains to the east of the site.

On the BIP itself, uncontaminated stormwater discharges into Springvale Drain. Treated trade waste effluent is discharged into the Sydney Water trade waste system.

2.3 Geology

In general, the site is underlain by the Botany Sands, a sequence of predominantly unconsolidated to semi-consolidated permeable sands. These are interspersed with lenses and layers of peat, peaty sands, silts and clay that become more common in the lower part of the sequence. The sand sequence which is 30 to 60 m thick is underlain by sandstone rock (Hawkesbury Sandstone) which has a very low permeability compared to the sand deposits. Extensive peat layers occur at or close to the surface throughout Southlands and the adjoining low lying areas. Peat layers have also been noted in many shallow foundation boreholes drilled over wide areas of the site.

2.4 Hydrogeology

In general, the Botany Sands contain and transmit groundwater and are referred to as the Botany aquifer. Water table gradients indicate that groundwater flows predominantly in a westerly and southwesterly direction under the Southlands area towards and then into Botany Bay. The main recharge areas are in the higher sandy country to the north and east of the site. There is evidence of temporary groundwater flow direction changes in the late 1960s and from 1977 to 1982 due to a combination of heavy pumping to the north of the BIP and two periods of below average rainfall.

The Botany aquifer is one of the few high yielding, low salinity coastal aquifers in New South Wales. It was one of the early sources of water for Sydney and it remains an important source of industrial water in the Botany area. A number of groundwater bores have been identified within the residential areas located to the east and west of the site. Not many of the bores within the residential area have been registered, however anecdotal information indicates that residential bores are reasonably common in the area assessed along the western margin of Northern Plumes.

2.5 Surrounding Land Use

The current land uses, based on council zoning, in the immediate vicinity of the BIP are shown on Figure 1. The following land uses occur within a distance of 2 km of the BIP:

- Residential;
- School;
- Commercial (including offices and shops);
- Industrial (including food processing);
- Recreational (golf courses, playing fields, Penrhyn Estuary and Botany Bay); and
- Public open space.

In addition the vegetated foreshore of Botany Bay, including the northern side of Penrhyn Estuary, is known to be an important habitat for migratory and other birds.

The nearest residential areas are located to the east of the plant site along Denison Street. Commercial/industrial premises, a golf course and areas of public open space occupy the area between the western boundary and Penrhyn Estuary. The public open space at Penrhyn Estuary has been developed as a boat launching facility and recreational fishing in the vicinity of Penrhyn Estuary takes place. Other recreational activities include bait worm collecting, wading and possibly swimming, general exercising and bird watching. At Botany Golf Course children have been known to wade in the small pond between Botany and Foreshore Roads.

2.6 Previous Investigations

A large number of environmental investigations have been conducted within and around the BIP over the last 10 years. The results of selected relevant investigations and associated assessment of risk are summarised in the following sections.

2.6.1 Stage 1 Survey

The Stage 1 Environmental Survey of the BIP conducted by AGEE (1990) was a preliminary investigation which was designed to provide a “snapshot” of the extent, nature and degree of contamination of the soil, groundwater, surface water and biota.

Groundwater monitoring indicated the presence of a range of volatile chlorinated hydrocarbons (CHCs) within the groundwater beneath the Orica site.

2.6.2 Stage 2 Survey

The Stage 2 Survey conducted by Woodward-Clyde (1996 a-f) was a more extensive investigation aimed at providing a more detailed understanding of the nature, extent and the degree of contamination, the potential risks to human health, and an evaluation of remediation options.

The Stage 2 investigation was predominantly focussed within and downgradient of the southern portion of the Botany site where historically most of the chemical manufacturing was undertaken, particularly CHCs.

The investigations included:

- An assessment of sediments and surface waters within Springvale Drain;
- An assessment of groundwater quality (by monitoring and modelling) on site and in areas down-gradient of the site;

- An assessment of sediments and surface water in the lower reaches of Springvale Drain, Penrhyn Estuary and the intertidal zone at the Botany Bay beach front immediately to the west of Penrhyn Estuary;
- An assessment of potential concentrations of hexachlorobenzene (HCB), hexachlorobutadiene (HCBD) and hexachloroethane (HCE) in edible fish species in the area;
- An assessment of potential emissions to air from the identified volatile CHC groundwater plumes on and downgradient of the Orica site;
- An assessment of risks associated with the contamination identified. The assessment was undertaken for a range of site derived target chemicals including HCB, HCBD, HCE and a range of CHCs in soil, sediment, surface water, groundwater, air and edible biota. The risk assessment concluded that potential human exposures on-site and off-site (including occupational, recreational and residential areas) to the target chemicals are not associated with unacceptable risks to human health.

2.6.3 Stage 3 and Stage 4 Survey

A number of investigations of specific areas have been undertaken within and surrounding the site (including off-site residential areas) as part of the Stage 3 and Stage 4 Surveys. These investigations included the ongoing sampling of groundwater, surface waters (in Springvale Drain, Floodvale Drain and Penrhyn Estuary) and air (flux emissions). In addition sampling and analysis has been undertaken to investigate inferred on-site sources of contamination. Summaries of the investigations and monitoring have been reported as required by the Voluntary Remediation Agreement (URS, 2001a; URS 2002a and URS 2003a). All sampling work carried out within the Stage 3 and Stage 4 programs has been reviewed with respect to implications to the assessment of risk undertaken as part of the Stage 2 Survey. The conclusions of the health risk assessment have not changed following the collection of the Stage 3 and Stage 4 data.

2.6.4 Orica / Kemcor Polyolefines Business Merger

The Orica group of companies, the Exxon group of companies and the Mobil group of companies formed the Qenos joint venture to merge their respective polythene businesses. Woodward Clyde undertook an investigation of the polythene business at the Orica Botany Facility to assess existing contamination and identify contamination caused, contributed, coming into existence, entering onto or emanating from the Olefines, Alkathene, Alkatuff and Site Utilities site.

2.6.5 HCB Waste Management Plan Human Health Risk Assessment (Car Park Waste)

An assessment of risks to human health associated with the HCB soil encapsulation located at the northern section of the site including the potential remediation and major failure of the encapsulation was undertaken by URS (2002b) in accordance with the requirements of the HCB Waste Management Plan (ANZECC 1996).

The assessment concluded that risks to off-site residential, recreational, industrial and on-site industrial workers associated with emissions to air from the existing car park waste encapsulation do not represent an unacceptable risk to human health. In addition, potential risks associated with accidental damage or failure of the car park waste encapsulation have been evaluated and are not expected to represent an unacceptable risk to human health.

2.6.6 Human Health Risk Assessment, Western Margin of Northern Plume

Following the reporting of increased concentrations of 1,2-dichloroethane (known as EDC) in the City of Botany Bay production bore (BMC-1) in Herford Street, Banksmeadow, a human health risk assessment was conducted (URS, 2003b) to evaluate potential risks to the health of residents (including evaluation of groundwater extraction and use in backyard and for irrigation) and users of Botany Golf Course located along the western margin of the northern groundwater plumes derived from the Orica Botany Site. This evaluation revised the assessment of potential exposure presented in the Stage 2 Risk Assessment and incorporated current (to end of 2003) data.

On the basis of the evaluation undertaken indicated that the exposures to target chemicals identified in groundwater for both the residential and recreational (users of the golf course) do not pose an unacceptable health risk. The assessment is currently being finalised (by URS) along with a full revision to the Stage 2 Health Risk Assessment in consultation with the DEC and NSW Health.

2.7 Proposed GTP Process

The proposed GTP process is described in detail in Section 5 of the EIS. In summary the proposal involves a number of key processes. These are:

- Extraction;
- Transfer;
- Treatment; and
- Re-use and discharge;

2.7.1 Extraction

The extraction of contaminated groundwater is designed to provide hydraulic containment of the identified contaminant plumes and remove the contaminated groundwater for treatment.

Extensive hydrogeological modelling has been undertaken to identify the required number of extraction wells, their locations, depths, and extraction rates, to ensure containment of the plumes is achieved with minimal adverse impact. The proposed well locations are based along containment lines (refer to Figure 2), to manage the three containment areas specified in the Notice of Clean-Up Action and include:

- Primary Containment Area: Core, Line A and Line 1 – Southern boundary of Southlands Block 2;
- Secondary Containment Area: Line 2 and Line 3 – Median strip of Foreshore Road; and
- DNAPL Areas: Lines 5 & 6 – Western Boundary of the BIP.

Contamination has been identified in both the shallow and deep aquifers, and hence two layers of extraction wells have been proposed to ensure that the groundwater flow is fully intercepted and the contamination contained. The two layers for the proposed extraction wells are:

- Layer 1 – Shallow wells i.e. total drilled depth is typically up to 9 m; and
- Layer 2 – Intermediate and Deep wells i.e. total drilled depth is typically between 10 m and 40 m.

2.7.2 Transfer

The contaminated groundwater pumped out via the extraction wells will be transferred to the GTP via dedicated transfer pipelines (refer to Figure 2), at a total rate of 15 ML/day. There would be three main pipelines, installed for each of the containment lines:

- Primary Pipeline: to transfer groundwater from the primary containment area (Southlands Block 2) to the GTP, at a rate of 3.38 ML/day;
- Secondary Pipeline: to transfer groundwater from the secondary containment area (Foreshore Road) to the GTP, at a rate of 2.45 ML/day; and
- DNAPL Pipeline: to transfer groundwater from the DNAPL source areas on BIPB to the GTP, at a rate of 9.17 ML/day.

2.7.3 Treatment

The GTP is proposed to be located on Orica-owned land on the BIP, and be designed to treat the groundwater flow from all three areas, at a rate up to 15 ML/day.

The groundwater transferred from each of the three different containment areas will be combined into a single feed stream into the treatment plant. In addition, the recovered CHC stream (containing primarily EDC) produced in the steam stripping unit and stored at the Terminals storage facility will be fed separately into the thermal oxidiser for destruction of the contaminants.

The proposed treatment will comprise a number of process steps for effective treatment of the contaminants within the groundwater, as follows:

- groundwater feed handling;
- air stripping;
- off-gas treatment: thermal oxidation;
- off-gas treatment: gas scrubbing;
- stripped water treatment: iron removal;
- stripped water treatment: organics polishing;
- stripped water treatment: dissolved solids removal; and
- treated water reuse and discharge.

Full details of the GTP, and of each of the process steps and operation is presented in Section 5.5 of the EIS.

2.7.4 Re-use and Discharge

The final off-gas from the thermal oxidation and gas scrubbing steps will be discharged to atmosphere via a single stack.

The treated water from the process will be divided following the organic polishing step. Approximately 9.5 ML/day will be treated in the final treatment step, dissolved solids removal, to produce water to a quality standard based on Australian Drinking Water standards (NHMRC 1996), ANZECC Water Quality Guidelines for the protection of aquatic ecosystems (ANZECC 2000), and process water standards of users on BIP. The treatment step will produce around 7.5 ML/day treated water for reuse by other process operations on the BIP, displacing the water currently sourced from the municipal water supply provided by Sydney Water. Provision will be made in the design of the GTP to allow the final water treatment stage to be expanded to handle the full GTP flow if the demand for treated water increases.

The remaining treated water from the organic polishing step plus the residues from the dissolved solids removal step, will meet the ANZECC (2000) Water Quality Guidelines for the protection of aquatic ecosystems and will be discharged to Bunnerong Canal, which in turn drains to Brotherson Dock and Botany Bay (refer to Figure 2). This will be undertaken using a refurbished existing underground pipeline with a dedicated discharge point installed. This pipeline was originally installed in the 1960s and connects the storage tanks located at the southern end of the BIP with the bulk liquids storage facility at Sydney Ports, crossing Bunnerong Canal alongside Bumborah Road. This pipeline was previously used (up to around 2002) to transfer caustic solution between the storage facility and the tanks on BIP.

The operation of the treatment plant will also result in discharges of wastewater to sewer as trade waste and solid waste for disposal to landfill.

Hydrochloric acid will be produced at the gas scrubbing step, which will be reused within the feed handling step of the treatment process.

3.1 General

Risks associated with the proposed GTP facility can be assessed by evaluating the following:

- Emissions and exposures associated with **construction** of the proposed facility. The GTP facility is to be constructed on the BIP on the site of the former Silicates Plant Site. During construction there is the potential for exposure to contaminants that may be present in the soil and groundwater in the area as well as emissions to air generated during construction.
- Emissions during **normal operation**. During normal operation of the proposed GTP facility there are expected to be a number of emissions. These include emissions to air (fugitive emissions as well as emissions via the stack) and water (via re-use or discharge).
- Emissions during **emergency release/failure** of the proposed process.

The following presents a review of the construction and operation (normal and accidental release) phases with an emphasis on the evaluation of processes and issues which have the potential to result in emissions to air, water or soils and potential for human exposure. The focus of the health risk assessment is the potential for exposures to occur in off-site areas. While emissions and exposures on-site are identified and discussed, they are not the focus of detailed risk quantification.

The review of processes and issues for the proposed GTP involves the identification of chemicals associated with the emissions that warrant further quantification as part of the health risk assessment, identified as chemicals of potential concern.

Chemicals of potential concern (COPC) are those chemicals which are known or suspected to be present at concentrations high enough to warrant inclusion in the assessment of risks to human health, or to pose a nuisance (eg. odours). The prime objective of identifying COPC is to focus the risk assessment on assessing chemicals that have the potential to significantly contribute to risks to human health. The identification of COPC is based on the assessment of the nature and extent of these chemicals in the environment associated with each of the stages of the GTP proposal.

3.2 Construction

3.2.1 General

The proposed GTP site is the site of the former Silicates Plant (refer to Figures 1 and 2 for location), a manufacturing facility that ceased operations in the early 1990's and was demolished to ground level in the early 1990s. Subsequently the northern end of the site was levelled and surfaced with asphalt, and is currently used as a tanker parking area. The southern end has not been redeveloped, and comprises a mix of building rubble and foundations of the former facility.

Existing infrastructure at the proposed GTP location includes:

- internal roads (10th Avenue and 2nd Street) providing access to two sides of the site, with existing roadways (9th Crescent) providing access and parking within the site itself;

- an existing piperack across the southern end of the site, on which the transfer pipes would be installed to access the treatment plant; and

- an existing transformer at the northern end of the site, from which electrical power will be supplied to the GTP.

The proposed layout of the GTP consists of three principal process areas:

- Materials Storage Area: at the southern end of the site adjacent to the piperack, with the contaminated groundwater feed tank and hydrochloric acid tank located in a bunded area, the treated water tank, and the bunded isotainer parking area;

- Gas Operations Area: in the middle of the site, with the bank of air strippers down the centre, and the off-gas treatment (thermal oxidation, acid recovery and caustic scrubbing) and discharge stack on the eastern side; and

- Water Treatment Area: on the western side of the site, with the iron filtration, organics polishing dissolved solids removal processes, and wastewater storage tanks in a bunded area.

The key construction stages would involve conventional construction techniques, summarised as follows:

- **Demolition** - the site has no structures that require demolition and only a small amount of heavy concrete to be removed. This would either be crushed on site and used as fill, or be disposed of to landfill or to a concrete recycler;

- **Earthworks** – the site is currently used for parking tanker trailers and trucks, and is raised and sealed with a two layer bitumen coating;

- **Site Drainage** - Site drainage lines will be laid to carry stormwater via a first flush system into the established BIP site stormwater system;

- **Concrete Work** – concrete will be imported for use on the BIP through concrete mixers from the nearest batch plant, to provide materials for the concrete work required;

- **Structural Steelwork** – steelwork will be fabricated off-site and transported to site by truck;

- **Buildings** - a control room and amenities building as well as an electrical switch room will be constructed on site to service the plant; and

- **Equipment and Plant Installation** - tank construction/erection, equipment installation, electrical, and pipe work will run concurrently.

The GTP is expected to operate for up to 30 years in order to treat the required volume of contaminated groundwater identified. As the GTP has been designed specifically for this task, once groundwater treatment is no longer required, the plant will be shut-down and decommissioned.

3.2.2 Soil Concentrations in Proposed GTP Area

Investigation of soil at the proposed GTP site was undertaken in September 2004 with the data provided to URS by Orica. The soil investigation involved sampling and analysis from two depths (0.5m and 1m) at 9 locations across the proposed site. All samples were analysed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, sulphide and total petroleum hydrocarbons (TPH). Soils were also tested for contamination by a range of volatile and semi-volatile chlorinated hydrocarbons.

It was noted during the investigations that the soils in the surface layers appeared to be backfill and mainly sandy without any obvious odour. At some sampling locations waste materials were noted to be present including pieces of concrete and timber chips.

No data quality assessment has been provided for the soil data from this investigation.

Chemicals of Potential Concern

The analytical results from the soil samples collected from the proposed GTP facility site indicated that concentrations of the analytes tested were below relevant human health risk based guidelines[2]. These investigation levels have been established to identify contaminants that may warrant further evaluation or assessment and are based on risks to human health associated with exposure under different exposure settings, including commercial industrial land use as is relevant in this case. Hence, they are screening level guidelines.

The proposed GTP facility is located within the BIP and as such is within an operational industrial area where there are no significant ecological systems on the site. Hence guidelines relevant to the protection of soil ecosystems such as phytotoxicity-based guidelines are not relevant.

On the basis of the available data, no COPC have been identified for soils within the proposed GTP site.

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[2] Relevant risk based criteria are those guidelines or criteria which have been derived utilising a risk based approach for soils in an industrial area. The criteria relevant for the screening of soils on the site are:

- Health-based soil investigation levels for industrial settings (NEPM, 1999 level F criteria);
- USEPA Region IX Preliminary Remediation Goals for Soils in Industrial Settings (2004); and
- NSW EPA (1994) Service Station Guidelines.

3.2.3 Groundwater Concentrations Beneath Construction Area

The analytical results for the groundwater samples collected from monitoring wells located on or near the proposed GTP facility site have been screened against criteria relevant to the protection human health. Review of the available data along with the proposed location of the GTP facility indicates that BP07 is the closest groundwater monitoring well which is considered representative of potential concentrations in groundwater beneath the proposed facility.

Chemicals of Potential Concern

Groundwater data from BP07 have been compared against relevant health based screening level values. The screening levels used are drinking water guidelines (these include the Australian Drinking Water Guidelines (1996) and the USEPA Region IX Preliminary Remediation Goals for Tap Water (2004)). The guidelines provide health-based and aesthetic values for a range of microorganisms, physical quality, inorganic chemicals, organic chemicals, radiological quality and pesticides. The health-based guideline values are concentrations which, based on present knowledge, do not result in a significant risk to the health of a consumer of the water over a lifetime. This approach is conservative for the assessment of groundwater, as groundwater in the area is not used as a source of drinking water. However, the process provides a basis for selecting chemicals in groundwater that may require further assessment.

Following review of groundwater concentrations reported from BP07, only 1,2-dichloroethane (EDC) exceeds the screening level guidelines. It is noted that the only pathway for potential exposure to the groundwater on the site during construction or operation of the GTP is via the inhalation of volatile emissions from the groundwater which may subsequently migrate through the soils and into the indoor and outdoor air. Concentrations of EDC in groundwater beneath the proposed site are similar to those beneath other areas of the site where workers may be exposed to volatile emissions indoors and outdoors as well as other emissions in the workplace. Therefore, the potential exposure by workers to EDC identified in groundwater beneath the proposed site is considered to be similar to the exposure in other areas of the BIP. Workplace exposure to chemicals used and handled by Orica (including EDC) is managed by a site occupational health and safety program. It is expected that this program would extend to workers within the proposed GTP facility. On this basis, risk associated with on-site workers exposure to chemicals in groundwater beneath the GTP does not require further assessment.

Due to the presence of EDC within groundwater beneath the proposed GTP there exists the potential for vapours to be present within soil and any site excavation work undertaken must be assessed and managed under an appropriate occupational health and safety plan.

3.2.4 Emissions to Air During Construction

A detailed evaluation of emissions to air from the proposed facility is presented in the Air Quality Impact Assessment (Chapter 22 of the EIS). The Air Quality Impact Assessment included an evaluation of potential emissions to air during the construction of the GTP facility. The following presents a general summary of the evaluation presented:

- Emissions during construction were identified to be products of fuel combustion from vehicles and equipment used in construction and transportation activities. There is also the potential for minor dust emissions to occur during construction works.
- The following is concluded with respect to emissions during construction:
  - "There is a significant buffer distance between the proposed GTP site and nearby sensitive receptors and residential areas, hence dust emissions from the construction phase would not be expected to result in off-site nuisance impacts. The construction period is relatively short (at less than one year), access roads are sealed and the project site is compact. A soil quality assessment has not shown any areas of significant soil contamination in the area. Dust mitigation measures would be specified in the [Construction Environmental Management Plan] for the project to minimise the potential for any emissions from excavation and soil handling activities."

Chemicals of Potential Concern

On the basis of the Air Quality Impact Assessment of potential emissions to air during the construction of the proposed GTP facility, no COPC have been identified.

3.3 Normal Operation of Facility

3.3.1 General

The GTP is intended to effectively achieve clean-up of the contaminated groundwater, based on a treatment process designed to minimise air emissions and generation of waste, according to 'best practice' design standards.

The GTP has been designed for continuous operation, treating 15 ML/day groundwater for 24 hours per day, 7 days a week, 365 days per year for a period of up to 30 years. The technical design specification includes a 95% availability with maximum maintenance shut-down period of a week to ensure that control of the groundwater movement and associated contaminant plumes is maintained. The groundwater modelling work has established a safety margin for shut-down of the groundwater pumping of up to two weeks without affecting the containment of the contaminant plumes.

The whole GTP project – groundwater extraction, transfer, treatment, discharge – would be operated as an integrated process, with an automatic central control system designed to operate and control the overall project to ensure the objectives are achieved, based on specific design parameters.

The control system would be located within a dedicated control room, and designed for automatic operation with minimal operator input. Operators based permanently at the GTP site would carry out regular inspections, and would be available to respond in the event of abnormal operation or plant upset.

During normal operation of the proposed GTP facility there are a number of areas which require further evaluation with respect to the potential for discharge or emissions, particularly those associated with the potential for off-site impacts. These include:

- Extraction and handling of groundwater from the containment lines;
- Use, storage and handling of process chemicals within the GTP;
- Stormwater impacts;
- Wastewater and other process wastes;
- Reuse and discharge of treated water from the GTP; and
- Emissions to air.

The following presents a review and evaluation of these areas with the aim of identifying COPC.

3.3.2 Contaminated Groundwater

The contaminated groundwater will be continuously extracted from the three containment lines, and transferred to the treatment plant on BIP (refer to Figure 2). The extraction and transfer of contaminated groundwater from the containment lines to the GTP facility will be undertaken within a fully 'sealed' system. Hence there is no point where exposure by workers or the general public to contaminated groundwater would occur under normal operation.

Once transferred to the GTP the three streams would be combined in the groundwater feed tank, to form a homogenous groundwater mixture, prior to treatment. The feed tank will be 9m in height with a diameter of 7.5m, with total design capacity of approximately 400 m^3. It will be constructed of duplex stainless steel to minimise corrosion and be installed within a sealed concrete bund of minimum 110% capacity of the tank, designed to meet the requirements of AS1940.

The tank will be installed with a 'nitrogen gas blanket' system to reduce the potential for flammable vapour mixtures to form within the tank. The nitrogen system will be maintained from the BIP site nitrogen supply. The gas will be vented to the thermal oxidiser to ensure destruction of organic vapours. The system is designed to contain all vapour in the thermal oxidiser if the GTP is offline.

The whole extraction and transfer system is designed to be a ‘sealed’ system, operating under a central PLC for the overall GTP, to avoid handling of the contaminated groundwater by site operators.

The recovered chlorinated hydrocarbon stream produced in the steam stripper unit and stored at the Terminals bulk storage facility (Port Botany) will be transferred by isotainer to the GTP for treatment. The isotainer, of capacity 20 m^3, will be filled from the storage tank by the existing loading facility and transferred to the GTP by truck. The truck will be parked in a specific parking bay, roofed and bunded to provide full containment of spills or leaks. The isotainer would be connected to the GTP and transferred automatically under the control of the PLC system.

Chemicals of Potential Concern

The proposed process for handling contaminated groundwater during normal operations of the facility is a ‘sealed’ system with no point where exposure to contaminated groundwater may occur either on or off the site. Small fugitive emissions of volatile organic compounds associated with leak from seals and flanges on the GTP as well as the pipework between the GTP and the groundwater wells may occur.

Fugitive emissions of total volatile organic chemicals (VOCs) from the BIP are provided for within the National Pollution Inventory (NPI) for the BIP. These emissions are estimated and reported on the NPI and have been used in the Air Quality Impact Assessment in the evaluation of background exposures to total VOCs. Fugitive emissions from the processes associated with the GTP extraction, pipeline and facility have not be quantified, however mitigation measures proposed by Orica (which include minimised number of flanged joints, preventative maintenance inspections especially with respect to rotating equipment seals) are expected to minimise emissions of VOCs to air during the operation of the GTP. It is expected that the fugitive emissions to air from the GTP would be small in comparison with other fugitive emissions from the BIP.

On this basis, the potential for fugitive emissions from the proposed GTP is expected to be low and does not warrant further assessment (i.e. no COPC have been identified). However, an evaluation of background exposure to VOCs (presented in the Air Quality Impact Assessment) that considers fugitive emissions from both the BIP and the GTP has been undertaken where possible.

3.3.3 Process Chemicals

The type and quantities of chemicals to be used and stored at the proposed GTP facility include:

- Caustic Soda (NaOH) – supplied from BIP and used as a scrubber liquor to neutralise hydrogen chloride gas evolved in the thermal oxidiser and to raise pH to precipitate iron in the water treatment stages supply;
- Hydrochloric Acid (HCl) – either recovered in the acid absorber or supplied from BIP and used to acidify groundwater feed to maintain iron in solution;

- Activated Carbon used as an adsorption medium to remove organics and other contaminants in the water treatment system;
- Flocculant used to flocculate precipitated iron in the water treatment system;
- Sodium Metabisulphite used as a reducing agent (chlorine scavenger) in the Caustic Scrubber; and
- Sodium Hypochlorite used for ammonia removal.

These process chemicals would be stored on site in designated chemical storage facilities, which would be constructed and bunded in compliance with:

- Australian Standard AS 1940 (1993): The Storage and Handling of Flammable and Combustible Liquids;
- Australian Standard AS 4452 (1997): The Storage and Handling of Toxic Substances;
- Australian Standard AS 3780 (1994): The Storage and Handling of Corrosive Substances; and
- Dangerous Goods Act 1975 and associated Regulations.

Chemicals of Potential Concern

Workers at the GTP facility may be exposed to process chemicals, however storage and use of these chemicals will be undertaken in accordance with relevant health and safety plans and safe work procedures. Based on the proposed process for storage of process chemicals on the site, no COPC have been identified (particularly for the evaluation of potential off-site risks) during normal operations.

3.3.4 Stormwater

The GTP facility will be connected to the BIP stormwater drainage system, for control and discharge of stormwater, via a dedicated first flush tank.

The majority of the site of the GTP will be hard-surfaced (concrete slab and asphalt roads / parking) with stormwater drains discharging to the first-flush tank. The first-flush tank would be sized to contain the first 2-3 mm of rainfall across the site, to retain potential contamination from material spills or leaks. Once full, subsequent rainwater would discharge directly to the BIP stormwater drainage system, which discharges in turn to the BIP effluent treatment system. In rain events, process wastewaters continue to be treated and discharged to sewer, whilst stormwater discharges to Springvale Drain.

The total quantity of stormwater discharged to Springvale Drain from the BIP would not change significantly as the proposed configuration of the plant does not constitute a major alteration to the total BIP site.

After cessation of the event , the water contained in the first-flush system would be discharged to the BIP effluent treatment system for treatment and discharge to sewer (or groundwater feed tank).

The bunded areas across the GTP site should be fitted with sumps and lockable drain valves that would be locked shut during operation. Stormwater collected in the bund would be analysed, prior to discharge. If contaminated, the water will be treated in the GTP or discharged to the effluent plant. If clean, the water will be discharged to the stormwater system.

The isotainer bund would also be roofed to minimise ingress of rainwater. Water collecting in the bund will be managed as described above.

The construction and operation of the groundwater wells and pipelines will not have a significant effect on stormwater drainage, and it is anticipated that stormwater drainage system would be maintained during the life of the proposed GTP.

Chemicals of Potential Concern

Based on the information available about impacts to stormwater from the proposed GTP, no COPC have been identified for normal operations.

3.3.5 Wastewater Treatment and Other Process Wastes

The GTP project will use the BIP's existing effluent treatment system and discharge to sewer through a dedicated connection line.

The effluent treatment plant consists of solid settlement in a sedimentation tank, followed by pH control prior to discharge to sewer. The discharge to sewer is licensed under a trade waste agreement with Sydney Water Corporation, and a variation to this agreement will be negotiated with Sydney Water to ensure that the proposed discharges are acceptable and would not adversely affect the sewer system.

The effluent treatment system is operated by Qenos on behalf of the operations on BIP, and Qenos would be responsible for the quality and compliance of the final discharge to sewer.

Limited toilet and washing facilities will be installed and domestic wastewater connections to sewer will be required.

The type, quantities, and proposed disposal routes for the process wastes generated in the proposed GTP facility are listed in Table 3.1.

These process wastes would be disposed of directly, with no intermediate storage on site. Full details of the waste classification and disposal routes are presented in the EIS.

Table 3.1 Process Wastes Generated in the GTP

Process Waste	Source	Annual Generation	Disposal Route
Neutralised caustic	Caustic scrubber in gas treatment system – liquid waste following reaction with hydrogen chloride gas evolved in the thermal oxidiser	Acid recovery 11,300 m^3	Discharge to sewer under trade waste agreement
		No acid recovery 161,000 m^3	
Iron precipitate	Iron filter – press filter to remove iron from concentrate solution	183 tonne	Disposed to landfill in accordance with EPA immobilisation guidelines
Spent Activated Carbon	Activated carbon– solid waste of activated carbon and adsorbed contaminants	90 tonnes	Disposed to landfill in accordance with EPA immobilisation guidelines

Chemicals of Potential Concern

Based on the expected discharge of treated wastewater to the sewer and other process wastes from the proposed GTP, no COPC have been identified for normal operations.

3.3.6 Emissions to Water

The treated water from the GTP process will be divided following the organic polishing step. Approximately 9.5 ML/day will be treated in the final treatment step (dissolved solids removal) to produce water to a quality standard based on Australian Drinking Water Guidelines (NHMRC 1996), ANZECC Water Quality Guidelines for the protection of aquatic ecosystems (2000), and process water standards of users on BIP. The treatment step, using reverse osmosis (RO), would produce around 7.5 ML/day treated water for reuse by other process operations on the BIP, displacing the water currently sourced from the municipal water supply provided by Sydney Water. Provision would be made in the design of the GTP to allow the final water treatment stage to be expanded to handle the full GTP flow if the demand for treated water increases.

The remaining treated water from the organic polishing step plus the residues from the dissolved solids removal step would be of a quality standard to meet the ANZECC (2000) Water Quality Guidelines for the protection of aquatic ecosystems, and be discharged to Bunnerong Canal, which in turn drains to Brotherson Dock and Botany Bay (refer to Figure 2).

In the event that the process plants on BIP cannot use the treated water, for example during process upset or shutdown, the unused water would be diverted to the discharge pipeline (as described below). The total capacity of the discharge pipeline is 12 ML/day, so in the unlikely event that all process operators are shut down, the full discharge capacity of the pipeline would be utilised. If this scenario were to occur the groundwater extraction would have to be reduced accordingly.

Any such scenario would be short term, and hence would not affect the overall effectiveness of hydraulic containment of the contaminated groundwater.

Treated Water Discharge

It is expected that 5 ML/day of treated water discharged from the activated carbon filters would be combined with the 2.5 ML/day salty wastewater from the RO unit, and discharged to the refurbished caustic pipeline for discharge to Bunnerong Canal and hence to Brotherson Dock and Botany Bay. A flow diffuser would be installed in Bunnerong Canal to reduce the energy of the discharge and minimise potential for disturbance of the sediment in the canal.

Chemicals of Potential Concern

Treated water can be screened against human health risk based guidelines to determine whether chemicals in the reuse or discharge water require further assessment. Discharge water can be screened against relevant drinking water guidelines (these include the Australian Drinking Water Guidelines (NHMRC 1996), World Health Organisation drinking Water Guidelines (2004) and the USEPA Region IX Preliminary Remediation Goals for Tap Water (October 2004)). The health-based guideline values are concentrations which, based on present knowledge, would not result in significant risk to the health of a consumer of the water over a lifetime.

This approach is conservative for the assessment of water proposed to be reused on the site or discharged into a canal and Botany Bay where dilution will occur after discharge. In addition none of these areas is accessed by the general public. On this basis it is considered reasonable to include an exposure modifying factor to the drinking water guidelines. This factor would reflect lower contact rates with the discharge water compared with drinking water. The drinking water guidelines assume the consumption of 2L of water per day every day. The derivation of recreational water quality guidelines by ANZECC (2000) considered it reasonable to assume that recreational contact may involve ingestion of 100 mL per day. Using these water ingestion rates the drinking water guidelines used for the purpose of screening discharge water can be multiplied by a modifying factor of 20 (2 L per day/0.1 L per day).

These screening levels are considered conservative as it is noted that the reuse of water on the site will be within closed systems and discharge to the canal and Botany Bay involves dilution and discharge to an area that would not be used for recreational activities such as swimming. Comparison of the proposed treated cater and RO effluent concentrations with the adopted screening levels is presented in Appendix A of this report.

Adopting this approach to reviewing the treated water proposed for reuse or discharge, no COPC have been identified.

3.3.7 Emissions to Air

A detailed evaluation of emissions to air from the proposed GTP facility is presented in the Air Quality Impact Assessment (Chapter 22 of the EIS). The following presents a general summary of the evaluation presented for emissions during normal operations:

- During the operation of the GTP, the processes associated with the potential for emissions to air are air stripping and thermal oxidation.
  - The air stripping stage is designed to remove the volatile organic compounds (VOCs) from the groundwater, and transfer them into the air stream (the 'off-gas' stream), by blowing air through a falling column of groundwater. The efficiency of removal of VOCs from water using air strippers is greater than 99%. The off-gas from the strippers, containing the volatile organic compounds extracted from the groundwater, is transferred to the off-gas treatment (thermal oxidation) section of the process.
  - Thermal oxidation is the process of oxidising materials by raising the temperature of the material in the presence of oxygen, and maintaining it at a high temperature for sufficient time to complete a reaction to carbon dioxide and water (and HCl where chlorinated hydrocarbons are present in the gas stream). Well designed and operated thermal oxidiser systems achieve destruction efficiencies (DRE) of 99.99% or greater.
- The exhaust air from the process will be vented to atmosphere via a single stack discharging 20 m above ground level, at a rate of around 78,000 m^3/hour and a temperature of 50°C.
- Atmospheric dispersion modelling was undertaken using the CALPUFF dispersion model and included an evaluation of the following:
  - proposed emissions from the GTP (oxides of nitrogen, sulphur dioxide, suspended particulates, carbon monoxide, chlorine and hydrogen chloride, hydrogen sulphide, VOCs and dioxins and furans); and
  - emissions from the GTP along with existing emissions sources located within the BIP. Regional background levels of criteria pollutants such as NO_2, PM_{10} and SO_2 were also included based on data collected by the NSW DEC at their Randwick monitoring site, located approximately 3 km northeast of the BIP.

  Maximum emission rates for these pollutants have been determined by Orica (design specifications for the plant) for these compounds based on guidance on international best practice design requirements.
- Predicted ground level concentrations were compared against requirements outlined in the following:
  - Protection of the Environment Operations Act 1997 (POEO Act) which licenses and regulates (amongst other issues) air emissions from Orica's activities within the BIP;

- Ambient air quality standards as presented in the NSW EPA's "Action for Air - the NSW Government's 25-year Air Quality Management Plan" and National Environment Protection Measure (NEPM) for Ambient Air Quality (including the 2003 variation);
- Air impact assessment criteria as outlined in NSW EPA's 2001 document entitled "Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW". It is noted that this guidance has incorporated a number of the ambient air quality standards from the Environment Protection Measure (NEPM) for Ambient Air Quality into their proposed modelling and impact assessment criteria; and
- Odour impacts as outlined in NSW EPA's 2001 document entitled "Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW".

- The following conclusions with respect to the assessment of air impacts from the proposed GTP have been made:
  - "Based on the results of the modelling study ……, the expected maximum emissions from the proposed GTP would not be expected to have a significant impact on air quality in the surrounding area. It is also noted that this assessment of potential air quality impacts has been undertaken based on the minimum performance specifications supplied by Orica to the plant designers, and they therefore represent potential worst case impacts."

Chemicals of Potential Concern

The air impacts assessment has provided a detailed evaluation of potential emissions to air from the proposed GTP facility. A comparison of the predicted impacts from the GTP as well as cumulative impacts, with regulatory requirements has been undertaken in the Air Quality Impact Assessment. This assessment indicates that the proposed GTP meets these regulatory requirements.

In addition to the air quality assessment, emissions to air need to be further evaluated with respect to health risk based levels. The following key emissions have been evaluated further.

Criteria Air Pollutants

The evaluation of "criteria" pollutants (carbon monoxide, nitrogen dioxide, photochemical oxidants (ozone), sulphur dioxide, lead and particles as PM_{10}) using the ambient air criteria as set out in the NEPM is considered to be an appropriate basis for the assessment of the potential for adverse health effects. The NEPM (Ambient Air) guidelines have been established to allow *"for the adequate protection of human health and well-being*" (NEPM 2003). It is noted that when reviewing the criteria set out in the NEPM for Ambient Air Quality, the criteria are designed for use in assessing regional air quality and are not intended for use as site boundary or atmospheric dispersion modelling criteria. They are, however, a useful guide in the evaluation of expected air quality for criteria pollutants (proposed GTP as well as background or other sources) with respect to the protection of human health and well-being. As all modelled emissions from the GTP facility for criteria pollutants are below the ambient air criteria, further assessment is not considered to be required.

Other Chemicals

The evaluation of other emissions from the GTP on the basis of NSW EPA (2001) Impact Assessment Criteria undertaken in the Air Quality Impact Assessment involved the comparison of predicted ground level concentrations with the relevant assessment criteria. While some criteria are established on the basis of toxicity to humans, others have been established on the basis of odour or other nuisance effects. In addition, many of the criteria are based on a 3-minute average ground level concentration used to evaluate impacts of proposed facilities. These criteria are not comprehensive and are not considered appropriate for the assessment of long-term risk to human health (such as exposures over 30 or 70 years) or to assess exposure via pathways other than inhalation that might be applicable to the deposition and accumulation of particulates. As such, further screening of predicted concentrations from the Air Quality Impact Assessment has been undertaken to identify COPC.

For air emissions there is the potential for migration via air dispersion beyond the site boundary and for exposure by nearby populations to occur via inhalation. In addition, some of the chemicals emitted are regarded as persistent in the environment with the potential to bioaccumulate and as such, exposure may occur via pathways other than inhalation. The persistent and bioaccumulative chemicals may accumulate in soils and in home-grown fruit and vegetable produce and may find their way into breast milk resulting in potential exposure by infants (refer to Section 4 for detailed evaluation of exposure). The identification of COPC for emissions to air has followed two approaches, namely:

1. Identification of persistent and bioaccumulative chemicals that may be emitted from the thermal oxidiser.
2. Screening of predicted 1-hr average and annual average concentrations against relevant health risk based screening criteria for chemicals in air. These are screening levels considered relevant for the assessment of long-term inhalation exposures.

This approach ensures identification of COPC relevant to the full range of potential exposure pathways for emissions from the GTP.

Persistent and Bioaccumulative Chemicals

On the basis of the information on the thermal oxidiser feed, concentrations reported in groundwater to be treated and the identification of priority persistent and bioaccumulative chemicals provided by the World Health Organisation and United Nations Economic Commission for Europe (WHO and UNECE), **mercury, dioxins and hexachlorobutadiene (HCBD)** have been identified as COPC on the basis of being persistent and having the potential to bioaccumulate. Hexachlorobenzene (HCB), while also identified as persistent and bioaccumulative, has not been detected in groundwater to be treated and hence has not been identified as a COPC.

Air Screening Levels

The selection of COPC has utilised US EPA Region 9 PRGs (October 2004) as screening level concentrations for chemicals in air. These values have been selected for the purpose of screening as there are no comprehensive human health risk based long-term air guidelines available in Australia and use of the Region IX PRGs has been agreed with the DEC and NSW Health. It should also be noted that the Region IX PRGs were also used (in consultation with the DEC) for the purpose of screening air emissions from the HCB Carpark (URS, 2002b). Region IX PRGs provide concentrations in air that can be inhaled by residential and commercial / industrial populations every day for a long period (i.e. effectively a lifetime). The long-term PRGs can be directly compared with the predicted annual average ground level concentrations. The annual average ground level concentrations from the air dispersion model are compared against the PRGs.

Assessment of potential exposure to chemicals in air has also involved an evaluation of hourly average concentrations predicted from the air dispersion modelling (which calculates ground level concentrations at each location for each hour of the day based on site-specific meteorological conditions). This has been undertaken to provide an additional level of screening to identify chemicals where there is the potential for increased exposure during some periods of time throughout the year (which may occur on one hour or a number of hours or days). The hourly average ground level concentrations of chemicals in the air can also be compared to the PRGs after application of a correction factor of 10 to provide a value appropriate for comparison with 1-hour average concentrations. The 10 times factor is commonly used in the US (derived from the Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs)) for converting long-term exposures to short-term exposures. The following has been provided by Jong-Song Lee (TCEQ, pers comm., October 2004) with respect to the basis for the factor of 10:

> "*The basis for the factor of 10 was based on the results from air dispersion modelling and ambient air monitoring studies. These results have shown that the maximum one-hour average concentration occurring at a given receptor is at least 10 times higher than the annual average. Because the majority of the current short-term ESLs are set at 1/100 the time-weighted average occupational exposure limits (TWA-OELs), these short-term ESLs are conservative. The long-term ESLs which are set at 10 times lower than the short-term ESLs are, therefore, conservative too (1/1000 the TWA-OELs). Using the factor of 10 in setting long-term (annual average) ESLs from the corresponding short-term ESLs, allows us to be able to determine the potential adverse short- and long-term effects by just evaluating the short-term air concentrations. Therefore, adverse effects are not expected to occur when the predicted or measured short-term air concentration of a chemical is below the short-term ESL.*"

Observation of the air dispersion modelling presented in the Air Quality Impact Assessment indicates that 1-hour average concentrates are more than 10 times greater than the annual average concentration in the study area. Hence use of the PRGs times 10 to screen 1 hour average concentrations provides a conservative approach to the evaluation of potential short-term health effects.

The PRGs are calculated utilising a hazard goal for the chemicals assessed. The hazard goals utilised in the Region IX PRGs are:

- Hazard index of 1 for a chemical assessed utilising threshold effects; and
- Increased lifetime cancer risk of 1 x 10^{-6} for chemicals assessed as carcinogenic.

URS understand through discussions with the DEC that their position on the use of hazard goals differs from the USEPA. According to the DEC, the hazard goal for a chemical should vary according to whether the chemical is ubiquitous in air and therefore represents common urban air contaminants. DEC require a lower hazard goal for these chemicals to account for background exposure. Appendix B of this report presents an assessment of the chemicals assessed in the Air Quality Impact Assessment and the selection of appropriate hazard goals. In general, the target chemicals can be placed into two groups depending on the nature of the chemical in the urban air environment. These groupings and their respective hazard goals are presented in Table 3.2.

Table 3.2 - Grouping Target Air Chemicals and Selected Hazard Goals

Common Urban Air Chemicals *Goals 0.1 for threshold effects* *1x10^{-7} for non-threshold effects*	**Local Chemicals** *Goals 1 for threshold effects* *1x10^{-6} for non-threshold effects*
Benzene	Carbon disulphide
Carbon Tetrachloride	2-Chlorophenol
Chloroethane	1,2-Dichlorobenzene
Chlorobenzene	1,1-Dichloroethene
Chloroform	cis-1,2-Dichloroethene
Chloromethane	trans-1,2-Dichloroethene
1,3-Dichlorobenzene	2,4-Dichlorophenol
1,4-Dichlorobenzene	2,6-Dichlorophenol
1,1-Dichloroethane	Hexachloroethane (HCE)
1,2-Dichloroethane (EDC)	2-Methylphenol
Dichloromethane (methylene chloride)	3&4-Methylphenol
Hexachlorobutadiene (HCBD)	Phenol
Tetrachloroethene (PCE)	1,2,4,5-Tetrachlorobenzene
Toluene	1,1,2,2-Tetrachloroethane
1,2,4-Trichlorobenzene	1,1,1,2-Tetrachloroethane
1,1,2-Trichloroethane	1,3,5-Trichlorobenzene
Trichloroethene (TCE)	2,4,5-Trichlorophenol
Vinyl Chloride	2,4,6-Trichlorophenol
Mercury	
Dioxins	

Note: for urban air chemicals, the hazard goals are 10 times lower than those typically used by the USEPA in the Region IX PRGs.

The ground level concentrations (GLC) used for the purpose of screening have been estimated on the following basis:

- The air dispersion model set up for assessment of the GTP only (as detailed in the Air Quality Impact Assessment) provided a calculation of GLC at a number of off-site receptor locations as well as across a grid that encompassed the site and surrounding residential, industrial/commercial and recreational areas.

- The maximum GLC calculated for total VOCs and dioxins from all these areas (located on the site) has been used in this assessment. The maximum GLC is located on the BIP.

- On the basis of information provided by Orica on the composition of VOCs in the feed gas, the maximum GLC of individual VOCs has been calculated.

- The emission rate of dioxins has been provided by Orica.

- The potential emission of mercury has been estimated based on information from Orica, which indicated that at most 0.16 g/day of mercury will be present in the feed water. While it is expected that a negligible or only a small fraction of this input (possibly less than 1%) would be present in the emissions from the thermal oxidiser, a conservative assumption has been made for the purpose of screening that 100% of the mercury in the feed will be discharged from the thermal oxidiser. On this basis the emission rate for mercury has been assumed to be 6.7×10^{-6} kg/hr (after converting 0.16 g/day to kg/hr).

Using this approach, the maximum estimated GLC for individual VOCs, dioxins and mercury have been compared with the PRGs adjusted in accordance with the hazard goals identified for the individual chemical (Table 3.2). Chemicals have been identified as COPC if the predicted maximum 1-hour average or annual average concentration exceeds the screening level. The results of this screening process is presented in Table 3.3 below with COPC highlighted.

Table 3.3 – Maximum Predicted GLC of Target Air Chemicals and Comparison with Screening Levels

Chemicals in Feed	Percent of total VOCs	Maximum GLC (µg/m³)			Screening Level Concentration (µg/m³)	
		Max 1-hr average	Annual average		1-hr average	Annual average
VOCs						
Total VOC		**5.8**	**0.15**			
Carbon Disulphide	0.17%	0.0099	0.00026		7300	730
Chloromethane	0.0005%	0.000026	0.00000068	u	95	9.5
Dichloromethane	0.037%	0.0021	0.000056	u	4.1	0.41
Chloroform	2.2%	0.13	0.0034	u	0.083	0.0083
Carbon Tetrachloride	7.07%	0.41	0.011	u	0.13	0.013
Chlorethane	0.0005%	0.000026	0.00000068	u	2.3	0.23
1,1-Dichloroethane	0.24%	0.014	0.00036	u	1.2	0.12
1,2-Dichloroethane (EDC)	75.81%	4.4	0.11	u	0.074	0.0074
1,1,2-Trichloroethane	0.37%	0.021	0.00055	u	0.12	0.012
1,1,1,2-Tetrachloroethane	0.0005%	0.000026	0.00000068		2.6	0.26

Chemicals in Feed	Percent of total VOCs	Maximum GLC (µg/m^3)		Screening Level Concentration (µg/m^3)		
		Max 1-hr average	Annual average		1-hr average	Annual average
1,1,2,2-Tetrachloroethane	0.65%	0.038	0.00098		0.33	0.033
Hexachloroethane (HCE)	0.019%	0.0011	0.000029		4.8	0.48
Vinyl chloride	2.68%	0.16	0.0040	u	0.11	0.011
1,1-Dichloroethene	0.21%	0.012	0.00032		2100	210
cis-1,2-Dichloroethene	0.58%	0.033	0.00087		370	37
trans-1,2-Dichlooethene	0.11%	0.0062	0.00016		730	73
Trichloroethene (TCE)	3.23%	0.19	0.0048	u	0.017	0.0017
Tetrachloroethene (PCE)	6.09%	0.35	0.0091	u	0.32	0.032
Hexachlorobutadiene (HCBD)	0.012%	0.00068	0.000018	b	0.086	0.0086
Benzene	0.37%	0.021	0.00056	u	0.25	0.025
Chlorobenzene	0.001%	0.000040	0.0000010	u	62	6.2
1,2-Dichlorobenzene	0.019%	0.0011	0.000029		2100	210
1,3-Dichlorobenzene	0.0004%	0.000026	0.00000067	u	3.3	11
1,4-Dichlorobenzene	0.014%	0.00081	0.000021	u	0.31	0.031
1,2,4-Trichlorobenzene	0.001%	0.000038	0.00000098	u	3.7	0.37
1,3,5-Trichlorobenzene	0.00001%	0.00000042	0.000000011		37	3.7
1,2,4,5-Tetrachlorobenzene	0.00004%	0.0000025	0.000000064		11	1.1
Toluene	0.002%	0.000091	0.0000024	u	400	40
Phenol	0.001%	0.000060	0.0000016		11000	1100
2-Chlorophenol	0.005%	0.00029	0.0000074		180	18
2,4-Dichlorophenol	0.045%	0.0026	0.000067		110	11
2,6-Dichlorophenol	0.014%	0.00079	0.000020		110	11
2,4,5-Trichlorophenol	0.001%	0.000031	0.00000081		3700	370
2,4,6-Trichlorophenol	0.009%	0.00050	0.000013		0.96	0.096
2-Methylphenol	0.0002%	0.000014	0.00000035		1800	180
3&4-Methylphenol	0.001%	0.000083	0.0000021		180	18
Other Emissions						
Dioxins (TEF)		5.8E-08	1.5E-09	u	4.5E-08	4.50E-09
Mercury		0.00015	0.0000040	u	0.31	0.031

u – urban air contaminant where a lower screening level has been adopted

On the basis of the evaluation undertaken, COPC that have been identified for further assessment with respect to inhalation exposures are **chloroform, carbon tetrachloride, EDC, vinyl chloride, TCE, PCE and dioxins**.

3.4 Accidental Releases

A Preliminary Hazard Analysis (PHA) presented in Chapter 23 of the EIS has been undertaken by Pinnacle Risk Management Pty Limited to identify and evaluate a range of failure scenarios associated with the proposed GTP. The PHA has been undertaken as follows:

- The design and location of the GTP was reviewed to identify credible, potential hazardous events;

- The frequency and consequence of each potential hazardous event were estimated;
- The risk results have been quantified by combining the frequency and consequence for each event and summing to give total (cumulative) risk as appropriate; and
- The risks associated with the facility are compared to relevant criteria. The risk associated with the proposed GTP at the BIP has been assessed and compared against the DIPNR (Department of Infrastructure, Planning and Natural Resources) risk criteria.

The PHA addressed risks associated with fatality, injury, irritation, property damage, cumulative risks, transport, combustion products and other accidental releases to soil, water and sewerage.

The results of the PHA indicate the following:

> *"The results of this PHA show that the risk associated with the proposed GTP complies with DIPNR guidelines for tolerable fatality, injury, irritation and societal risk. Also, transport risk, risks to biophysical environment, the risk of propagation and the impact on cumulative risk in the Port Botany / Randwick area from releases are broadly acceptable. These conclusions apply to both off-site (e.g. residential areas) and on-site (i.e. neighbouring industrial facilities) risk.*
>
> *The primary reason for the low risk levels is that significant consequential impacts from potential hazardous events associated with the GTP operation do not reach the nearest site boundary or, for the neighbouring industrial facilities, their likelihood is acceptably low."*

While the PHA has addressed hazards and accidental releases to meet DIPNR guidelines, further evaluation of potential emissions to air from accidental releases is required to address potential risks to human health associated with releases to air. The key areas which have been identified for further assessment are associated with the following worst-case accidental release scenarios:

3. Increased dioxin emissions over an extended period; and
4. No destruction of chemicals in the air stream entering the thermal oxidiser.

The following presents issues associated with these scenarios.

3.4.1 Increased Dioxin Emissions

A higher than normal emission of dioxin may occur during a situation where the thermal oxidiser may not be operating correctly, e.g. a fault with the temperature control (giving a lower than optimal temperature in the thermal oxidiser), as well as low temperature trips not working the operator not responding to other indications of incorrect operation (e.g. viewing flame, stack CO meter, less than normal steam production, stack EDC/VC meter) or these other indicators may not be working.

The high level dioxin emission may continue until the next stack measurement is made. Initially the monitoring period will be 3-monthly and is expected to change to yearly. The higher dioxin emission may theoretically occur for up to 12 months.

It is estimated (by Orica) that dioxin emissions may be as high as five times the predicted normal emission rate under the above circumstances. The frequency of the event has been estimated (by Orica) to be at most once per 50,000 years.

As dioxins are considered to be persistent and bioaccumulative chemicals, further evaluation of dioxin emissions under this release scenario (of duration of 1 year) is warranted to evaluate all potential exposures in off-site areas. The scenario identified that may result in increased emissions of dioxins is not expected to be associated with increases in other emissions from the thermal oxidiser. Hence emissions of other COPC will remain the same during this scenario.

3.4.2 No Destruction of Chemicals in Thermal Oxidiser

In a similar vein to the scenario leading to increased emissions of dioxins, the thermal oxidiser could operate at a much lower temperature than design, such that the effective destruction of the contaminants was minimal. As above, this would be a very unusual situation, requiring the simultaneous failure of the temperature controls, numerous trips and operator inaction in the light of many indicators of unusual performance.

As the circumstance leading to lack of destruction of chemicals in the thermal oxidiser require major failures, it is considered unlikely that these failures would go unnoticed for an extended period. As a worse case the incorrect operation could be missed until the next shift change, a maximum of 12 hours. That is, the maximum duration of worst-case emissions would be 12 hours. The estimated (by Orica) frequency of occurrence of this scenario would be at most once per 50,000 years.

In the assessment of a worst-case situation, it is assumed that the air stream entering the thermal oxidiser does not get destroyed at all and is emitted from the stack untreated.

The composition and flow of chemicals from the scrubber which enter the thermal oxidiser have been provided by Orica. It is assumed that no destruction occurs in the thermal oxidiser and air leaving the stack may be at 20^{o}C (worst case), a volumetric flow 51417 m^3/hr and the stack velocity may drop to 10 m/s. Since no destruction occurs in the thermal oxidiser, dioxins are not expected to be generated (no combustion). However at worst, it can be assumed that dioxin emissions remain the same as that estimated during normal operations.

This data has been modelled using the CALPUFF air dispersion model (as set up in the Air Quality Impact Assessment) to estimate the maximum 15-minute and 1-hour average ground level concentrations associated with this release scenario. Due to the nature of the release scenario and the length of release (12 hours) the release is considered to be representative of an acute exposure event and predicted concentrations should be screened against relevant acute and emergency release criteria. In addition, the increased emission of persistent and bioaccumulative **COPC (dioxins, mercury and HCBD**) must also be evaluated with respect to potential long-term effects.

Screening Level Criteria for Acute or Accidental Release

A range of different criteria are available for the assessment of potential human health effects associated with short-term emissions to air. No single organisation or methodology has developed acute criteria values or benchmarks for all potential compounds of concern. Hence, a hierarchical approach has been utilised for selecting existing guidelines for acute inhalation exposure levels.

Acute inhalation exposure criteria have been developed by a number of organisations which include: American Conference of Governmental Industrial Hygienists (ACGIH); Occupational Safety and Health Administration (OSHA); National Institute of Occupational Safety and Health (NIOSH); American Industrial Hygiene Association (AIHA), National Research Council on Toxicology (NRCT) USEPA; Agency for Toxic Substances and Disease Control (ATSDR), California Environmental Protection Agency (CalEPA); National Advisory Committee (NAC) and the US Department of Energy (DOE); Subcommittee on Consequence Assessment and Protective Actions (SCAPA); and Worksafe Australia.

The acute inhalation exposure criteria have been established by the above organisations and agencies to:

- Be protective of a range of exposure groups including occupational workers, military personnel and the general public;
- Based on a range of exposure durations, typically relevant to the exposure group, but ranging from 15 minutes, to 8 hours (typically for occupational settings) to 24-hours; and
- Protective of a range of toxicological endpoints such as mild discomfort, irritation, serious debilitating and potentially life-threatening effects up to and including death.

The hierarchical approach utilised in this assessment is based on that recommended by the USEPA Office of Solid Waste and detailed in the document “Human Health Risk Assessment protocol for Hazardous Waste Combustion Facilities” (Draft, July 1998). The hierarchical approach is focused on the protection of the general public and is summarised below in order of preference:

5. Acute Exposure Guideline Levels (AEGL’s) developed by the NAC/AEGL Committee and available from the USEPA;
6. Emergency Response Planning Guidelines (ERPG’s) developed by the AIHA and SCAPA;
7. Acute Reference Exposure Levels (AREL’s) developed by the CalEPA
8. Temporary Emergency exposure limits (TEEL’s) developed by SCAPA; and
9. SCAPA toxicity-based approach as presented by the DOE;

Appendix C of this report presents further detail on each of these guideline and relevant basis for the levels proposed by each agency. Acute exposure criteria are established for the protection of a range of health effects. These range from **Level 0** to **Level 1** which is protective of all individuals, including sensitive groups, from mild transient effects; **Level 2** which is protective of individuals who may be exposed without developing irreversible or serious health effects (injury); **Level 3** which is generally the maximum concentration below which individuals will not experience life-threatening effects.

Table 3.4 presents the range of chemicals which cover 98.7 % of the VOC emissions plus hydrogen sulfide (H_2S), with a comparison of the maximum predicted ground level concentration associated with the relevant averaging period with the acute exposure criteria selected using the above approach. The comparison presented in the table is expressed as a percentage of the ground level concentration against the relevant criteria.

Table 3.4 – Assessment of Acute Release Scenario with Assessment Criteria

Chemical	Comparison of Maximum Predicted GLG with Acute Exposure Criteria (% GLC/criteria)		
	Level 0/1 Irritation	Level 2 Injury	Level 3 Life-Threatening
Chloroform	NA	0.03%	0.001%
Carbon Tetrachloride	0.4%	0.1%	0.03%
1,2-Dichloroethane (EDC)	2.3%	0.4%	0.3%
1,1,2-Trichloroethane	0.05%	0.02%	0.005%
1,1,2,2-Tetrachloroethane	0.2%	0.1%	0.007%
Vinyl Chloride	0.02%	0.004%	0.001%
Trichloroethene (TCE)	0.02%	0.006%	0.0007%
Tetrachloroethene (PCE)	0.1%	0.02%	0.003%
Hexachlorobutadiene (HCBD)	0.36%	0.002%	0.0005%
Benzene	0.01%	0.001%	0.0001%
1,4-Dichlorobenzene	0.0002%	0.0001%	0.0001%
H_2S	23%	0.4%	0.2%

The maximum ground level concentrations predicted for the acute release scenario are less than the relevant acute exposure assessment criteria. On this basis no further evaluation of inhalation exposures associated with accidental releases of this nature is required. However, there is the potential for the release of higher concentrations of persistent and bioaccumulative chemicals to result in increased concentrations in other media such as soils, fruit and vegetables and breast milk all of which are associated with long-term (possibly up to a year) exposure by residents following the release.

3.5 Summary of Issues

On the basis of the review and evaluation undertaken, the following risk issues and COPC have been identified.

Table 3.5 – Summary of Issues Associated with GTP

Potential Issues	Potential exposures and management measures	Key Issues and Chemicals of Potential Concern
Construction of GTP		
Exposure to chemicals in soil and groundwater on site	Any exposure to chemicals identified in groundwater managed under health and safety plan for the site	None identified
Emissions to air	Products of fuel combustion and dust emissions. All these are to be managed and controlled on site	None identified
Normal Operation of GTP		
Extraction and handling of contaminated groundwater	Sealed system with fugitive emissions to be managed and expected to be low	None identified
Storage, handling as use of process chemicals	Compliance with relevant Australian Standards and on-site health and safety plans	None identified
Impacts to stormwater drainage system	Control using bunding and on-site stormwater management system to minimise impacts	None identified
Impacts to wastewater and other process wastes.	Discharges to sewer in accordance with trade waste agreement. Other waste discharges to meet EPA guidelines	None identified
Treated water reuse within the BIP or discharge via Bunnerong Canal to Brotherson Dock and Botany Bay	Quality of treated water to meet Australian Drinking Water Guidelines and ANZECC Water Quality Guidelines for the protection of marine waters. In addition expected quality of water screened against human health based screening levels. No exceedances of human health based levels expected.	None identified
Emissions to air from thermal oxidiser	Air Quality Impact Assessment indicated compliance with regulatory requirements.	None identified
	Air dispersion modelling used to predict maximum ground level concentrations in areas on and off the site. Predicted emissions and concentrations compared with relevant human health risk based screening levels in air. Chemicals which exceeded either the 1-hr average or annual average screening level identified as COPC.	**Potential for inhalation of:** ○ **Chloroform** ○ **Carbon tetrachloride** ○ **EDC** ○ **Vinyl chloride** ○ **TCE** ○ **PCE** ○ **Dioxins**
	Chemicals identified as persistent and bioaccumulative identified for further assessment in off-site areas (multiple exposure pathway assessment).	**Potential for exposure via non-inhalation routes for:** ○ **HCBD** ○ **Dioxins** ○ **Mercury**
Accidental Releases		
Identification and evaluation of hazards and failure scenarios	Preliminary hazard assessment provided review in accordance with DIPNR guidance. Indicated risks comply with relevant guidance.	

Potential Issues	Potential exposures and management measures	Key Issues and Chemicals of Potential Concern
Worst case scenarios for emissions to air (frequency of failure for both scenarios estimated to be once per 50,000 years)	**Increased emission of dioxin** associated with subtle failure in oxidiser, temperature controls and other indicators. This may go un-noticed between dioxin measurements which may be up to 12 months	**Potential for exposure via non-inhalation routes for:** **Dioxins**
	No destruction of chemicals in the thermal oxidiser resulting in emissions to air which are equal to that in the air stream from the strippers. Significant failure event which may occur for up to 12 hours. Increasd emissions modelled with maximum ground level concentrations compared with relevant acute exposure criteria. Potential increased emission of persistent and bioaccumulative chemicals identified.	**No COPC identified for exposure via inhalation** **Potential for exposure via non-inhalation routes for:** ○ **HCBD** ○ **Dioxins** ○ **Mercury**

The following sections present detailed evaluation of the key issues and COPC identified.

4.1 General

This section identifies the human populations (receptors) who may be exposed to the COPC, outlines the mechanisms (pathways) by which these populations may be exposed and provides a quantitative estimate of exposure and chemical intake.

The exposure assessment is undertaken to be representative of a particular population and does not calculate the exposure for a given individual. Populations are grouped so as to reflect common activities undertaken by that group (such as workers or children) or by the location of the population in relation to the contaminant distribution. For this reason it is important that the exposure assessment be undertaken in such a way that the most sensitive individuals within the potentially exposed population are adequately protected. The exposure assessment has been structured in the following way:

- Identification of the population that may be exposed to the COPC;
- Identification of the activities by which exposure may take place for each population;
- Identification of parameters which define activity (such as time spent indoors) and physiological exposure parameters (such as body weight and inhalation rate); and
- Identification of the chemical concentration at the point of exposure. This may include the identification and use of models to estimate chemical concentrations for receptors and exposure pathways that cannot be measured directly.

4.2 Key Pathways and Receptors

4.2.1 General

Receptor populations are similar groups of people who live or work in the study area and who may be exposed to the COPC in the workplace, residence or in recreational areas.

An exposure pathway describes a unique mechanism by which an individual or population may be exposed to chemicals or physical agents at or originating from a source. Each exposure pathway includes:

- a source or release from a source;
- a transport/exposure medium or exposure route; and
- an exposure point.

If any one of these mechanisms is missing (such as transport mechanism or exposure point) then the pathway is considered to be incomplete. An exposure pathway can be considered to be less significant if the potential for a receptor or population to be exposed to the COPC is considered to be low. This may be due to a number of factors, which may including dilution during the transport from the source to the point of exposure or limited time for exposure.

4.2.2 Key Issues Associated with the GTP

The evaluation of the proposed GTP facility and identification of issues associated with potential emissions from the facility are presented in Section 3. This process identified potential emissions to air during normal and accidental release scenarios where there are key issues, which require further detailed evaluation with respect to human health risks. The key issues identified are:

- Inhalation exposure to COPC identified in air following normal emissions from the thermal oxidiser;
- Multiple pathway exposure to persistent and bioaccumulative COPC which may be emitted to air during normal operation of the thermal oxidiser;
- Inhalation and multiple pathway exposure associated with the potential upset to operating conditions that may give rise to increased dioxin emissions for up to 12 months; and
- Multiple pathway exposure to persistent and bioaccumulative COPC which may be emitted to air following a worst-case accidental release where no destruction occurs in the thermal oxidiser for up to 12 hours.

All other emissions evaluated in Section 3 are expected to result in exposure pathways that can be considered to be less significant (resulting in concentrations which are less than human health risk based screening criteria) or incomplete (no off-site exposures) and do not warrant further evaluation.

4.2.3 Multiple-Pathway Exposure

The emission to air (long-term or accidental release) of chemicals that are considered to be persistent and bioaccumulative in the environment has the potential to result in exposure in off-site areas by a number of exposure pathways in addition to inhalation. These exposures are associated with the potential for these chemicals to deposit (wet and dry deposition) onto soils and waterways and accumulate throughout the environment in a range of media.

This process is illustrated in the following diagram (not all pathways illustrated will be of relevance to the assessment at the Botany site).

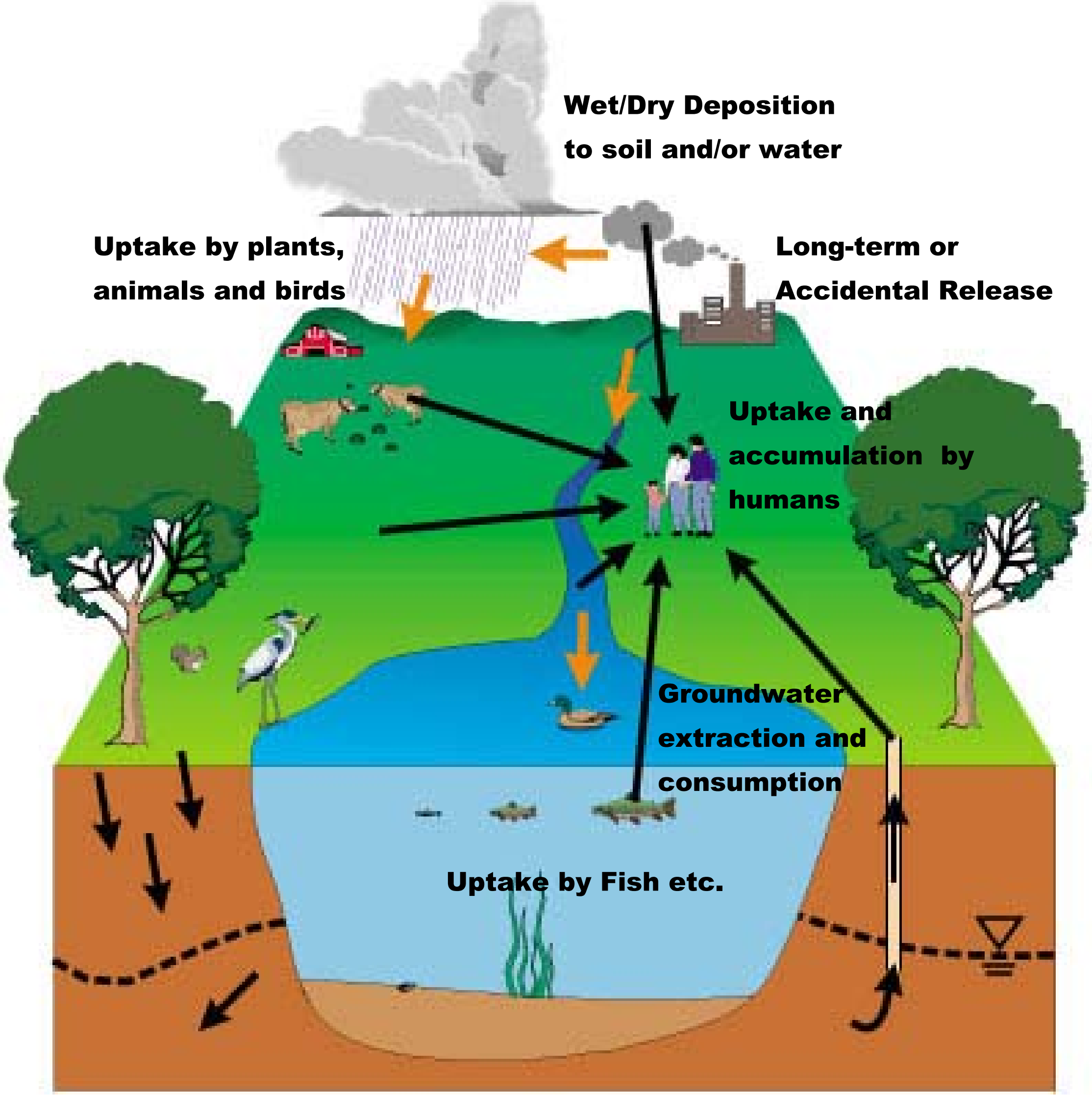

Figure 4.1 Potential Exposure Pathways to Persistent and Bioaccumulative Chemicals Released During Normal Operations or Accidental Release

The following identifies exposure pathways for the Orica site and surrounding areas that are relevant to emissions during normal operations and accidental releases.

Deposition to Soils

Following release to the atmosphere, persistent chemicals may be deposited onto the soils by a process of dry or wet deposition. There is the potential for deposition of these chemicals during both normal operations (long-term emission of low concentrations) and accidental releases (short-term emission of higher concentrations) to result in elevated concentrations within surface soils and dusts. Hence, persistent and bioaccumulative chemicals within soil and dust have the potential to result in exposure by off-site populations via ingestion and dermal absorption.

Once accumulated within soil, persistent chemicals have the potential to be taken up and accumulated by plants and animals. Animals have the potential to accumulate the chemicals resulting in elevated concentrations of the persistent chemicals in meat, eggs or milk produced from these animals. The Botany area is neither rural nor semi-rural. Rather, it is an urban area where meat, egg and milk producing livestock are not present; hence potential intake of persistent chemicals via this mechanism is not considered relevant.

There is the potential for some residential properties to have backyard gardens which have home-grown produce such as fruit and vegetables, hence the potential accumulation of persistent chemicals within these plants and subsequent consumption by residents is considered to be a relevant exposure pathway.

Deposition to Water

Persistent chemicals may be deposited into waterways in the surrounding area. In addition, deposited dusts may runoff from surrounding surfaces and end up within the waterways or leach to groundwater. Once in the waterways, there is the potential for fish and birds to accumulate these chemicals. The waterways surrounding the Botany site where the GTP is proposed to be located are principally Botany Bay, associated stormwater drains and Penrhyn Estuary.

The deposition of chemicals derived from the GTP into water bodies such as the drains, estuary and the Botany Bay would be expected to result in substantial dilution of the deposited chemicals. The effect of dilution is expected to result in an insignificant impact on the potential concentrations of these chemicals within the water, and hence fish and other aquatic organisms.

Accumulation in Human Body

Following intake of persistent and bioaccumulative chemicals into the human body via the range of exposure pathways, there is the potential for these chemicals to accumulate in body tissues and fat. In particular persistent organic chemicals have the potential to accumulate in breast milk fat. Hence there is the potential for nursing infants to be exposed to these chemicals during breastfeeding.

4.2.4 Key Exposure Pathways

On the basis of the above assessment, the following are identified as key exposure pathways relevant to off-site populations and the emissions to air associated with the proposed GTP:

- Inhalation of COPC in air by all groups in the area surrounding the site (residents, workers and recreational groups);
- Direct contact (ingestion and dermal contact) by residents with soils that may have accumulated levels of persistent and bioaccumulative chemicals;

- Ingestion of home-grown produce by residents which may have been grown in soils which have accumulated levels of persistent and bioaccumulative chemicals; and
- Ingestion of persistent and bioaccumulative organic chemicals by infants during breastfeeding.

4.3 Quantification of Chemical Intake

4.3.1 Background

When calculating chemical intake or exposure, the risk assessment process focuses on exposure occurring over a prolonged period, that is chronic exposure that occurs over years and possibly a lifetime. Whilst an activity may occur infrequently (i.e. several days a year), it may occur regularly over a long period and therefore have the potential to increase long term or chronic intake of the chemical. The following steps have been followed to estimate chemical intake:

- Identification of ***exposure parameters*** for each of the identified exposure pathways and receptors. These are values that describe the physical and behavioural parameters relevant to the potentially exposed population and the pathway of exposure. Some examples include ingestion rate (e.g. amount of backyard vegetables eaten), inhalation rate (volume of air inhaled during different activities), exposure frequency (i.e. hours per day or days per year), and exposure duration (e.g. number of years as a resident, golf player etc.) and body weight (refer to Section 4.3.2 for detail).
- Calculation of ***intake factors***. An intake factor is calculated using the exposure parameters defined above and provides a site specific and receptor specific value which, when multiplied by the concentration of each COPC, provides an estimate of the daily chemical intake of the COPC for each receptor and pathway.
- Estimation of the ***chemical concentration*** in each medium relevant to the receptor groups and exposure pathways. This involves the use of relevant data from air modelling and modelling of potential concentrations in other media such as soils, fruit and vegetables and mother’s milk (refer to Sections 4.4.2 to 4.4.4); and
- Calculation of the ***daily chemical intake*** using the intake factor and the chemical concentration. This is calculated for each exposure pathway assessed for each site using the following equation:

$$\textbf{\textit{Daily Chemical Intake}} = (\textbf{\textit{Intake Factor}} \bullet \textbf{\textit{Concentration}})$$

The assessment presented has addressed potential worst-case exposure to COPC and exposure has been calculated for a ***Reasonable Maximum Exposure (RME)*** scenario estimated by using intake variables and chemical concentrations that define the highest exposure that is reasonably likely to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and therefore health risk. This approach follows ANZECC/NHMRC guidance (1992) supplemented by

USEPA guidance (USEPA, 1989). Details on the calculation of daily chemical intake are presented in Appendix E of this report.

4.3.2 Exposure Parameters

Exposure parameters which are considered representative of RME have been selected for the receptor groups evaluated, namely residents (adults, children and infants), commercial industrial workers and recreational users in the area (including golfers and users of the athletics field). Where available, additional exposure data has been obtained from Australian sources (enHealth 2002, CSMS, 1991, 1993, 1996 and 1998, ANZECC 1992 and NEPM 1999). The exposure parameters selected have been reviewed by the DEC and NSW Health prior to use the health risk assessment.

As discussed in Section 4.2.2, key issues for the proposed GTP are associated with inhalation exposures and multiple pathway exposures to persistent and bioaccumulative chemicals under normal operating conditions as well as some worst-case accidental release scenarios.

The following presents a summary of the exposure parameters utilised in the quantification of exposure for the relevant receptor groups and pathways. Appendix E also presents a detailed summary of the exposure parameters and intake factors calculated for each receptor group and pathway.

Inhalation Exposures

Receptor Population	Exposure Pathways	Chemical Concentrations	Exposure Parameters**
Adult Resident	Inhalation of emissions from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Body weight of 70 kg Exposure for 24 hours per day (i.e. whole day at home) for 337 days/year for 70 years Inhalation of 1.17 m^3 air per hour indoors (20 hours) and 2.2 m^3 air per hour outdoors (4 hours).
Child Resident (aged 0-5 years, most sensitive)*	Inhalation of emissions from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Body weight of 13.2 kg Exposure for 24 hours per day (i.e. whole day at home) for 337 days/year for 5 years Inhalation rate of 0.45 m^3 air per hour indoors (20 hours) and 1.25 m^3 air per hour outdoors (4 hours)
Off-site industrial/ commercial worker (maximum)	Inhalation of emissions from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Body weight of 70 kg Workday exposure for 8 hours indoors and 2 hours outdoors per day for 240 days/year for 30 years. Inhalation of 1.17 m^3 air per hour indoors and 2.2 m^3 air per hour outdoors.
Adult Recreational (Athletics Field, Golf Course)	Inhalation of emissions from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Body weight of 70 kg Exposure for 3 hours per day (exercising) or 6 hours per day (golf). It is assumed exercise or golfing occurs for 104 days/year for 70 years. Inhalation rate of 3.5 m^3 air per hour for exercising (running at 8 km/hr) or 2.2 m^3 air per hour for golfing (equivalent to walking).
Child Recreational (Athletics Field, Golf Course) (aged 5-15 years)	Inhalation of emissions from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Body weight of 34.5 kg Exposure for 4 hours per day for 104 days/year for 10 years. Inhalation rate of 2.2 m^3 air per hour (equivalent to running at 7.2 km/hr)

Notes:

* A child aged 0 to 5 years is considered to be more sensitive to exposure at home as they are more likely to spend more hours per day at home and have a lower body weight (resulting in a higher intake per kg of body weight)

** It is assumed that indoor and outdoor air concentrations are equal and that chemicals in air are primarily in a vapour phase.

Multiple Pathway Exposures

Receptor Population	Exposure Pathways	Chemical Concentrations	Exposure Parameters**
			Parameters relevant for all pathways*** Body weight of 70 kg Exposure for 24 hours per day (i.e. whole day at home) for 337 days/year for 70 years
	Inhalation* persistent and bioaccumulative chemicals from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Inhalation of 1.17 m^3 air per hour indoors (20 hours) and 2.2 m^3 air per hour outdoors (outdoors). Inhalation of particulates* assumes 75% inhaled dust retained in respiratory tract (rest exhaled) and 50% of inhaled dust will reach pulmonary alveoli.
Adult Resident	Ingestion and Dermal Contact with Chemicals in Soils	Soil concentrations estimated using soil accumulation model (refer to Section 4.4.2)	Ingestion of 25 mg of soil per day by adults. Once ingested it is assumed that 100% is absorbed into the body. When outdoor it is assumed that the hands, forearms and lower legs get dirty each day (4580 cm^2 of skin). Once dirt it is assumed that 0.51 mg of soil adheres to each cm^2 of skin. In addition when on the skin, 3% of dioxins, 10% of HCBD and 0% of mercury are absorbed through the skin. Assume an adult will wash at the end of each day resulting in up to 12 hours of the day dirty.
	Ingestion of home-grown fruit and vegetable crops	Uptake of chemicals in plants calculated assuming concentration is the sum of deposition and uptake from soil by roots (refer to Section 4.3.3)	An adult may consume 164 g/day of home-grown produce where 100% is absorbed via ingestion. This is averaged over the year as some days an adult may consume more and other none or much less.

* Inhalation exposure evaluated for persistent and bioaccumulative chemicals assumes that these chemicals are present as vapour phase as well as bound to particulates resulting in a conservative estimation of inhalation exposure as well as exposure associated with resultant deposition.

** It is assumed that chemicals in air may be vapour phase and bound to particulates. Indoor and outdoor concentrations conservatively assumed to be equal. Studies indicate that inspirable particulates indoors are approximately 75% of those outdoors.

*** The evaluation of exposure during the worst-case accidental release assumes that the event may occur during 1 year only, inhalation exposure is relevant for 12 hours of 1 day only, soil concentrations derived from the event may be available for exposure for 1 year, uptake into plants may occur over 1 year (deposition on 1 day only).

Receptor Population	Exposure Pathways	Chemical Concentrations	Exposure Parameters**
			Parameters relevant for all pathways* Body weight of 13.2 kg Exposure for 24 hours per day (i.e. whole day at home) for 337 days/year for 5 years
Child Resident (aged 0-5 years, most sensitive)	Inhalation* persistent and bioaccumulative chemicals from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Inhalation rate of 0.45 m^3 air per hour indoors and 1.25 m^3 air per hour outdoors. Inhalation of particulates* assumes 75% inhaled dust retained in respiratory tract (rest exhaled) and 50% of inhaled dust will reach pulmonary alveoli.
	Ingestion and Dermal Contact with Chemicals in Soils	Soil concentrations estimated using soil accumulation model (refer to Section 4.4.2)	Ingestion of 100 mg of soil per day by children. Once ingested it is assumed that 100% is absorbed into the body. When outdoor it is assumed that the hands, legs and feet get dirty each day (2100 cm^2 of skin). Once dirt it is assumed that 0.51 mg of soil adheres to each cm^2 of skin. In addition when on the skin, 3% of dioxins, 10% of HCBD and 0% of mercury are absorbed through the skin. Assume a child may not wash at the end of each day resulting in up to 24 hours of the day dirty.
	Ingestion of home-grown fruit and vegetable crops	Uptake of chemicals in plants calculated assuming concentration is the sum of deposition and uptake from soil by roots (refer to Section 4.4.3)	A child may consume 70.7 g/day* of home-grown produce where 100% is absorbed via ingestion. This is averaged over the year as some days a child may consume more and other none or much less.

* Inhalation exposure evaluated for persistent and bioaccumulative chemicals assumes that these chemicals are present as vapour phase as well as bound to particulates resulting in a conservative estimation of inhalation exposure as well as exposure associated with resultant deposition.

** It is assumed that chemicals in air may be vapour phase and bound to particulates. Indoor and outdoor concentrations conservatively assumed to be equal. Studies indicate that inspirable particulates indoors are approximately 75% of those outdoors.

*** The evaluation of exposure during the worst-case accidental release assumes that the event may occur during 1 year only, inhalation exposure is relevant for 12 hours of 1 day only, soil concentrations derived from the event may be available for exposure for 1 year, uptake into plants may occur over 1 year (deposition on 1 day only).

Receptor Population	Exposure Pathways	Chemical Concentrations	Exposure Parameters**
Infant/ Young Child (0 to 1 years)	Ingestion of accumulated chemicals in breastmilk	Concentrations or organic chemicals such as HCBD and dioxins estimated using model based on maternal intake as outlined in Section 4.4.4.	Body weight of 6 kg (average for 3 month age, DEH 2004, National Dioxins Program, Technical Report 12). It is assumed that exposure (breastfeeding) occurs for 12 months (1 year) Ingestion of 0.751 kg/day breastmilk (DEH 2004 for 3 months of age). It is assumed that there is 3.7% lipid content in the mother's milk (DEH 2004) It is also assumed that 90% is absorbed following ingestion (USEPA 1998 and DEH 2004)
	Inhalation persistent and bioaccumulative chemicals from GTP process	Ground level concentration estimated using air dispersion model (refer to Section 4.4.1)	Inhalation rate of 0.19 m^3 air per hour for an infant. Inhalation of particulates* assumes 75% inhaled dust retained in respiratory tract (rest exhaled) and 50% of inhaled dust will reach pulmonary alveoli.

* Inhalation exposure evaluated for persistent and bioaccumulative chemicals assumes that these chemicals are present as vapour phase as well as bound to particulates resulting in a conservative estimation of inhalation exposure as well as exposure associated with resultant deposition.

** It is assumed that chemicals in air may be vapour phase and bound to particulates. Indoor and outdoor concentrations conservatively assumed to be equal. Studies indicate that inspirable particulates indoors are approximately 75% of those outdoors.

4.4 Potential Concentration of COPC in Various Media

4.4.1 Air

Normal Operation of GTP

The concentration of COPC in air in off-site areas has been assessed using air dispersion modelling as detailed in the Air Quality Impact Assessment. The modelling used in this assessment is associated with the impact from the GTP only. As many of the COPC identified are VOCs, it is difficult to include background sources of VOCs due to the limitation of reporting of VOCs. Only total VOCs are reported and available in the NPI database for the BIP with no breakdown of individual chemicals available. It is also necessary to evaluate the impact of the GTP only, as the criteria used for the evaluation of non-threshold chemicals is associated with an incremental (no background) lifetime risk. For other threshold chemicals, the presence of background concentrations (and intake) has been considered during the characterisation of risk (refer to Section 6.3). Hence the concentrations used in this assessment are for the GTP only.

From the modelling provided, data is available for a number of discrete receptor locations surrounding the site as well as over a grid that encompasses the site and surrounding areas. While it is possible to identify chemical concentrations in air in residential, industrial and recreational areas surrounding the site, a conservative assessment has been undertaken using the maximum concentration predicted from all areas. This maximum concentration may occur on the site, however it is noted that the concentrations reported at some receptor locations off-site are not much lower than the maximum value adopted for use in this assessment.

Accidental Release – Increased Dioxin Emission

The evaluation of concentrations associated with the increased emission of dioxin has assumed that dioxin emissions may increase by up to 5 times the normal emission rate during this period. The maximum modelled GLC (located on the BIP) relevant to an emission which may occur for up to 12 months (as an annual average) has been used in the assessment. The emission of other COPC from the GTP are not expected to change as a consequence of this type of accidental release.

Accidental Release – Worst-Case Emission

The evaluation of worst-case releases has assumed no destruction of COPC occurs in the thermal oxidiser. Air dispersion modelling has been used (with relevant discharge parameters within the air dispersion model) to determine the maximum GLC. As this release is only expected to occur for up to 12 hours at most, the maximum 1 hour average GLC have been used in the assessment of this scenario.

Summary

Table 4.1 presents the air concentrations used in the assessment if inhalation exposures for COPC identified for all areas (residential, recreational and commercial/industrial).

Table 4.1 – Concentration of COPC in Air

	Maximum GLC		
COPC	**Normal Operating Conditions** **µg/m³ annual average**	**Increased Dioxin Emission** **µg/m³ annual average**	**Worst-Case Release*** **µg/m³ 1-hour average**
Chloroform	0.0034	N	na
Carbon tetrachloride	0.0106	N	na
1,2-Dichloroethane (EDC)	0.114	N	na
Vinyl chloride	0.0040	N	na
Trichloroethene (TCE)	0.0048	N	na
Tetrachloroethene (PCE)	0.0091	N	na
Dioxins**	1.5×10^{-9}	7.7×10^{-9}	8.3×10^{-8}
Mercury**	4.0×10^{-6}	N	2.2×10^{-4}
Hexachlorobutadiene (HCBD)**	1.7×10^{-5}	N	0.54

* Air concentrations for worst-case release used in the evaluation of maternal intake. As noted in Section 3.4 inhalation exposure to chemical concentrations during this event are less than the relevant human health criteria for acute and emergency releases.

** Dioxins, Mercury and HCBD evaluated for multi-pathway exposures.

N Chemical concentration unchanged from that used in the evaluation of normal operating conditions.

na Not assessed as chemical was not identified as a COPC.

It has been assumed that for the evaluation of inhalation exposures the predicted GLCs are representative of vapour phase concentrations. This will be directly relevant for the evaluation of VOCs as they would be expected to be in vapour phase in an untreated emission from the thermal oxidiser. Hence the evaluation of inhalation exposures to VOCs has assumed exposure via inhalation.

Dioxins, mercury and HCBD are likely to be present as both a vapour and bound to particulates. No data is available to indicate the potential breakdown of vapours and particulates which may be emitted from the thermal oxidiser. Hence, the estimation of potential inhalation exposures associated with these chemicals has assumed that the maximum intake is derived from vapour phase concentrations (as above) as well as particulates (assuming 100% is particulate phase as well). While this may be considered highly conservative, it provides a worst-case evaluation of potential exposure.

4.4.2 Soils

The potential accumulation of persistent and bioaccumulative chemicals in soils (identified to be dioxins, mercury and HCBD), which may be the result of deposition from an air emissions source, can be estimated using a soil accumulation model (Stevens 1991).

The concentration in soil, which may be the result of deposition following emission of persistent chemicals, can be calculated using Equation 1.

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000 \qquad \text{(mg/kg)}$$ **....Equation 1**

where:
DR = Particle deposition rate for accidental release (mg/m^2/year)
k = Chemical-specific soil-loss constant (1/year) = ln(2)/T$^{0.5}$
T$^{0.5}$ = Chemical half-life in soil (years)
t = Accumulation time (years)
d = Soil mixing depth (m)
ρ = Soil bulk-density (g/m^3)
1000 = Conversion from g to kg

The particle deposition rate during normal operations as well as both accidental release scenarios has been estimated utilising the plume dispersion model CALPUFF (refer to Air Quality Impact Assessment for model details) assuming that the emission will be in particulate form (rather than a combination of particulate and gas form).

The maximum particle deposition rate within off-site residential areas has been used in this assessment since the key exposure mechanism being evaluated is the potential long-term exposure by adults and children who may live in the area surrounding the site. The calculation has been undertaken to estimate the potential concentration of dioxins, mercury and HCBD within soils on the basis of the following:

- Emissions may occur for 30 years (assumed life of GTP), 1 year (maximum time assumed for increased dioxin emissions) and 12 hours (maximum time assumed for worst-case release).
- For dioxins, HCBD and mercury, soil half-lives of 12 years, 6 years and 2 years respectively have been used in this assessment. It should be noted that a soil half-life for HCBD has not been identified from the literature. It has been assumed that the half-life is similar to that of hexachlorobenzene. This is considered to be conservative given the greater volatility of HCBD compared to HCB which would be expected to result in a lower half life.
- It is assumed that the soil where deposition occurs is not well mixed (as would be the case in a garden or cultivated bed), and hence the mixing depth for deposited soils and dusts has been taken to be 1 cm, with a soil bulk density of 1.6 g/cm^3 (typical of the Botany area).

The particle deposition rate will decrease with increasing distance from the site and hence the calculations presented here, which have used the maximum deposition rate, are expected to be conservative for all off-site residential areas.

Following this approach, the following maximum concentrations of dioxins, mercury and HCBD have been estimated in soils within residential areas immediately surrounding the site.

Table 4.2 – Concentration of COPC in Soils

	Maximum Concentration (mg/kg)		
COPC	**Normal Operating Conditions**	**Increased Dioxin Emission**	**Worst-Case Release**
Dioxins	3.6×10^{-9}	1.21×10^{-9}	1.8×10^{-11}
Mercury	1.9×10^{-6}	N	5.8×10^{-8}
Hexachlorobutadiene (HCBD)	2.5×10^{-5}	N	1.4×10^{-4}

N Deposition and accumulation in soils unchanged from that calculated for normal operating conditions.

It should be noted that the concentrations calculated in soils during the accidental release scenarios are generally less than those calculated during normal emissions. This is due to a number of factors:

- the limited duration of release (12 months for dioxin and 12 hours for worst-case release) which results in a limited time for accumulation in soil; and
- the emission rate of dioxins and mercury during the worst-case release scenario is unchanged from that used in the evaluation of normal operations. This is due to the assumption used in the assessment of mercury where no destruction occurs under normal operating conditions and for dioxins no data is available however it can be assumed that at no more dioxin would be formed without the thermal oxidiser in operation.

4.4.3 Edible Plants

Plants may become contaminated with persistent chemicals via deposition directly onto the plant outer surface and following uptake via the root system. Both mechanisms have been assessed.

Deposited Material on Aboveground Plants

The potential concentration of persistent chemicals that may be present within the plant following atmospheric deposition can be estimated using the following equation (Stevens, 1991):

$$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k} \quad \text{(mg/kg plant – wet weight)} \qquad \textbf{....Equation 2}$$

where:
DR = Particle deposition rate for accidental release (mg/m^2/day)
F = Fraction for the surface area of plant (unitless)
k = Chemical-specific loss constant for particles on plants (1/days) = ln(2)/$T^{0.5}$
$T^{0.5}$ = Chemical half-life on plant (day)
t = Deposition time or length of growing season (days)
Y = Crop yield (kg/m^2)

The following assumptions have been adopted in the application of this model:

- Given that the residential areas surrounding the site are urban low-density residential properties, the types of edible plant expected to be grown on the properties include tomatoes and beans. Corn, hay and wheat are not expected to be grown for human consumption in significant quantities in the area. For typical crops grown aboveground an average crop yield of 2 kg/m^2 has been used.
- For leafy aboveground crops the surface area fraction (or plant interception fraction – how much of the depositing material remains on the plant and crops) is estimated to be 0.051 (Stevens, 1991).
- Weathering of particulates on plant surfaces does occur and in the absence of measured data, it is generally assumed that organics deposited onto the outer portion of plant surfaces have a weathering half life of 14 days (Stevens, 1991).
- The growing season for typical above ground crops varies, however it may be up to 70 days (tomatoes) which has been used in the calculation of concentrations during normal operations and following an increase in dioxin emissions. The assessment of worst-case emissions has assumed deposition may occur over 1 day.

The particle deposition rate has been estimated using dispersion modelling with the maximum particle deposition rate for the off-site residential areas used in this assessment as discussed above for assessing potential concentrations in soils.

Uptake of Chemicals via Roots

The potential uptake of persistent chemicals into edible crops via the roots can be estimated using Equation 3 (USEPA 1998).

$$C_{rp} = C_s \bullet RUF \qquad \text{(mg/kg plant – wet weight)}$$ **....Equation 3**

where:
C_s = Concentration of persistent chemical in soil assuming 15 cm mixing depth within gardens, calculated using Equation 1 for each chemical assessed (mg/kg)
RUF = Root uptake factor which differs for each chemical (unitless)

The uptake of dioxins and HCBD via the roots is essentially insignificant with root uptake factors of approximately 0.031 and 0.013 respectively (based on wet weight of plant) (RAIS, 2004). The root uptake factor for mercury[3] is greater and estimated to be 0.3 (RAIS, 2004).

Utilising Equations 2 and 3, Table 4.3 presents the estimated concentrations of dioxins, mercury and HCBD which may be present within edible plants grown within residential properties near the site. In

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[3] The evaluation of mercury in this assessment has assumed that mercury may be present in its most toxic form, which is considered to be methyl mercury (refer to Section 5.2). No plant root uptake factors are available for methyl mercury, hence uptake factors for mercury as inorganic salts have been used in this assessment.

calculating potential intake of fruit and vegetable crops it has been assumed that 19% of daily intake is derived from below-ground crops and 81% is derived from above-ground crops.

Table 4.3 – Concentration of COPC in Edible Fruit and Vegetables

	Maximum Concentration (mg/kg wet weight plant)		
COPC	**Normal Operating Conditions**	**Increased Dioxin Emission**	**Worst-Case Release**
Dioxins			
- deposition	$2.5x10^{-10}$	$1.2x10^{-9}$	$1.5x10^{-11}$
- root uptake	$7.4x10^{-12}$	$2.5x10^{-12}$	$3.8x10^{-14}$
Mercury			
- deposition	$1.5x10^{-8}$	N	$4.6x10^{-8}$
- root uptake	$3.9x10^{-8}$		$1.2x10^{-9}$
Hexachlorobutadiene (HCBD)			
- deposition	$6.4x10^{-8}$	N	$1.1x10^{-4}$
- root uptake	$2.1x10^{-8}$		$1.2x10^{-7}$

N = Deposition, accumulation in soils and plant uptake unchanged from that calculated for normal operating conditions.

4.4.4 Breast Milk

Persistent chemicals, particularly organic chemicals such as dioxin and HCBD, have the potential to accumulate within the human body and be passed to a nursing infant in the fat of breast milk. Infants may then be exposed to the chemicals. The potential concentration of dioxins and HCB within breastmilk can be estimated using Equation 4, which is dependent on the maternal intake of dioxins or HCBD (USEPA, 1998).

$$C_{milk\,fat} = \frac{m \bullet h \bullet f_1}{0.693 \bullet f_2} \quad \text{(mg/kg milk fat)} \qquad \textbf{....Equation 4}$$

where:
m = Average maternal intake of dioxin or HCBD (mg/kg/day)
h = Half-life of dioxin or HCBD in adults (days)
f_1 = Fraction of ingested dioxin or HCBD stored in fat (unitless)
f_2 = Fraction of mothers weight that is fat (unitless)

The potential maternal intake is a highly variable parameter in the above equation. It can be assumed that the calculations undertaken to calculate adult intake of dioxins and HCBD via inhalation (vapour and particulate), soil ingestion and dermal contact and ingestion of home-grown produce is relevant for a mother who may be breastfeeding an infant.

In addition the following assumptions are considered relevant:

- The half-life of dioxins in adults is taken to be 2738 days, which is equivalent to 7.5 years, as reported by the DEH (2004). For HCBD, no data is available. Some data is available for HCB which suggests that the half-life in the body may be as high as 1095 days (3 years). In the absence of specific data for HCBD, the value available for HCB has been adopted in this assessment for HCBD.
- The fraction of dioxin ingested which is stored as fat is recommended to be 0.9 (USEPA, 1998). No data is available concerning the fraction of HCBD which may be stored as fat, so to be conservative the same fraction of dioxins stored as fat has been utilised in estimating potential concentrations of HCBD.
- The recommended fraction of mother's body weight which is fat is 0.35 (DEH, 2004 for females in SE urban areas of Australia aged 31 to 45 years).

Table 4.4 presents the potential maximum concentrations of HCBD and dioxins estimated within milk fat utilising the above equation.

Table 4.4 – Concentration of COPC in Breast Milk

COPC	Maximum Concentration (mg/kg milk fat)		
	Normal Operating Conditions	Increased Dioxin Emission	Worst-Case Release
Dioxins	2.3×10^{-8}	1.1×10^{-7}	1.5×10^{-9}
Hexachlorobutadiene (HCBD)	5.9×10^{-5}	NA	4.2×10^{-3}

NA Not assessed as chemical was not identified as a COPC for the increased emission of dioxin.

4.5 Potential Intake of COPC

The potential intake of COPC associated with key exposure pathways which have been identified for the proposed GTP has been calculated using the exposure parameters and chemical concentrations in the various media. Calculation of intake (and relevant equations) for each exposure pathway identified is presented in Appendix E of this report. Tables 4.5 and 4.6 present a summary of the daily intake calculated for COPC identified for the evaluation of inhalation exposures and multiple pathway exposure.

Table 4.5 - Calculated Daily Intake – Inhalation Exposures

COPC**	Daily Chemical Intake (mg/kg/day)					
	Residential		Workers	Recreational		
	Adults	Children		Golfers	Adults Exercising	Children Exercising
Normal Operation of GTP						
EDC*	$4.8x10^{-5}$	$8.0x10^{-6}$	$6.3x10^{-6}$	$6.1x10^{-6}$	$4.9x10^{-6}$	$1.2x10^{-6}$
Vinyl chloride*	$1.7x10^{-6}$	$2.8x10^{-7}$	$2.2x10^{-7}$	$2.2x10^{-7}$	$1.7x10^{-7}$	$4.2x10^{-8}$
Chloroform	$1.4x10^{-6}$	$3.3x10^{-6}$	$4.3x10^{-7}$	$1.8x10^{-7}$	$1.4x10^{-7}$	$2.4x10^{-7}$
Carbon tetrachloride	$4.5x10^{-6}$	$1.0x10^{-5}$	$1.4x10^{-6}$	$5.7x10^{-7}$	$4.5x10^{-7}$	$7.7x10^{-7}$
TCE*	$2.1x10^{-6}$	$3.4x10^{-7}$	$2.7x10^{-7}$	$2.6x10^{-7}$	$2.1x10^{-7}$	$5.0x10^{-8}$
PCE	$3.9x10^{-6}$	$8.9x10^{-6}$	$1.2x10^{-6}$	$4.9x10^{-7}$	$3.9x10^{-7}$	$6.6x10^{-7}$

* COPC evaluated using a non-threshold approach for inhalation exposures only, refer to Section 5 for detail.

** Note that inhalation exposure to dioxin is evaluated as part of the multiple pathway evaluation presented.

Table 4.6 – Calculated Daily Intake – Multiple Exposure Pathways

COPC	Daily Chemical Intake (mg/kg/day)		
	Residential*		Infants**
	Adults	Children	
Normal Operation of GTP			
Dioxin	$2.2x10^{-12}$	$3.1x10^{-12}$	$9.7x10^{-11}$
Mercury	$3.3x10^{-9}$	$5.5x10^{-9}$	$4.1x10^{-9}$
HCBD	$1.5x10^{-8}$	$2.4x10^{-8}$	$2.6x10^{-7}$
Increased Dioxin Emissions			
Dioxin	$1.1x10^{-11}$	$1.5x10^{-11}$	$4.8x10^{-10}$
Mercury	$3.3x10^{-9}$	$5.5x10^{-9}$	$1.4x10^{-7}$
HCBD	$1.5x10^{-8}$	$2.4x10^{-8}$	$2.6x10^{-7}$
Worst-Case Release			
Dioxin	$1.5x10^{-13}$	$2.1x10^{-13}$	$6.4x10^{-12}$
Mercury	$4.3x10^{-10}$	$6.0x10^{-10}$	$3.2x10^{-10}$
HCBD	$1.0x10^{-6}$	$1.5x10^{-6}$	$1.8x10^{-5}$

* Intake from ingestion of chemicals in soil, dermal absorption of chemicals in soil, inhalation of particulates and vapour phase chemicals, ingestion of home-grown fruit and vegetable crops.

** Intake from inhalation of chemicals in air as particulate and vapour and ingestion of chemicals accumulated in breast milk.

5.1 General

The objective of the toxicity assessment is to identify toxicity values for the COPC that can be used to quantify potential risks to human health associated with calculated intake. Toxicity can be defined as *"the quality or degree of being poisonous or harmful to plant, animal or human life"* (NEPM, 1999).

The steps involved in this process include the following:

- Obtain relevant qualitative and quantitative toxicity information on the chemicals of potential concern relevant to the significant exposure pathways being assessed (namely oral, dermal or inhalation); and

- Identify the appropriate toxicity values for assessing both threshold effects and non-threshold carcinogenic effects.

5.1.1 Non-Threshold Response

Non-threshold toxicity values assumes that any amount of exposure to the chemical has the potential to result in an increased risk. These chemicals are typically carcinogens with their toxicity values referred to as cancer risk slope factors. The WHO assigns slope factors to chemicals identified as genotoxic carcinogens with other carcinogens identified evaluated on the basis of a threshold response relationship (refer below). A slope factor is an upper bound estimate of the probability of a response occurring following the intake of a chemical over a lifetime via a specific exposure pathway (such as ingestion or inhalation). Therefore the higher the slope factor, the higher the risk that may be associated with a given exposure.

5.1.2 Threshold Response

This relationship assumes that there is a level of exposure below which there is no (or no appreciable) risk of an adverse health effect. This is in contrast to the non-threshold relationship where there is an increased risk associated with any exposure. The WHO identifies threshold chemicals as those which are not suspected of exhibiting carcinogenic effects (non-carcinogens) or those which exhibit non-genotoxic carcinogenicity. Toxicity factors for these chemicals are referred to as an acceptable daily intake (ADI, by the WHO) or reference dose (RfD, by the USEPA) for oral exposures (in units of mg per kg body weight per day) and a tolerable concentration (TC, by WHO) or reference concentration (RfC, by USEPA) for inhalation exposures (in units of mg per cubic metre of air). The lower the ADI, RfD, TC or RfC, the more toxic the chemical and the lower the concentration above which there exists a potential for an adverse health effect.

5.1.3 Identification of Toxicity Values

The identification of toxicity values undertaken in this risk assessment has followed ANZECC (1992) guidance, which is in accordance with the NEPC (1999) policy. enHealth (2002) provides a list of toxicological data sources. These are classified as Level 1, 2 or 3 data, with Level 1 sources recommended. In order of preference the Level 1 sources are:

10. National Health and Medical Research Council documents and documents from other joint Commonwealth, State and Territory organisations.
11. ADI List from the Therapeutic Goods Administration.
12. World Health Organisation (WHO) documents.
13. enHealth Council documents.
14. National Environmental Health Forum documents.
15. International Agency for Research on Cancer (IARC) monographs.
16. WHO/FAO Joint Meeting on Pesticides (JMPR) monographs.
17. NICNAS Priority Existing Chemical (PEC) reports.
18. US Agency for Toxic Substances and Disease Registry (ATSDR) documents.
19. National Toxicology Program (NTP) carcinogenicity appraisals.
20. OECD Standard Information Data Sets (SIDS) and SID Initial Assessment Reports (SIAR).
21. EPA Reference Doses.

Level 2 sources include peer-reviewed journals and industry publications and reference to Level 2 sources is considered warranted where Level 1 sources do not provide applicable criteria. Level 3 sources are other sources not covered in Levels 1 or 2. The use of Level 3 sources requires justification that no other data is available and that the appraisal presented meets the required level of conservatism as required.

5.2 Toxicity Reviews

Toxicity profiles have been prepared for the COPC identified with the exception of dioxins. These profiles provide a review of potential health effects associated with exposure and identification of relevant toxicity values for the quantification of risk associated with oral, dermal and inhalation exposures. The toxicity profiles for the COPC identified in this assessment are presented in Appendix D of this report. The Department of the Environment and Heritage (DEH, 2004) has undertaken an extensive review of dioxins in Australia and have published a summary document "*National Dioxins Program, Dioxins in Australia: A Summary of the Findings of Studies conducted from 2001 to 2004*".

This document provides a summary of key exposures and health effects associated with dioxins and is also included in Appendix D of this report for reference.

Table 5.1 presents a summary of the toxicity evaluation and data identified for use in this risk assessment. The toxicity values have been reviewed by the DEC and NSW Health prior to use in this assessment.

The evaluation of potential exposure to mercury emissions from the proposed facility has adopted a conservative approach. Two toxicity values have been presented in Table 5.1 that are relevant to the assessment of oral exposures to mercury. Limited data is available with respect to expected mercury emissions from the proposed GTP hence the evaluation undertaken in estimating potential daily intake has been conservative. It is not considered likely that a significant proportion of the mercury released from the GTP facility will be in the form of methylmercury (which is usually found in fish). Rather the mercury emitted from the proposed GTP facility is more likely to be in the form of inorganic chlorides and oxides. However, to provide a conservative evaluation of exposures to mercury, the lower toxicity value for mercury, which is relevant to methylmercury has been used in this assessment. This approach is expected to overestimate the assessment of risk.

The toxicological data presented are considered to be appropriate for the assessment of risks to human health associated with the potential exposure to the COPC. It is accepted that toxicological data has some uncertainties (as outlined in Section 7 of this report). However, the approaches adopted by the different regulatory bodies in determining the relevant toxicological values are considered to be conservative and likely to overestimate the risks.

Table 5.1 – Summary of Toxicity for COPC

Chemical	Non-Cancer Toxicity Endpoint	Animal Carcinogen and Mechanism	Genotoxic	Oral Slope Factor (mg/kg/day)$^{-1}$	Oral TDI (mg/kg/day)	Inhalation Unit Risk (μg/m^3)$^{-1}$	Inhalation TC (or equivalent) (mg/m^3)	Occupational Inhalation Standard TWA (6) (mg/m^3)	Potential for background intake
Hexachlorobutadiene (HCBD)	Kidney	Yes, M,C	Equivocal	T	0.0002(3)	T	O	0.21	Refer to Section 6.3
1,2-Dichloroethane (EDC)	Liver	Yes, M,G	Yes	0.012(1),(3)	NT	(0.5 to 2.8)x10^{-6} (2) **2.8x10^{-6} proposed**	NT	40	---
Vinyl Chloride	Liver	Yes, G	Yes	2.3(1)	NT	4.4x10^{-6} adulthood **8.8x10^{-6} lifetime** (4)	NT	13	---
Chloroform	Liver, kidney, CNS	Yes, P, C	No	T	0.013(1)	4.2x10^{-7} (2)*	0.14(2)	10	Yes (50%)
Carbon Tetrachloride	Liver, kidney	Yes, P, C	No	T	0.00142(1)	T	0.0061(2)	0.63	Yes (65%)
Trichloroethene (TCE)	CNS, liver	Yes, P, C, MG	Equivocal	T	0.0238(1)	4.3x10^{-7} (2)	NT	54 (proposed)	Yes, low
Tetrachloroethene (PCE)	Liver, kidney, CNS	Yes, P, C, MG	No	T	0.014(3)	T	0.25(2)	335	Yes (34%)
Mercury	Elemental: CNS Inorganic: Kidney Methyl: CNS	No Equivocal Yes	--- No No	T	0.00071(1) for total mercury and **0.00023 for methylmercury(1)***	T	0.001(2) total mercury	Elemental:0.255 Divalent Inorganic:0.025 Monavalent Inorganic 0.1 Alkyl: 0.01	Yes (80%)
Dioxin (TEQ)	Hormonal, reproductive and developmental	Yes	No	T	1 to 4 pg/kg/day(2)) **2.3 pg/kg/day(8)**	T	1 to 4 pg/kg/day (2)) **2.3 pg/kg/day(8)**	NA	1.25 pg/kg/day based on data for young children (9)

(1) Derived from WHO Drinking Water Guidelines (1993, 1996, 1998 and 2004)

(1)* Derived from revision to PTWI for methylmercury provided by JECFA 2003

(2) Derived from WHO Air Quality Guidelines (2000, 2000b or CICAD 58 (2004) for chloroform).

Where a range is presented, the most conservative value (higher unit risk and lower ADI) has been adopted.

(3) Derived from NHMRC Australian Drinking Water Guidelines (1996 and draft 2002)

(4) Derived by USEPA (IRIS evaluations, current 2004)

(6) Occupational data available from NOHSC except where noted, TWA values based on 8-hour average

(8) Dioxin evaluation presented by NHMRC as presented by Therapeutic Goods Administration (TGA), endorsed 2002. Value recommended for use in risk assessment.

(9) Background intake derived from upper bound estimates from Australian data of 22% for adults and 54% for young children, National Dioxins Program, DEH 2004.

O Inhalation exposure evaluated using oral data as no relevant chronic inhalation data available

T Threshold approach adopted, hence no oral slope factor or inhalation unit risk considered relevant.

NT Non-threshold approach adopted

NA Not available

NG = Non-genotoxicC = Cytotoxic P = Peroxisome proliferation G = Genotoxic

M = metabolite mediated with questionable relevance to humans

MG = species specific α2-microglobulin mechanism

TEQ = Toxicity Equivalence

6.1 General

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure assessment and toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold health effects. Calculations of risk have been undertaken using an in-house Excel spreadsheet-based risk model RiskE (Version 4a, 2002). Calculations undertaken in the assessment of risk for each exposure pathway and receptor are presented in Appendix E of this report.

6.2 Approach and Assessment Criteria

6.2.1 Risk for Non-Threshold Effects

The potential for unacceptable non-threshold carcinogenic risks associated with exposure to COPC has been evaluated using US EPA methodology.

Non-threshold carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential non-threshold carcinogen. The numerical estimate of excess lifetime cancer risk is calculated as follows:

Carcinogenic Risk = Daily Chemical Intake • Cancer Slope Factor

The total non-threshold carcinogenic risk is the sum of the risk for each chemical for each pathway.

Deciding whether the calculated cancer risk is of concern or not requires identification of an acceptable cancer risk value. The calculation of a cancer risk implies that any exposure to these chemicals may result in an increased risk or probability of contracting cancer over a lifetime. The cancer risk value is expressed as a probability such as 1 in 10,000 ($1x10^{-4}$) or 1 in 1,000,000 ($1x10^{-6}$). At the simplest level these probability values can be converted to population risks as follows:

- An incremental lifetime cancer risk of $1x10^{-6}$, means that in a population of 1 million people which has been exposed to the chemical for their lifetime one additional cancer is predicted over and above the background incidence of cancer in that population (1 million people). For the same population a cancer risk of $1x10^{-4}$ implies that 100 additional cancers are predicted over and above the background incidence (for 1 million people).

These values are extremely low when compared to the background incidence of cancer in our society. The background incidence is in the order of 1 in 4 to 1 in 3 (Fitzgerald 1993). This means that for a population of 1,000,000 around 250,000 individuals are expected to contract cancer over a lifetime. An additional $1x10^{-6}$, risk predicts 1 additional individual may develop cancer.

Specific Australian guidance related to the significance of cancer risk estimates is not currently available. Current US EPA policy states that: *"Where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4},..action is generally not warranted unless there are adverse environmental impacts"* (US EPA, 1991). If risks are found to be greater than the 10^{-4} probability, then the US EPA recommends that a preliminary remediation goal of 10^{-6} cancer risk be developed as the point of departure (ibid).

A review of the origins of the 10^{-6} cancer risk number has been undertaken by Kelly (1991) and a review of the development of an Australian approach to the assessment of carcinogenic contaminants has been prepared for discussion by Fitzgerald (1993). Both these reviews indicate that the 10^{-6} was suggested by the United States Food and Drug Authority (USFDA) in 1961, as representing the *de minimis* legal risk. That is, the level of risk that can be identified, in a legal sense, as being representative of negligible or trivial risk. As the more recent US EPA policy (quoted above) indicates, the application of cancer risks has seen the acceptance of higher risk values i.e. 10^{-4} or 1 in 10,000 in the assessment of contaminated sites.

The application of cancer risk values in Australia and elsewhere is generally consistent with the US EPA policy. That is, the 10^{-6} risk value is commonly identified as the point of departure from negligible risk and the 10^{-4} risk value is commonly adopted as indicative of unacceptable risks. The 10^{-6} risk value is sometimes used as the basis for defining ambient standards applicable to wide scale population exposure, for example, the NHMRC and the Agricultural and Resources Management Council of Australia and New Zealand (NHMRC/ARMCANZ 1996) have used the 10^{-6} value for the derivation of the Australian drinking water guidelines for genotoxic carcinogens. The WHO, on the other hand, have used the 10^{-5} risk as the basis for the derivation of the WHO drinking water guidelines (WHO 1993) and the Dutch use the 10^{-4} lifetime cancer risk as the basis for the derivation of human Intervention Values for soil and groundwater for genotoxic carcinogens.

URS understand that a goal of 10^{-5} is generally accepted by Victorian EPA accredited auditors as indicating conditions that might warrant specific management or remedial action. URS is not aware of any stated policy by the NSW EPA.

Adopted Risk Targets

Based on the above discussion URS consider that the following guidance with respect to incremental lifetime cancer risks is representative of current practice in NSW:

- Calculated incremental risks below 1 x 10^{-6} would be considered to be effectively zero;
- Calculated incremental risks between 1 x 10^{-6} and 1 x 10^{-5} would be considered acceptable; and
- Calculated risks greater than 1x 10^{-4} would be considered to warrant some form of action or management to reduce the risk.

Where risks fall between 1 x 10^{-5} and 1 x 10^{-4}, then this may warrant further evaluation of the risks to determine whether action is required to reduce the risks.

URS have adopted a Target Risk value of 1 x 10^{-5} as indicating conditions that would warrant further assessment. Risks values below 1 x 10^{-5} are representative of acceptable risks.

6.2.2 Hazard Index for Threshold Effects

The potential for adverse threshold effects, resulting from exposure to a COPC, has been evaluated by comparing an exposure level, expressed as a daily chemical intake, with the adjusted acceptable daily intake (ADI) or equivalent threshold value (tolerable daily intake (TDI), reference dose (RfD) or TWA). The resulting ratio is referred to by the USEPA as the hazard quotient (USEPA, 1989) and is derived in the following manner:

$$Hazard\ Quotient = \frac{(Daily\ Chemical\ Intake\ from\ GTP)}{(ADI) - (Background\ Intake)}$$

The evaluation of risk associated with threshold chemicals involves a comparison of the total daily intake with the adjusted ADI. The adjusted ADI is that which has been adjusted for background intake from all other sources so that the hazard quotient calculated compares the chemical intake derived from the proposed GTP with the ADI allowable from sources other than background. If the total daily chemical intake exceeds the adjusted ADI, TDI, RfD or TWA (i.e. if the hazard quotient exceeds one), then this would indicate potentially unacceptable chemical intakes. The hazard quotient does not represent a statistical probability of an effect occurring.

To assess the overall potential for adverse health effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway have been summed. The resulting sum is referred to by the USEPA as the hazard index (HI) (USEPA, 1989). The HI approach assumes that multiple sub-threshold exposures to several chemicals could result in a cumulative adverse health effect, and exposures are summed over all intake routes.

If the Hazard Index is less than one, cumulative exposure to the site chemicals is judged unlikely to result in an adverse effect. If the index is greater than one, a more detailed and critical evaluation of the risks (including consideration of specific target organs affected and mechanisms of toxic action of the chemicals of concern) would be required to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

6.3 Background Intake of Threshold COPC

The calculation of risk associated with threshold chemicals (using a hazard index) presented above requires assessment of background intake.

Background exposure to chemicals in air has been accounted for in the initial stage of screening the predicted ground level concentrations as outlined in Section 3.3.7. The potential intake of COPC associated with key emissions from the proposed GTP are presented in Section 4.5. Background intake associated with typical urban exposures has been reviewed as part of the toxicity profiles for the COPC presented in Appendix D of this report. The following presents a discussion on the background intake values identified for the threshold COPC identified and potential relevance for use in the assessment of risk in areas surrounding the BIP. Other COPC identified have been evaluated on the basis of a non-threshold approach where background intake is not used in the assessment of risk (refer to Section 6.2.1).

6.3.1 Hexachlorobutadiene (HCBD)

No data is available regarding environmental levels of HCBD in Australia, other than noting that HCBD has not been found in drinking water in Australia (NHMRC 1996). HCBD is not a common urban air contaminant and as such background intakes of HCBD are generally considered to be negligible in urban areas of Australia. However in areas surrounding the BIP, possible emissions to air of HCBD have been identified and evaluated as part of the assessment of risks to human health associated with the HCB car park encapsulation (URS 2002b) which is located in the north-eastern corner of the BIP (near the athletics field). Whilst exposure to HCBD from this source will vary markedly across the area due to processes of dispersion, it is appropriate to allow for some contribution to the total intake of HCBD to derive from the HCB encapsulation. The worse case estimates from the HCB Car Park Health Risk Assessment indicates that exposure in the worst affected areas surrounding the car park may result in the following:

- Residential areas: intakes of HCBD of 30% to 60% (adult and children respectively) of the ADI;
- Recreational areas: intakes of HCBD of 10% to 20% (adult and children respectively) of the ADI by users of the athletics field; and
- Commercial/Industrial areas: intakes of HCBD of up to 0.1% of the adopted ADI.

It is noted that the adopted ADI used in the HCB Car Park HRA is the same as adopted in this assessment (refer to Table 5.1). On the basis of this data, background intake of HCBD has assumed to be up to 60% of the adopted ADI. This value has been adopted as representing background exposures in areas surrounding the BIP. It is noted that this approach is considered to be highly conservative for residential areas not located near the HCB car park area (i.e. areas not in the vicinity of the athletics field, where Denison Street, Fraser Street, Boonah Street and Smith Street intersect) as no other key sources of HCBD emissions are expected to be present in the area.

6.3.2 Carbon Tetrachloride

Intake of carbon tetrachloride from soil, water and food can be considered to be insignificant. Limited data is available, however intakes from air can be calculated from urban air concentrations from a light industrial area in Brisbane (Hawas, 2001) which indicate a background concentration of 0.0025 mg/m^3 (average) to 0.004 mg/m^3 (max) which is approximately 40 to 65% of the tolerable concentration in air (equivalent to an ADI) as adopted from the WHO (2000b). On this basis, the suggested threshold values should be adjusted to account for background intakes. Concentrations of carbon tetrachloride in air in areas surrounding the BIP are expected to reflect industrial urban air concentrations with no localised significant emission source of carbon tetrachloride expected. To provide a conservative assessment of potential exposure to carbon tetrachloride from the proposed GTP, background intake has been assumed to be 65% of the adopted tolerable concentration and ADI.

6.3.3 Chloroform

The average intake of chloroform from food, water and air has been estimated (WHO 2004) to be between 0.6 to 10 µg/kg/day. Data available from Australia indicate a similar range of potential intakes from water (NHMRC 1996) and air (Hawas 2001). Given the available TDI levels, it is considered relevant to assume a 50% intake from background. On this basis, the suggested threshold values for chloroform have been adjusted to account for 50% background intake.

6.3.4 Tetrachloroethene (PCE)

The intake of PCE from soil, water and food can be considered to be insignificant. Intakes from air have been calculated from industrial air concentrations reported in Brisbane (Hawas O. et. Al., 2001), with the average and maximum concentrations reported of 0.015 mg/m^3 and 0.085 mg/m^3 respectively (consistent with data from other cities, NICNAS 2001). This represents up to 34% intake from background air sources. On this basis, the oral TDI and inhalation GV identified have been reduced to account for approximately 34% background intake.

6.3.5 Mercury

Evaluation of background intakes for elemental mercury, inorganic mercury compounds and organic mercury compounds by Imray P. and Neville G. (CSMS,1996) indicates that background may contribute up to 50% of the ADI. Since the closure of the Chlor-Alkali plant in 2002, which was a key source of mercury emissions from the BIP, mercury emissions are expected to have reduced from the BIP. While other sources of mercury may be present within the BIP and other industrial sites in the area it has been assumed that background emissions are similar to those calculated by Imray and Neville (1996) in urban areas. Hence, background intake is expected to be up to 80% of the adopted ADI.

6.3.6 Dioxin

Dioxin exposures have been extensively reviewed by the Department of the Environment and Heritage (DEH, 2004). The summary of the findings is provided in Appendix D of this report. Review of potential intake of dioxins from all sources indicates that dioxin intake (based on upper bound estimates) may represent between 22% and 54% (adults and young children respectively) of the tolerable monthly intake (which can be used to calculate an ADI). These data are considered to be conservative as they are based on upper bound estimates. No other significant localised sources of dioxin emissions have been identified in the BIP area and hence the upper bound estimates provided by the DEH are considered to be relevant for the evaluation of exposure in the areas surrounding the BIP. Hence background intake is expected to be approximately 54% of the adopted ADI.

6.4 Summary of Risk

6.4.1 Risk Calculations

Table 6.1 presents a summary of the calculated non-threshold risks and threshold hazard indices estimated for potential exposure (reasonable maximum exposures) associated with normal operation of the GTP. Table 6.2 presents a summary of risk associated with the worst-case accidental release scenarios evaluated. It should be noted that the calculated risk presented in the Tables 6.1 and 6.2 has been rounded to 1 significant figure and hence totals presented may not add up to the sum of rounded values presented.

Further evaluation of risk has also been undertaken for the normal operations of the GTP and is presented in Table 6.3 for a range of specific locations surrounding the BIP site. These represent specific receptor locations modelled in the Air Quality Impact Assessment and include the following (refer to Diagram 6.1):

1. Botany Golf Course.
2. Banksmeadow Primary School.
3. Garnet Jackson Reserve.
4. Pagewood Primary School (corner Holloway Street and Dalley Avenue).
5. Botany Athletic Centre.
6. Denison Street north.
7. Denison Street south.
8. Girl Guide Hall.
9. Hoban House Retirement Village (Maroubra Road, Pagewood).
10. Marist College Pagewood (school located on Bunnerong Road, adjacent to Wentworth Avenue intersection)
11. Marist College Pagewood (school on Bunnerong Road, just south of Receptor 10)
12. Vera Lever Childcare Centre.
13. St Agnes’ Primary School (Bunnerong Road)
14. South Sydney High School.

Recreational areas such as the golf course, reserves, athletics fields and the girl guide hall have been evaluated on the basis of recreational inhalation exposure scenarios. Other areas which include residential areas and schools have been evaluated on the basis of residential type exposure scenarios which includes inhalation and multiple pathway assessment. This has been undertaken for schools as it is assumed that children will live near the school and undertake similar types of outdoor activities at school as would occur at home. The assessment for a child presented in the tables below is for a young child and will overestimate the risk for an older child as an older child will have a greater body weight and the intake of chemical per unit body weight will be lower for primary and secondary aged school children undertaking similar activities.

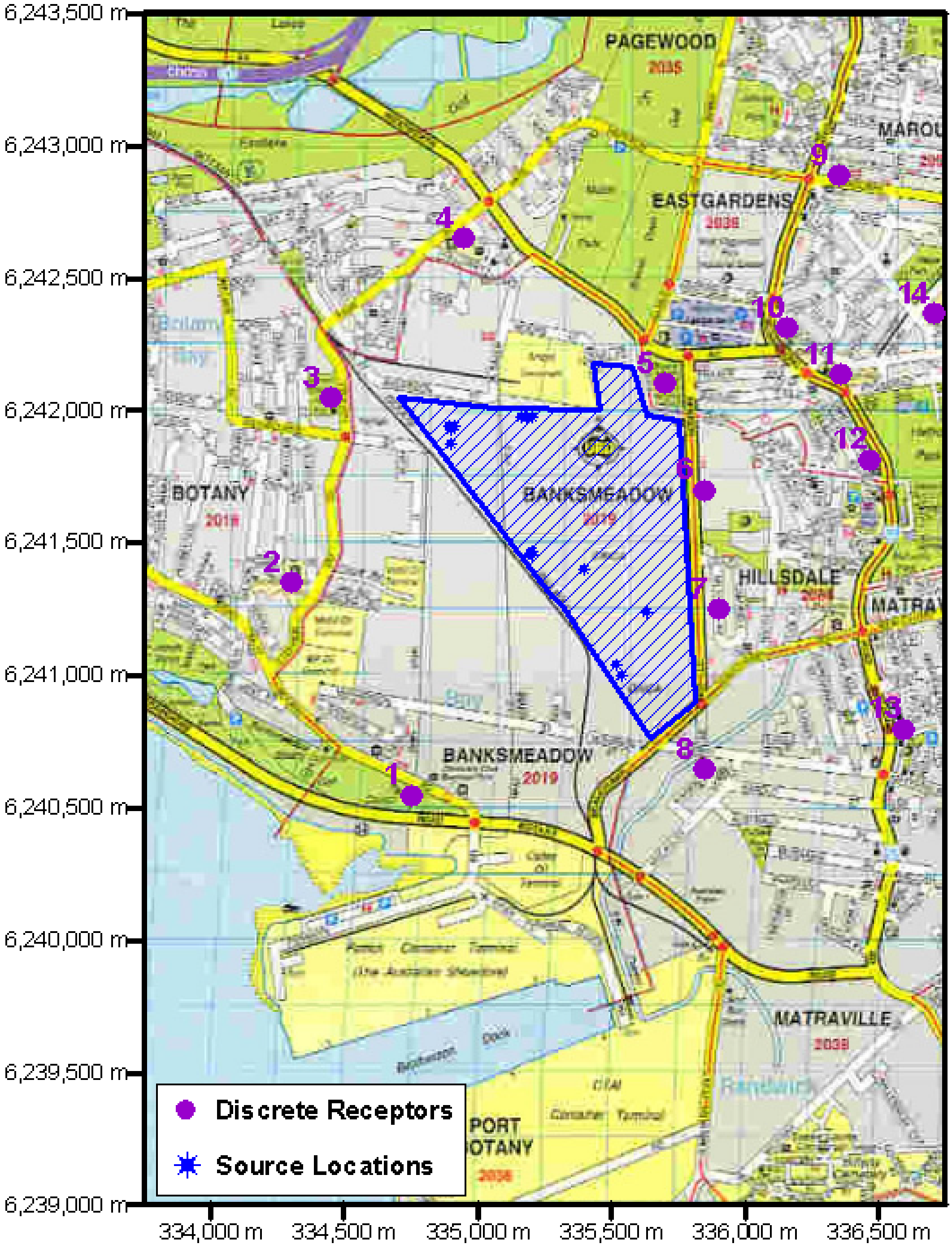


Diagram 6.1 Discrete Receptor Locations (ref: Air Quality Impact Assessment)

Table 6.1 – Summary of Risk Associated with Normal Operation of the GTP – Maximum

		Adults		Children		Infants	
Receptors and COPC	**Background Intake**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**
Residential Exposure							
Carbon tetrachloride	65%		0.007		0.02		
Chloroform	50%	2×10^{-9}	0.00007	4×10^{-10}	0.0002		
EDC	NA	5×10^{-7}		8×10^{-8}			
Vinyl Chloride	NA	5×10^{-9}		8×10^{-10}			
TCE	NA	3×10^{-9}		5×10^{-10}			
PCE	34%		0.00008		0.0002		
Dioxins**	54%		0.001		0.003		0.09
Mercury**	80%		0.00004		0.0001		0.00007
HCBD**	60%		0.0001		0.0003		0.003
TOTAL		**5×10^{-7}**	**0.009**	**8×10^{-8}**	**0.02**	**NA**	**0.1**
Recreational Exposure*							
Carbon tetrachloride	65%		0.0009		0.001		
Chloroform	50%	3×10^{-10}	0.000009	5×10^{-11}	0.00001		
EDC	NA	6×10^{-8}		1×10^{-8}			
Vinyl Chloride	NA	7×10^{-10}		1×10^{-10}			
TCE	NA	4×10^{-10}		8×10^{-11}			
PCE	34%		0.00001		0.00001		
Dioxins	54%		0.00008		0.0001		
TOTAL		**6×10^{-8}**	**0.001**	**1×10^{-8}**	**0.001**	**NA**	**NA**
Target Risk Levels	**Acceptable** **Negligible**	**1×10^{-5}** **1×10^{-6}**	**1**	**1×10^{-5}** **1×10^{-6}**	**1**		**1**

* Highest level of risk estimated from exercising and golfing activities for adult. ** Chemicals evaluated for multiple pathway exposure, other chemicals evaluated for inhalation only

NA – Not assessed as chemical has been evaluated on the basis of threshold HI. No non-threshold chemicals identified as COPC for relevant receptor and pathway.

Table 6.1 (continued) – Summary of Risk Associated with Normal Operation of the GTP – Maximum

		Adults		Children		Infants	
Receptors and COPC	**Background Intake**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**
Worker Exposure							
Carbon tetrachloride	33%		0.002				
Chloroform	50%	3×10^{-10}	0.00002				
EDC	NA	6×10^{-8}					
Vinyl Chloride	NA	7×10^{-10}					
TCE	NA	4×10^{-10}					
PCE	34%		0.00003				
Dioxins	54%		0.0002				
TOTAL		**6×10^{-8}**	**0.003**				
Target Risk Levels	**Acceptable** **Negligible**	**1×10^{-5}** **1×10^{-6}**	**1**				

* Highest level of risk estimated from exercising and golfing activities for adult. ** Chemicals evaluated for multiple pathway exposure, other chemicals evaluated for inhalation only

NA – Not assessed as chemical has been evaluated on the basis of threshold HI. No non-threshold chemicals identified as COPC for relevant receptor and pathway.

Table 6.2 – Summary of Risk Associated with Accidental Release Scenarios - Residents

		Adults		Children		Infants	
Receptor and COPC	**Background Intake**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**	**Non-threshold incremental risk**	**Threshold HI**
Increased Dioxin Emission over 12 months							
Other COPC normal operation		5×10^{-7}	0.008	8×10^{-8}	0.02		0.003
Dioxins**	54%		0.003		0.01		0.5
TOTAL		**5×10^{-7}**	**0.01**	**8×10^{-8}**	**0.03**	**NA**	**0.5**
Accidental Release – No Destruction							
Dioxins**	54%		0.00009		0.0002		0.006
Mercury**	80%		0.000005		0.00001		0.0002
HCBD**	60%		0.008		0.02		0.2
TOTAL		**NA**	**0.008**	**NA**	**0.02**	**NA**	**0.2**
Target Risk Levels	**Acceptable** **Negligible**	**1×10^{-5}** **1×10^{-6}**	**1**	**1×10^{-5}** **1×10^{-6}**	**1**		**1**

NA – Not assessed as chemical has been evaluated on the basis of threshold HI. No non-threshold chemicals identified as COPC for relevant receptor and pathway.

Table 6.3 – Risks Calculated for Off-Site Receptor Areas

Receptor Area	**Adult**		**Child**		**Infant**
	Total Non-Threshold Risk	**Total HI**	**Total Non-Threshold Risk**	**Total HI**	**Total HI**
Maximum (on-site)	**5×10^{-7}**	**0.009**	**8×10^{-8}**	**0.02**	**0.1**
1: Golf Course (Recreational)	3×10^{-9}	0.00005	na	na	na
2: Banksmeadow Primary School (Residential)	9×10^{-9}	0.0006	2×10^{-9}	0.001	0.04
3: Garnet Jackson Reserve (Recreational)	4×10^{-9}	0.00006	9×10^{-10}	0.0001	na
4: Primary School (Residential)	8×10^{-8}	0.002	1×10^{-8}	0.004	0.05
5: Botany Athletic Centre (Recreational)	8×10^{-9}	0.0001	2×10^{-9}	0.0002	na
6: Denison Street north (Residential)	1×10^{-7}	0.002	2×10^{-8}	0.005	0.05
7: Denison Street south (Residential)	2×10^{-7}	0.003	3×10^{-8}	0.008	0.06
8: Guides Hall (Recreational)	5×10^{-9}	0.00008	1×10^{-9}	0.0001	0.1
9: Retirement Village (Residential)	2×10^{-8}	0.0008	4×10^{-9}	0.002	0.04
10: School (Residential)	5×10^{-8}	0.001	8×10^{-9}	0.003	0.05
11: School (Residential)	4×10^{-8}	0.001	6×10^{-9}	0.003	0.04
12: Childcare Centre (Residential)	6×10^{-8}	0.001	9×10^{-9}	0.003	0.05
13: School (Residential)	5×10^{-8}	0.001	8×10^{-9}	0.003	0.05
14: South Sydney High (Residential)	3×10^{-8}	0.0009	4×10^{-9}	0.002	0.04
Target Risk Levels **Acceptable** **Negligible**	**1×10^{-5}** **1×10^{-6}**	**1**	**1×10^{-5}** **1×10^{-6}**	**1**	**1**

6.4.2 Discussion

Inhalation Exposures

Further evaluation of the assessment presented above for inhalation exposures only indicates the following:

- Approximately 97% of the calculated total non-threshold risk is derived from inhalation of EDC.
- Approximately 90% of the calculated total threshold HI (excluding infant exposure) is derived from inhalation exposure to carbon tetrachloride.
- The evaluation of exposure chemicals from the thermal oxidiser has been undertaken based on composition data provided by Orica. The emission rate of vinyl chloride is based on 7 g/hr during normal operation of the GTP. The maximum incremental lifetime risk associated with this emission has been calculated to be $5x10^{-9}$ (refer to Table 6.1), well below the risk level of $1x10^{-6}$ defined as negligible. Orica has proposed an emission limit for vinyl chloride of 50 g/hr, approximately 7 times higher than the emission rate assessed. Exposures relevant to the emission of vinyl chloride are associated with inhalation only; hence the calculated risk will be directly proportional to the emission rate the emission rate of vinyl chloride. On this basis, the risk associated with the proposed vinyl chloride emission limit will be approximately 7 times higher at $3.5x10^{-8}$, still less than the risk level associated with negligible risk and one tenth of the estimated total risk for an adult resident (Table 6.1). Emissions of vinyl chloride would need to increase by a factor of 200 before the risk increased above the level considered to be negligible.

Multiple Pathway Evaluation

In relation to persistent and bioaccumulative chemicals evaluated on the basis of multiple pathway exposures the following is noted:

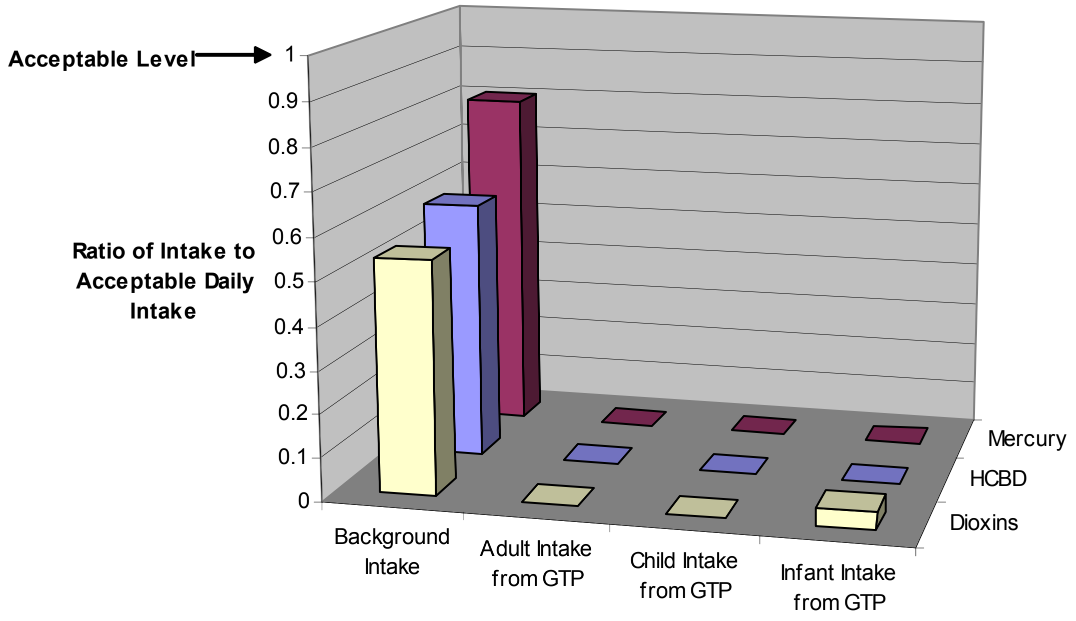
- Approximately 70% intake for adults and children is derived from inhalation exposures
- Approximately 30% intake for adults and children is derived from ingestion of chemicals which may accumulate in home-grown fruit and vegetable crops;
- The remaining intake (less than 1%) for adults and children is derived from contact with soils;
- The evaluation of infant exposure indicates that 98% of intake is derived from ingestion of organic chemicals which may accumulate in breast milk. Hence inhalation exposures are only a minor part of the infant exposure (2%);

- For the evaluation of risk associated with normal operations or the situation where dioxin emissions increase for a period of 12 months, the chemical which contributes most to the total risk is dioxin; and

- For the evaluation of risk associated with worst-case emissions, the chemical which contributes most to the total risk is HCBD.

Diagram 6.2 presents a graph of the calculated intake of persistent and bioaccumulative chemicals by residents during normal operation of the GTP. The graph illustrates the background intake (such as food, water and urban air) assumed for HCBD, mercury and dioxins as well as the estimated intake for adults, children and infants associated with exposure from the GTP. Observation of Diagram 6.2 indicates the negligible contribution of exposures associated with the operation of the GTP to the background intake and the adopted acceptable daily intake.

Diagram 6.2 - Intake of Persistent and Bioaccumulative Chemicals by Residents During Normal Operation of GTP



Total Risk in All Areas

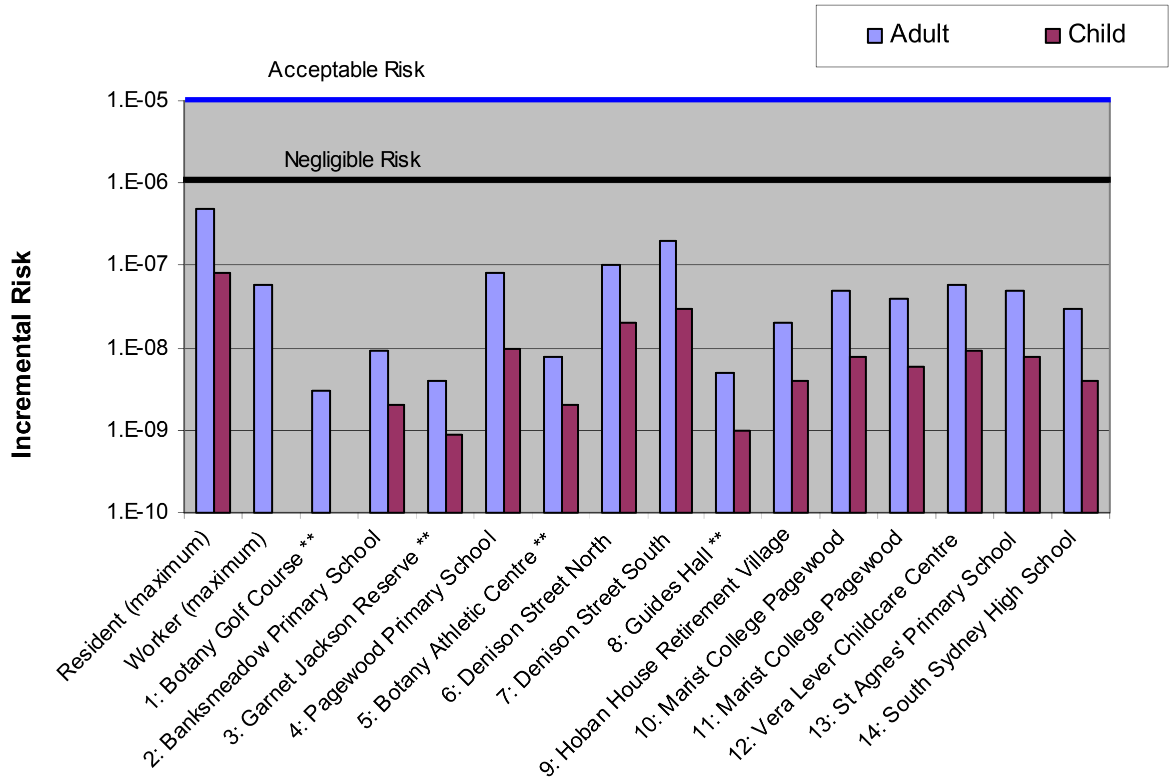
The total risk to human health associated with normal operation of the GTP is presented in Diagrams 6.3 (non-threshold risk) and 6.4 (threshold HI) for all areas evaluated in this risk assessment. Areas evaluated include:

- maximum concentration and deposition (located on the site) where residential and worker exposures have been calculated;
- off-site residential and school areas; and
- off-site recreational areas (denoted with ** in following diagrams)

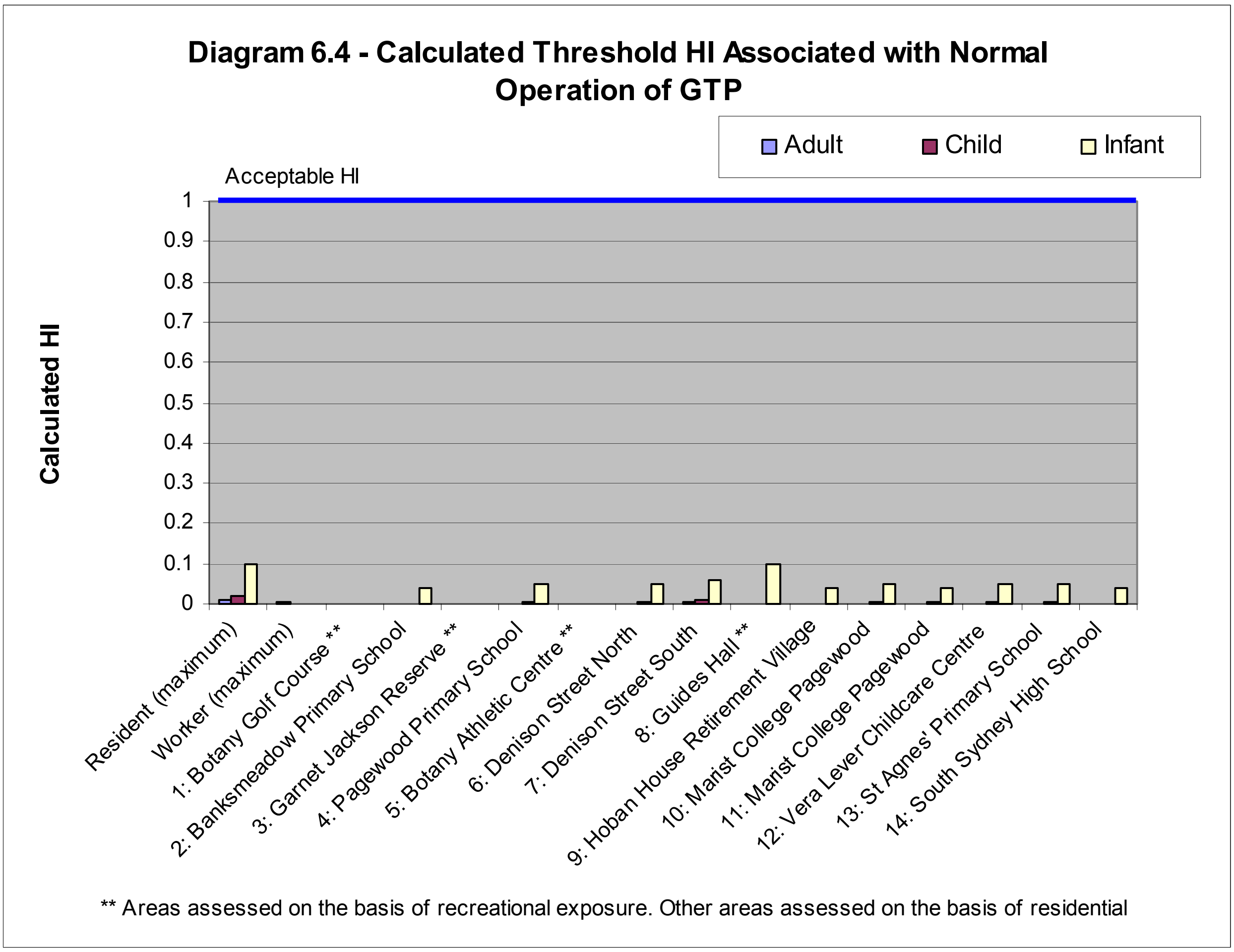
While some areas have been calculated individually, the maximum risk calculated is considered to be conservative for all areas on and off the site.

The diagrams illustrate that the contribution of intake for all COPC for normal operation of the GTP are associated with risks that are less than the acceptable (non-threshold risk of 1x10^{-5} and threshold HI of 1) and negligible (non-threshold risk of 1x10^{-6}) values.

Diagram 6.3 - Calculated Total Non-Threshold Risk Associated with Normal Operation of GTP



** Areas assessed on the basis of recreational exposure. Other areas assessed on the basis of residential exposure



6.4.3 Evaluation of Risk

The characterisation of risk associated with the operation of the proposed GTP has identified the following for the key receptors and pathways identified:

- Normal operation of the GTP:
  - The evaluation has focused on potential inhalation exposure to COPC identified in air following normal emissions from the thermal oxidiser and multiple pathway exposure (inhalation, ingestion and dermal contact with chemicals in soils, ingestion of home-grown fruit and vegetable crops and accumulation of chemicals in breast milk and subsequent exposure by infants).
  - Relevant receptors have been identified as residents (inhalation and multiple pathway exposure), recreational groups (inhalation only) and workers (inhalation only).

  - The total hazard index value for all receptor groups evaluated for all threshold COPC falls below 1. This indicates that the estimated intake associated with reasonable maximum exposures by all receptor groups plus background intakes, fall below the acceptable intake for the COPC as defined by the ADI (or equivalent including background intakes).
  - The total incremental lifetime risk for all receptor groups evaluated for all non-threshold COPC falls below the incremental risk level of 10^{-6} adopted as representative of negligible or effectively zero risk.
  - The evaluation of risk to human health associated with emissions during normal operation of the proposed GTP is therefore considered to be low and representative of negligible risks.
- Accidental releases from the GTP:
  - The evaluation has focused on potential inhalation and multiple pathway exposure to COPC identified in air following two worst-case accidental release scenarios identified for the thermal oxidiser.
  - Relevant receptors have been identified as residents (inhalation and multiple pathway exposure), as these are the most sensitive population group in the area.
  - The total hazard index value for all receptor groups evaluated for all threshold COPC falls below 1. This indicates that the estimated intake associated with reasonable maximum exposures by all receptor groups plus background intakes, falls below the acceptable intake for the COPC as defined by the ADI (or equivalent including background intakes).
  - The total incremental lifetime risk for all receptor groups evaluated for all non-threshold COPC falls below the incremental risk level of 10^{-6} adopted as representative of negligible or effectively zero risk.
  - The evaluation of risk to human health associated with emissions during the worst-case accidental release scenarios evaluated is therefore considered to be low and representative of negligible risks.

Because of the low to very low concentrations of other chemical emissions predicted from the GTP (normal operations and accidental releases), the cumulative impact of such chemicals on the estimated reasonable maximum risk for all receptor groups is also expected to be negligible.

These calculated levels of risk are indicative of acceptable levels of risk for potential exposures to the proposed GTP.

Combination of Receptors and Exposures

In characterising the risks it is also reasonable to assume that the following groups may also be present in the area:

- A resident who lives their whole life at the house (i.e. as an infant, child and an adult);
- A resident (adult or child) who also uses the athletics field, golf course or other parks for recreational activities; and
- A resident adult who also works for Orica, lives near the BIP and uses the athletics field, golf course or other parks for recreational activities.

It is not possible to characterise the risks for these groups by simply adding up the incremental risk or HI values for the following reasons:

- The risk or HI values reflect the calculated chemical intake associated with a particular activity averaged over the period of exposure (such as the time spent as a child or an adult, which is typically an extended period of time).
- The calculated chemical intake varies according to the activity due to physical factors (e.g. inhalation rate varying according to level of activity and body weight for children and adults) and, in the case of children, differing age groups (e.g. less than 5 year olds for residents and 5 to 12 year old children at the park) selected to ensure that the most sensitive group for a specific activity is assessed.
- The residents are assumed to spend all day every day at home. Thus while they are at work or at the park they are not at home and receive a lower chemical intake from either inside or outside of the house.

Not withstanding the above, the following conclusions can be made:

- The HI value for a resident who remains at one house for a whole lifetime (i.e. as a child and an adult) indicates that whilst they are a child (including an infant) they may have a greater daily intake of the COPC than when they are an adult. Thus as they grow older exposure reduces and the risk becomes less, with the HI value always less than one over this period of time (i.e. from infant to child to adult).
- The HI values for workers have been assessed on the basis of sensitive inhalation exposure values which are used to evaluate exposure by all groups including the more sensitive children and elderly. Workers on the Orica site would be expected to be assessed on the basis of occupational exposure standards in air (TWA values as presented in Table 5.1). These values are designed to be protective of exposures by the working population and are less conservative than the approach presented.
- The calculated exposure by on-site and off-site workers during work hours would be expected to be similar to the calculated exposure for the time spent at home living near the site. This is because the

intake parameters would remain essentially the same and the concentrations of COPC would not be higher than used in this assessment (as the maximum concentrations have been used). In fact it is more likely that the concentrations in commercial and residential areas off-site will be lower than those used in this assessment (noted in Table 6.3). Thus an adult resident who also works on site or near the site would be expected to have a similar chemical intake as an adult resident that stays at home 24 hours per day.

- An adult or child resident who also spends time at the athletics field or golf course might be expected to have a higher chemical intake during the time they are at the playing field due to higher inhalation rates whilst they are actively exercising. However, this would only occur for a relatively small proportion of the total hours that a resident might be exposed to the COPC (i.e. 24 hours per day 365 days per year). Nonetheless, this may mean that the average intake for a resident who also exercises at the playing field may, using the worst-case assumptions would be higher than the resident who doesn't exercise at the playing field. The resultant level of risk and HI value would therefore be greater than that calculated for residents (see Table 6.3), however, it would remain below the acceptable risk levels as it would be less than the sum of the full time resident and the recreational user which is less than 10^{-6} (incremental risk) and 1 (threshold HI).
- The calculation of risk associated with the GTP are low and if it were assumed that the risks should be added to those calculated for residents along the western margin of the northern plumes[4] (URS 2003), then the total risk and HI would remain less than the acceptable risk target, and the increase in risk attributable to the GTP being negligible.

In conclusion, the calculated exposures to the COPC are indicative of negligible risks for all of the receptors considered. As the calculations have been undertaken for worst-case scenarios both in terms of concentration and potential human exposure, it can be concluded that the risks to human health associated with emissions from the proposed GTP are negligible.

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[4] Evaluation involved an assessment of risk associated with use of groundwater in backyard (sprinkler use, irrigation and in wading pool), irrigation of homegrown fruit and vegetable crops and inhalation of volatile chemicals which may migrate from the groundwater plume into the ambient and indoor air.

Uncertainties

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Sampling and analysis;
- Receptor exposure assessment; and
- Toxicological assessment.

The risk assessment process following enHealth, NEPM, ANZECC/NH&MRC and USEPA guidance documents provide a systematic means for organising, analysing and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. This section discusses the uncertainties and limitations associated with this risk assessment. Table 7.1 summarises the major uncertainties associated with the conduct of the risk assessment and their potential affect on the outcome and conclusions.

Table 7.1 - Uncertainties

Uncertainty	Potential Impact	Comments
Issue Identification		
Available data on the proposed operation of the GTP – emissions to water, air and accidental releases	May underestimate or overestimate emissions.	Data provided by Orica. Where limited data is available, conservative assumptions adopted which is expected to overestimate risk.
Exposure Assessment		
Use of assumptions to characterise potential exposures to chemicals in the air.	Over-estimate actual risk.	All exposure assumptions have been based on relevant guidance or scientific judgement. The assumptions tend to be conservative, particularly those adopted for the assessment of reasonable maximum exposure.
Use of maximum GLC and deposition rate in the calculation of chemical intake.	Over-estimate actual risk.	The maximum GLC or deposition rate identified from the air dispersion modelling may occur on the BIP. Concentrations in off-site areas, residential, recreational and occupational are lower than used in the assessment.

Uncertainty	Potential Impact	Comments
Models used to estimate soil concentrations, plant concentrations and breastmilk concentrations.	Under or over-estimate actual risk.	Models have not been fully validated for all chemicals and soil types. In general, the models adopted are generally considered to be conservative.
Toxicological Assessment		
Extrapolating from one species to another. Extrapolating from the high exposure doses, usually used in experimental animal studies, to the lower doses usually estimated for human exposure situations.	Over-estimate actual risk	The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short term or subchronic animal studies to humans exposed over a lifetime has inherent uncertainty. In order to adjust for these uncertainties, ADIs and RfDs incorporate safety factors that may vary from 10 to 1000. The US EPA assumes that humans are as sensitive to carcinogens as the most sensitive animal species. The policy decision, while designed to minimise the potential for underestimating risk, introduces the potential to over estimate carcinogenic risk. It also does not allow for the possibility that humans may be more sensitive than the most sensitive animal species. The model used by the US EPA to determine slope factors is a linearised multistage model, which provides a conservative estimate of cancer risk at low doses and is likely to overestimate the actual slope factor. It is assumed in this approach that a genotoxic mechanism applies, however, most carcinogens do not actually cause cancer by this mechanism. The result is that the use of slope factors has the general effect of overestimating the incremental cancer risks.
Evaluating risks to mixtures of chemicals assumes dose additively.	May over or under-estimate actual total risk.	The approach for evaluating risks to mixtures of chemicals assumes dose additively and does not account for potential synergism, antagonism or differences in target organ specificity and mechanism of action. In general, the additively approach has the effect of over estimating the risks. This is because chemicals that have no additive effects are included together as well as chemicals which may have additive effects.

Conclusions

Risks to human health associated with the construction and operation of the proposed GTP facility have been evaluated using a systematic approach as outlined in guidance provided by enHealth (2002). This includes the identification of key issues, evaluation and quantification of exposure, evaluation and quantification of hazards or chemical toxicity and the characterisation of risk.

On the basis of the information available on the proposed GTP the following key issues have been identified and have been evaluated in detail in the health risk assessment:

- Inhalation exposure by residents, recreational users in the area and workers to chemicals identified in air following normal emissions from the thermal oxidiser;
- Multiple pathway exposure by residents to persistent and bioaccumulative chemicals which may be emitted to air during normal operation of the thermal oxidiser;
- Inhalation and multiple pathway exposure by residents associated with the potential upset operating condition which may give rise to increased dioxin emissions for up to 12 months; and
- Multiple pathway exposure by residents to persistent and bioaccumulative COPC which may be emitted to air following the worst-case accidental release where no destruction occurs in the thermal oxidiser for up to 12 hours.

The assessment presented has indicated that exposure by residents, recreational users of areas surrounding the BIP and workers are negligible and representative of acceptable risks to human health.

In addition to this conclusion, review of proposed GTP facility with respect to potential risk to human health has highlighted the following:

- The construction and operation of the proposed GTP is expected to be undertaken using an appropriate occupational health and safety plan for construction workers on the site as well as long-term employees in the facility. The plan should require the preparation of safe work method statements to address specific activities; and
- All operational procedures and controls noted in the Preliminary Hazard Analysis should be followed.

The assessment of operational conditions (normal and worst-case releases) has been based on estimated emissions from the facility which are expected to be conservative; however emissions from the facility once operational should be monitored and re-evaluated against the assumptions used in this risk assessment.

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Limitations

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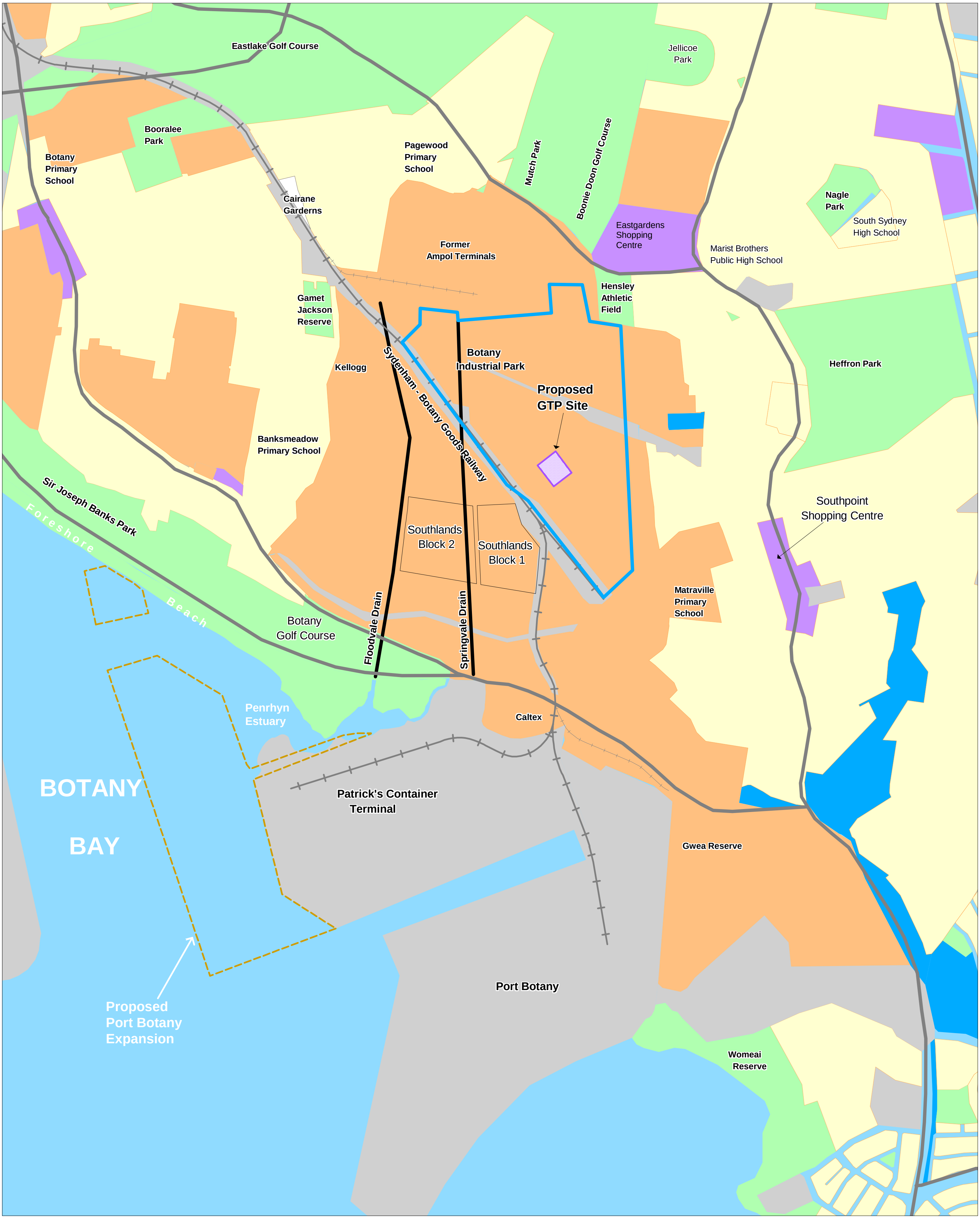
The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared in November 2004 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Figures

FIGURE 1
Surrounding Land Use



LEGEND

- 🟨 Residential
- 🟪 Business
- 🟧 Industrial
- 🟩 Open Space & Recreation
- 🟦 Non Urban
- ⬜ Major Infrastructure

- ▨ GTP Site
- ▭ BIP Boundary
- ― Main Roads
- ┅ Proposed Port Botany Expansion

0 300 600
meters

N W E S

PROJECT: 39408 - 033
FILE NAME: Figure 10-1.WOR
DATE: 11/11/2004
PROJECTION: MGA Zone 56

URS

FIGURE 2

Botany Groundwater Cleanup Overview

Aerial Photo Source: Webmap Pty Ltd, captured 2000. © Webmap Pty Ltd.

LEGEND

🟧	Treated Water Discharge
🟨	Treated Water Distribution
🟥	DNAPL Pipeline
🟦	Primary Pipeline
🟩	Secondary Pipeline
▨	GTP Site
▭	Hydraulic Containment Lines

PROJECT: 39408 - 033
FILE NAME: Figure 1_3.WOR
DATE: 11/11/2004
PROJECTION: MGA Zone 56

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Appendices

Appendix A

Screening of Treated Water Quality

Appendix A
Screening of Treated Water Quality

A1.1 Introduction

This appendix presents the evaluation of proposed treated water quality from the GTP. As discussed in Section 3.3.6 of the Health Risk Assessment Report, treated water can be screened against human health risk based guidelines to determine whether chemicals in the reuse or discharge water require further assessment.

Discharge water has been screened against relevant drinking water guidelines (these include the Australian Drinking Water Guidelines (1996), World Health Organisation drinking Water Guidelines (2004) and the USEPA Region IX Preliminary Remediation Goals for Tap Water (October 2004)). The health-based guideline values are concentrations, which based on present knowledge, would not result in significant risk to the health of a consumer of the water over a lifetime.

This approach is conservative for the assessment of water proposed to be reused on the site or discharged into a canal and Botany Bay where dilution will occur after discharge. In addition none of these areas are accessed by the general public. On this basis it is considered reasonable to include an exposure modifying factor to the drinking water guidelines. This factor reflects the lower contact rates with the discharge water compared with drinking water. The drinking water guidelines assume the consumption of 2L of water per day every day. The derivation of recreational water quality guidelines by ANZECC (2000) assumes that recreational contact may involve ingestion of 100 mL per day. Using these water ingestion rates the drinking water guidelines used for the purpose of screening discharge water can be multiplied by a modifying factor of 20 (2 L per day/0.1 L per day).

These screening levels are considered conservative as it is noted that the reuse of water on the site will be within closed systems and discharge to the canal and Botany Bay involves dilution and discharge to an area that would not be used for recreational activities such as swimming.

Table A1 presents the proposed quality of the treated water, available guidelines from the Australian Drinking Water Guidelines, WHO Drinking Water Guidelines and the US Region IX PRG;s (in order of preference), and the adopted modified recreational water screening level.

It is noted that three of the chemicals listed in table A1 have been compared against the screening level (PRG) relevant to threshold effects. A detailed review of toxicity of key chemicals identified in groundwater (as evaluated in the Stage 2 Risk Assessment, Woodward-Clyde 1996) has been undertaken in October 2004 with review by DEC and NSW Health. On the basis of the review undertaken for the three chemicals identified, namely 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane and hexachloroethene (summarised in Table A2), it is considered inappropriate (and conservative) to adopt PRGs which have been derived using a non-threshold approach for the assessment of oral exposures. PRGs are derived for both non-threshold carcinogenic effects and threshold (non-carcinogenic) effects with the lower value suggested as the overall PRG for the chemical. Both evaluations are available for the tap water PRG derived for the three chemicals identified. Review of the adopted threshold oral toxicity value (reference dose) used for the threshold PRG with that suggested following review of these chemicals by URS (Table A2) indicates that these values are equal and hence the threshold PRGs are appropriate for use in the screening of these chemical.

Appendix A
Screening of Treated Water Quality

No concentrations in treated water exceed the adopted screening levels for recreational water contact and hence no chemicals of potential concern have been identified.

Table A1 – Screening of Treated Water with Health Risk Based Screening Levels (Recreational Contact)

Name	Specification Treated Water mg/L	RO Effluent mg/L	Guidelines (mg/L) ADWG	WHO DWG	US PRG		Adjusted Screening Level (mg/L)
1.1.1.2-Tetrachloroethane	0.0005	0.0005			0.0004		0.008
1.1.2.2-Tetrachloroethane	0.4000	0.4000			0.365	T	7.3
1.1.2-Trichloroethane	0.0050	0.0050			0.024	T	0.48
1.1-Dichloroethane	0.0300	0.0300			0.81		16.2
1.1-Dichloroethene	0.0070	0.0070	0.03				0.6
1.2-Dichloroethane	0.0030	0.0030	0.003				0.06
Carbon Disulphide	0.0200	0.0200			1		20
Carbon tetrachloride	0.0030	0.0030	0.003				0.06
Chloroethane	0.0005	0.0005			0.0046		0.092
Chloroform	0.2500	0.2500	0.25				5
Chloromethane	0.0005	0.0005			0.16		3.2
cis-1.2-Dichloroethene	0.0600	0.0600			0.061		1.22
Methylene chloride	0.0040	0.0040	0.004				0.08
Tetrachloroethene	0.0500	0.0500	0.05				1
trans-1.2-Dichloroethene	0.0600	0.0600			0.12		2.4
Trichloroethene	0.0050	0.0050		0.07			1.4
Vinyl chloride	0.0003	0.0003	0.0003				0.006
Hexachloroethane	0.2900	0.2900			0.036	T	0.72
Hexachlorobutadiene	0.00003	0.00003	0.0007				0.014
Benzene	0.0010	0.0010	0.001				0.02
Toluene	0.0250	0.0250	0.8				16
2-Methylphenol	1.8000	1.8000			1.8		36
3- & 4-Methylphenol	0.1800	0.1800			0.18		3.6
Chlorobenzene	0.0100	0.0100	0.3				6
1.2-Dichlorobenzene	0.0010	0.0010	1.5				30
1.3-Dichlorobenzene	0.0200	0.0200	0.02				0.4
1.4-Dichlorobenzene	0.0003	0.0003	0.04				0.8
2.4-Dichlorophenol	0.0003	0.0003			0.11		2.2
2.6-Dichlorophenol	0.0340	0.0340					0
1.2.4-Trichlorobenzene*	0.0050	0.0050	0.03				0.6
2.4.5-Trichlorophenol	0.0005	0.0005			3.6		72
2.4.6-Trichlorophenol	0.0020	0.0020	0.02				0.4
2-Chlorophenol	0.0001	0.0001			0.03		0.6
Phenol	0.0020	0.0020			11		220
Arsenic	0.0070	0.0450	0.007				0.14
Cadmium	0.0002	0.0055	0.002				0.04
Chromium	0.0010	0.0044	0.05				1
Copper	0.0013	0.0013	2				40
Iron	0.3000	0.3000	0.3				6
Lead	0.0044	0.0044	0.01				0.2
Mercury	0.0004	0.0004	0.001				0.02
Nickel	0.0200	0.0700	0.02				0.4
Zinc	0.0150	0.0150	3				60
Selenium - Filtered	0.0050	0.0800	0.01				0.2
Manganese - Filtered	0.0800	0.0800			0.88		17.6
2,4-D	0.0300	0.2800	0.03				0.6
Aluminium - Filtered	0.0005	0.0005	0.2				4
Barium - Filtered	0.7000	-	0.7				14
Cyanide (Free)	0.0040	0.0040	0.08				1.6
Silver - Filtered	0.0014	0.0014	0.1				2

ADWG - Australian Drinking Water Guideline (1996)

WHO DWG - World Health Organisation Drinking Water Guideline (2004)

US PRG - US Region IX Preliminary Remediation Goal for Tap Water (October 2004)

T - Use of PRG relevant to threshold evaluation of chemical, evaluation using cancer slope factor not relevant following review in accordance with enHealth guidance

Table A2 – Summary of Toxicity for Key Chemicals

Chemical	**Non-Cancer Toxicity Endpoint**	**Animal Carcinogen and Mechanism**	**Genotoxic**	**Oral Slope Factor (mg/kg/day)$^{-1}$**	**Oral TDI (mg/kg/day)**	**Inhalation Unit Risk (µg/m^3)$^{-1}$**	**Inhalation TC (or equivalent) (mg/m^3)**	**TWA $^{(6)}$ (mg/m^3)**	**Potential for background intake**
Hexachloroethane (HCE)	Kidney, CNS	Yes, C, MG	No	T	0.001$^{(4)}$	T	O	9.7	Negligible
1,1,2-Trichloroethane	Liver, immune	Yes, C	No	T	0.004$^{(4)}$	T	O	55	Negligible
1,1,2,2-Tetrachloroethane	Liver	Equivocal	Equivocal	T	0.04$^{(5)}$	(0.6 to 3)x10^{-6} $^{(2)}$ 3x10^{-6} proposed	NT	6.9	---

(1) Derived from WHO Drinking Water Guidelines (1993, 1996, 1998 and 2004)
(2) Derived from WHO Air Quality Guidelines (2000, 2000b or CICAD 58 (2004) for chloroform). Where a range is presented, the most conservative value (higher unit risk and lower ADI)has been adopted.
(3) Derived from NHMRC Australian Drinking Water Guidelines (1996 and draft 2002)
(4) Derived by USEPA (IRIS evaluations)
(5) Derived by ATSDR (chronic exposures)
(6) Occupational data available from NOHSC except where noted, TWA values based on 8-hour average
(7) Occupational data available from ACGIH, TWA value based on 8-hour average
(8) Dioxin evaluation presented by NHMRC as presented by Therapeutic Goods Administration (TGA), endorsed 2002. Value recommended for use in risk assessment.
(9) Background intake derived from upper bound estimates from Australian data of 22% for adults and 54% for young children, National Dioxins Program, DEH 2004.
O Inhalation exposure evaluated using oral data as no relevant chronic inhalation data available
T Threshold approach adopted, hence no oral slope factor or inhalation unit risk considered relevant
NT Non-threshold approach adopted NA Not available

NG = Non-genotoxic C = Cytotoxic P = Peroxisome proliferation G = Genotoxic
M = metabolite mediated with questionable relevance to humans
MG = species specific α2-microglobulin mechanism

Appendix B

Identification of Urban Air Contaminants

Contents

Appendix B Identification of Urban Air Contaminants

Appendix B
Identification of Urban Air Contaminants

B1.1 Introduction

It is the DEC's position that an individual chemical hazard goal utilised within a risk assessment associated with the air environment should depend on whether the chemical is likely to have a number of sources other than the source being assessed. To assess the potential for the range of chemicals relevant to emissions associated with the GTP, a review of data in Sydney has been undertaken. Data collected within the urban air in Sydney, which relates to the composition of volatile organic compounds in the air has been reviewed.

B1.2 Urban Air in Sydney

The NSW EPA published a review of hazardous air pollutant studies in Australia and New Zealand in 1999. In Sydney, measurements of volatile organic compounds and non-methane hydrocarbons have been undertaken by a number of organizations. These include:

- The CSIRO Division of Coal and Energy Technology, which has collected data between 1976 and 1993. Samples were collected from a number of locations within the urban air environment.
- The Department of Chemistry, University of Technology, Sydney, which collected levels of benzene and toluene in Sydney in 1994.
- The NSW EPA collected data on the levels of volatile organic compounds within ambient air near the Castlereagh Waste Management Centre in 1995. As part of the study two background sites were sampled within the Sydney region.
- The NSW EPA also collected samples from a number of suburban locations within Sydney as part of a Pilot Air Toxics Program from 1995 to 1998. Areas sampled included Botany, Mascot, City and other suburban areas.

Data collected from these studies indicated that a range of organic compounds was commonly reported within the ambient air in Sydney. The following presents a listing of the chemicals that have been detected in these studies[1,2].

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[1] NSW EPA, June 1999. *Hazardous Air Pollutants. A Review of Studies Performed in Australia and New Zealand*. New South Wales Environment Protection Authority, Publication 650.

[2] Linfoot S. and Freeman K. (1998). *Measurement of Ambient Levels of Selects Air Toxics in the Greater Sydney Region*. Proceedings of the 14th International Clean Air and Environment Conference, Melbourne, 18-22 October 1998, p324-330.

Appendix B
Identification of Urban Air Contaminants

Listing of Organic Chemicals detected in Sydney's Air

acetaldehyde
acetophenone
benzene
1,3-butadiene
carbon tetrachloride
chlorobenzene
chloroform
chloroethane
cumene
m-dichlorobenzene
o-dichldrobenzene
1,1-dichloroethane
1,2-dichloroethane
dichloromethane
trans-1,3-dichloropropene
ethylbenzene
ethylchloride
ethylene
4-ethyltoluene
freon 11
freon 113
freon 12
hexane
methanol
methyl chloride
methyl chloroform
naphthalene
propionaldehyde
methyl ethyl ketone
methyl isobutyl ketone
styrene
tetrechloroethylene
toluene
1,2,4-trichlorobenzene
1,1,2-trichloroethane
trichloroethylene
1,3,5-trimethylbenzene
2,2,4-trimethylpentane
vinyl acetate
vinyl chloride
o-xylene
m-xylene
p-xylene

Note that no hexachlorobutadiene (HCBD) was detected in any of the studies noted above in Sydney, however HCBD was identified as a key chemical in air associated with the HCB carpark Health Risk Assessment (URS, 2001), it has been included as a background contaminant in the areas surrounding the Orica site.

B1.3 Selection of Hazard Goal for Chemicals Assessed

The selection of the individual chemical hazard goal for the range of chemicals assessed in the HCB Carpark Waste risk assessment has been undertaken using the following method:

- Where a chemical is identified as a chemical commonly found in Sydney urban air (as listed above) or considered background air chemicals in the area, the hazard goal has been set at 0.1 for chemicals assessed on the basis of threshold effects and $1x10^{-7}$ for chemicals assessed on the basis of non-threshold carcinogenic effects.

- For other chemicals, it has been assumed that these are associated with emissions from the GTP and are localised. For these chemicals, a hazard goal has been set at1 for chemicals assessed on the basis of threshold effects and $1x10^{-6}$ for chemicals assessed on the basis of non-threshold carcinogenic effects.

On this basis, the key air chemicals associated with the GTP can be grouped into two main assessment groups.

- The first associated with commonly found chemicals within the Sydney Urban air environment and considered background chemicals in the area; and

- The second associated with localised emissions to air.

These can be grouped as listed in the following table.

Appendix B

Identification of Urban Air Contaminants

Grouping of the Key Air Chemicals for Hazard Assessment

Urban Air Chemicals	**Local Chemicals**
Goals 0.1 for threshold effects* *1x10^{-7} for non-threshold effects*	*Goals 1 for threshold effects* *1x10^{-6} for non-threshold effects*
Benzene	Carbon disulphide
Carbon Tetrachloride	2-Chlorophenol
Chloroethane	1,2-Dichlorobenzene
Chlorobenzene	1,1-Dichloroethene
Chloroform	cis-1,2-Dichloroethene
Chloromethane	trans-1,2-Dichloroethene
1,3-Dichlorobenzene	2,4-Dichlorophenol
1,4-Dichlorobenzene	2,6-Dichlorophenol
1,1-Dichloroethane	Hexachloroethane (HCE)
1,2-Dichloroethane (EDC)	2-Methylphenol
Dichloromethane (methylene chloride)	3&4-Methylphenol
Hexachlorobutadiene (HCBD)	Phenol
Tetrachloroethene (PCE)	1,2,4,5-Tetrachlorobenzene
Toluene	1,1,2,2-Tetrachloroethane
1,2,4-Trichlorobenzene	1,1,1,2-Tetrachloroethane
1,1,2-Trichloroethane	1,3,5-Trichlorobenzene
Trichloroethene (TCE)	2,4,5-Trichlorophenol
Vinyl Chloride	2,4,6-Trichlorophenol
Mercury	
Dioxins	

Appendix C

Acute Inhalation Assessment Criteria

Appendix C
Acute Inhalation Assessment Criteria

C1.1 Introduction

This appendix presents the criteria which are available for the evaluation of acute exposures to accidental or emergency releases of chemicals to air.

A range of different criteria are available for the assessment of potential human health effects associated with short-term emissions to air. No single organisation or methodology has developed acute criteria values or benchmarks for all potential compounds of concern. Hence, a hierarchical approach has been utilised for selecting existing guidelines for acute inhalation exposure levels.

Acute inhalation exposure criteria have been developed by a number of organisations which include: American Conference of Governmental Industrial Hygienists (ACGIH); Occupational Safety and Health Administration (OSHA); National Institute of Occupational Safety and Health (NIOSH); American Industrial Hygiene Association (AIHA), National Research Council on Toxicology (NRCT) USEPA; Agency for Toxic Substances and Disease Control (ATSDR), California Environmental Protection Agency (CalEPA); National Advisory Committee (NAC) and the US Department of Energy (DOE); Subcommittee on Consequence Assessment and Protective Actions (SCAPA); and Worksafe Australia.

The acute inhalation exposure criteria have been established by the above organisations and agencies to:

- Be protective of a range of exposure groups including occupational workers, military personnel and the general public;
- Based on a range of exposure durations, typically relevant to the exposure group, but ranging from 15 minutes, to 8 hours (typically for occupational settings) to 24-hours; and
- Protective of a range of toxicological endpoints such as mild discomfort, irritation, serious debilitating and potentially life-threatening effects up to and including death.

The hierarchical approach utilised in this assessment is based on that recommended by the USEPA Office of Solid Waste and detailed in the document "*Human Health Risk Assessment protocol for Hazardous Waste Combustion Facilities*" (Draft, July 1998). The hierarchical approach is focused on the protection of the general public, as well as the working population, and is summarised below in order of preference:

1. Acute Exposure Guideline Levels (AEGL's) developed by the NAC;
2. Emergency Response Planning Guidelines (ERPG's) developed by the AIHA and SCAPA;
3. Acute Reference Exposure Levels (AREL's) developed by the CalEPA
4. Temporary Emergency Exposure Limits (TEEL's) developed by SCAPA; and
5. SCAPA toxicity-based approach as presented by the DOE. These have not been used in this assessment, hence further reference and description is not provided.

C1.2 Acute Criteria

C1.2.1 Acute Exposure Guideline Levels (AEGL's)

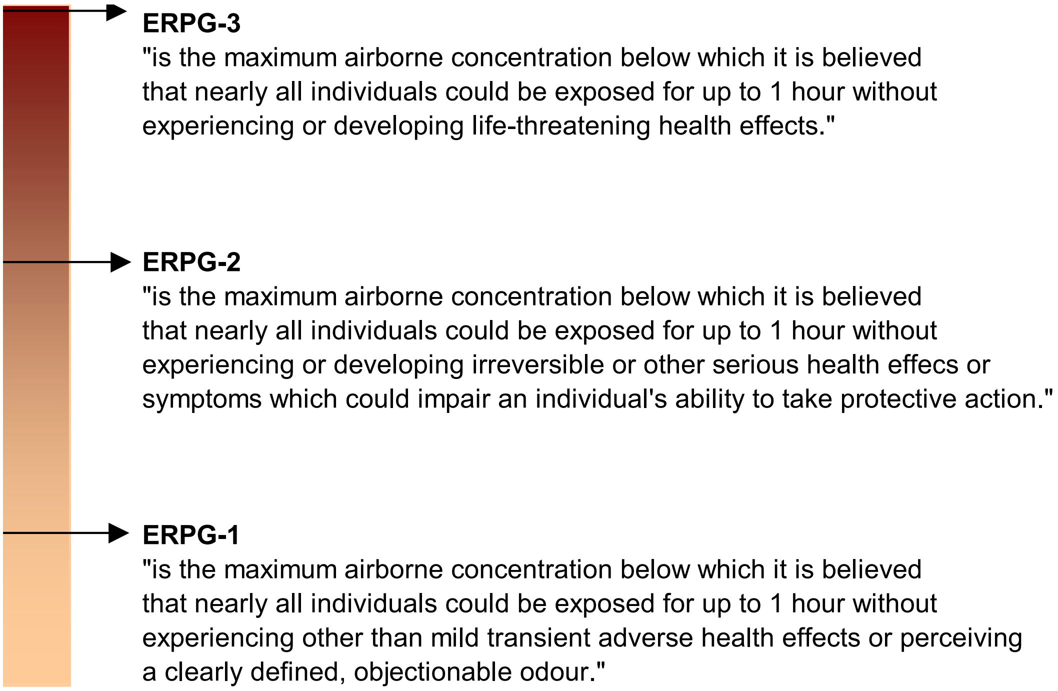
Acute Exposure Guideline Levels (AEGLs) are under development by the US National Research Council's Committee on Toxicology. The committee developed detailed guidelines for developing uniform, meaningful emergency response standards for the general public. The criteria in the guidelines take into account sensitive individuals and are meant to protect nearly all people. The committee has started to put the guidelines into practice in developing AEGLs for specific chemicals. The guidelines define three-tiered AEGLs as follows:

- ***AEGL 1***: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- ***AEGL 2***: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- ***AEGL 3***: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Each of the three levels of AEGL: AEGL-1, AEGL-2, and AEGL-3, have generally been developed for each of five exposure periods: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours.

C1.2.2 Emergency Response Planning Guidelines (ERPG's)

The Emergency Response Planning Guidelines (ERPGs) were developed by the ERPG committee of the American Industrial Hygiene Association. The ERPGs were developed as planning guidelines, to anticipate adverse human health effects caused by potential exposure to toxic chemicals. The ERPGs are a three-tiered guideline with one common denominator: a 1-hour contact (or average) duration. Each guideline identifies the substance, its chemical and structural properties, animal toxicology data, human experience, existing exposure guidelines, the rationale behind the selected value, and a list of references.



ERPG-3
"is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects."

ERPG-2
"is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effecs or symptoms which could impair an individual's ability to take protective action."

ERPG-1
"is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odour."

FIGURE C1 The three-tiered ERPG Exposure Guidelines. (Definitions and figure are from the ERPG publication).

The ERPG guidelines are not designed to be protective of all individuals. Hypersensitive individuals may suffer adverse reactions to concentrations far below those suggested in the guidelines. ERPGs do not contain safety factors usually incorporated into exposure guidelines such as the AEGL. Rather, they estimate how the general public would react to chemical exposure.

C1.2.3 Acute Reference Exposure Levels (AREL's)

Acute Reference Exposure Levels (AREL) have been established by the California EPA (Air Resources Board) for the protection of all individuals from any health impacts associated with short-term emissions to air. The AREL is an exposure level that is not likely to cause adverse health effects in human populations, including sensitive individuals, exposed to those concentrations for 1-hour on an intermittent basis. They are not specifically designed for accidental release situations but are designed for assessing the acute impacts of normal operations (with typical fluctuations). The derivation of the levels includes the use of safety factors and is considered to protective of mild adverse effects, similar to the ERPG-1 or TEEL-1 level.

C1.2.4 Temporary Emergency Exposure Limits (TEEL's)

TEELs have been established (published by US DOE, January 2002) for a range of chemicals that are relevant for a range of potential health effects (defined as TEEL-0 to TEEL-3). They have been derived using an approved methodology utilised by the American Industrial Hygiene Association in developing a range of Emergency Response Planning Guidelines for a similar range of health effects (ERPGs, ranging from ERPG-1 to ERPG-3). ERPGs are only available for a small number of chemicals. The TEELs cover a much wider range of chemicals. TEELs are only considered "temporary" levels until ERPGs have been established for the chemical. Like ERPGs, they do not incorporate safety factors. Rather, they are designed to represent the predicted response of members of the general public to different concentrations of a chemical during an incident. TEEL's are a four-tiered guideline based as follows:

- **TEEL-0** The threshold concentration below which most people will experience no appreciable risk of health effects;
- **TEEL-1** The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odour. This level is similar to the ERPG-1;
- **TEEL-2** The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. This level is similar to the ERPG-2; and
- **TEEL-3** The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects. This level is similar to the ERPG-3.

TEEL's are recommended to be relevant to the assessment of peak 15-minute time-weighted average concentrations.

C1.3 Screening of Accidental release with Guidelines

Maximum ground level concentrations of VOCs, dioxins and mercury which may be released in the event that the thermal oxidiser is not operating have been modelled using an air dispersion model. The maximum concentrations have been screened against the following:

- 1-hour average concentrations used for screening long-term emissions (refer to text of report for detail) from the proposed GTP which are protective of all sensitive individuals for exposure over a lifetime. While these are not directly relevant for acute accidental release, they have been used to screen out chemicals where the predicted concentrations are very low and do not require further comparison. These screening levels have been used to identify chemicals which require evaluation against the more relevant acute inhalation assessment criteria.

Appendix C
Acute Inhalation Assessment Criteria

- Relevant acute inhalation assessment criteria selected as outlined above. Criteria currebt to 2004 have been used in this assessment. Note that the averaging times vary depending on the source of the criteria.

The following table presents the outcome of the comparison

Table C1 – Screening of Accidental release with Acute Inhalation Criteria

	Prediced GLC (ug/m3)			Long-Term Screening Level Concentration (ug/m3)	Cal AREL (ug/m3)	Accicental release exposure levels (AEGL, ERPG, TEEL) (ug/m3)				Relevant Criteria
Chemicals in Feed	**Max 1-hr**	**15-minute**		**1-hr**	**1-hr**	**Level-0**	**Level-1**	**Level-2**	**Level-3**	
Carbon Disulphide	7.941406614	10.47883694		7300						
Chloromethane	0.02102137	0.027738098		95						
Dichloromethane	1.728423792	2.28068804	u	4.1						
Chloroform	104.4395071	137.8099144	u	0.083	150 (7 hr)			313000	8301000	AEGL proposed 1 hr
Carbon Tetrachloride	329.3348037	434.563532	u	0.13	1900 (7 hr)		76000	352000	1070000	AEGL interim 1 hr
Chlorethane	0.02102137	0.027738098	u	2.3						
1,1-Dichloroethane	11.14466306	14.7055947	u	1.2						
1,2-Dichloroethane (EDC)	3530.255545	4658.239279	u	0.074		200000	202000	810000	1210000	ERPG (1hr) and TEEL-0 (15min)
1,1,2-Trichloroethane	17.05066714	22.49867932	u	0.12		50000	50000	100000	500000	TEELs (15-min)
1,1,1,2-Tetrachloroethane	0.02102137	0.027738098		2.6						
1,1,2,2-Tetrachloroethane	30.46430352	40.19822743		0.33		20000	20000	35000	600000	TEELs (15-min)
Hexachloroethane (HCE)	0.900915876	1.18877562		4.8						
Vinyl chloride	124.7935325	164.6674377	u	0.11	180000		639000	3067000	12269000	AEGL proposed 1 hr
1,1-Dichloroethene	9.876707385	13.03250309		2100						
cis-1,2-Dichloroethene	26.89400727	35.48715368		370						
trans-1,2-Dichlodoethene	5.005088202	6.604308997		730						
Trichloroethene (TCE)	150.4863186	198.5695572	u	0.017			699000	2418000	20422000	AEGL proposed 1 hr
Tetrachloroethene (PCE)	283.6216648	374.2441765	u	0.32	20000		237000	1560000	8140000	AEGL interim 1 hr
Hexacblorobutadiene (HCBD)	0.543886251	0.717668244	b	0.086		200	10700	32100	107000	ERPG (1hr) and TEEL-0 (15min)
Benzene	17.25087067	22.76285168	u	0.25			166000	2556000	12778000	AEGL proposed 1 hr
Chlorobenzene	0.032366237	0.042707865	u	62						
1,2-Dichlorobenzene	0.887568974	1.171164129		2100						
1,3-Dichlorobenzene	0.020687698	0.027297811		3.3						
1,4-Dichlorobenzene	0.653998192	0.862963042		0.31		400000	600000	600000	750000	TEELs (15-min)
1,2,4-Trichlorobenzene	0.030364202	0.040066141	u	3.7						
1,3,5-Trichlorobenzene	0.000333673	0.000440287	u	37						
1,2,4,5-Tetrachlorobenzene	0.002002035	0.002641724		11						
Toluene	0.07340796	0.096863199	u	400						
Phenol	0.048382519	0.063841654		11000						
2-Chlorophenol	0.229566712	0.302917639		180						
2,4-Dichlorophenol	2.085453417	2.751795416		110						
2,6-Dichlorophenol	0.633977839	0.836545806		110						
2,4,5-Trichlorophenol	0.025025441	0.033021545		3700						
2,4,6-Trichlorophenol	0.403743782	0.532747592		0.96						
2-Methylphenol	0.011011194	0.01452948		1800						
3&4-Methylphenol	0.066734509	0.088057453		180						
H2S	164.1			10	42		710	37630	70000	AEGL interim 1hr
Dioxins (TEF)	8.34E-08		u	4.5E-08		0.6	1.5	7.5	7.5	TEELs (15-min)
Mercury	2.24E-04	0.000294992	u	0.31						

Note: Shaded rows – maximum glc exceeds long-term 1-hr average concentration

Appendix D

Summary of Toxicity for Chemicals of Potential Concern

Appendix D
Summary of Toxicity for Chemicals of Potential Concern

D1.1 Introduction

This appendix presents reviews of toxicity undertaken for the COPC identified for detailed evaluation in the health risk assessment. The toxicity reviews present information on the chemical, chemical properties, exposures, health effects and classifications. In addition the toxicity reviews provide a review of information which is available from recognised agencies. From the information available, relevant toxicity values used to quantify toxicity have been identified.

The identification of toxicity values undertaken in this risk assessment has followed ANZECC (1992) guidance, which is in accordance with the NEPC (1999) policy. enHealth (2002) provides a list of toxicological data sources. These are classified as Level 1, 2 or 3 data, with Level 1 sources recommended. In order of preference the Level 1 sources are:

1. National Health and Medical Research Council documents and documents from other joint Commonwealth, State and Territory organisations.
2. ADI List from the Therapeutic Goods Administration.
3. World Health Organisation (WHO) documents.
4. enHealth Council documents.
5. National Environmental Health Forum documents.
6. International Agency for Research on Cancer (IARC) monographs.
7. WHO/FAO Joint Meeting on Pesticides (JMPR) monographs.
8. NICNAS Priority Existing Chemical (PEC) reports.
9. US Agency for Toxic Substances and Disease Registry (ATSDR) documents.
10. National Toxicology Program (NTP) carcinogenicity appraisals.
11. OECD Standard Information Data Sets (SIDS) and SID Initial Assessment Reports (SIAR).
12. EPA Reference Doses.

Level 2 sources include peer-reviewed journals and industry publications and reference to Level 2 sources is considered warranted where Level 1 sources do not provide applicable criteria.

D1.2 Toxicity Reviews

Toxicity profiles have been prepared for the following COPC identified:

- Hexachlorobutadiene (HCBD)
- 1,2-Dichloroethane (EDC)
- Vinyl chloride
- Chloroform
- Carbon tetrachloride
- Trichloroethene (TCE)
- Tetrachloroethene (PCE)
- Mercury
- Dioxin – No toxicity profile has been prepared for dioxins. The Department of the Environment and Heritage (DEH, 2004) has undertaken an extensive review of dioxins in Australia and have published a summary document "*National Dioxins Program, Dioxins in Australia: A Summary of the Findings of Studies conducted from 2001 to 2004*". This document provides a summary of key exposures and health effects associated with dioxins and is included for reference.

Toxicity reviews for these chemicals are presented in this Appendix.

D1.3 Background intake

The evaluation of toxicity has indicated the requirement to evaluate chemicals based on non-threshold dose reponse and threshold dose response.

Non-threshold

Non-threshold toxicity values assumes that any amount of exposure to the chemical has the potential to result in an increased risk. These chemicals are typically carcinogens with their toxicity values referred to as cancer risk slope factors. The WHO assigns slope factors to chemicals identified as genotoxic carcinogens with other carcinogens evaluated generally identified as exhibiting a threshold relationship (refer below). A slope factor is an upper bound estimate of the probability of a response occurring following the intake of a chemical over a lifetime via a specific exposure pathway (such as ingestion or inhalation). Therefore the higher the slope factor the higher the risk that may be associated with a given exposure.

Threshold Response

This relationship assumes that there is a level of exposure below which there is no (or no appreciable) risk of an adverse health effect. This is in contrast to the non-threshold relationship where there is an increased risk associated with any exposure. The WHO identifies non-threshold chemicals as those which are not suspected of exhibiting carcinogenic effects (non-carcinogens) or those which exhibit non-genotoxic carcinogenicity. Toxicity factors for these chemicals are referred to as an acceptable daily intake (ADI, by the WHO) or reference dose (RfD, by the USEPA) for oral exposures (in units of mg per kg body weight per day) and a tolerable concentration (TC, by WHO) or reference concentration (RfC, by USEPA) for inhalation exposures (in units of mg per cubic metre of air). The lower the ADI, RfD, TC or RfC, the more toxic the chemical and the lower the concentration above which there exists a potential for an adverse health effect.

While the calculation of risk for non-threshold dose response chemicals involves a calculation of incremental lifetime risk, the evaluation of threshold dose response chemicals involves a comparison of the intake derived from the source against an acceptable daily intake.

The potential for adverse threshold effects, resulting from exposure to a COPC, is evaluated by comparing an exposure level, expressed as a daily chemical intake, with the adjusted acceptable daily intake (ADI) or equivalent threshold value (tolerable daily intake (TDI), reference dose (RfD) or TWA). The resulting ratio is referred to by the USEPA as the hazard quotient (USEPA, 1989) and is derived in the following manner:

$$Hazard\ Quotient = \frac{(Daily\ Chemical\ Intake\ from\ GTP)}{(ADI) - (Background\ Intake)}$$

The evaluation of risk associated with threshold chemicals involves a comparison of the total daily intake with the adjusted ADI. The adjusted ADI is that which has been adjusted for background intake from all other sources so that the hazard quotient calculated compares the chemical intake derived from the proposed GTP with the ADI allowable from sources other than background.

Hence background exposures are presented in the toxicity summaries where the evaluation presented is relevant to threshold effects.

General

Hexachlorobutadiene (also known as perchlorobutadiene; 1,1,2,3,4,4-hexachloro-1,3-butadiene; 1,3-hexachlorobutadiene; dolen-pur; GP-40-66:120 and commonly abbreviated to **HCBD**) is a synthetic organic compound that does not naturally occur. HCBD is used as an intermediate in the production of rubber compounds. It is also used a s a solvent, a fluid for gyroscopes, a heat transfer fluid, hydraulic fluid and has been used as a fumigant. HCBD has also been used as a means of recovering chlorine containing gas (snift) in chloride production plants. It is a by-product in the manufacture of chlorinated solvents such as tetrachloroethylene and carbon tetrachloride.

Properties

HCBD is a colourless, oily liquid at room temperature with a turpentine like, pungent odour. HCBD is non-flammable, non-combustible, poorly soluble in water but miscible with ethanol and ether. Key properties are presented below (ATSDR 1994 and USEPA 2002):

CAS No.	87-68-3
Chemical Formula	C_4Cl_6
Molecular Weight	260.76
Vapour Pressure	0.15 mmHg at 25°C
Vapour Density	9
Density	1.55 g/ml at 20°C
Solubility (Water)	2 to 2.55 mg/L at 20°C
Air Diffusion Coefficient	0.0561 cm^2/s
Water Diffusion Coefficient	6.16×10^{-6} cm^2/s
Henry's Law Coefficient	0.0103 $atm.m^3/mol$
	= 0.421 at 25°C (unitless)
Koc	5181 cm^3/g
Odour Threshold	12 mg/m^3

Exposure

Exposure of the general population to HCDB may by inhalation, oral or dermal routes. Exposure is most likely to occur in occupational environments which handle or produce the chemical. Other environmental exposures may be associated with inhalation, ingestion of HCBD in drinking water or ingestion of fish or other foods. HCBD has not been found in Australian drinking waters (NHMRC, 1996 and draft 2002).

If released into the environment the following can be noted with respect to HCBD (UNECE, 2002):

- Air: Intercompartmental transport of HCBD will occur by volatilisation (limited), adsorption to particulate matter, and subsequent deposition or sedimentation. In addition to deposition, reaction with hydroxyl radicals is assumed to be an important sink of HCBD in the troposphere with an estimated atmospheric half-life of up to 2.3 years. Due to its persistence in the troposphere HCBD meets the criteria for long-range transport in the atmosphere.

- Soil and Water: HCBD is expected to bind with soil and sediments. In water, HCBD is considered persistent unless there is high turbulence. Information available n the persistence of HCBD in water, sediment and soil shows conflicting results, however expert judgement has identified HCBD as persistent. Half lives in natural waters and soils have been reported to be 4-52 and 4-26 weeks respectively. There is conflicting data available about biodegradation. Based on the Structure of HCBD it can be expected that dechlorination is required before aerobic biodegradation can occur. Model calculations indicate that HCBD does not biodegrade fast. The substance has a high bioaccumulating potential as has been confirmed by both laboratory and field observations. Average steady-state bioconcentration factors of 5800 and 17 000, based on wet weight, have been determined experimentally in rainbow trout. Biomagnification has not been observed either in the laboratory or in the field (WHO, 1994).

HCBD is not listed as a key persistent organic pollutant under the Stockholm Convention. However, on the basis of the potential for long-range transport, persistence in water, soil and sediment, bioaccumulation, toxicity and ecotoxicity, HCBD meets the UN-ECE Persistent Organic Pollutant (POP) criteria (UNECE, 2002). On this basis evaluation of HCBD should consider the potential for persistence in the environment and bioaccumulation in the food chain.

Health Effects

General

The following information is available from WHO (1994) and ATSDR (1994). There is no clinical disease which is unique to HCBD toxicity. As there have been very few human studies, the evaluation of toxicity is mainly based on studies in experimental animals. However, limited human *in vitro* data suggest that the metabolism of HCBD in humans is similar to that observed in animals.

There is limited data available on the absorption of HCBD in animals. Oral experiments indicate that HCBD absorption is rapid and complete, however little data are available concerning absorption following dermal and inhalation exposures.

When orally administered, HCBD or its metabolites have been observed to be distributed primarily in the kidney (outer medulla) and adipose tissue. HCBD has also been located in the liver following intraperitoneal administration. HCBD and its metabolites are excreted in exhaled air, urine and faeces.

HCBD vapour is considered to be irritating to the mucous membranes of humans, and the liquid is corrosive. The compound should also be regarded a sensitising agent.

The main target organs for toxicity are the kidney and, to a much lesser extent, the liver. Reduced birth weight and neonatal weight gain has only been observed at maternally toxic doses, as was developmental toxicity.

Biotransformation to a reactive sulphur containing metabolite probably accounts for the observed nephrotoxicity, genotoxicity and carcinogenicity.

Genotoxic Effects

HCBD has been found to induce gene mutations, chromosomal aberrations, increased sister chromatid exchanges and unscheduled DNA synthesis, although some studies have reported negative results. There is limited evidence for the genotoxicity of HCBD in animals, and insufficient evidence in humans.

Cancer	There is limited evidence for carcinogenicity in animals and insufficient evidence in humans. Review of carcinogenicity by OEHHA (2000) indicated that there is sufficient evidence for the carcinogenicity of HCBD, based on the development of renal tubular neoplasms in rats. Review of HCBD by the WHO (guidelines 2003) also note the development of kidney tumours in a long-term oral study in rats. HCBD has not been shown to be carcinogenic by other routes of exposure. On the basis of available metabolic and toxicological information the WHO considered that a TDI approach was appropriate for the derivation of an oral drinking water guideline.

Toxicity Classification

HCBD has been classified as a "possible" human carcinogen (Category C) by the USEPA.

IARC (1999) has classified HCBD in Group 3 (not classifiable as to its carcinogenicity to humans) based on inadequate evidence in humans and limited evidence in experimental animals for carcinogenicity.

The National Occupational Health and Safety Commission (NOHSC) as Category 3 carcinogen (possibly carcinogenic to humans). NICNAS has classified not classified HCBD.

Exposure Limits/Toxicity Evaluations

Exposure limits and toxicity evaluations which are available in Australia, World Health Organisation, European Union and the US:

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002) have derived a drinking water guideline of 0.0007 mg/L for HCBD using a ***TDI of 0.0002 mg/kg/day*** based on a NOAEL of 0.2 mg/kg/day based on renal effects in rats and a 1000 fold safety factor.

Worksafe Australia (NOHSC) have established “Exposure Standards for Atmospheric Contaminants in the Occupational Environment”. For HCBD, the following have been established:

TWA: 0.02 ppm, equivalent to 0.21 mg/m^3

STEL: NA

Potential exposure via skin absorption is noted.

WHO

The WHO (Drinking Water Guideline 1993 and 2003) provide a guideline value for HCBD of 0.0006 mg/L based on a ***TDI of 0.0002 mg/kg/day*** following the same approach outlined by NHMRC (as above).

The WHO has not published any review of inhalation exposures to HCBD.

EU

No assessment of HCBD is available from the EU.

US

The USEPA (IRIS current in 2004) has derived an ***oral slope factor of 0.078 (mg/kg/day)$^{-1}$*** for HCBD based on a linear multistage model based on renal tubular adenomas and adenocarcinomas in rats; and an ***inhalation unit risk of 2.2x10^{-5} (μg/m^{3})$^{-1}$*** using a linear multistage model based on oral data used to derive the oral slope factor. The USEPA does not present any data relevant to the assessment of non-carcinogenic effects for HCBD. An oral reference dose of 0.0002 mg/kg/day was derived by the USEPA, however it was withdrawn in 1993.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with HCBD. The levels established (valid in 2004) are:

- Intermediate oral MRL = 0.0002 mg/kg/day based on kidney damage in mice

The California Air Resources Board (CARB and OEHHA) has not established any reference exposure levels (REL) or inhalation unit risk values for HCBD.

Suggested Toxicity Values for Risk Characterisation

Toxicity data relevant for use in the characterisation of risk to human health have been selected for HCBD following review of the available information in general accordance with enHealth (2002) and NEPM (1999).

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. No data is available regarding environmental levels of HCBD in Australia, other than noting that HCBD has not been found in drinking water in Australia (NHMRC). HCBD is not a common urban air contaminant and as such background intakes of HCBD are considered to be negligible. On this basis, the assessment of risk associated with potential intake of HCBD does not need to be adjusted account for background unless other sources of HCBD are present in the study area.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for HCBD following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**TDI = 0.0002 mg/kg/day (NHMRC, 1996 and proposed 2002)**
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**TDI = 0.0002 mg/kg/day** (equivalent to oral TDI as no inhalation specific data is available. In addition, there is no data to suggest that inhalation exposures to HCBD should be evaluated using a non-threshold approach). Occupational inhalation exposure (NOHSC):

	TWA: 0.02 ppm, equivalent to 0.21 mg/m^3 **STEL: NA**

References

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General

1,2-Dichloroethane (also known as ethylene dichloride, ethylene chloride, glycol dichloride, freon 150, dutch liquid, 1,2-ethylene dichloride, alpha, beta-dichloride and commonly abbreviated to **EDC**) is a synthetic product which is primarily used in the production of the vinyl chloride monomer. It is also an intermediate in the manufacture of fluorocarbons and chlorinated solvents such as trichloethane, trichloroethylene, perchloroethylene and vinylidene. These solvents are used to remove dirt, grease, resins and glue as well as in the manufacture of polystyrene and SBR latex. EDC is also added to leaded petrol as an anti-knock compound and has been used as a fumigant.

EDC is one on the most widely produced chemicals in the world. The majority of EDC released to the environment is in emissions to air. It is moderately persistent in the air, however it is not considered to be an ozone depleting substance.

Properties

EDC is a volatile, colourless liquid at room temperature with a pleasant smell and sweet taste. EDC evaporates into air very quickly and is soluble in water and several organic solvents such as alcohol, chloroform and ether. Key properties are presented below (ATSDR 2001 and USEPA 2002):

CAS No.	107-06-2
Chemical Formula	$C_2H_4Cl_2$
Molecular Weight	98.96
Vapour Pressure	79.1 mmHg at 25°C
Vapour Density	3.4
Density	1.23 g/ml at 20°C
Solubility (Water)	8690 mg/L at 20°C
Air Diffusion Coefficient	0.104 cm^2/s
Water Diffusion Coefficient	9.9×10^{-6} cm^2/s
Henry's Law Coefficient	0.0011 $atm.m^3/mol$ = 0.0401 at 25°C (unitless)
Koc	17.4 cm^3/g
Odour Threshold	48.6 to 405 mg/m^3

Exposure

Exposure of the general population to EDC may be by inhalation, oral or dermal routes. In most cases inhalation is the primary route of exposure. Exposure may also occur through oral ingestion and dermal contact with drinking/household water and/or soils. Intake from food sources is expected to be negligible. Children maybe exposed via the same pathways as adults. EDC has been detected in human milk and hence infancies could be exposed via breast-feeding. Occupational exposures (particularly inhalation and dermal contact) may occur in industries which handle the product.

If released into the environment the following can be noted with respect to EDC:

- Air: EDC is expected to remain in vapour phase where it is moderately persistent with an estimated half-life of between 43 and 111 days. Once EDC reaches the troposphere, it undergoes photo-oxidation to produce formyl chloride, chloroacetyl chloride, hydrochloric acid, carbon monoxide and carbon dioxide EDC is transported to the stratosphere where photolysis may produce chloride radicals which may in turn reach with ozone. EDC is not expected to contribute to ozone depletion. Due to its persistence in the troposphere there in the potential for long-range transport of EDC.

- Soil and Water: EDC is not expected to adsorb strongly in soils and may leach to groundwater where it has the potential to persist for years. EDC is expected to volatilise from surface soils and water.

- Biodegradation: Biodegradation is expected to occur slowly with hydrolysis and photolysis is not expected to be important fate processes. The potential for bioaccumulation in aquatic or terrestrial organisms appears to be low.

Health Effects

General

There is no clinical disease which is unique to EDC toxicity. Primary effects are associated with the liver, kidneys and neurological, cardiovascular and immune systems.

EDC is readily absorbed into the body via inhalation, ingestion and dermal exposure. Following absorption into the body, EDC is widely distributed throughout the body. In animals the highest concentrations were generally within adipose tissue; however it is also distributed to the blood, liver, kidney, brain and spleen. EDC is metabolised extensively. Unmetabolised EDC is eliminated in expired air, while its metabolites (principally sulphur containing metabolites) are largely excreted in the urine. Although EDC is eliminated more slowly from adipose tissue than from blood or other tissues (lung and liver) following exposure, it is unlikely to bioaccumulate significantly.

The following summary has been derived from ATSDR (2001).

Death

Acute inhalation and oral exposure of EDC has been known to result in death in humans. Cause of death is typically attributed to cardiac arrhythmia.

Hepatic Effects

Liver effects have been identified following acute inhalation or ingestion of EDC by humans and animals. Hepatic effects in animals were not limited to any specific route or duration of exposure and included increased levels of serum markers of liver dysfunction, increased liver weight and fatty degeneration.

Renal Effects

EDC is acutely nephrotoxic in humans following both inhalation and ingestion. Renal effects in humans include diffuse necrosis, tubular necrosis and kidney failure. Renal effects in animals include increased kidney weight, cloudy swelling of the tubular epithelium, tubular degeneration and regeneration, karyomegaly, dilation, protein casts and mineralisation.

Immunological Effects

Immunological effects have not been reported in humans. In mice, immunological effects have been reported following both acute inhalation and oral exposure. Due to interspecies differences in immunotoxicity, it is unclear whether the immune system may be a target of EDC in humans based on the mice studies.

Neurological Effects

Neurological effects reported by people acutely exposed to high concentrations of EDC via inhalation or ingestion include headache, irritability, drowsiness, tremors, partial paralysis and coma. Animal studies indicate the CNS is a target of high concentrations of EDC. Available data do not enable characterisation of the potential for EDC to cause more subtle neurotoxic effects following low-level prolonged exposures by inhalation, oral or dermal exposure.

Cardiovascular Effects

Cardiac effects (arrhythmias, insufficiency and haemorrhage) have been observed in humans acutely exposed to high concentrations of EDC. The available animal data suggests that the heart could be a target of EDC following acute high level exposure and possibly longer-term inhalation exposure.

Developmental Effects

Some developmental effects have been reported in humans and animals. However, the available information does not indicate that EDC is a developmental toxicant in animals at doses below those that cause other toxic effects.

Genotoxic Effects

The genotoxicity of EDC has been extensively investigated in non-mammalian and mammalian test systems. Following review of the available data by WHO (1998), EDC has been identified as genotoxic in *in vitro* and *in vivo* assays, and binds to DNA in rodents *in vivo*. Review of genotoxicity by Woodward-Clyde (1996) indicated that the available evidence in animals suggests that EDC is genotoxic.

Cancer

Available data on the carcinogenicity of EDC in humans are limited. There are no epidemiological studies which show an associated between EDC exposure and cancer. There is convincing evidence of increases in the incidence of both common and rare tumours in experimental animals at several sites (including squamous cell carcinomas of the stomach, haemangiosarcomas, fibromas of the subcutaneous tissue and adenocarcinomas and fibroadenomas of the mammary gland in rats; and alveolar/bronchiolar adenomas, mammary gland adenocarcinomas, endometrial stromal polyp or endometrial stromal sarcoma combined and hepatocellular carcinomas in mice) following oral exposure studies (WHO, 1998).

The incidence of benign lung papillomas was significantly increased in mice following long-term dermal application of EDC, while a non-significant increase in the number of pulmonary adenomas per animal was reported in a screening bioassay on mice and in the incidence of benign mammary gland tumours in rats exposed by inhalation for 2 years (WHO 1998).

Toxicity Classification

EDC was classified as a "probable" human carcinogen (Category B2) by the USEPA for all routes of exposure based upon evidence from animal studies.

IARC (1999) has classified EDC in Group 2B (possibly carcinogenic to humans) based on inadequate evidence in humans for carcinogenicity and sufficient evidence in experimental animals.

NICNAS has classified not classified EDC.

Exposure Limits/Toxicity Evaluations

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002 and derived from WHO, see below) have derived a drinking water guideline of 0.003 mg/L for EDC based on an lifetime excess cancer risk of 1 in 1,000,000. The slope factor used in the derivation of the drinking water guideline can be calculated as follows:

SF (mg/kg/day)$^{-1}$ = *Risk/Intake(mg/kg/day)*

= *[Risk x Body Weight]/[Concentration (water) x Ingestion Rate)]*

= *[1 x10^{-6} x 70kg]/[0.003mg/L x 2 L/day]*

= 0.012 (mg/kg/day)$^{-1}$

Worksafe Australia (NOHSC) have established "Exposure Standards for Atmospheric Contaminants in the Occupational Environment". For EDC, the following have been established:

TWA: 10 ppm, equivalent to 40 mg/m^3

STEL: NA

It should be noted that this chemical is flagged for further review based on carcinogenic potential.

WHO

The WHO (Drinking Water Guideline 1993 and 2004) established a guideline of 0.03 mg/L using a linearised multistage model and an excess lifetime cancer risk of 1 in 100,000. This corresponds to an ***oral slope factor of 0.012 (mg/kg/day)$^{-1}$*** (as used by NHMRC).

The WHO also notes that data indicate that EDC is less potent when inhaled.

WHO (2000) has undertaken a review of EDC for inhalation exposures. The review indicates that there is sufficient evidence of carcinogenicity in animals based on oral ingestion data. However, animal inhalation data do not provide sufficient evidence of carcinogenicity. Because of deficiencies in extrapolating oral data to inhalation, neither the oral slope factor nor any inhalation value have been recommended by the WHO in this assessment. A guideline value of 0.7 mg/m^3 for a 24-hour average has been derived for non-carcinogenic endpoints by the WHO (2000) based on a lowest-observed-adverse-effect level from animal studies. It is noted that this guideline value is of short duration exposures only and is recommended for the assessment of accidental release episodes or specific indoor pollution problems.

WHO (2000b) have published a parallel review from a task force which had the aim of providing a more global application of air quality guidelines, in conjunction with the Air Quality Guidelines for Europe (WHO, 2000). WHO (2000b) provide a range of inhalation unit risk values for exposure to EDC in air based on tumour formation in rats. The range of inhalation unit risk values is (0.5 to 2.8)x10^{-6} (μg/m^3)$^{-1}$ (i.e. for an air concentration of 1 μg/m^3, the lifetime risk is estimated to be (0.5 to 2.8)x10^{-6}). This is equivalent to the following inhalation slope factor:

SF $(mg/kg/day)^{-1}$ = *Risk/Intake(mg/kg/day)*

= *[Risk x Body Weight]/[Concentration (in air) x Inhalation Rate)]*

= $[(0.5 \text{ to } 2.8) \times 10^{-6} \times 70kg]/[0.001 mg/m^3 \times 20\ m^3/day]$

= **0.0018 to 0.0098 $(mg/kg/day)^{-1}$**

The higher value in the range presented above for inhalation exposures is considered the more conservative (higher risk). This value is approximately equal to the NHMRC slope factor used to derive the drinking water guideline, namely 0.012 $(mg/kg/day)^{-1}$ and is recommended for a conservative evaluation of inhalation exposures.

EU

The European Commission published a directive in 1990 in which limit values for emission of EDC were specified for various types of industrial plants. These limits ranged from 0.1 mg/litre (monthly) for plants using EDC for degreasing metals away from an industrial site to 12 mg/litre (daily) for plants producing EDC and processing or using the substance at the site (WHO, 1998). No other assessment of EDC is available from the EU.

US

The USEPA (IRIS current in 2004) has derived an ***oral slope factor of 0.091*** ***$(mg/kg/day)^{-1}$*** for EDC based on a linear multistage model based on hemangiosarcomas in rats; and an ***inhalation unit risk of*** ***2.6×10^{-5} $(\mu g/m3)^{-1}$*** using a linear multistage model based on oral data used to derive the oral slope factor. The USEPA does not present any data relevant to the assessment of non-carcinogenic effects for EDC.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with EDC. The levels established (valid in 2004) are:

- Chronic (and intermediate) inhalation MRL = 0.6ppm based on liver histopathology in rats; and
- Intermediate oral MRL = 0.2 mg/kg/day based on increased kidney weights in rats.

The California Air Resources Board (CARB 2002, OEHHA 2000) has established ***inhalation unit risk value of*** ***2.1×10^{-5} $(\mu g/m^3)^{-1}$*** and a ***chronic reference exposure level for EDC of 0.4*** ***mg/m^3*** based on hepatotoxicity (elevated liver enzyme levels in serum of rats).

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. However, as EDC has been evaluated to be a genotoxic carcinogen it is considered appropriate to evaluate exposure using a slope factor for oral, inhalation and dermal exposures where an incremental probability of cancer is calculated. Hence background intake is not relevant in the evaluation of non-threshold dose response chemicals.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for EDC following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**Oral Slope Factor = 0.012 (mg/kg/day)$^{-1}$ (NHMRC, 1996 and proposed 2002)**
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**Inhalation unit risk of 2.8x10^{-6} (per µg/m^3),** equivalent to **0.0098 (mg/kg/day)$^{-1}$** (WHO 2000b). Occupational inhalation exposure (NOHSC): **TWA: 10 ppm, equivalent to 40 mg/m^3** **STEL: NA**

References

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General

Vinyl chloride (also known as, chloroethene, 1-chloroethylene, ethylene monochloride and vinyl chloride monomer and commonly referred to as VC) is man-made or results from the breakdown of other manmade substances, such as trichloroethene, trichloroethane, and tetrachloroethene. It is used mainly for the manufacture of polyvinyl chloride (PVC) plastics and resins, and VC copolymers. It is used as a monomer with vinyl acetate or vinylidene chloride in the production of resins. It is also used for the production of chlorinated solvents, such as methyl chloroform and 1,1,1-trichloroethane, and other chemicals; and in the production of adhesives. Other uses include furniture, automotive upholstery, wall coverings, house wares and automotive parts. Up until the mid 1970's it was used as a coolant, propellant in spray cans and in some cosmetics.

Properties

VC is a volatile, colourless gas with a pleasant, sweet, ethereal odour. It is a colourless liquid below -14°C. VC is slightly soluble in water and highly soluble in diethyl ether, soluble in ethanol, benzene and most organic liquids. Key properties are presented below (ATSDR 1997 and USEPA 2002):

CAS No.	75-01-4
Chemical Formula	C_2H_3Cl
Molecular Weight	62.5
Vapour Pressure	2600 mmHg at 25°C
Vapour Density	2.16
Density	0.91 g/ml at 20°C
Solubility (Water)	2760 mg/L at 25°C
Air Diffusion Coefficient	0.106 cm^2/s
Water Diffusion Coefficient	1.2×10^{-6} cm^2/s
Henry's Law Coefficient	0.027 $atm.m^3/mol$
	= 1.107 at 25°C (unitless)
Koc	18.6 cm^3/g
Odour Threshold	7650 mg/m^3

Exposure

The main route of exposure for the general public to VC is via inhalation (since VC commonly exists as a gas). Atmospheric concentrations of VC are generally low resulting in very little exposure to the general public. Similarly, the main route of occupational exposure is via inhalation. Dermal exposure is generally considered to be low.

In some countries exposure may also occur via ingestion of contaminated drinking water. In Australia, there are stringent requirements on the maximum permissible residual VC concentrations in PVC pipes and fittings used to carry potable water. Hence VC has not been reported in Australian drinking waters (ADWG 1996).

In the past, VC had been detected in food that was stored in materials that contained PVC. Many countries now regulate the amount of VC in food packaging materials.

If released into the environment the following can be noted with respect to VC:

- Air: Reaction with photochemically produced OH* radicals is the dominant atmospheric transformation process, which results in half-lives of 1 to 4 days in the troposphere. Several critical compounds, such as chloroacetaldehyde, formaldehyde and formyl chloride, are generated during experimental reactions.

- Soil: Volatilization half-lives are approx. 0.2-0.5 days. VC has a low soil sorption potential and therefore a high mobility in soil. VC may leach through soil into groundwater where it may persist for years.

- Water: With few exceptions, VC is not easily degraded. However under anaerobic conditions PCE and TCE can be intrinsically biodegraded to form DCE and VC (below).

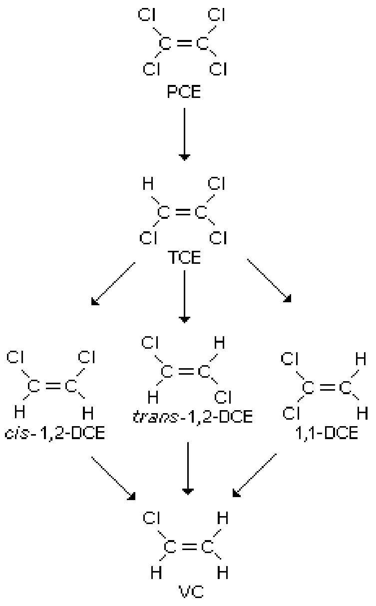

Figure 1. Pathway for anaerobic microbial degradation of chlorinated ethenes to form VC (from: WHO, 1999)

NB: PCE=tetrachloroethene, TCE=trichloroethene, DCE=dichloroethene

Health Effects

General

Numerous human population studies and reports have led to the identification of significant long-term health effects which are sometimes collectively referred to as "*vinyl chloride disease*" and characterised by Raynaud's Phenomenon, acroosteolysis, joint and muscle pain, enhanced collagen deposits, stiffness of the hands and scleroderma-like skin changes. Most of these effects are associated with inhalation exposures in the workplace (particularly during the 1970's). Primary effects are associated with the liver/spleen, vascular, skeletal, immune system, skin, respiratory and higher central nervous system (CNS) effects. It is well recognised that VC is a genotoxic carcinogen.

VC is rapidly and well absorbed after inhalation or oral exposure. The primary route of exposure to VC is inhalation. Dermal absorption of VC in the gaseous state is not significant. Following exposure VC is distributed rapidly throughout the body. Placental transfer of VC occurs.

The main route of metabolism of VC after inhalation or oral uptake involves oxidation by cytochrome P-450 (CYP2E1) to form chloroethene oxide (CEO), a highly reactive, short-lived epoxide which rapidly rearranges to form chloroacetaldehyde (CAA).

After inhalation or oral exposure to low doses, VC is metabolically eliminated and non-volatile metabolites are excreted mainly in the urine. CEO is thought to be the most important metabolite *in vivo,* concerning the mutagenic and carcinogenic effects of VC.

The following summary has been derived from WHO (1999) and ATSDR (1997).

Death

Acute inhalation exposure of VC has been known to result in death in humans. Cause of death was associated with congestion of lungs and kidneys and failure of blood to clot. Increased mortality in rats following exposure to high concentrations of VC over different exposure duration periods has been observed. No studies indicate lethal effects associated with acute or intermediate ingestion of VC. Chronic ingestion of VC has been associated with decreased longevity in rats.

Respiratory Effects

Respiratory effects associated with occupational VC exposure are contradictory and inconclusive. Animal studies indicate high concentrations cause respiratory inflammation in a variety of species.

Cardiovascular Effects

Occupational exposure to VC has been associated with development of Raynaud’s Phenomenon. Increased incidence of hypertension, cardiovascular and cerebrovascular disease has been reported in workers. Animal studies indicate the potential for cardiac arrhythmias, myodegeneration in the heart and thickening of the walls of the arteries.

Haematological Effects

Exposure to high levels of VC has indicated that blood clotting is impaired. Occupational studied have indicated decreased platelets during early pregnancy, thrombocytopenia and increased levels of two plasma proteins. Animal studies have indicated a failure of blood to clot during exposure to high concentrations.

Musculoskeletal Effects

Acroosteolysis (shortening of the terminal digits) has been observed in occupationally exposed workers.

Hepatic Effects

The liver is a primary toxicity endpoint for VC. Liver damage and liver disease (including angiosarcoma of the liver) has been reported in animal and human studies with the effects correlated with increased concentration and duration of exposure.

Renal Effects

Animal studies (mice and rats) indicate acute exposure to VC can result in kidney congestion.

Endocrine Effects	Some endocrine effects have been reported in occupational workers and rats.
Dermal/Ocular Effects	Exposure to liquid VC has been associated with frostbite. Other skin effects associated with workers include scleroderma, thickening of the skin, while scaly appearance and Raynaud’s Phenomenon. Burns to the conjunctiva and cornea have occurred following exposure to VC gas in the occupational environment.
Body Weight Effects	Workers exposed to high concentrations of VC have reported anorexia. Decreased body weights were also identified in some animal studies.
Immunological Effects	Some studies indicate immune system effects in VC workers. These effects include increased circulating immune complexes and presence of abnormal protein in the blood (cryoglobulinemia). Studies of workers who developed “vinyl chloride disease” indicate that the disease may have an immunologic basis.
Neurological Effects	VC was once used as an in halation anaesthetic. Exposure to very high concentrations of VC in air causes depression of the central nervous system (CNS). The most commonly observed CNS effects are weakness, dizziness, nausea, fatigue, headache, incoordination and loss of consciousness. Chronic occupational exposure to VC has been associated with peripheral neuropathy and Raynaud’s Phenomenon.
Reproductive Effects	Reproductive effects (decreased male fertility, decrease in testicular weight) have been observed in animal studies following exposure to VC.
Developmental Effects	Studies associated with environmental exposures to VC and birth defects found no significant correlation. Results of animal studies indicate developmental effects at concentrations that are also toxic to maternal animals.
Genotoxic Effects	Genotoxic studies of VC include a large number of assays for occupationally exposed workers. Studies indicate VC is mutagenic and clastogenic in humans with the frequencies of chromosomal aberrations (CA), micronuclei (MN) and SCE in the peripheral blood lymphocytes of workers exposed to high levels of VC shown to be raised. The mutagenic and genotoxic effects of VC have been detected in a number of *in vitro* test systems in animals, predominantly after metabolic activation. VC showed clastogenic effects in rodents, increased SCE in hamsters and induced DNA breaks in mice. Review of VC by Woodward-Clyde (1996) indicates that there is sufficient evidence to indicate that VC is genotoxic.
Cancer	Exposure to VC via inhalation has been associated with increase in liver cancer including a rare form of angiosarcoma and biliary tract cancer. Other studies have indicated increase incidence of CNS and brain cancer. While most data is associated with inhalation exposures, ingestion studies suggest evidence of carcinogenicity via oral exposure.

Toxicity Classification

VC is classified as a known human carcinogen (Category A) by the USEPA based upon sufficient evidence from animal studies. VC is a known human carcinogen via the inhalation and oral routes of exposure and a highly likely carcinogen via the dermal route of exposure.

IARC has classified VC in Group 1 (carcinogenic to humans) based in sufficient evidence from animal studies.

NICNAS has classified VC as a Carcinogen Category 1, which is a substance regarded as carcinogenic to humans.

Exposure Limits/Toxicity Evaluations

Exposure limits and toxicity evaluations which are available in Australia, World Health Organisation, European Union and the US.

Australia

The Australian Drinking Water Guidelines (1996 and proposed 2002) set the guideline value based on practical limit of determination which is similar to the WHO guideline (noted below) based on an excess cancer risk of 1 in a million.

Worksafe Australia (NOHSC) have established “Exposure Standards for Atmospheric Contaminants in the Occupational Environment”. For VC, the following have been established:

TWA: 5 ppm, equivalent to 13 mg/m^3

STEL: NA

WHO

The WHO Drinking Water Guidelines (1996) (also noted in the Australian Drinking Water Guidelines, 1996 and proposed 2002) have assessed VC as a genotoxic carcinogen and have established a guideline value of 0.005 mg/L based on an excess risk of 10^{-5}. The revision to the WHO Drinking Water Guidelines (2004) derived a guideline value of 0.0003 mg/L on the basis of linear extrapolation from an oral exposure study in rats associated with the upper-bound risk of 10^{-5} and assuming a doubling of the risk of exposure from birth. The WHO slope factor used in the derivation of the drinking water guideline can be calculated as follows:

$$\textbf{SF (mg/kg/day)}^{-1} = \text{Risk/Intake(mg/kg/day)}$$

$$= \text{[Risk x Body Weight]/[Concentration (water) x Ingestion Rate)]}$$

$$= [2 \times 10^{-5} \times 70\text{kg}]/[0.0003\text{mg/L} \times 2 \text{ L/day}]$$

$$= \mathbf{2.3\ (mg/kg/day)^{-1}}$$

The WHO (2000 and 2000b) provides a review of VC. Using human data, mainly occupational studies, associated with inhalation exposures, the WHO has derived ***an inhalation unit risk of*** $\mathbf{1 \times 10^{-6}\ (\mu g/m^3)^{-1}}$ (i.e. for an air concentration of 1 μg/m^3, the lifetime risk is estimated to be 1×10^{-6}). This value is unchanged from that derived from the same studies in 1987.

The WHO notes that studies indicate that risks may be higher in childhood (i.e. ages less than 10 years) and the above (inhalation) value must be used with caution.

US

The USEPA undertook a comprehensive review of VC in 2000 where the following dose response values were established (based on animal studies):

Oral cancer ***slope factor*** ***= 0.72 (mg/kg/day)$^{-1}$*** ***exposures in adulthood***

=1.44 (mg/kg/day)$^{-1}$ ***exposures over a lifetime***

Oral non-cancer reference dose ***(RfD)*** ***= 0.003 mg/kg/day*** based on liver cell polymorphism in animals, application of the PBPK model to derive a NOAEL and an uncertainty factor of 30.

Inhalation unit risk ***= 4.4x10^{-6} (μg/m^3)$^{-1}$ = 0.016 (mg/kg/day)$^{-1}$exposures during adulthood***

= 8.8x10^{-6} (μg/m^3)$^{-1}$ = 0.03 (mg/kg/day)$^{-1}$exposures over a lifetime

Inhalation non-cancer reference concentration ***(RfC)*** ***= 0.1 mg/m^3*** based on the oral study used to derive the RfD.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with TCE. The levels established (valid in 2004) are:

- Acute inhalation MRL = 0.5ppm based on developmental effects in mice;
- Intermediate inhalation MRL = 0.03ppm based on increased liver weights in rats; and
- Chronic oral MRL = 0.00002 mg/kg/day based on cellular alteration in livers of rats.

The California Air Resources Board (CARB 1990 and OEHHA 1999) has adopted an ***acute reference exposure level (REL) of 180 mg/m^3*** for VC based on effects identified in occupational studies. An ***inhalation cancer slope factor of 0.27 (mg/kg/day)$^{-1}$*** has also been established for VC based on lung carcinoma in mice.

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. However, as VC has been evaluated to be a genotoxic carcinogen it is considered appropriate to evaluate exposure using a slope factor for oral, inhalation and dermal exposures where an incremental probability of cancer is calculated. Hence background intake is not relevant in the evaluation of non-threshold dose response chemicals.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for VC following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	***Oral Slope Factor = 2.3 (mg/kg/day)$^{-1}$*** (WHO, 2004)
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	***Inhalation slope factor = 0.016 (mg/kg/day)$^{-1}$exposures during adulthood (USEPA 2000)**** ***= 0.03 (mg/kg/day)$^{-1}$exposures over a lifetime (USEPA 2000)**** Occupational inhalation exposure (NOHSC): ***TWA: 5 ppm, equivalent to 13 mg/m^3*** ***STEL: NA***

*Following the approach outlined in NEPM (1999), the WHO inhalation assessment should be used in preference, however due to the limitations associated with the assessment of childhood exposure (noted by WHO), the more recent assessment presented by the USEPA is recommended for the evaluation of inhalation exposures to VC.

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General

Chloroform (also known as trichloromethane, methenyl chloride, methane trichloride, methyl trichloride and formyl trichloride) is both a synthetic and naturally occurring compound, with anthropogenic sources responsible for most of the chloroform in the environment. Chloroform is mainly used in the production of other materials, principally fluorocarbons, used in the synthesis of tetrafluoroethylene and polytetrafluoroethylene, and as a refrigerant and propellant. Chloroform is also widely employed as an organic solvent in industry and in analytical laboratories. It has also been used as an ingredient of pharmaceuticals, drugs, cosmetics, grain fumigants, dyes and pesticides.

In the past, chloroform has been extensively used as a surgical anaesthetic, but this use was discontinued because exposure to narcotic concentrations resulted in adverse side effects. The US Food and Drug Administration has banned the use of chloroform as an ingredient in human drug and cosmetic products in 1976. Chloroform is commonly listed as a poison in Australia and some states have enacted legislation which restricts the concentration and use of poisons. The Australian Therapeutic Goods Administration (TGA) has not banned chloroform in medicines; however it does place restrictions on the concentration of chloroform in products.

Properties

It is a colourless liquid with a pleasant, non-irritating odour and a slightly sweet taste. It is only slightly soluble in water, but is miscible with alcohol, benzene, ether, petroleum ether, carbon tetrachloride, carbon disulfide, and oils. Decomposition may produce phosgene, carbon dioxide and hydrogen chloride. Key properties are presented below (ATSDR 1997 and USEPA 2002):

CAS No.	67-66-3
Chemical Formula	$CHCl_3$
Molecular Weight	119.38
Vapour Pressure	160 mmHg at 20°C
Vapour Density	4.1
Density	1.48 g/ml at 25°C
Solubility (Water)	7920 mg/L at 25°C
Air Diffusion Coefficient	0.104 cm^2/s
Water Diffusion Coefficient	1×10^{-5} cm^2/s
Henry's Law Coefficient	0.00367 $atm.m^3/mol$ = 0.15 at 25°C (unitless)
Koc	39.8 cm^3/g
Odour Threshold	85 ppm (421 mg/m^3)

Exposure

Human exposure to chloroform can occur orally, dermally, or by inhalation. Chloroform is the principal trihalomethane generated as by-products during the chlorination of drinking water. The primary sources of chloroform in the environment are chlorinated drinking water and wastewater, pulp and paper mills, and chemical and pharmaceutical manufacturing plants. The general population is exposed to chloroform mainly in food, drinking-water and indoor air. Most of the chloroform released to the environment eventually enters the atmosphere, while much smaller amounts enter groundwater as a result of filtration through the soil. NHMRC indicate that concentrations of total trihalomethanes (including chloroform) in major Australian reticulates supplies are range up to 0.6 mg/L (NHMRC, 1996 and draft 2002).

If released into the environment the following can be noted with respect to chloroform (WHO 1994):

- Air: Nearly all chloroform tetrachloride released to the environment will ultimately be present in the atmosphere due to its volatility. Chloroform has a residence time in the atmosphere of several months. In the atmosphere, chloroform may be transported long distances before degrading via indirection photochemicals reactions with free radicals such as hydroxyl (which form low levels of phosgene and hydrogen chloride).

- Soil and Water: Following releases to soil, most chloroform is expected to evaporate rapidly due to its high volatility and low soil adsorption. Most of the remaining chloroform will travel through the soil because of its low adsorption onto soils with leaching of chloroform to groundwater considered to be a significant pathway. Because of its volatility, evaporation is considered to be the main process for the removal of chloroform from aquatic systems. Chloroform is not expected to adsorb significantly to sediment or suspended organic matter in surface water.

- Biodegradation: Hydrolysis or direct photolysis are not considered to be significant degradation processes in water for chloroform. Chloroform is generally considered persistent in water and soils with a low potential for degradation. Under correct condition, chloroform may undergo anaerobic biodegradation. Concentrations of chloroform in soil or water above a certain threshold levels results in toxic conditions which inhibits bacteria, methane-fermenting bacteria under anaerobic conditions.

- Chloroform does not bioconcentrate in higher aquatic organisms.

Health Effects

General

The following information is available from WHO (1999) and ATSDR (2003). There is no clinical disease which is unique to chloroform toxicity.

Chloroform is rapidly absorbed through the lungs, the gastrointestinal tract and to some extent through the skin. In humans, the respiratory absorption of chloroform ranges from 49 to 77% and absorption from the gastrointestinal tract approximates 100%, with peak blood levels being reached within 1 hour.

Following its absorption, chloroform is distributed to all organs. The distribution of chloroform in the body does not differ qualitatively between the various routes of exposure. A number of studies have shown that chloroform will distribute to fat tissue. It is lipid soluble, readily passes through cell membranes, reaching relatively high concentrations in nervous tissue. Chloroform concentrations in tissues are dose-related and occur in the following order: adipose > brain > liver > kidney > blood. Chloroform passes through the placenta and has been detected in fresh cow's milk and foetal blood at levels equal to or greater than those in maternal blood.

Chloroform is metabolised by oxidative dehydrochlorination of its carbon-hydrogen bond to form phosgene (CCl_2O). The reaction is P450-mediated and occurs in both the liver and the kidney. The major end product of chloroform metabolism is carbon dioxide (CO_2), most of which is eliminated via the lungs, but some is incorporated into endogenous metabolites and may be excreted as bicarbonate, urea, methionine and other amino acids, inorganic chloride ion, and carbon monoxide. Elimination of chloroform is not affected by the route of exposure. About 60 - 70% is eliminated unchanged in expired air; 30 - 40% is metabolised and excreted in urine and faeces. The extent of metabolism is dose-dependent.

Target organs for chloroform toxicity are the liver, kidneys, and central nervous system. The most universally observed toxic effect of chloroform is damage to the liver. Liver effects (hepatomegaly, fatty liver, and hepatitis) were observed in individuals occupationally exposed to chloroform. Several subchronic and chronic studies by the oral or inhalation routes of exposure documented hepatotoxic effects in rats, mice, and dogs. Renal effects have been reported in rats and mice following oral and inhalation exposures, but evidence for chloroform-induced renal toxicity in humans is sparse.

Chloroform is a central nervous system depressant, inducing narcosis and anaesthesia at high concentrations. Lower concentrations may cause irritability, lassitude, depression, gastrointestinal symptoms, and frequent and burning urination.

Genotoxic Effects

The weight of the available evidence (WHO 1994 and Woodward-Clyde 1996) indicates that chloroform has little, if any, capability to induce gene mutation, chromosomal damage and DNA repair. However, there is some evidence of low-level binding to DNA. Chloroform does not appear capable of inducing unscheduled DNA synthesis *in vivo.* Review of chloroform by USEPA (2001) indicates that chloroform is not a mutagen and is not likely to cause cancer through a genotoxic mode of action.

Cancer

Human data on the carcinogenic potential of chloroform are limited and there have been no conclusive associated between chloroform exposure and cancer in humans. In experiments with mice and rats, chloroform induced liver and kidney tumours. The carcinogenic effects of chloroform on the mouse liver appear to be closely related to cytotoxic and cell replicative effects. Liver tumours in rat and mice studies have only occurred where signs of hepatoxicity have been seen. In the rat and mice studies, the development of renal tumours in males is a consequence of nephrototoxicity of chloroform.

The pattern of development of tumours following chloroform treatment in animals is consistent with a tumour promoting mechanism rather than a genotoxic one. On the basis of available evidence, a dose threshold for the development of liver tumours is considered appropriate. It was considered plausible by the WHO (1996) that kidney tumours in rats may be associated with a threshold mechanism, however there area some limitations of the database.

Review of chloroform by the USEPA (2001) indicates that it is considered likely to be carcinogenic to humans by all routes of exposure under high-dose conditions that lead to cytotoxicity and regenerative hyperplasia. Chloroform is no likely to be carcinogenic to humans by any routes of exposure at doses that do not cause cytotoxicity and cell regeneration. Hence the USEPA has concluded that the threshold effects value established (RfD) is also protective against increased risk of cancer.

Toxicity Classification

Chloroform has been classified as a "probable" human carcinogen (Category B2) by the USEPA based on carcinogenicity in animals. Under the Proposed Guidelines for Carcinogen Risk Assessment (U.S. EPA, 1996; U.S. EPA, 1999), chloroform is *likely to be carcinogenic to humans by all routes of exposure* under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia in susceptible tissues (U.S. EPA, 1998a,b). Chloroform is *not likely to be carcinogenic to humans by any route of exposure* under exposure conditions that do not cause cytotoxicity and cell regeneration.

IARC (1999) has classified chloroform in Group 2B (possibly carcinogenic to humans) based on inadequate evidence in humans and sufficient evidence in experimental animals for carcinogenicity.

The National Occupational Health and Safety Commission (NOHSC) as Category 3 carcinogen (possible human carcinogen). NICNAS has classified not classified chloroform.

Exposure Limits/Toxicity Evaluations

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002) have derived a drinking water guideline for total trihalomethanes, which included chloroform (as well as bromodichloromethane, dibromochloromethane and bromoform) of 0.25 mg/L as a total or individually using a ***TDI of 0.07 mg/kg/day*** derived from a no effect level based on a 90-day gavage study on rats and the application of 100 safety factor.

Worksafe Australia (NOHSC) have established “Exposure Standards for Atmospheric Contaminants in the Occupational Environment”. For chloroform, the following have been established (as amended 2001):

TWA: 2 ppm, equivalent to 10 mg/m^3

STEL: NA

WHO

Review of chloroform by the WHO in 1994 has derived a number of tolerable daily intake (TDI) values for oral exposure. The values derived are:

- TDI = 0.015 mg/kg/day based on non-neoplastic effects (hepatoxicity) in a 7.5 year study on dogs (lowest identified effects level of 15 mg/kg), 1000 uncertainty factor.
- TDI = 0.01 mg/kg/day for neoplastic effects (liver tumours) based on a 3 week study in mice (NOAEL of 10 mg/kg), 1000 uncertainty factor.
- Based on induction of renal tumours in male rats a total daily intake associated with a 10^{-5} excess cancer risk (linearised multistage model) is 0.0082 mg/kg/day.

The WHO (Drinking Water Guideline 1996 and 2004) provide a guideline value for chloroform of 0.2 mg/L based on a ***TDI of 0.013 mg/kg/day*** derived from a 7.5 year study on dogs (same study and derivation as noted above for non-neoplastic effects with the addition of a 5/7 conversion) . It is noted that the guideline derived is approximately equal to that which would be derived using a linearised multistage model for renal tumours and a lifetime excess cancer risk of 10^{-5}.

The WHO have published a ***TDI of 0.015 mg/kg/day (WHO 2000b)*** based on hepatoxicity in dogs (derived in 1994 from oral studies) and a ***TC =0.14 mg/m^3 (WHO, 2004).*** WHO (2000b) have also published an inhalation unit risk of ***$4.2x10^{-7}(\mu g/m^3)^{-1}$*** based on kidney tumours in rats (derived in 1994 from oral studies). No more relevant reviews of inhalation toxicity are available from the WHO.

EU

No assessment of carbon tetrachloride is available from the EU.

US

The USEPA (IRIS current in 2004) has derived an oral reference dose ***(RfD) of 0.01 mg/kg/day*** for the assessment of non-carcinogenic effects of chloroform. The RfD is based on liver effects in dogs. Evaluation of carcinogenicity of chloroform indicated that the derived RfD was considered to be protective of potential cancer effects. Hence no slope factor was derived for chloroform.

The USEPA (IRIS current in 2004) has derived an inhalation unit risk value for chloroform. The value derived is ***$2.3x10^{-5}$ $(\mu g/m^3)^{-1}$***. It is noted that this value was not reviewed as part of the 2001 review for oral data and is currently being reviwed by the USEPA.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with chloroform. The levels established (valid in 2004) are:

- Acute inhalation MRL = 0.1 ppm (0.496 mg/m^3) based on hepatic effects in mice (inhalation study)
- Intermediate inhalation MRL = 0.05 ppm (0.248 mg/m^3) based on toxic hepatitis in workers (inhalation study)
- Chronic inhalation MRL = 0.02 ppm (0.099 mg/m^3) based on hepatic effects in workers (inhalation study)
- Acute oral MRL = 0.3 mg/kg/day based on hepatic effects in mice (oral study)
- Intermediate oral MRL = 0.1 mg/kg/day based on liver effects in dogs (oral study)
- Chronic oral MRL = 0.01 mg/kg/day based on liver effects in dogs (oral study)

The California Air Resources Board (CARB and OEHHA) has established the following with respect to chloroform:

- Inhalation unit risk of ***$5.3x10^{-6}$ $(\mu g/m^3)^{-1}$*** .
- Chronic Inhalation reference Exposure Level (***REL) = 0.3 mg/m^3*** based on liver toxicity, kidney toxicity and developmental toxicity.
- Acute inhalation ***REL = 0.15 mg/m^3*** (7 hour average) based on histological changes in nasal epithelium.

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. With respect to chloroform the average intake from food, water and air has been estimated (WHO 2004) to be between 0.6 and 10 µg/kg/day. Data available from Australia indicate a similar range of potential intakes from water and air. Given the available TDI levels, it is considered relevant to assume a 50% intake from background. On this basis, the suggested threshold values should be adjusted to account for background intakes.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for chloroform following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**TDI = 0.013 mg/kg/day (WHO, 2004)*** **Adjusted tolerable intake = 0.0065 mg/kg/day (accounting for 50% background intake)**
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**TC = 0.14 mg/m^3 (annual average, WHO 2004)** **Adjusted TC = 0.07 mg/m^3 (accounting for 50% intake from background)** **Inhalation unit risk of 4.2x10^{-7}(µg/m^3)$^{-1}$** Occupational inhalation exposure (NOHSC): **TWA: 2 ppm, equivalent to 10 mg/m^3** **STEL: NA**

* Oral TDI value adopted from the WHO Drinking Water Guidelines (2004, also reviewed in CICAD 58, 2004) which provide a more recent evaluation of chloroform than presented in the Australian Drinking Water Guidelines (1996). The adoption of the new WHO value provides a more conservative evaluation.

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General

Carbon Tetrachloride (also known as carbona, carbon chloride, tetrachloromethane, carbon tet, methane tetrachloride, perchloromethane, tetrachlorocarbon) is predominantly a man-made compound, however it has been detected in volcanic emission gasses. It has also been suggested that carbon tetrachloride can be formed in the troposphere by solar induced photochemical reactions of chlorinated alkenes (WHO, 1999). Production of carbon tetrachloride began in about 1907 in the US. Since 1990 the production of carbon tetrachloride has dropped due to the Montreal protocol which established a phase-out by 1996 of the production of carbon tetrachloride and chloroflurocarbons (CFCs) by major manufacturing countries. Most of the carbon tetrachloride produced is used in the production of CFCs, which were primarily used as refrigerants, propellants, foam-blowing agents and solvents and in the production of other chlorinated hydrocarbons. Carbon tetrachloride has also been used as a grain fumigant, pesticide, solvent for oils and fats, metal degreaser, fire extinguisher and flame retardant, and in the production of paint, ink, plastics, semi-conductors and petrol additives. It was previously also widely used as a cleaning agent. All these uses have tended to be phased-out as production has dropped.

Properties

Carbon tetrachloride is a clear, colourless, volatile liquid with a characteristic, sweet odour. It is miscible with most aliphatic solvents and is itself a solvent. The solubility in water is low. Carbon tetrachloride is non-flammable and is stable in the presence of air and light. Decomposition may produce phosgene, carbon dioxide and hydrochloric acid. Key properties are presented below (ATSDR 1994 and USEPA 2002):

CAS No.	56-23-5
Chemical Formula	CCl_4
Molecular Weight	153.8
Vapour Pressure	91.3 mmHg at 20°C
Vapour Density	5.32
Density	1.59 g/ml at 25°C
Solubility (Water)	800 mg/L at 20°C
Air Diffusion Coefficient	0.078 cm^2/s
Water Diffusion Coefficient	8.8×10^{-6} cm^2/s
Henry's Law Coefficient	0.03 $atm.m^3/mol$
	= 1.2 at 25°C (unitless)
Koc	170 cm^3/g
Odour Threshold	10 to 71000 mg/m^3

Exposure

Exposure of the general population to carbon tetrachloride maybe by inhalation, oral or dermal routes. Inhalation is expected to be the major route of exposure, particularly in occupational environment, but also in the general population. Dermal contact has not been shown to be a significant route of exposure to carbon tetrachloride (ATSDR, 2003). NHMRC indicate that concentrations of carbon tetrachloride in major Australian reticulates supplies are significantly less than 0.001 mg/L (NHMRC, 1996 and draft 2002).

If released into the environment the following can be noted with respect to carbon tetrachloride (WHO 1999):

- Air: Nearly all carbon tetrachloride released to the environment will ultimately be present in the atmosphere, due to its volatility. Since the atmospheric residence time of carbon tetrachloride is long, it is widely distributed. Estimates of atmospheric lifetime are variable, but 45-50 years is accepted as the most reasonable value. Carbon tetrachloride contributes both to ozone depletion and to global warming.

- Soil and Water: Following releases to soil, most carbon tetrachloride is expected to evaporate rapidly due to its high vapour pressure. A small fraction of carbon tetrachloride may adsorb to organic matter. Carbon tetrachloride is expected to be moderately mobile in most soils, depending on organic carbon content, and leaching to groundwater may occur. Carbon tetrachloride introduced into water resources is transported by movement of surface water and groundwater. Because of its volatility, evaporation is considered to be the main process for the removal of carbon tetrachloride from aquatic systems. The amount of carbon tetrachloride dissolved in the oceans is reported to be less than 1-3% of that in the atmosphere.

- Biodegradation: Carbon tetrachloride is very stable in the troposphere primarily because carbon tetrachloride, in contrast to most other volatile halocarbons, has low reactivity towards hydroxyl radicals. The principal degradation process for carbon tetrachloride occurs in the stratosphere, where it is dissociated by short wave length (190- 220 nm) UV radiation to form the trichloromethyl radical and chlorine atoms. Simmonds et al. (1983) estimated a half-life of 18-80 years for this photo dissociation process. Carbon tetrachloride dissolved in water does not photodegrade or oxidize in any measurable amounts with the rate of hydrolysis calculated with a half-life of 7000 years (concentration of 1 ppm). Carbon tetrachloride has been shown to be resistant to aerobic biodegradation, however biodegradation may occur within 16 days under anaerobic conditions. Carbon tetrachloride may undergo reductive dechlorination to form chloroform and other products in the presence of free sulphide and ferrous ions.

- Carbon tetrachloride has a low tendency to bioconcentrate in aquatic or marine organisms. Most animals readily metabolise and excrete carbon tetrachloride following exposure and hence biomagnification is not expected.

Health Effects

General

The following information is available from WHO (1999) and ATSDR (2003). There is no clinical disease which is unique to carbon tetrachloride toxicity.

Carbon tetrachloride is well absorbed from the gastrointestinal and respiratory tract in animals and humans. Dermal absorption of liquid carbon tetrachloride is possible, but dermal absorption of the vapour is slow.

Carbon tetrachloride is distributed throughout the whole body, with highest concentrations in liver, brain, kidney, muscle, fat and blood. The parent compound is eliminated primarily in exhaled air, while minimal amounts are excreted in the faeces and urine.

Carbon tetrachloride has depressant effects on the central nervous system particularly following high levels of exposure. It can also produce irritation effects on the gastrointestinal tract and skin. Most other toxic effects associated with exposure to carbon tetrachloride are associated with it metabolism by mixed function cytochrome P-450 oxygenases.

The liver and kidney are target organs for carbon tetrachloride toxicity via oral and inhalation exposures. The severity of the effects on the liver depends on a number of factors such as species susceptibility, route and mode of exposure, diet or co-exposure to other compounds, in particular ethanol. Furthermore, it appears that pre-treatment with various compounds, such as phenobarbital and vitamin A, enhances hepatotoxicity, while other compounds, such as vitamin E, reduce the hepatotoxic action of carbon tetrachloride.

In humans, acute symptoms after carbon tetrachloride exposure are independent of the route of intake and are characterized by gastrointestinal and neurological symptoms, such as nausea, vomiting, headache, dizziness, dyspnoea and death. Liver damage appears after 24 h or more. Kidney damage is evident often only 2 to 3 weeks following the poisoning.

Epidemiological studies have not established an association between carbon tetrachloride exposure and increased risk of mortality, neoplasia or liver disease. Some studies have suggested an association with increased risk of non-Hodgkin's lymphoma and, in one study, with mortality and liver cirrhosis. However, not all of these studies pinpointed specific exposure to carbon tetrachloride, and the statistical associations were not strong.

Genotoxic Effects

It was concluded that carbon tetrachloride can induce embryotoxic and embryolethal effects, but only at doses that are maternally toxic, as observed in inhalation studies in rats and mice. Carbon tetrachloride is not teratogenic (WHO 1999).

Many genotoxicity assays have been conducted with carbon tetrachloride. On the basis of available data, carbon tetrachloride can be considered (WHO 1999) as a non-genotoxic compound. Review of genotoxicity associated with carbon tetrachloride by Woodward-Clyde (1996) supported this outcome.

Cancer

Human data on the carcinogenic potential of carbon tetrachloride are limited and there have been no conclusive associated between carbon tetrachloride exposure and cancer in humans. In experiments with mice and rats, carbon tetrachloride proved to be capable of inducing hepatomas and hepatocellular carcinomas. The doses inducing hepatic tumours were higher than those inducing cell toxicity. It is considered likely that the carcinogenicity of carbon tetrachloride is secondary to its hepatotoxic effects (WHO 1999) and may be related to its metabolism (ATSDR 2003).

The available data (WHO 1999 and review by Woodward-Clyde 1996) indicate that hepatic tumours are induced by a non-genotoxic mechanism, and it therefore seems acceptable to develop a tolerable daily intake (TDI) and a tolerable daily concentration in air (TC) for carbon tetrachloride.

Toxicity Classification

Carbon tetrachloride has been classified as a "probable" human carcinogen (Category B2) by the USEPA based on carcinogenicity in rats, mice and hamsters.

IARC (1999) has classified carbon tetrachloride in Group 2B (possibly carcinogenic to humans) based on inadequate evidence in humans and sufficient evidence in experimental animals for carcinogenicity.

The National Occupational Health and Safety Commission (NOHSC) as Category 2 carcinogen (probable human carcinogen). NICNAS has classified not classified carbon tetrachloride.

Exposure Limits/Toxicity Evaluations

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002) have derived a drinking water guideline of 0.0033 mg/L for carbon tetrachloride using a ***TDI of 0.00086 mg/kg/day*** derived from a no effect level based on a 90-day gavage study on mice and the application of 1000 safety factor and a 5/7 study duration adjustment factor.

Worksafe Australia (NOHSC) have established “Exposure Standards for Atmospheric Contaminants in the Occupational Environment”. For carbon tetrachloride, the following have been established:

TWA: 0.1 ppm, equivalent to 0.63 mg/m^3

STEL: NA

Potential exposure via skin absorption is noted.

WHO

Review of carbon tetrachloride by the WHO in 1999 has derived a number of tolerable daily intake (TDI) values for oral exposure and tolerable concentrations (TC) for inhalation exposure. The values derived are:

- TDI = 0.00142 mg/kg/day based on a 12 week oral rat study (NOAEL of 1 mg/kg), 500 uncertainty factor and a 5/7 conversion.
- TDI = 0.00172 mg/kg/day based on a 90-day oral study on mice (NOAEL of 1.2 mg/kg), 500 uncertainty factor and 5/7 conversion.
- TC = 0.0061 mg/m^3 based on 90-day inhalation study on rats (NOAEL 6.1 mg/m^3) and 100 uncertainty factor.
- TC = 0.0067 mg/m^3 based on 6-month inhalation study on rats (NOAEL 32 mg/m^3), 1000 uncertainty factor and 5/7 conversion.
- TC = 0.0114 mg/m^3 based on a 2-year inhalation study on rats (LOAEL 32 mg/m^3), 500 safety factor and 5/7 conversion.

The WHO (Drinking Water Guideline 1996) provide a guideline value for carbon tetrachloride of 0.002 mg/L based on a ***TDI of 0.00071 mg/kg/day*** derived from a 12-week oral study on rats. The WHO revision to the Drinking Water Guideline (2004) derives a guideline of 0.004 mg/L based on a ***TDI of 0.00142 mg/kg/day*** derived from a 12-week oral study in rats (as per WHO 1999). It is noted that the guideline derived (1996 and 2004) is lower than values calculated using linear extrapolation and a lifetime excess cancer risk of 10^{-4} to 10^{-6}.

The WHO (2000b) have published a ***TC of 0.0061 mg/m³*** based on 90-day inhalation study on rats, the lower TC value derived by WHO (1999, noted above) based on an annual average.

EU

No assessment of carbon tetrachloride is available from the EU.

US

The USEPA (IRIS current in 2004) has derived an ***oral slope factor of 0.13*** $(mg/kg/day)^{-1}$ for carbon tetrachloride based on a linear multistage model based on hepatocellular carcinomas and hepatomas; and an ***inhalation unit risk of*** $1.5x10^{-5}$ $(\mu g/m^3)^{-1}$ using a linear multistage model based on oral data used to derive the oral slope factor. The USEPA has also derived an oral reference dose ***(RfD) of 0.0007 mg/kg/day*** for the assessment of non-carcinogenic effects. The RfD is based on liver lesions in a sub-chronc rat study.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with carbon tetrachloride. The levels established (valid in 2004) are:

- Intermediate inhalation MRL = 0.03 ppm (0.19 mg/m^3) based on hepatic effects in animals (inhalation study).
- Chronic inhalation MRL = 0.03 ppm (0.19 mg/m^3) based on hepatic effects in rats (inhalation study).
- Acute oral MRL = 0.05 mg/kg/day based on hepatic effects in rats (oral study).
- Intermediate oral MRL = 0.02 mg/kg/day based on hepatic effects in rats (oral study).

The California Air Resources Board (CARB and OEHHA) has established the following with respect to carbon tetrachloride:

- Inhalation unit risk of $4.2x10^{-5}$ $(\mu g/m^3)^{-1}$.
- Chronic Inhalation reference Exposure Level (***REL) = 0.04*** mg/m^3 based on hepatic effects in guinea pigs.
- Acute inhalation REL = 1.9 mg/m^3 (1 hour average).

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. Intake of carbon tetrachloride from soil, water and food can be considered to be insignificant. Intakes from air can be calculated from urban air concentrations from a light industrial area in Brisbane (Hawas, 2001) which indicate a background concentration of 0.0025 mg/m^3 (average) to 0.004 mg/m^3 (max) which is approximately 40 to 65% of the tolerable concentration in air (equivalent to an ADI) as adopted from the WHO (2000b). On the basis of maximum concentrations of carbon tetrachloride in air from this study, background intake can be assumed to be up to 65 40% of the TC (WHO 2000b). On this basis, the suggested threshold values should be adjusted to account for background intakes.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for carbon tetrachloride following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**TDI = 0.00142 mg/kg/day (WHO 1999 and 2004)** **Adjusted tolerable intake = 0.000497 mg/kg/day (accounting for 65% background intake)**
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**TC = 0.0061 mg/m^3 (annual average, WHO 1999 and 2000b)** **Adjusted TC = 0.0021 mg/m^3 (accounting for 65% intake from background)** Occupational inhalation exposure (NOHSC): **TWA: 0.1 ppm, equivalent to 0.63 mg/m^3** **STEL: NA**

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General

Trichloroethene (also known as 1,1,2-trichloroethylene, ethylene trichloride, and commonly abbreviated to **TCE**) is a synthetic product that was first prepared in 1864 by the reduction of hexachloroethane with hydrogen. It is mainly used as a liquid or vapour degreasing solvent, particularly in the metal fabricating industry. International concern about the environmental and health and safety concerns of chlorinated solvents has reduced the use of TCE.

TCE was manufactured in Australia from the 1950's to the early 1980's, with current demand met by imports of the chemical. TCE is also recycled in Australia. TCE is used widely in both large and small industries in Australia for vapour degreasing, cold cleaning as well as use in adhesives, waterproofing agents, paint strippers, carpet shampoos and some other cleaning products. It is also an effective cleaning agent for organic materials as it has a low latent heat of vaporisation and is non-flammable.

Properties

TCE is a volatile, colourless or blue mobile liquid with a sweet chloroform-like odour. TCE evaporates into air very quickly and dissolves slightly in water. Key properties are presented below (ATSDR 1995 and USEPA 2002):

CAS No.	79-01-6
Chemical Formula	C_2HCl_3
Molecular Weight	131.4
Vapour Pressure	74 mmHg at 25°C
Vapour Density	4.53
Density	1.465 g/ml at 20°C
Solubility (Water)	1100 mg/L at 20°C
Air Diffusion Coefficient	0.079 cm^2/s
Water Diffusion Coefficient	9.1×10^{-6} cm^2/s
Henry's Law Coefficient	0.0103 $atm.m^3/mol$
	= 0.422 at 25°C (unitless)
Koc	166 cm^3/g
Odour Threshold	115 mg/m^3 (recognition of TCE, WHO 2000)

Exposure

Exposure of the general population to TCE may be by inhalation, oral or dermal routes. In most cases inhalation is the primary route of exposure. Exposure may occur through oral ingestion of drinking water or soils, however exposure to TCE in food is generally low. Apart from occupational exposures, the primary concern is inhalation indoors. TCE in the outdoor air may originate from indoor or outdoor sources. Outdoor sources include outdoor air, contaminated soils or groundwater. Indoor air sources include new building construction materials or home cleaning products. The potential for bioaccumulation of TCE is considered to be low.

If released into the environment the following can be noted with respect to TCE:

- Air: TCE is expected to remain in vapour phase. Removal is primarily through reaction with hydroxyl radicals to produce low levels of phosgene, dichloroacetyl chloride, formyl chloride and other degradation products. Half-life pf TCE varies from 1 day to months.
- Soil and Water: TCE is expected to volatilise from surface soils and water. TCE may leach through soil into groundwater where it may persist for years.
- Water: Depending on conditions reductive dehalogenation to vinyl chloride may occur. Under anaerobic conditions TCE can be intrinsically biodegraded to form DCE and vinyl chloride (below).

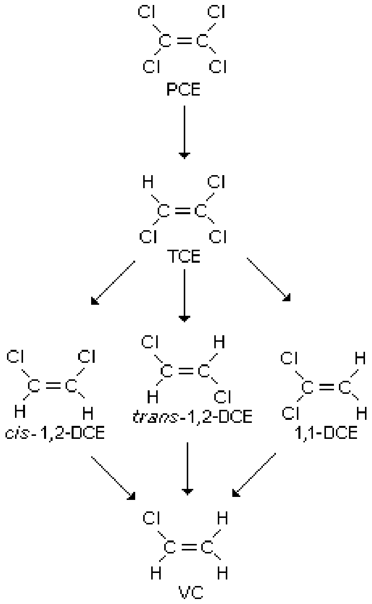

Figure 1. Pathway for anaerobic microbial degradation of chlorinated ethenes to form vinyl chloride (from: WHO, 1999)

NB: PCE=tetrachloroethene, TCE=trichloroethene, DCE=dichloroethene

Health Effects

General

There is no clinical disease which is unique to TCE toxicity. In the past, TCE was used as a human anaesthetic. TCE has also been inhaled by people intentionally for its narcotic effect. Hence most toxicological data is associated with inhalation exposures. Primary effects are associated with the central nervous system (CNS).

TCE can be absorbed into the body via inhalation, ingestion and dermal exposure. Following absorption into the body, TCE is distributed to the blood, then transported to various tissues where it is metabolised. The toxicities associated with TCE are thought to be mediated by metabolites rather than the parent compound. Major sites of TCE distribution appear to be the body fat and liver.

Humans and animals excrete un-metabolised TCE via expiration, while the metabolites are excreted primarily in urine. Urinary metabolites include trichloroacetaldehyde, trichloroethanol, and trichloroacetic acid; the reactive epoxide TCE oxide is an essential feature of the metabolic pathway.

The following summary has been derived from NICNAS (2000) and ATSDR (1995).

Death

Acute inhalation and oral exposure of TCE has been known to result in death in humans. Cause of death is typically attributed to hepatorenal failure (ingestion), ventricular fibrillation or CNS depression.

Gastrointestinal Effects

Acute inhalation exposure to TCE has results in nausea and vomiting. Chronic exposure to TCE in the occupation environment has been associated with anorexia and vomiting.

Hepatic Effects

There is some evidence for TCE inducted hepatotoxic effects in humans. Reports (occupational) support the liver as the end point of TCE toxicity. Studies in animals (inhalation and oral) over acute and intermediate periods indicate liver enlargement.

Dermal/Ocular Effects

Exposure to high doses of TCE through contact with the air or skin has resulted in skin irritation and rashes. Stevens-Johnson syndrome (severe erythema), dermatitis and scleroderma have been reported in occupational environments. Adverse effects have not been reported from exposure to dilute aqueous solutions of TCE.

Ocular effects such as mild eye irritation have been observed in occupational environments.

Body Weight Effects

Body weight loss has been reported in humans occupationally exposed to TCE in air for intermediate of chronic durations at concentrations resulting in neurological effects. No significant effects were observed from oral studies.

Immunological Effects

No significant effects have been reported following inhalation an oral exposures and animal studies.

Neurological Effects

Primary effects identified following inhalation exposures to TCE are associated with the CNS. Effects include headache, vertigo, fatigue, nausea, memory loss, decreased word associations, depression of the CNS, and anaesthesia. Animal studies have reported neurotoxicity and neuropathology effects following oral exposure studies. These effects in part are thought to be due to the sedative properties of the metabolite trichloroethanol (TCOH).

Reproductive Effects

Reproductive effects (increases in miscarriages) have been observed in following exposure to TCE in humans and animals.

Developmental Effects

Other than reproductive effects, no significant developmental effects have been identified following inhalation exposures to TCE. Evidence of birth defects following TCE exposure in drinking water is not clear, however animal studies indicate TCE can act as a developmental toxicant following oral exposure.

Genotoxic Effects

Studies are not conclusive but may be suggestive of clastogenic effects. No human oral studies are available, and animal oral studies indicate conflicting findings. Review of TCE by Woodward-Clyde (1996) indicates that the weight of evidence suggests that TCE has a limited ability to cause genotoxicity. TCE is only weakly mutagenic in bacteria and yeast and the ability of TCE to interact with DNA in whole animals is observed only at high doses. Review by NICNAS (2000) indicates that TCE can be classified a category 3 mutagen – "*as a substance which cause concern for humans owing to possible mutagenic effects, but in respect of which* *available information does not satisfactorily demonstrate heritable genetic damage.*"

Cancer

No clear unequivocal evidence is available that TCE inhalation exposure is linked to increased cancer risk. The link between oral exposure to TCE and cancer in humans is controversial. Studies in rats and mice have indicated TCE and its metabolites are carcinogenic in animals. TCE has been shown to induce lung and liver tumours in various strains of mice at toxic doses. However, there are no conclusive data that the chemical causes cancer in other species. Review of TCE by Woodward-Clyde (1996) indicates similar findings.

Toxicity Classification

TCE was classified as a "probable" human carcinogen (Category B2) by the USEPA for all routes of exposure based upon evidence from animal studies. This classification has been withdrawn pending further review (not finalised as of June 2004).

IARC has classified TCE in Group 2A (probably carcinogenic to humans) based in limited evidence from several human epidemiological studies and on sufficient evidence from animal studies.

NICNAS has classified TCE as a Carcinogen Category 2, which is a substance regarded as if it is carcinogenic to humans, on the basis of the occurrence of tumours in experimental animals and limited evidence in workers.

Exposure Limits/Toxicity Evaluations

Exposure limits and toxicity evaluations which are available in Australia, World Health Organisation, European Union and the US:

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002) have indicated that there are no long-term studies available to establish a no effect level associated with TCE, hence the available data was considered inadequate to establish an Australian guideline.

Worksafe Australia (NOHSC) have established "Exposure Standards for Atmospheric Contaminants in the Occupational Environment". For TCE, the following have been established:

TWA: 50 ppm, equivalent to 270 mg/m^3

STEL: 200 ppm, equivalent to 1080 mg/m^3

It should be noted that changes have been proposed to these levels. Changes have been issued by NOHSC for public comment in November 2003. They have not been adopted as of June 2004, however the proposed changes are noted:

TWA: 10 ppm, equivalent to 54 mg/m^3

STEL: 40 ppm, equivalent to 216 mg/m^3

WHO

The WHO (Drinking Water Guideline 1996 and 2004) established a ***TDI of 23.8 µg/kg of body weight*** (including allowance for 5 days per week dosing). This was calculated by applying an uncertainty factor of 3000 to a LOAEL of 100 mg/kg of body weight per day for minor effects on relative liver weight in a 6-week study in mice. The uncertainty factor components are 100 for inter- and intra-species variation, 10 for limited evidence of carcinogenicity, and an additional factor of 3 in view of the short duration of the particular study and the use of a LOAEL rather than a NOAEL.

Draft review of TCE by the WHO in 2004 as part of the rolling revision to the guidelines (not endorsed at this stage) has provided a provisional guideline value for cancer effects and non-cancer effects. With respect to the evaluation of cancer effects, the LSM was used to calculate a unit risk (slope factor) for kidney tumours observed in rates. Use of the LMS model is considered relevant based on possible genotoxicity associated with some TCE metabolites (particularly DCVC and DCVG). The slope factor derived was ***$7.8x10^{-4}$ $(mg/kg/day)^{-1}$*** following review of data from oral and inhalation studies. Review of non-cancer effects has resulted in the derivation of a TDI (which is lower than that presented by WHO in 1996 and 2004). The TDI was derived using a LOAEL from a developmental toxicity study, applying a benchmark dose approach to estimate a NOAEL, and application of an uncertainty factor of 100. The TDI derived was ***0.00146 mg/kg/day***. As these values are only available for review and are not endorsed, they have not been considered as approved values for the purpose of selecting relevant toxicity values following enHealth guidance.

The WHO (2000) provided toxicity data for a range of chemicals which were considered to have carcinogenic endpoints. TCE was one of those chemicals identified and an inhalation unit risk of $4.3x10^{-7}$ (per $\mu g/m^3$) for the assessment of exposures to TCE in air has been established. (i.e. for an air concentration of 1 $\mu g/m^3$, the lifetime risk is estimated to be $4.3x10^{-7}$). The unit risk has been established by the WHO based on increase tumours in lungs and testes in animal bioassays. In utilising this data, the WHO note that "*it cannot be conclusively established whether a threshold with regard to carcinogenicity in the action of TCE may be assumed.*" Hence a conservative approach (deriving a unit risk) has been adopted by the WHO.

The unit risk value is equivalent to the following slope factor:

$$SF\ (mg/kg/day)^{-1} = Risk/Intake(mg/kg/day)$$

$$= [Risk\ x\ Body\ Weight]/[Concentration\ (in\ air)\ x\ Inhalation\ Rate)]$$

$$= [4.3x10^{-7}\ x\ 70kg]/[0.001mg/m^3\ x\ 20\ m^3/day]$$

$$\mathbf{= 0.0015\ (mg/kg/day)^{-1}}$$

EU

Review of TCE by the European Union (EU) in 2004 indicates that TCE gives rise to concern for humans owing to possible mutagenic and carcinogenic effects and because it is not possible to identify a threshold exposure level below which these effects would not be expressed. TCE is an *in vitro* mutagen in the presence of an exogenous metabolic activation system. Conflicting data exists, however the weight of evidence indicates that TCE can also exhibit genotoxic activity in somatic tissues *in vivo*. TCE is considered to have the potential to cause cancer in humans. The evaluation of exposure by the EU has focused on workers, consumers and environmental exposures. The evaluation has reviewed relevant toxicity end points, evaluated body burden associated with exposure and calculated a Margin of Exposure (MOE). The most sensitive threshold effect evaluated was associated with CNS disturbance following repeated dose where a NOAEL of 38 mg/kg/day was used.

The EU has presented a calculation of lifetime cancer risk based on the T25 method in relation to non-Hodgkin lymphoma. From an inhalation study in female mice a HT25 dose descriptor for humans was derived as 130 mg/kg/day. Following the approach presented the EU calculated increased cancer risk for TCE for all groups using an ***equivalent slope factor of 0.0019 (mg/kg/day)$^{-1}$***. This value was used in the quantification of risk associated with exposure from oral, dermal and inhalation pathways.

US

The USEPA has withdrawn the slope factor and reference dose for TCE in 1994, pending review. Prior to being withdrawn, the USEPA had determined an oral slope factor of 0.013 (mg/kg/day)$^{-1}$ and an inhalation slope factor of 0.006 (mg/kg/day)$^{-1}$.

The USEPA issued an evaluation of TCE as a draft for review in 2001. The evaluation indicated that mechanistic research indicates that TCE-induced carcinogenesis is complex, involving multiple carcinogenic metabolites acting through multiple modes of action. Under EPA's proposed (1996, 1999) cancer guidelines, TCE can be characterized as ``highly likely to produce cancer in humans."   For effects other than cancer, an oral reference dose (***RfD) of 3x10^{-4} mg/kg/d*** was based on critical effects in the liver, kidney, and developing fetus. An inhalation reference concentration (***RfC) of 4x10^{-2} mg/m^3*** was based on critical effects in the central nervous system, liver, and endocrine system. Several cancer slope factors were developed, with most between 0.02 and 0.4 per mg/kg/d. Several sources of uncertainty have been identified and quantified. The review process has not been completed to date.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with TCE. The levels established (valid in 2004) are:

- Acute inhalation MRL = 2ppm based on neurological effects in humans
- Intermediate inhalation MRL = 0.1ppm based on neurological effects in rats
- Acute oral MRL = 0.2 mg/kg/day based on developmental effects in mice

The California Air resources Board (CARB, 1990) has established an inhalation unit risk for the evaluation of chronic exposure to TCE. The inhalation unit risk is 2x10^{-6} to 3x10^{-6} (µg/m^3)$^{-1}$.

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. With respect to TCE, intakes from soil, water and food can be considered to be insignificant. Intakes from air have been calculated from industrial air concentrations in reported in Brisbane (Hawas O. et. Al., 2001), with the maximum concentration reported of 0.000546 mg/m^3 (representing an intake of approximately 0.00018 mg/kg/day). Hence background intakes of TCE can be considered to be low and do not affect the use of available ADI, TDI or RfD values.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**TDI = 0.0238 mg/kg/day** (WHO Drinking Water Guidelines, 2004)*
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**Inhalation unit risk of 4.3x10^{-7} (per µg/m^3),** equivalent to **0.0015 $(mg/kg/day)^{-1}$** (WHO 2000, also similar to that derived by EU 2004). Occupational inhalation exposure evaluated using the proposed levels (NOHSC, proposed November 2003): **TWA: 10 ppm, equivalent to 54 mg/m^3** **STEL: 40 ppm, equivalent to 216 mg/m^3**

* Proposed revision to this value is available from WHO, however as these values are only available for review and have not been endorsed, they have not been considered in this assessment. Once endorsed, the oral exposure to TCE will be revised accordingly.

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General

Tetrachloroethene (also known as tetrachloroethylene, perchloroethylene, ethylene tetrachloride, per, perc, perchlor, 1,1,2,2-tetrachloroethylene and commonly abbreviated to **PCE**) is a synthetic chemical that is widely used for dry cleaning of fabrics and for metal-degreasing operations. It is also used as a building block for making other chemicals and is used in some consumer products. PCE manufacture in Australia ceased in 1991. Use in Australia has declined from 1995, consistent with declining use worldwide. PCE is primarily imported in its "pure" form with approximately 80 % used in the dry cleaning industry in Australia.

PCE is widespread in the environment and is found in trace amounts in water, aquatic organisms, air, foodstuffs, and human tissue. The highest environmental levels of PCE are found in the commercial dry-cleaning and metal-degreasing industries. The Australian Drinking Water Guidelines (1996 and Draft 2002) indicate that PCE has not been detected in Australian drinking water supplies.

PCE may degrade in the environment to more toxic compounds, including vinyl chloride.

Properties

PCE is a volatile, colourless liquid. It is a non-flammable liquid at room temperature which evaporates easily into the air and has a sharp, sweet odour. PCE is practically insoluble in water but miscible with ethanol, ether and oils. Key properties are presented below (ATSDR 1997 and USEPA 2002):

CAS No.	127-18-4
Chemical Formula	C_2Cl_4
Molecular Weight	165.83
Vapour Pressure	18.5 mmHg at 25°C
Vapour Density	5.8
Density	1.62 g/ml at 20°C
Solubility (Water)	200 mg/L at 20°C
Air Diffusion Coefficient	0.072 cm^2/s
Water Diffusion Coefficient	8.2×10^{-6} cm^2/s
Henry's Law Coefficient	0.0184 atm.m^3/mol = 0.754 at 25°C (unitless)
Koc	155 cm^3/g
Odour Threshold	6.8 mg/m^3 (ATSDR) and 33.9 mg/m^3 (NOHSC)

Exposure

Exposure to PCE may be derived from environmental and occupational sources as well as from consumer products. Common background levels of PCE in the environment are generally several thousand times lower than levels found in some workplaces. Background levels are found in the air, water, and food. The most significant exposure pathway is via the air, particularly in the workplace. PCE gets into air by evaporation from industrial or dry cleaning operations and released from stores of chemical wastes. It is frequently found in surface water.

Common consumer products that may contain PCE include water repellents, silicone lubricants, fabric finishers, spot removers, adhesives, and wood cleaners. Although uncommon, small amounts of PCE have been found in food, especially food prepared near a dry cleaning facility. PCE has also been detected in the breast milk of mothers who have been exposed to the chemical. PCE is considered (NICNAS, 2001) to have a low potential for bioaccumulation.

If released into the environment the following can be noted with respect to PCE:

- Air: PCE is expected to remain in vapour phase. Removal is primarily through reaction with hydroxyl radicals, or chlorine atoms produced through photo-oxidation of PCE, which results in half-lives of 1 hour to 2 months.
- Soil and Water: PCE is expected to volatilise from surface soils and water. PCE has a low to medium mobility in soil and may leach slowly through soil into groundwater where it may persist for years. Depending on conditions reductive dehalogenation to vinyl chloride may occur. Under anaerobic conditions PCE and TCE can be intrinsically biodegraded to form DCE and vinyl chloride (below).

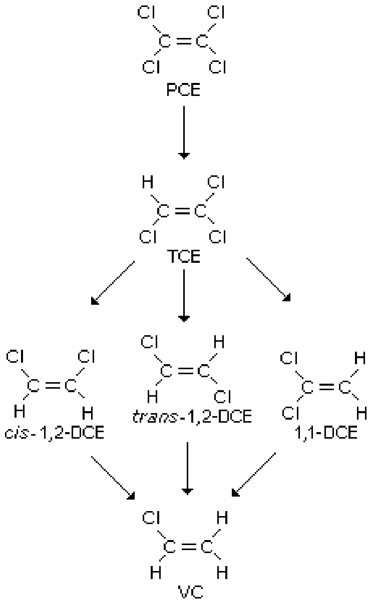

Figure 1. Pathway for anaerobic microbial degradation of chlorinated ethenes to form vinyl chloride (from: WHO, 1999)

NB. PCE=tetrachloroethene, TCE=trichloroethene, DCE=dichloroethene

Health Effects

General There is no clinical disease which is unique to PCE toxicity. PCE is absorbed mainly through inhalation, causing both irritation and neurobehavioral effects. Skin burns, blistering and erythema can occur from severe direct contact with PCE. Some skin absorption can occur but does not appear to be of major significance. The amount of the chemical in the body increases with increasing exposure level and with an increase in physical exercise during exposure. It accumulates to a limited extent in the fatty tissues of man and of animals. Because of its affinity for fat, PCE is found in milk. PCE has also been shown to cross the placenta and distribute to the foetus.

PCE is eliminated slowly through the lungs. A small amount is metabolised to trichloroethanol and trichloroacetic acid The concentrations of the compound in blood and breath can be used for estimating exposure levels in man.

At high concentrations, PCE causes central nervous system depression. Lower concentrations of PCE have been reported to damage the liver and the kidneys.

The following summary has been derived from ATSDR (1997).

Death

At high concentrations PCE is a potent anaesthetic agent and a cardiac sensitiser. Hence death resulting from excessive depression of the respiratory centre or the onset of fatal cardiac arrhythmia may occur. Deaths associated with PCE exposure (inhalation and ingestion) have been reported.

Respiratory Effects

Exposure to high concentrations of PCE has been associated with respiratory irritation.

Gastrointestinal Effects

Acute inhalation exposure to PCE has resulted in nausea and vomiting.

Hepatic Effects

The liver is a target organ in humans exposed to high concentrations of PCE in air. In animals, liver effects are characterised by hypertrophy, fatty degeneration and peroxisome proliferation. Hepatic lesions are also induced in experimental animals during inhalation exposure to PCE. The liver has not been shown to be a target organ in humans exposed via the oral route, however it is a target organ in animals exposed orally.

Renal Effects

Symptoms of renal dysfunction (including proteinuria and hematuria) have been associated with exposure to anaesthetic concentrations of PCE vapour. Weak (or no) effects have reported in people with chronic occupational exposures. Adverse renal effects have been observed in rodents exposed to PCE via inhalation and oral ingestion.

Dermal/Ocular Effects

Exposure to high doses of PCE through contact with the air or skin has resulted in burning or stinging in the eyes, transient eye irritation, acute burning and maculapapular rashes. Skin burns, blistering and erythema can occur from severe direct contact with PCE.

Body Weight Effects

Body weight loss has been reported in rats exposed to PCE in air and via oral ingestion.

Immunological Effects

No significant effects have been reported following inhalation exposures. Limited data supports immunotoxic effects on B cells/humoral immunity associated with oral exposures.

Neurological Effects

The nervous system is a major target organ in humans exposed to PCE via inhalation and ingestion. Anaesthetic and preanesthetic central nervous system effects (including mood changes, ataxia, faintness, dizziness, loss of motor coordination collapse, coma and seizures) have been reported from exposures over different periods of time. While acute symptoms seem to improve after cessation of exposure, chronic exposure has been associated with chronic encephalophy (memory and concentration impairment) is persistent after cessation of exposure. Neurological effects and biochemical changes in the brain have been reported in animals exposed to PCE.

Reproductive Effects

Some adverse reproductive effects in occupationally exposed women have been reported which include increased risk of spontaneous abortion. Animal studies indicate reproductive effects associated with PCE exposure.

Developmental Effects

Limited animal studies indicate the potential for a slight increase in maternal and foetal toxicity following inhalation exposure to PCE. Animal studies associated with oral exposure to PCE indicate maternal toxicity, increased numbers of postnatal deaths and increased micro/anophthalmia. Acute studies indicate developmental neurotoxicity (with the LOAEL utilised by the ATSDR in the establishment of an acute oral MRL).

Genotoxic Effects

Assays of clastogenic effects in humans have shown inconsistent results in occupational human studies. No animal studies show genotoxic effects. From weight of evidence, PCE is considered to be non-genotoxic (WHO 2000). Lack of strong genotoxic effects is considered (by ATSDR) to be consistent with the metabolism of the compound. Review of PCE undertaken by Woodward-Clyde (1996) indicated that the weight of evidence indicates that PCE is non-genotoxic. However, genotoxicity is observed when PCE is stabilised with known genotoxicants such as compounds containing epoxide groups.

Cancer

Some epidemiological studies indicate a possible association between chronic exposure to PCE and an increased cancer risk, however the evidence provided is considered to be inconclusive. This is mainly due to concurrent exposure to other petroleum solvents as well as PCE, confounding factors (smoking, alcohol, socio-economic status) and small numbers of cancers in the studies.

An association between exposure to PCE (inhalation and ingestion) and an increased risk of cancer (mononuclear cell leukaemia and hepatic tumours) in animals has been suggested. Review of PCE by Woodward-Clyde (1996) indicates that PCE is a non-genotoxic animal carcinogen. Review of the possible mechanisms of tumour formation by PCE in animals suggests that the tumours observed may have little relevance for humans. Therefore a threshold type of exposure parameter would be relevant as a basis for human health risk assessment.

NICNAS has classified PCE as a Carcinogen Category 3, which is a substance regarded as a possible risk of irreversible effects.

Toxicity Classification

PCE was classified as a "probable" human carcinogen (Category B2) by the USEPA for all routes of exposure based upon evidence from animal studies. This classification has been withdrawn pending further review (not finalised as of June 2004).

IARC has classified PCE in Group 2A (probably carcinogenic to humans) based in limited evidence in humans (epidemiological studies showed elevated risks for oesophageal cancer, non-Hodgkin's lymphoma and cervical cancer) and sufficient evidence in experimental animals (induce peroxisome proliferation in mouse liver and induced leukaemia in rats).

Exposure Limits/Toxicity Evaluations

Exposure limits and toxicity evaluations which are available in Australia, World Health Organisation, European Union and the US are presented below:

Australia

The Australian Drinking Water Guidelines (1996 and proposed 2002) has followed the WHO Drinking Water Guidelines (1996) which established health based guidelines derived from a **TDI of 0.014 mg/kg/day**. The TDI was derived from both a 6 week mice study and 90 day rat oral drinking water study, both of which indicated a NOAEL of 14 mg/kg/day. An uncertainty factor of 1000 was applied to the NOAEL (100 for inter- and intraspecies variation and 10 for carcinogenic potential). On this basis, the TDI established by WHO can be used for the evaluation of oral exposures to PCE.

Worksafe Australia (NOHSC) have established "Exposure Standards for Atmospheric Contaminants in the Occupational Environment". For PCE, the following have been established:

TWA: 50 ppm, equivalent to 335 mg/m^3

STEL: 150 ppm, equivalent to 1020 mg/m^3

WHO

Oral TDI used to derive drinking water guidelines (1996) as outlined above in the derivation of Australian Drinking Water Guidelines. The guideline has remained unchanged in the latest WHO guideline (WHO 2004).

Review of inhalation evaluations for PCE as presented by the WHO (2000, 2000b)indicates the following:

Reference	Inhalation Guideline Value	Averaging Time	Basis
WHO 2000	GV = 0.25 mg/m^3	24 hours	Non-carcinogenic LOAEL associated with kidney effects from long-term occupational study
WHO 2000	GV = 8 mg/m^3	30 minutes	Non-carcinogenic odour annoyance level
WHO 2000b	GV = 0.25 mg/m^3	annual	Non-carcinogenic kidney effects in workers (as per WHO 2000) above.

There appears to be some inconsistency in air quality guideline values published by the WHO, particularly with respect to the relevant averaging time for the GV of 0.25 mg/m^3. It should also be noted that the WHO (2000b) indicates that the guideline value is established based on non-carcinogenic end-points and that review of possible carcinogenic end points should be undertaken in the future.

US

The USEPA have established an oral reference dose (RfD) of 0.01 mg/kg/day (available from IRIS 2004) based on hepatotoxicity in mice and increased liver and kidney weights in rats over 13 weeks. An uncertainty factor of 1000 was used to derive the RfD. The USEPA provides no data relevant to non carcinogenic inhalation or carcinogenicity. The slope factor previously provided by the USEPA (0.051 $mg/kg/day)^{-1}$) based on mouse liver tumour data has been withdrawn (1990).

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with PCE. The levels established (valid in 2004) are:

- Acute inhalation MRL = 0.2ppm based on neurological effects in humans;
- Chronic inhalation MRL = 0.04ppm based on neurological effects in rats; and
- Acute oral MRL = 0.05 mg/kg/day based on developmental effects in mice.

The California Air Resources Board (CARB, current to 2004) has listed PCE as a toxic air contaminant and evaluated cancer and non cancer effects. Cancer effects for PCE have been evaluated on the basis of an inhalation unit risk of 5.9×10^{-6} $(\mu g/m^3)^{-1}$ (equivalent to 0.021 $(mg/kg/day)^{-1}$, provided in 1991). Values established to evaluate non cancer effects include and acute inhalation value of 20000 $\mu g/m^3$ (reviewed 1999) based on CNS effects and a chronic inhalation value of 35 $\mu g/m^3$ (reviewed in 2000) based on effects to the kidney, liver and gastrointestinal system.

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI, GV or RfD in assessing potential exposures to site related chemicals. With respect to PCE, intakes from soil, water and food can be considered to be insignificant. Intakes from air have been calculated from industrial air concentrations in reported in Brisbane (Hawas O. et. Al., 2001), with the average and maximum concentrations reported of 0.015 mg/m^3 and 0.085 mg/m^3 respectively (consistent with data from other cities, NICNAS 2001). This represents up to 34% intake from background air sources. On this basis, the oral TDI and inhalation GV identified should be reduced to account for approximately 34% background intake.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**Oral TDI = 0.014 mg/kg/day** (NHMRC 1996 and WHO 1996) **Adjusted tolerable intake = 0.0092 mg/kg/day** (background intake of 34%)
Dermal	No dermal guidelines are available; hence it has been assumed that dermal toxicity is equivalent to oral toxicity.

Inhalation	**Inhalation GV = 0.25 mg/m^3** (WHO, 2000b) based on an annual average. **Adjusted GV = 0.17 mg/m^3** (background intake of 34%) Occupational inhalation exposure levels (NOHSC): **TWA: 50 ppm, equivalent to 335 mg/m^3** **STEL: 150 ppm, equivalent to 1020 mg/m^3**

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General

Mercury is a heavy metal which exists in three oxidation states: 0 (elemental), +1 (mercurous) and +2 (mercuric). As well as the common mercurous and mercuric inorganic salts, mercury can also bind covalently to at least one carbon atom. Thus the most commonly encountered exposures associated with mercury are with elemental mercury, inorganic mercuric compounds and methylmercury.

Mercury occurs naturally as a mineral is widely distributed by natural and anthropogenic processes. The most significant natural source of atmospheric mercury is the degassing of the Earth's crust and oceans and emissions from volcanoes. Man-made sources such as mining, fossil fuel combustion and industrial emissions generally contribute less on a global scale, but more on a local scale. Wet and dry deposition to land and surface water result in mercury sorption to soil and sediments.

Uses of mercury include use in the electrical and chlor-alkali industry (lamps, batteries and as cathodes in the electrolysis of sodium chloride to produce caustic soda and chloride), industrial and domestic instruments, laboratory and medical instruments and dental amalgam (mixed in proportion of 1:1 with a silver-tin alloy).

Properties

Elemental mercury is a dense, silvery white metal which is liquid at room temperature, readily volatilises and is considered to be the predominant form of mercury in the atmosphere. Mercury compounds differ greatly in general properties and solubility. Due to the wide range in properties associated with the forms of mercury, key properties have not been listed here. These are available from many sources including the ATSDR review (1999).

Exposure

Exposure of the general population to mercury may occur via inhalation, oral or dermal contact. Exposure to elemental mercury may occur in the workplace or home if mercury is spilled. Inorganic mercury compounds are found in some batteries, pharmaceuticals, ointments and herbal medicines. Exposure to inorganic mercury can occur via inhalation or ingestion. Methylmercury is most commonly found in fish, especially larger fish at the top of the food chain with exposure typically associated with ingestion.

If released into the environment the following can be noted with respect to mercury (USEPA 1997, WHO 1989 and 1991):

- Air: Mercury is released into the atmosphere from anthropogenic emissions as either vapour (elemental or oxidized mercury) or as particles (oxidized compounds). Natural emissions are mainly in elemental mercury form. Mercury may reside in the atmosphere for about one year, allowing global circulation systems to transport elemental mercury emissions from source of emission to anywhere on earth before transformation and deposition take place. Mercury is transferred from the atmosphere to the earth's surface via wet or dry deposition.

- Soil: The majority of mercury in surface soil is in the form of oxidized mercury complexes/compounds; however, a small fraction is methylmercury and elemental mercury. Mercury complexes deposited in soils can be transformed back into gaseous mercury by light and humic substances and re-enter the atmosphere. Studies have consistently shown that plant uptake is negligible and consequently, animals foraging on plants accumulate little mercury. In addition to direct deposition, mercury can also reach water from soil run-off, although the amount partitioning to run-off is expected to be small since mercury binds to soil; run-off is probably in the form of suspended sediments.

- Water: Once in water, mercury can either enter the food chain, settle into sediment, or volatilise back into the atmosphere. Entrance into the food chain begins with bacteria in water which can take up mercury in its inorganic form and metabolise it to methylmercury. The methylmercury-containing bacteria may be consumed by the next level in the food chain, or they may excrete the methylmercury into the water where it can adsorb to plankton, which are also consumed by the next level in the food chain. Even small environmental concentrations of mercury in water can readily accumulate to potentially harmful concentrations in fish and fish-eating people. Fish higher in the food chain have much higher mercury concentrations than fish lower on the food chain.

- Mercury is continuously mobilized, deposited and re-mobilized in the environment. The only sinks for removal from the biosphere are deep-seas sediments or well-controlled landfills. If the release of mercury into the environment is reduced, resultant decreases in mercury concentrations in the environment would occur slowly, most likely over many decades or centuries.

On the basis of the potential for long-range transport, persistence in water, soil and sediment, bioaccumulation, toxicity and ecotoxicity, mercury is considered persistent and is addressed in the 1998 UN-ECE Convention on Long-Range Transboundary Air Pollution on Heavy Metals (UN-ECE, 1998). The United Nations Environment Programme (UNEP) Governing Council concluded, at its 22nd session in February 2003, after considering the key findings of the Global Mercury Assessment report, that there is sufficient evidence of significant global adverse impacts from mercury to warrant further international action to reduce the risks to humans and wildlife from the release of mercury to the environment. The Governing Council decided that national, regional and global actions should be initiated as soon as possible and urged all countries to adopt goals and take actions, as appropriate, to identify populations at risk and to reduce human-generated releases. While mercury is not listed as one of the 12 chemicals listed in the Stockholm Convention on Persistent Organic Pollutants (POPs), it chemical meets criteria listed (annex D) in the convention for consideration as persistent and bioaccumulative.

Health Effects

The following information is available from UK (2002) and ATSDR (1999).

Elemental Mercury

Limited data is available concerning the absorption of elemental mercury. Inhaled mercury vapour by humans indicates approximately 80% of the vapour crosses the alveolar membranes into the blood. Liquid metallic mercury is poorly absorbed via the oral route with studies indicating less than 0.01% absorption. Dermal absorption of mercury vapour contributes approximately 2.5% of absorbed mercury following inhalation exposures. No data are available concerning dermal absorption of liquid metallic mercury.

Absorbed mercury is lipophilic and rapidly distributed to all tissues and able to cross the blood-brain and foetal barriers easily. Mercury is oxidised in the red blood cells by catalase and hydrogen peroxide to divalent ionic mercury. Approximately 7-14% of inhaled mercury vapour is exhaled within a week after exposure. The rest of the elemental mercury is either excreted via sweat and saliva, or is excreted as mercuric mercury. Approximately 80% is excreted as mercuric mercury via faeces and urine. Half-life elimination is approximately 58 days.

Acute exposure to high concentrations of mercury vapour has been associated with chest pains, haemoptysis, breathlessness, cough and impaired lung function with the lung identified as the main target following acute exposure.

The central nervous system is generally the most sensitive indicator of toxicity of metallic mercury vapour. Data on neurotoxic effects are available from many occupation studies.

Chronic exposure to metallic mercury may result in kidney damage with occupational studies indicating an increased prevalence of proteinuria.

Genotoxicity and Carcinogenicity

Both USEPA and IARC indicate that elemental mercury is not classifiable as to its human carcinogenicity.

No adequate animal studies are available for elemental mercury and occupational studies have indicated conflicting results.

Inorganic Mercury Compounds

Limited data is available concerning the absorption of inhaled mercury compounds, however it is expected to be determined by the size and solubility of the particles. Absorption of ingested inorganic mercury has been estimated to be approximately 5 to 10% with absorption be children greater than for adults. No dermal absorption data is available.

Inorganic mercury compounds are rapidly distributed to all tissues following absorption. The fraction that crosses the blood-brain and foetal barriers is less than for elemental mercury due to poor lipid solubility. The major site of systemic deposition of inorganic mercury is the kidney. Most inorganic mercury is excreted in the urine or faeces.

Acute exposure to high concentrations of ingestion of inorganic mercury has been associated with gastrointestinal damage, cardiovascular damage, acute renal failure and shock.

The kidney is the critical organ associated with chronic exposure to inorganic mercury compounds. The mechanism for the end toxic effect on the kidney, namely autoimmune glomerulonepkritis, is the same for inorganic mercury compounds and elemental mercury and results in a condition sometimes known as nephrotic syndrome.

There is some evidence that inorganic mercury may cause neurological effects, particularly associated with studies of mercuric chloride. Reproductive and developmental effects have been observed in rats given mercuric chloride.

Genotoxicity and Carcinogenicity

IARC have considered inorganic mercury compounds not classifiable as to human carcinogenicity. The USEPA has classified mercuric chloride as a possible human carcinogen (Class C) based on increased incidence of squamous cell papillomas of the forestomach and marginally increased incidence of thyroid follicular cell adenomas and carcinomas from a long term oral studies in rats. Mercuric chloride has produced some evidence of an action on the chromosomes, and mixed results associated with mutagenic activity has been reported. The USEPA evaluation of mercuric chloride indicate that a linear low-dose extrapolation is not appropriate as kidney tumour seen in mice occurred at doses that were also nephrotoxic.

Methylmercury

Limited data are available concerning the absorption of inhaled methylmercury compounds, however studies on rats indicates rapid and almost complete absorption of inhaled methylmercury vapour. Ingested methylmercury is almost completely absorbed. No dermal absorption data are available.

Methylmercury is distributed via the blood to all tissues. It can cross into the brain and foetus. The major site of systemic deposition of methylmercury is the kidney. Hair levels are typically used as an index of exposure to mercury and there is a proportional relationship between mercury intake, blood mercury and hair mercury. Methylmercury is converted to mercuric mercury in animals and humans, though less readily than for elemental mercury.

The key target of methylmercury in humans is the CNS, particularly the brain. Evidence from animal and human studies indicates that the embryo and foetus are more sensitive to methylmercury than adults.

Other effects associated with methylmercury include damage to other tissues and organs including the lung, cardiovascular system, liver and kidney. In animals, the most sensitive indicator of damage other than CNS effects, are renal effects.

Genotoxicity and Carcinogenicity

USEPA and IARC have classified methylmercury as a possible human carcinogen (USEPA Class C and IARC Group 2B) on the basis of long term animal studies. Both agencies consider that the evidence for carcinogenicity of methylmercury in humans is inadequate. The USEPA (2001) have concluded that methylmercury is not a potent genotoxic agent. Methylmercury induced tumours in mice were considered likely to have a non-genotoxic origin.

Exposure Limits/Toxicity Evaluations

Exposure limits and toxicity evaluations which are available in Australia, World Health Organisation, European Union and the US:

Australia

The Australian Drinking Water Guidelines (NHMRC, 1996 and proposed 2002) have derived a drinking water guideline of 0.001 mg/L for total mercury using the provisional tolerable weekly intake (***PTWI) of 0.0033 mg/kg*** (equivalent to ***TDI of 0.00047 mg/kg/day***) for methylmercury recommended by JECFA and used by the WHO (as below). The guideline was considered sufficient to be protective of pregnant women and nursing mothers.

Worksafe Australia (NOHSC) have established "Exposure Standards for Atmospheric Contaminants in the Occupational Environment". For mercury the following have been established:

Elemental mercury: ***TWA = 0.255 mg/m^3***, STEL = NA

Monovalent mercury: ***TWA = 0.1 mg/m^3***, STEL = NA

Divalent mercury: ***TWA = 0.025 mg/m^3***, STEL = NA

Alkyl mercury compounds: ***TWA = 0.01 mg/m^3, STEL = 0.03 mg/m^3***

WHO

The WHO (Drinking Water Guideline 1993 and 1996) provide a guideline value for total mercury of 0.001 mg/L based on the provisional tolerable weekly intake (***PTWI) of 0.005 mg/kg*** for total mercury for the general population of which no more than ***0.0033 mg/kg*** should be present as methylmercury recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The value for methylmercury was used in the derivation of the drinking water guideline "to be on the conservative side". JECFA note that pregnant women and nursing mothers may be at greater risk. The TDI remained unchanged in the WHO 2004 documentation (WHO, 2004). The PTWI for methylmercury was revised by the JECFA in June 2003 to ***0.0016 mg/kg*** to be "sufficient to protect the developing foetus, the most sensitive subgroup of the population".

Draft revision to the WHO Drinking Water Guideline as part of rolling revisions to the guidelines for mercury released in July 2004 (not endorsed) derived a drinking water guideline value of 0.006 mg/L for inorganic mercury on the basis of a ***TDI of 0.002 mg/kg/day.*** The TDI for inorganic mercury is based on kidney effects in a 26-week study in rats, uncertainty of 100 and adjustment for 5 day/week dosing. As this guideline is in draft form which has been released for comment and has not been endorsed or adopted by WHO, it has not been considered at this stage for quantification of effects associated with mercury exposure.

WHO (2000) have derived a ***guideline value of 0.001 mg/m^3*** for mercury in air as an annual average based on a LOAEL derived from occupational studies on mercury vapour. The WHO note that "since cationic inorganic mercury is retained only half as much as the vapour, the guideline also protects against mild renal effects caused by cationic inorganic mercury". "Present knowledge suggests, however, that effects of the immune system at lower exposures cannot be excluded". The WHO have not proposed an air quality guideline value for methylmercury due to the potential for adverse health impacts associated with post-depositional methylmercury formation and bioaccumulation.

US

The USEPA have provided separate evaluations for elemental mercury, mercuric chloride and methylmercury.

Elemental mercury: The USEPA have derived an inhalation reference concentration (***RfC) of 0.0003 mg/m^3*** based on CNS effects in occupationally exposed workers.

Mercuric chloride: The USEPA have derived an oral reference dose (***RfD) of 0.0003 mg/kg/day*** based on autoimmune glomerulonephritis observed in rats (sub-chronic studies).

Methylmercury: The USEPA have derived an oral ***RfD of 0.0001 mg/kg/day*** based on neurological effects in children exposed in utero as a consequence of maternal intake of methylmercury in food.

The ATSDR has established Minimum Risk levels (MRLs) associated with non-carcinogenic effects associated with mercury. The levels established (valid in 2004) are:

- ***Chronic inhalation MRL for elemental mercury = 0.0002mg/m^3*** based on CNS effects in occupational workers
- ***Acute oral MRL for inorganic mercury = 0.007 mg/kg/day*** based on renal effects in rats exposed to mercuric chloride
- ***Intermediate oral MRL for inorganic mercury = 0.002 mg/kg/day*** based on kidney effects in rats exposed to mercuric chloride
- ***Chronic oral MRL for methylmercury = 0.0003 mg/kg/day*** based on developmental effects in children

The California Air Resources Board (CARB and OEHHA) has established the following:

- Acute inhalation reference exposure level (***acute REL, 1999) for mercury and compounds of 0.0018 mg/m^3*** based on CNS disturbances in offspring following inhalation of metallic mercury vapours. The same value is also presented for mercuric chloride;
- ***Chronic inhalation REL (2000) of 0.00009 mg/m^3*** for mercury and compounds (mercuric chloride) and elemental mercury based on CNS effects in occupational studies;
- ***Chronic oral REL (2000) of 0.0003 mg/kg/day*** for mercury and compounds (mercuric chloride) adopted from the USEPA RfD;

- Chronic inhalation REL (1991) of 0.001 mg/m^3 for methylmercury

Suggested Toxicity Values for Risk Characterisation

Background Intake

For common contaminants, intakes from background sources such as food, water and/or air must also be considered in the evaluation and use of the ADI, TDI or RfD in assessing potential exposures to site related chemicals. Ysing data available on background intakes for inorganic mercury compounds and organic mercury compounds via air, food (including fish) and water from Imray P. and Neville G. (CSMS, 1996), it has been calculated that background may contribute 13% (adult) to 72% (children) of the TDI for total mercury and 15% (adult) to 79% (children) of the TDI for organic mercury (methyl mercury. To provide a conservative assessment it has therefore been assumed that up to 80% of the TDI (and hence the PTWI) is derived from background intakes. Hence the suggested toxicity values should be adjusted to account for background intakes.

Toxicity Values

Toxicity data relevant for use in the characterisation of risk to human health have been selected for mercury following review of the available information in general accordance with enHealth (2002) and NEPM (1999), accounting for background intake where relevant.

Oral	**TDI = 0.00071 mg/kg/day for total mercury** (based on WHO PTWI of 0.005 mg/kg for total mercury, 2004) **TDI = 0.00023 mg/kg/day for methylmercury** (based on revised PTWI of 0.0016 mg/kg provided by JECFA 2003 for the protection of the developing foetus) **Intake adjusted for background = 0.00014 mg/kg/day for total mercury and 0.000046 mg/kg/day for methylmercury** (accounting for 80% background intake)
Dermal	No dermal guidelines are available, hence it has been assumed that dermal toxicity is equivalent to oral toxicity.
Inhalation	**GV = 0.001 mg/m^3 as an annual average (WHO 2000 for elemental mercury, inorganic mercury and methylmercury)** **Intake adjusted for background = 0.0002 mg/m^3** (accounting for 80% background intake) Occupational inhalation exposure (NOHSC): **Elemental mercury**: ***TWA = 0.255 mg/m^3***, STEL = NA **Monovalent mercury**: ***TWA = 0.1 mg/m^3***, STEL = NA **Divalent mercury**: ***TWA = 0.025 mg/m^3***, STEL = NA **Alkyl mercury compounds**: ***TWA = 0.01 mg/m^3, STEL = 0.03 mg/m^3***

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national dioxins program

dioxins in australia: a summary of the findings of studies conducted from 2001 to 2004

Department of the Environment and Heritage

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background

The term "dioxins" describes a group of toxic organic chemicals that remain in the environment for a long time. These compounds can accumulate in the body fat of animals and humans and tend to remain unchanged for long periods. Several hundred of these compounds exist and are members of three closely related families:

- the polychlorinated dibenzo–p–dioxins (PCDDs)
- the polychlorinated dibenzofurans (PCDFs or furans)
- certain co–planar polychlorinated biphenyls (PCBs).

The National Dioxins Program (NDP) has focused on the 29 most toxic of these compounds which are recognised internationally as being harmful to humans and animals. To assist the reader, the term "dioxins" is used in this report to refer to the three families, but there are instances where specific mention is made to furans and PCBs.

The Australian Government established the program in 2001 to improve knowledge about dioxins in Australia. The program aims to determine levels, assess the risks to Australians and our environment, and to consider appropriate management actions.

Previously, limited Australian studies showed environmental levels were low, but a lack of information made it difficult to assess dioxin impacts on the environment and human health. The current studies are designed to fill this gap.

Starting in mid 2001, information studies were undertaken by leading Australian scientific organisations, with assistance from overseas experts, under contract to the Australian Government Department of the Environment and Heritage. The studies gathered information by measuring, emissions from sources such as bushfires, as well as dioxin levels in the environment, food and population. The findings of these studies were used to determine the risk dioxins pose to our health and the environment.

Completed in 2004, these studies provide the largest survey of dioxin levels ever undertaken in Australia. This document summarises the results of these studies and the conclusions of the risk assessments.

The findings will contribute to debate on how to deal with dioxins in Australia, as well as assisting Australia meet its obligations under the Stockholm Convention on Persistent Organic Pollutants (POPs). The Convention sets out a range of obligations for countries to reduce and, where feasible, eliminate releases of persistent organic pollutants, including emissions of by–product POPs such as dioxins.

The complete reports from the information studies and the risk assessment can be accessed on a CD–ROM attached to the inside back cover of this publication or from the Department of the Environment and Heritage website at http://www.ea.gov.au/industry/chemicals/dioxins/index.html. Hard copies of the reports are also available on request.

Note: the measured dioxin levels in this summary and the full reports use very small units such as nanograms, picograms and femtograms. Definitions of these and other technical terms are provided in the glossary on Page 16.

sources of dioxin emissions

Dioxin emissions from bushfires

Dioxins are mainly unintended by–products of combustion processes. It has been estimated that 96 per cent of dioxins in the environment are from emissions to air. In 1998, an inventory of sources of dioxin emissions to air in Australia estimated that between 150–2,100 grams TEQ/year of dioxins are emitted each year. Wildfires, agricultural and prescribed fires were thought to be the major sources of these emissions.

Because no Australian data existed, the 1998 dioxins inventory used overseas studies and gave an estimate of between 72–1700 g TEQ/year from bushfires – a very wide range, reflecting the great uncertainty involved in the estimations. The bushfire study aimed to reduce this uncertainty by measuring the emissions of dioxins from fires in laboratories and from fires in several States and the Northern Territory. Emissions were analysed from smoke and samples of ash collected from 19 laboratory and 21 field burns.

The laboratory tests burned wheat straw, sorghum, sugarcane and forest litter. The study found that laboratory burns do not adequately simulate the combustion processes occurring in the field. Dioxin emissions from the laboratory tests were up to ten times higher than those from field fires but were comparable to other laboratory tests.

It is thought that the key difference between field and laboratory emissions may be the time the smoke plume remains at high temperatures. In field burns, air in the smoke plume rapidly cools to temperatures not supportive of dioxin formation. In wood combustion heaters, where the gases are confined, they remain at temperatures suitable for dioxin formation. A similar situation probably occurs during laboratory burns.

The field burns comprised 13 prescribed fuel reduction fires in south–east Queensland, central Victoria and south–west Western Australia, two sugarcane burns in Queensland, four fires in tropical savanna woodlands in the Northern Territory and two wildfires in north–east Victoria.

The dioxin levels, particularly from south–east Queensland, were consistent with other studies of prescribed fires. Total emissions of dioxins from field fires ranged from 0.1–2.9 pg TEQ/g of fuel.

Based on these levels and the total area of land burnt in each year in Australia, the total emissions of dioxins to air from bushfires are estimated to be 31–494 g TEQ/year, significantly lower than the 1998 estimate. Savanna fires in northern Australia accounted for most of these emissions.


A pump is used to collect smoke samples during a prescribed burn. Photo by C Meyer.

Dioxin emissions from motor vehicles

Although motor vehicles are a source of dioxins, the level of their emissions remains uncertain. There are several reasons for this. Firstly, there is little data available on dioxins emissions from road traffic and tests on vehicles. Secondly, dioxin emissions can vary greatly due to factors including vehicle technology and age, fuel composition and ambient temperatures. Finally, in many cases, published information on dioxins emissions is contradictory. Determining dioxin emissions from motor vehicles must take account of these uncertainties.

For this study, motor vehicle emissions were determined using existing estimates and calculating the total emissions based on the total distance travelled by all Australian vehicles in 1998. This gave a range of 0.7–16.5 g TEQ/year or about 2 per cent of total emissions to air.

sources of dioxin emissions

Leaded petrol vehicles accounted for 40–45 per cent of this amount, due to the presence of chlorinated and brominated fuel additives in leaded petrol. The presence of these chemicals is believed to account for the higher levels of dioxins in leaded petrol vehicles. However, the banning of leaded petrol from January 2002 is expected to have already substantially reduced dioxins emissions.

Diesel vehicles account for 35–50 per cent of total dioxin emissions from motor vehicles, with most from diesel trucks. Despite unleaded petrol vehicles accounting for 65 per cent of total kilometres travelled, they account for only 5–20 per cent of total dioxins emissions from motor vehicles.

Emissions from all dioxin sources

Using the findings of the NDP studies on emissions from bushfires and motor vehicles, as well as publicly available data on emissions from industries, a new inventory was prepared for 2002. This inventory included dioxin emissions to air, water and land, based on guidelines developed by the United National Environment Program. These guidelines identified nine major emission source categories. A summary, in decreasing order, for emissions to all media is shown in the table below.

The new inventory estimates that total emissions to air in Australia are between 160–1,787 g TEQ/year with a best estimate being 500 g. Uncontrolled combustion, which includes bushfires, waste burning and accidental fires, is estimated to contribute nearly 70 per cent of total emissions to air and over 80 per cent of total emissions to land, with most being emitted from grass fires.

Disposal and landfilling is estimated to be the largest source of dioxin emissions to water, contributing over 75 per cent of total emissions.

View the full reports of the emissions studies on the CD–ROM at:

1. Dioxins emissions from Bushfires in Australia
2. Dioxins emissions from Motor Vehicles in Australia
3. Inventory of Dioxin emissions in Australia 2004

Prescribed burning and wildfires are likely to contribute at least 20–30 per cent of total dioxin emissions to the environment.

Dioxins from motor vehicles account for less than 2 per cent of total dioxins emissions to air.

Summary of dioxin emissions to air, water and land in Australia for 2002

Source Categories (from UNEP)	AIR		WATER		LAND		
	Best estimate*	Total to Air (%)	Best estimate*	Total to Water (%)	Best estimate*	Total to Land (%)	Total to all media *
uncontrolled combustion processes	330	66.52	0.00	0.00	1030	80.21	1360
ferrous and non–ferrous metal production	114	22.83	0.02	0.44	44.4	3.45	158
production of chemicals and consumer goods	0.43	0.09	0.43	12.64	110	8.35	111
power generation and heating	35	7.01	0.00	0.00	31.8	2.47	67
disposal/landfilling	0.00	0.00	2.61	76.34	48.9	3.80	51
Waste incineration**	6.5	1.29	0.36	10.58	21.9	1.71	29
mineral products	1.9	0.37	0.00	0.00	0	0.00	2
transportation	9.1	1.82	0.00	0.00	0	0.00	9
Miscellaneous	0.31	0.06	0.00	0.00	0.15	0.01	0.46
Total	500	100	3.42	100	1,300	100	1787

*g TEQ/annum

**waste incineration includes activities such as medical waste and sewerage sludge incineration

dioxins in our environment

Four studies were undertaken to measure the levels of dioxins in the environment (air, soils, aquatic environments and fauna). They were not designed to identify dioxin 'hotspots' such as contaminated industrial sites, but rather to get a picture of the background levels of dioxins in the Australian environment.

For the purposes of these studies, Australia was divided into three geographic regions:

- northern – Northern Territory and Queensland
- south–eastern – New South Wales, Victoria, South Australia and Tasmania
- south–western – south west Western Australia

Samples were collected from locations in each region, representing four different land–uses (agricultural, urban, industrial, and remote areas).

Air

Air samples were collected continuously over monthly intervals from September 2002 to August 2003 to establish seasonal variations in dioxin levels, related, for example, to emissions from sources such as domestic wood heaters and bushfires.

The ten sites representing the four land–uses were:

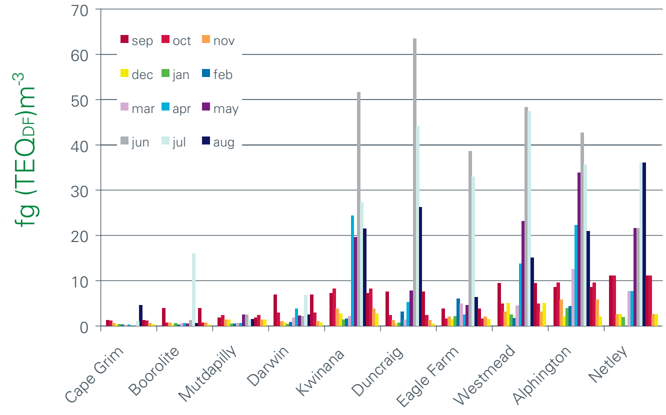
- Darwin, NT (urban)
- Eagle Farm, south–east Qld (industrial)
- Mutdapilly, south–east. Qld (agricultural)
- Westmead, Sydney, NSW (urban)
- Boorolite, lower north–east Vic (agricultural)
- Alphington, Melbourne, Vic (urban)
- Cape Grim, Tas (remote – an Australian Baseline Atmospheric Pollution Station)
- Netley, Adelaide SA (industrial)
- Kwinana, Perth, WA (industrial)
- Duncraig, Perth, WA (urban)

The findings indicate an obvious seasonal cycle, with levels higher during winter in all cities, most likely due to smoke from domestic wood heaters.

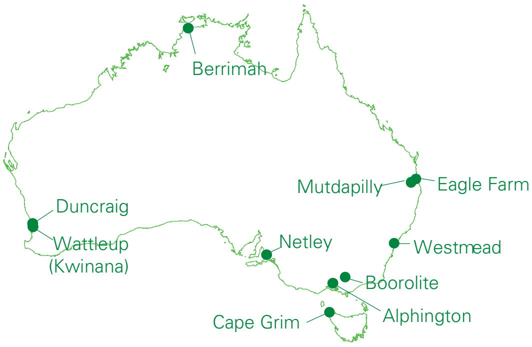
Despite the winter increase, overall mean annual levels in the major cities are still very low by world standards, with levels around 14–17 fg TEQ/m^3 compared with northern hemisphere cities with ranges of 20 to several hundred fg TEQ/m^3.

Seasonal cycles were also observed in rural Queensland and Victoria, although the cycles were weaker than in the cities.

Dioxins and furans increase over the winter months in the cities



Location of air sampling sites



dioxins in our environment

A dry to wet season difference was observed in Darwin with levels in the dry season around six times higher than the wet season. Nevertheless, mean annual levels in Darwin are still very low (less than 4 fg TEQ/m^3).

Extremely low levels were observed in clean marine air at Cape Grim and in agricultural locations (typically less than 1.5 fg TEQ/m^3).

The relative contributions of dioxins, furans and PCBs vary across locations. The Netley site in SA has higher levels of dioxin–like PCBs compared with other sites, but these are still very low compared with other countries. Further testing is currently being undertaken to determine the source of these PCBs.

Soils

Soils samples were collected from 86 locations across three regions and from remote sites in central and north–west Australia. Agricultural land–uses were classified according to the main agricultural practice (grazing, cotton, vegetables, sugarcane, forestry, cereals). Ten archived soils originally collected from a location near Adelaide since the 1920s were assessed for possible changes in dioxin levels.

Dioxins were found in most soils, with levels ranging from 0.05–23 pg TEQ/g dry weight. Levels across all land–use types in the northern and south–eastern regions were similar, but the levels in the south–western region were lower. Western Australia and inland areas recorded low levels.

Dioxins in soils from urban and industrial locations were substantially higher than levels in agricultural and remote locations, with the highest levels found in soils near south–east coast population centres.

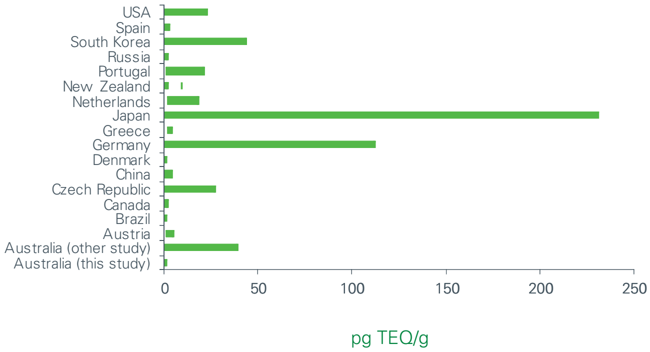
Across agricultural land–uses, dioxins levels were similar, with the exception of sugarcane districts. The higher levels are not likely to be related to sugarcane cultivation since they are the same as found in non–sugarcane growing areas throughout coastal Queensland. These dioxins may be formed through natural processes.

Archived samples contained detectable levels of dioxins, with levels in the 1925 sample greater than in the samples from the 1930s and 1940s. This may have been due to storage contamination so it is difficult to determine the causes for such variation.

Across all land–uses, dioxin levels in soils are on average much lower than those reported in many industrial countries.

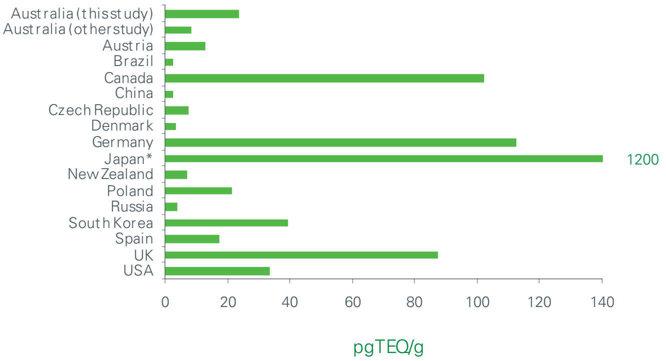
Dioxin levels in agricultural and remote soils in Australia compared with other countries

Note: the separate level for New Zealand represents a single sample



Dioxin levels in industrial and urban soils in Australia compared with other countries

* figure for Japan is 1200 pg TEQ/g



dioxins in our environment

Aquatic environment

As dioxins are insoluble in water, the most effective way of determining levels in aquatic environments is to analyse sediments and aquatic animals. Sediment samples were collected from 58 locations in freshwater, estuarine and marine locations. Samples of bivalves, such as oysters and mussels, were also collected. Fish from local commercial fisheries were included, with an emphasis on table species.

Dioxins were found in all sediments, with levels ranging from 0.002–520 pg TEQ/g dry weight. Urban/industrial areas had significantly greater levels of dioxins than samples from remote and agricultural locations.

Highest levels were found in the lower Parramatta River (100 and 520 pg TEQ/g) and the western section of Port Jackson (78 and 130 pg TEQ/g) in Sydney. These elevated levels may be due to historical contamination from former industrial sites near Homebush Bay. These sites are under going clean–up which will continue for the next five years.

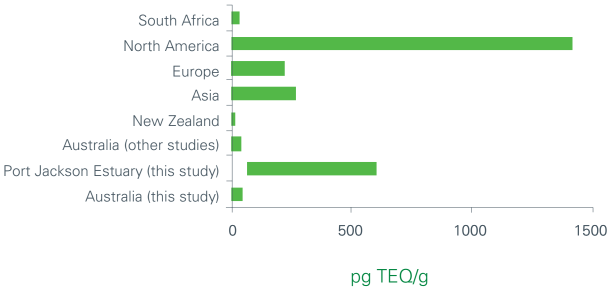
Elevated levels were found in other estuarine waters of Sydney (Botany Bay) as well as the estuaries in or near Brisbane, Melbourne, Hobart, Perth and Wollongong. Average levels across marine, freshwater and estuarine locations did not differ significantly.

The levels of dioxins in 18 bivalve samples ranged from 0.0043–0.2 pg TEQ/g wet weight, with highest levels from Port Jackson and the Yarra River, Victoria.

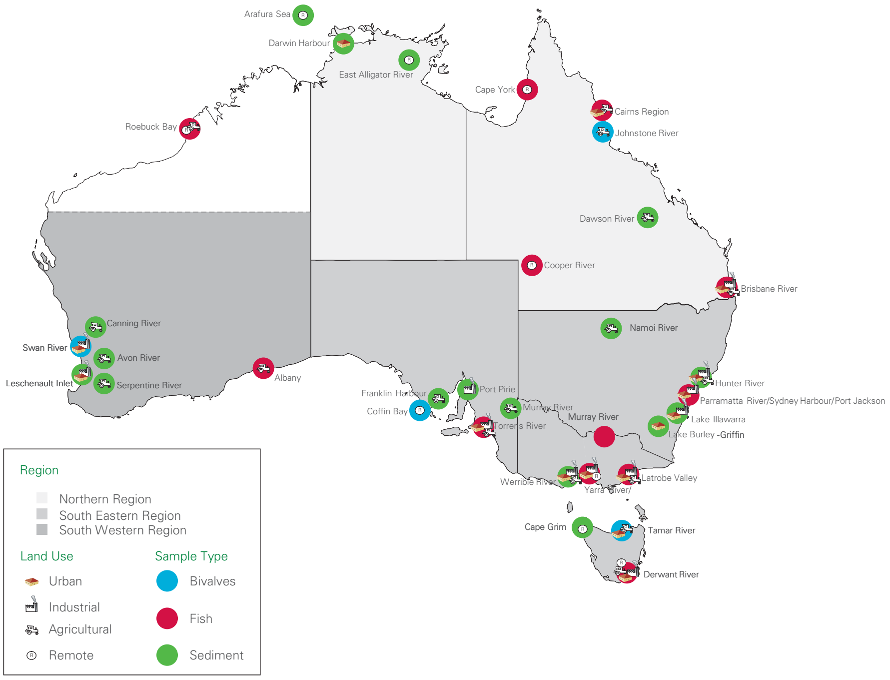
Dioxins in 23 fish samples ranged from 0.0053–0.49 pg TEQ/g wet weight. The level of dioxins was highest in fish sampled from the Sydney/Port Jackson area.

The results show dioxins levels in the aquatic environment are generally lower than for other industrialised countries but there are some sites where levels are elevated. Bivalve levels followed a similar pattern to the sediment levels. However, the fish had consistently low levels of dioxins.

Dioxin levels in sediments in Australia compared with other countries



Sampling locations for the aquatic study



Fauna

Dioxins emitted to air can deposit on plant, soil and water surfaces. Dioxins can then enter the food chain when animals eat contaminated leaves, soils or sediments. The dioxins are then absorbed into animal fat. Dioxins increase in concentration as they move up the food chain, so that carnivores are more likely to have higher levels than herbivores.

Around 66 fauna samples were collected, mainly from dead animals, such as those near roads or stranded on beaches.

The study found the highest levels in birds of prey, with a maximum level of 3,900 pg TEQ/g lipid. Marine mammals also had comparatively high levels, with PCBs more prevalent than dioxins or furans. However, compared with other countries, the levels in marine mammals are low.

Levels were generally much lower in herbivorous animals such as kangaroos, galahs and dugongs. Levels in kangaroos ranged from 0.001–25 pg TEQ/g lipid. The levels in other marsupials (possums, koalas and bandicoots) were low and comparable to the kangaroos. Levels in platypus and echidnas ranged from 9.3–60 pg TEQ/g lipid.

Compared with fauna from other countries the levels are generally lower. The levels in birds of prey were lower than comparable species from other countries. The levels in one kangaroo sample was higher than for caribou in Canada (0.7–6.4 pg TEQ/g lipid) but less than sika deer from Japan (3.2–330 pg TEQ/g lipid). The levels in kangaroo on a fresh weight basis are even lower due to the lean nature of kangaroo meat.

For an assessment of the risk that dioxins pose to fauna, see the section What is the risk to our environment?

View the full reports of the environment studies on the CD–ROM at:

4. Dioxins in Ambient Air in Australia
5. Dioxins in Soils in Australia
6. Dioxins in Aquatic Environments in Australia
7. Dioxins in Fauna in Australia

Dioxin levels:
– in the environment are generally very low compared with other countries
– increase in air during winter in cities and are most likely due to emissions from domestic wood heaters
– in soils and sediments are highest in urban and industrial areas
– are higher in birds of prey than in other animals.

dioxins in our food

Dietary exposure

Food Standards Australia New Zealand has examined the dioxin levels in a range of foods to determine the level of dioxin exposure of Australians through food and to assess the human health risk.

Dioxin exposure through food is determined by examining dioxin levels in various foods and combining this with information on the daily diet of the population. Foods likely to contain dioxins are those that contain animal fats, such as dairy products, meat and meat products, fish and eggs.

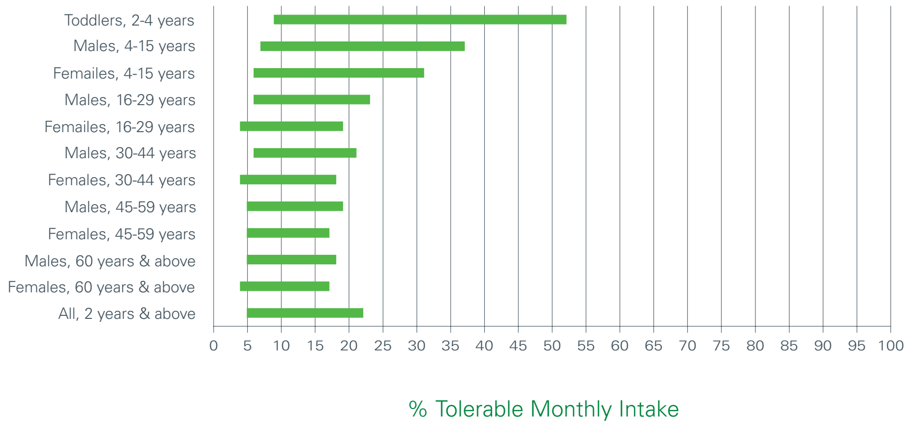
Dioxin levels in food were determined by analysis of 168 samples of 22 randomly sampled foods from Australian retail outlets which were prepared ready to eat. The mean range of dioxin concentrations found in the foods analysed are shown in the table on this page. The survey found that Australian foods have low levels of dioxins – similar to those reported in New Zealand and lower than other countries. These results were then combined with dietary information from the 1995 National Nutrition Survey to assess the population's dietary exposure.

As shown in the figure below, for all age groups from two years and over, the estimated monthly dietary levels of exposure to dioxins, for the average consumer, were well below the Australian Tolerable Monthly Intake (TMI) of 70 pg TEQ/kg body weight/month. Estimated monthly dietary exposures for high consumers were also below the TMI for all age groups.

Because of their high dietary intake relative to body weight, highest mean intakes for all age groups occur in infants and toddlers. In general terms, the estimated monthly level of exposure to dioxins for Australians (3.7–15.6 pg TEQ/kg body weight/month, lower to upper range) is similar to that of New Zealand (11.1 pg TEQ/kg body weight/month, middle value for adult males) and lower than that of other industrialised nations. For example, in the United Kingdom, the estimated exposure to dioxins for the population was 15–21pg TEQ/kg bw/month.

The major foods contributing to dioxin exposure for the Australian population over a lifetime were fish (including crustaceans and molluscs), milk and dairy products. For toddlers and children, the major foods contributing to dioxins exposure were milk and dairy products.

Mean range of exposures to dioxins for each population group in Australia, as a percentage of the Tolerable Monthly Intake.



Mean range of dioxin concentrations in food, in pg TEQ/g fresh weight

Food	Concentration range
Bacon	0.025–0.083
Baked beans	0.0012–0.016
Bread, white	0.00067–0.026
Butter	0.028–0.27
Chicken breast	0.0044–0.021
Eggs	0.0088–0.057
Fish fillets	0.59–0.64
Fish portions	0.019–0.039
Hamburger	0.00050–0.027
Infant formula	0.0036–0.018
Lamb chops	0.0044–0.045
Leg ham	0.0016–0.017
Liver pate	0.0025–0.043
Margarine	0.0025–0.058
Milk chocolate	0.0077–0.056
Milk, whole	0.0023–0.012
Minced beef	0.0054–0.048
Orange juice	0.00018–0.007
Peanut butter	0.035–0.25
Potatoes	0.00029–0.014
Sausage	0.0096–0.058
Tuna, canned	0.029–0.041

dioxins in our food

As there are limitations associated with the data used to characterise the risk associated with exposure to dioxins from food, in general, conservative assumptions were used to minimise the possibility that risks would be underestimated. On the basis of this analysis the public health and safety risk for all Australians from exposure to dioxins from foods is very low.

Agricultural commodities

The National Residue Survey, managed by the Australian Government Department of Agriculture, Fisheries and Forestry, collected around 220 samples of meat, fish and milk during November and December 2002.

The study found dioxin levels in these commodities are low and compare favourably with overseas products.

In the absence of an Australian commodity standard for dioxins and furans, the levels were compared against the European Union (EU) standard, as shown in the table below. None of the samples contained dioxin and furans exceeding this standard. The EU standard only refers to dioxins and furans and does not currently include dioxin–like PCBs. It is expected a new EU standard will be developed in the next few years which will include dioxin–like PCBs.

View the full reports of the food studies on the CD–ROM at:

8. Dioxins in Agricultural Commodities in Australia FSANZ dietary study, Technical report No. 27.

Dioxin levels in food are low and pose a very low health risk for all Australians.

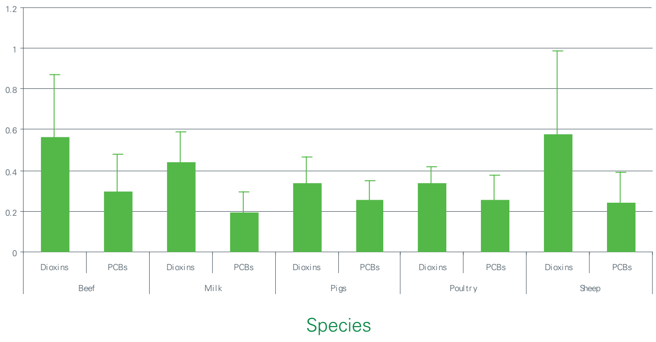
Dioxin levels in agricultural commodities compared with EU standards

Species	Number of Samples	EU Standard Maximum pg TEQ/g*	Mean result from this study** pg TEQ/g	Australian results compared with EU standard %
Beef	109	3	0.56	18.6
Sheep	45	3	0.57	19.1
Pig	20	1	0.33	33.1
Poultry	15	2	0.33	16.5
Fish (salmonids)	10	4	0.23	5.7
Milk	19	3	0.43	14.5

* on a fat basis except for fish where it is expressed on a fresh weight basis
** mean results for all upper bounds concentrations.

Mean dioxin and furan levels (pg TEQ/g fat) in all agricultural commodities except aquaculture fish

(T–lines indicate the highest level)



dioxins in our bodies

Dioxins emitted to air can deposit on plant, soil and water surfaces. Dioxins can then enter the food chain when animals eat contaminated leaves, soils and sediments. In aquatic environments, filter–feeding animals can absorb dioxins when they filter sediments in the water. The dioxins are then absorbed into animal fat. Dioxins increase in concentration as they move up the food chain.

The consumption of animal products with high fat content, such as meat and dairy products, can increase human exposure to dioxins. Dioxins accumulate in body fat and the average concentration increases with age.

To determine dioxin levels in Australians, two studies were undertaken – one assessed levels in blood serum of the whole population and the other assessed levels in the milk of first–time mothers.

Blood serum

Blood serum samples were collected through a national pathology laboratory from over 9,000 individuals. They were pooled into 96 samples based on gender, age (under 16, 16–30, 31–45, 46–60 and over 60 years), and the following five regions:

- north–east (Brisbane, Tweed and Gold Coast and major population centres in Qld)
- south–east (Sydney, Canberra, Wollongong, Newcastle and other major population centres from NSW)
- south (Melbourne, Adelaide, Hobart and other major population centres from Victoria)
- west (Perth and other major population centres in WA)
- one rural region (all States and the NT).

The levels in the Australian population are very low by international standards, with a mean of 10.9 pg TEQ/g of lipid. They are comparable with, although lower than, those in the New Zealand population.

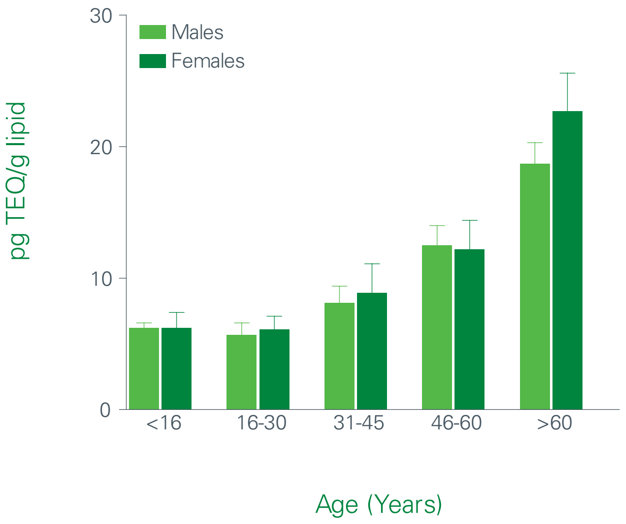
Dioxins levels between males and females showed no differences, except that slightly higher levels of dioxins were observed in females in the over 60 years age group. This result could not be explained on the basis of differences in the mean age between males and females in this group.

The study found dioxin levels increased with age. Reasons for this include on–going accumulation over a lifetime, the possibility that older people were exposed to much higher levels in the 1940s–1960s, and potential differences in metabolism and body fat.

Dioxin levels across the five regions were similar in each age range. Samples from the south–east region have slightly higher dioxin levels and females under 16 years have the highest levels of dioxins in rural regions.

As samples did not identify the donor, an assessment of any regional differences was complicated. The samples did not allow assessment of how long an individual lived in an area, their food intake or exposure to environmental contaminants.

Levels of dioxins in different age groups



dioxins in our bodies

Breast milk

Since breast milk is a rich source of fat, analysis of the levels of dioxins is valuable for estimating the total amount of dioxins in humans.

In order to compare the results with previous World Health Organization studies, mothers were selected using the following criteria:

- first–time mother with a baby aged two to eight weeks
- exclusively breast feeding
- willing to provide a minimum of 100 ml of milk over a six week period (two–eight weeks after birth)
- healthy pregnancy, mother and child
- a resident of the area for the past five years.

In total, 173 individual samples were collected from 12 metropolitan and rural regions (Brisbane, Sydney, Melbourne, Adelaide, Perth, Hobart, rural inland NSW, rural Queensland, rural Victoria, Newcastle, Wollongong and Darwin). These were pooled into 17 samples for dioxin analysis.

Dioxins were detected in all groups, with a mean of 9 pg TEQ/g of lipid. There were no significant differences observed in the levels collected from the different regions.

These samples were compared with samples collected from Melbourne women in 1993 and showed that levels had almost halved from 1993 to 2003.

Breast milk may contain low levels of dioxins because of its fat content, but all babies are exposed to dioxins even if they are not breastfed. Alternative foods for babies, such as infant formula, may also contain dioxins because of their fat content. Breast feeding of babies is the healthiest option, as supported by numerous studies.

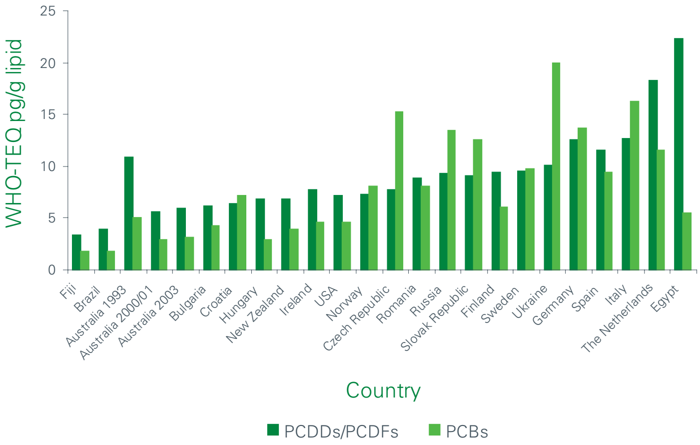
View the full reports of the studies of dioxins in our bodies on the CD–ROM at:

9. Dioxins in the Australian Population: Levels in Blood
10. Dioxins in the Australian Population: Levels in Human Milk

Dioxin levels in our bodies
– are low by international standards and have declined, reflecting similar world–wide trend over recent decades
– increase with age.

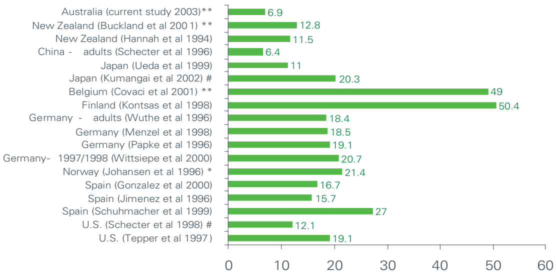
Levels of dioxins in the breast milk of Australian women compared with other countries

All data is from a World Health Organization study in 2001 except for the “Australia 2003” figure, which represents the National Dioxins Program study.



Levels of dioxins and furans in Australians compared with other countries

Note this figure does not include PCBs



what is the risk to our environment?

Risk assessment is the process of estimating the potential impact of chemicals or other factors on people or on the environment, under a set of conditions and for a certain timeframe. Risk assessment identifies and characterises potential hazards, and determines the likelihood of their occurrence at the known levels of exposure.

Ecological risk assessment determines if chemicals will have adverse impacts on organisms in the environment. Unlike human health risk assessment, which seeks to characterise risks to individuals, ecological risk assessments aim to characterise risks to ecosystems, populations and species.

Dioxins can adversely affect many vertebrate species. At low levels they can disrupt the development of the endocrine, reproductive, immune and nervous systems of the offspring of fish, birds and mammals.

This ecological risk assessment has three main parts: the hazard assessment, the exposure assessment, and the risk characterisation. This hazard assessment used published studies examining the toxic effects of dioxins on a limited number of species. The data from these studies were adopted to assess the potential risk to native wildlife, for which no toxicity data is available. The exposure assessment was based on the data from the soil, aquatic environment and fauna studies. The risk characterisation was performed by combining information from the hazard and exposure assessments, to estimate the likelihood of harm.

The risk assessment found that:

- Dioxins, furans and PCBs contributed equally to the load in birds and terrestrial mammals, while for marine mammals, PCBs contributed over 90 per cent of the load in dolphins and seals, and over 80 per cent in whales
- There is a potential risk to birds of prey from exposure to dioxins
- Terrestrial mammals are at a low risk when exposed to background levels of dioxins. However, the absence of data on the toxicity of dioxins to native marsupials and monotremes adds significant uncertainties to this assessment. The effect of different reproduction strategies between placental mammals and marsupials for dioxin exposure at sensitive life stages is not known
- Fish are at a low risk when exposed to the dioxin levels found in the Australian aquatic environment. This assessment is based on levels found in fish caught for the aquatic environment study
- Marine mammals living in the open oceans of Australia have no risk
- Based on the small number of samples collected in the fauna study, a potential risk is indicated for dolphins living in the vicinity of urban/industrial estuaries, which had higher levels of dioxins in their bodies than mammals living in the open ocean.

what is the risk to our environment?

Limitations of the assessment

All risk assessments have uncertainties due to knowledge and data gaps, which require the adoption of assumptions to cover these gaps. This assessment was no exception. The conclusions are based on the small number of fauna samples, comprising a limited number of species whose sensitivity to the toxic effects of dioxins is unknown.

A conservative approach has been adopted in this risk assessment to prevent underestimation of the risk. Inherent uncertainties should be taken into account when interpreting the results of the risk assessment.

More reliable risk estimations would require information on the toxicity of dioxins to Australian wildlife. Animal ethics committees and current State legislation generally do not allow toxicity testing on native species. More targeted sampling of birds of prey and other species, in association with field observations of potentially exposed populations, would help to clarify whether dioxins are having a real impact on bird populations.

View the full report of the ecological assessment on the CD–ROM at:
11. Ecological Risk Assessment of Dioxins in Australia

Dioxins are higher in carnivorous animals such as birds of prey and lower in herbivores such as kangaroos. There is a potential risk to marine mammals living near urban areas and to birds of prey.

what is the risk to our health?

Dioxins in the general population

The human health risk assessment used data from the information studies and the findings of overseas studies.

For the general population, over 95 per cent of exposure to dioxins is through the diet, with foods of animal origin such as meat, dairy products and fish being the main sources. Based on the dietary study of dioxins, the intake of dioxins for the Australian population is lower than in most other countries.

An Australian Tolerable Monthly Intake value for dioxins of 70 pg TEQ/kg body weight/month, was recommended by the National Health and Medical Research Council and the Therapeutic Goods Administration in 2002. This human health standard was based on the most sensitive reproductive effects of dioxins in animals. The risk assessment found that for Australians aged 2 years or older, the monthly intake of dioxins was between 3.9–15.8 pg TEQ/kg bw/month or between 6–23 per cent of the Tolerable Monthly Intake.

Intakes are lower in females than males for the same age, and decline with age in both sexes, the most rapid decline occurring after puberty. Infants and toddlers had a higher intake.

Using the findings of the blood serum study, body burdens and average lifetime daily exposures (ALDE) were calculated. The mean ALDE was estimated as 1.32 TEQ pg/kg bw/day (minimum of 0.13 pg/kg bw/day for ages under 16 years; maximum of 2.96 pg/kg bw/day for 60 years and older). The ALDE estimate is higher than the estimated dietary intake because it includes historical exposures, which are likely to have been higher than current exposures, as well as intake of dioxins from non–food sources.

These intake figures are not a significant cause of concern and are lower than those in other developed countries.

Exposure to dioxins from other sources

Dioxins enter the environment mainly from combustion processes.

Intake of dioxins through the skin, ingestion from soil and from breathing are minor contributors to exposure of the general population. Cigarette smokers are likely to have higher intakes of dioxins than non–smokers.

Australia has low dioxin levels compared to other industrialised countries. It is possible that the largest emitters to the environment are not the major contributors of dioxins contamination of food. Nevertheless, protection of land and aquatic environments used for food production is important to reduce the intake of dioxins.

This assessment, whilst not an occupational health and safety risk assessment, also briefly considered ‘special’ populations who may have been exposed to dioxins above background levels e.g. workers who used pentachlorophenol (PCP) for treating timber and dioxin–contaminated 2,4,5–T herbicide. In view of the relatively small number of occupationally exposed cases known or studied in Australia, as well as the lack of data on blood levels of dioxins in these workers, it has not been possible to draw clear conclusions about the health effects of such exposures. PCP and 2,4,5–T were withdrawn from use in Australia a number of years ago.

what is the risk to our health?

Dioxins in breast milk

Unborn children are exposed to dioxins in the womb, and nursing infants are exposed to dioxins in breast milk. Because of their high dietary intake relative to bodyweight, the highest mean intake of dioxins for all age groups occurs in infants and toddlers. These findings do not take anything away from the health advice that breast feeding is the best. The intake in question is low and gets lower as the child matures.

Dioxins and cancer

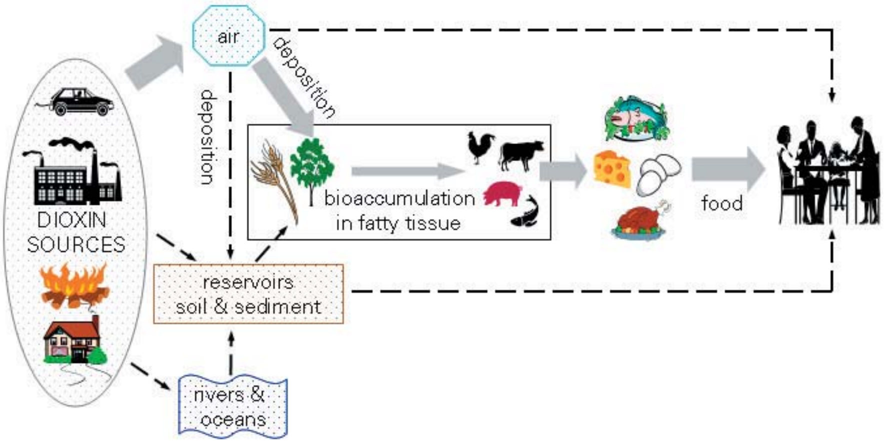
A number of agencies in other countries have tried to provide quantitative estimates of cancer risk, based on low–dose extrapolation from both animal and human data. The difficulties with estimating cancer risk include ongoing debate about the existence of a threshold level below which dioxins will not increase cancer risk and questions about the potency of the dioxins in causing cancer. Consequently, given the variability in quantitative risk estimates, this assessment has not attempted to make a quantitative risk conclusion.

The estimated intakes are below the Tolerable Monthly Intake, providing an adequate margin of safety for any possible increased risk of cancer. Furthermore, it is noted that the levels of dioxins in Australians are well below the levels associated with increased cancer risk in humans that has been seen in highly exposed industrial workers and communities exposed to industrial accidents in other countries.

View the full report of the health assessment on the CD–ROM at:
12. Human Health Risk Assessment of Dioxins in Australia

The monthly intake of dioxins from food for Australians older than 2 years was between 3.9–15.8 pg TEQ/kg bw/month or between 6–23 per cent of the Tolerable Monthly Intake. The risk to the health of Australians is very low.

Pathway for dioxins entering our bodies



glossary

Lipids	Lipids include fats and oils.
Limit of detection	Limit of detection, the lowest level at which a chemical can be measured in a sample by the analytical method used.
TEQ	Toxic Equivalents – allows the toxicity of a complex mixture to be estimated and expressed as a single number. A set of weighting factors has been determined for each type of dioxin, which expresses the toxicity of each type in terms of its equivalent mass of TCDD (2,3,7,8–Tetrachlorodibenzo–p–dioxin). Multiplication of the mass of the congener by its weighting factor (or toxic equivalency factor, TEF) yields the corresponding TCDD mass (or TEQ). The total toxicity of any mixture is the sum of the TEQs for each type of dioxin.
Upper bound	The maximum possible TEQ.
Units of measurement	
ng	nanogram $=10^{-9}$ gram (0.000 000 001g)
pg	picogram $=10^{-12}$ gram (0.000 000 000 001g)
fg	femtogram $=10^{-15}$ gram (0.000 000 000 000 001g)
Tolerable monthly intake	The amount of a substance which can be consumed over a month with no appreciable risk to health.

Copies of the reports contained in this CD–ROM can be accessed electronically from:

http://www.deh.gov.au/industry/chemicals/dioxins/index.html

Appendix E

Risk Calculations

Appendix E
Risk Calculations

E1.1 Introduction

This appendix presents the calculations undertaken to evaluate risk to human health associated with the key issues and COPC identified for the proposed GTP. The calculations presented are relevant to the estimation of maximum risk utilising maximum ground level concentrations and deposition rates for emissions to air during normal operations and the two accidental release scenarios evaluated.

Risk calculations have been undertaken using an in-house spreadsheet based model RiskE (2002) using the assumptions presented in the main report. This appendix presents the inputs and outputs used in the RiskE models set-up for this assessment.

E2.1 Normal Operations

E2.2 Inhalation Exposures

Exposure Parameters

Adult Resident

Exposure Parameters	Units	RME	References
Global Parameters			
Exposure Frequency (EF)	days/yr	337	At home most days except for 4 weeks per year
Exposure Duration (ED)	yrs	70	CSMS 1996
Body Weight (BW)	kg	70	USEPA 1989b, CSMS 1996
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989a
Averaging Time - Threshold (ATn)	days	25550	USEPA, 1989a
Inhalation Indoors and Outdoors			
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoors at 1.17 m3/hr and 4 hours
Exposure Time (ET)	hr/day	24	Whole day spent at home
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time at home affected by emissions
Intake Factor = $\frac{IR*ET*FI*EF*ED}{BW*AT}$	m^3/kg-day	4.25E-01	NonThreshold
		4.25E-01	Threshold

Child Resident (0-5 years)

Exposure Parameters	Units	RME	References
Global Parameters			
Exposure Frequency (EF)	days/yr	337	At home most days except for 4 weeks per year
Exposure Duration (ED)	yrs	5	Duration of exposure for age group
Body Weight (BW)	kg	13.2	enHealth 2002
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989a
Averaging Time - Threshold (ATn)	days	1825	USEPA, 1989a
Inhalation Indoors and Outdoors			
Inhalation Rate (IR)	m^3/hr	0.58	Inhalation rate assuming 20 hours indoors at 0.45 m3/hr and 4 hours
Exposure Time (ET)	hr/day	24	Whole day spent at home
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time at home affected by emissions
Intake Factor = $\frac{IR*ET*FI*EF*ED}{BW*AT}$	m^3/kg-day	6.99E-02	NonThreshold
		9.79E-01	Threshold

Inhalation Indoors and Outdoors

Residents

General Data/ Equations	Exposure Calculations Adult Resident	Exposure Calculations Child Resident
Intake Factor for NonThreshold Effects (m^3/kg/day)	4.2E-01	7.0E-02
Intake Factor for Threshold Effects (m^3/kg/day)	4.2E-01	9.8E-01

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations Adult Resident					Exposure Calculations Child Resident				
	Non-Threshold Slope Factor (mg/kg day)$^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**4.8E-7**	**7.5E-3**				**8.0E-8**	**1.7E-2**
Dichloroethane (EDC) (1,2-)	9.8E-03		1.14E-04	4.8E-05		4.7E-7	--	1.14E-04	8.0E-06		7.8E-8	--
Vinyl Chloride	3.0E-03		4.02E-06	1.7E-06		5.1E-9	--	4.02E-06	2.8E-07		8.4E-10	--
Chloroform	1.5E-03	2.0E-02	3.36E-06	1.4E-06	1.4E-06	2.1E-9	7.1E-5	3.36E-06	2.4E-07	3.3E-06	3.5E-10	1.6E-4
Carbon tetrachloride		6.1E-04	1.06E-05		4.5E-06	--	7.4E-3	1.06E-05		1.0E-05	--	1.7E-2
Trichloroethylene (TCE)	1.5E-03		4.85E-06	2.1E-06		3.1E-9	--	4.85E-06	3.4E-07		5.1E-10	--
Tetrachloroethene (PCE)		4.7E-02	9.14E-06		3.9E-06	--	8.2E-5	9.14E-06		8.9E-06	--	1.9E-4

Exposure Parameters

Commercial/Industrial Areas

Exposure Parameters	Units	RME	References
Global Parameters			
Exposure Frequency (EF)	days/yr	240	Days at work per year
Exposure Duration (ED)	yrs	30	enHealth 2002
Body Weight (BW)	kg	70	USEPA 1989b, CSMS 1996
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989a
Averaging Time - Threshold (ATn)	days	10950	USEPA, 1989a
Inhalation Indoors and Outdoors			
Inhalation Rate (IR)	m^3/hr	1.38	Based on 2 hours outdoors at 2.2 m3/hr and 8 hours indoors at 1.17 m3/hr
Exposure Time (ET)	hr/day	10	Time outdoors
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time at work affected by emissions
Intake Factor = $\frac{IR*ET*FI*EF*ED}{BW*AT}$	m^3/kg-day	5.54E-02 1.29E-01	NonThreshold Threshold

Inhalation Indoors and Outdoors

Commercial/Industrial Workers

General Data/ Equations	Exposure Calculations Outdoor Exposure
Intake Factor for NonThreshold Effects (m^3/kg/day)	5.5E-02
Intake Factor for Threshold Effects (m^3/kg/day)	1.3E-01

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data						
	Non-Threshold Slope Factor (mg/kg-day)[1]	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**6.3E-8**	**2.5E-3**
Dichloroethane (EDC) (1,2-)	9.8E-03		1.14E-04	6.3E-06		6.2E-8	--
Vinyl Chloride	3.0E-03		4.02E-06	2.2E-07		6.7E-10	--
Chloroform	1.5E-03	2.0E-02	3.36E-06	1.9E-07	4.3E-07	2.7E-10	2.2E-5
Carbon tetrachloride		6.1E-04	1.06E-05		1.4E-06	--	2.2E-3
Trichloroethylene (TCE)	1.5E-03		4.85E-06	2.7E-07	6.3E-07	4.0E-10	--
Tetrachloroethene (PCE)		4.7E-02	9.14E-06		1.2E-06	--	2.5E-5
Dioxin (TEF)		1.1E-09	1.54E-12		2.0E-13	--	1.9E-4

Exposure Parameters

Adult Recreational User in Area

Exposure Parameters	Units	RME	References
Global Parameters			
Exposure Frequency (EF)	days/yr	104	Time spent exercising in area
Exposure Duration (ED)	yrs	70	CSMS 1996
Body Weight (BW)	kg	70	USEPA 1989b, CSMS 1996
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989a
Averaging Time - Threshold (ATn)	days	25550	USEPA, 1989a
Inhalation during exercise			
Inhalation Rate (IR)	m^3/hr	3.50	Rate representative of runnig at 8 km/hr
Exposure Time (ET)	hr/day	3	Time spent exercising
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	4.27E-02	NonThreshold
BW*AT		4.27E-02	Threshold
Inhalation playing golf			
Inhalation Rate (IR)	m^3/hr	2.20	Rate equal to walking 4 km/hr, CSMS 1996
Exposure Time (ET)	hr/day	6	Time spent playing golf
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	5.37E-02	NonThreshold
BW*AT		5.37E-02	Threshold

Child Recreational User in Area (5-15 years)

Exposure Parameters	Units	RME	References
Global Parameters			
Exposure Frequency (EF)	days/yr	104	Time spent exercising in area
Exposure Duration (ED)	yrs	10	Duration of exposure for age group
Body Weight (BW)	kg	34.5	enHealth 2002
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989a
Averaging Time - Threshold (ATn)	days	3650	USEPA, 1989a
Inhalation during exercise			
Inhalation Rate (IR)	m^3/hr	2.20	Outdoor rate durin exercise
Exposure Time (ET)	hr/day	4	Time spent exercising in area
Fraction Inhaled from Contaminated Source (	unitless	1	Whole time at home affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	1.04E-02	NonThreshold
BW*AT		7.27E-02	Threshold

Inhalation Outdoors

Recreational Users in Area

General Data/ Equations	Exposure Calculations Adults Exercising	Exposure Calculations Adults Playing Golf
Intake Factor for NonThreshold Effects (m^3/kg/day)	4.3E-02	5.4E-02
Intake Factor for Threshold Effects (m^3/kg/day)	4.3E-02	5.4E-02

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations Adults Exercising					Exposure Calculations Adults Playing Golf				
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**4.9E-8**	**8.2E-4**				**6.1E-8**	**1.0E-3**
Dichloroethane (EDC) (1,2-)	9.8E-03		1.14E-04	4.9E-06		4.8E-8	--	1.14E-04	6.1E-06		6.0E-8	--
Vinyl Chloride	3.0E-03		4.02E-06	1.7E-07		5.2E-10	--	4.02E-06	2.2E-07		6.5E-10	--
Chloroform	1.5E-03	2.0E-02	3.36E-06	1.4E-07	1.4E-07	2.1E-10	7.2E-6	3.36E-06	1.8E-07	1.8E-07	2.7E-10	9.0E-6
Carbon tetrachloride		6.1E-04	1.06E-05		4.5E-07	--	7.4E-4	1.06E-05		5.7E-07	--	9.3E-4
Trichloroethylene (TCE)	1.5E-03		4.85E-06	2.1E-07		3.1E-10	--	4.85E-06	2.6E-07		3.9E-10	--
Tetrachloroethene (PCE)		4.7E-02	9.14E-06		3.9E-07	--	8.3E-6	9.14E-06		4.9E-07	--	1.0E-5
Dioxin (TEF)		1.1E-09	1.54E-12		6.6E-14	--	6.3E-5	1.54E-12		8.3E-14	--	7.9E-5

Inhalation Outdoors

Recreational Users in Area

General Data/ Equations	Exposure Calculations Children Exercising
Intake Factor for NonThreshold Effects (m^3/kg/day)	1.0E-02
Intake Factor for Threshold Effects (m^3/kg/day)	7.3E-02

Chemical	Toxicity Data						
	Non-Threshold Slope Factor (mg/kg-day)[1]	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Air (mg/m^3)	Daily Intake from Air - NonThreshold Effects (mg/kg/day)	Daily Intake from Air - Threshold Effects (mg/kg/day)	NonThreshold Risk (unitless)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for al						**1.2E-8**	**1.4E-3**
Dichloroethane (EDC) (1,2-)	9.8E-03		1.14E-04	1.2E-06		1.2E-8	--
Vinyl Chloride	3.0E-03		4.02E-06	4.2E-08		1.3E-10	--
Chloroform	1.5E-03	2.0E-02	3.36E-06	3.5E-08	2.4E-07	5.1E-11	1.2E-5
Carbon tetrachloride		6.1E-04	1.06E-05		7.7E-07	--	1.3E-3
Trichloroethylene (TCE)	1.5E-03		4.85E-06	5.0E-08		7.6E-11	--
Tetrachloroethene (PCE)		4.7E-02	9.14E-06		6.6E-07	--	1.4E-5
Dioxin (TEF)		1.1E-09	1.54E-12		1.1E-13	--	1.1E-4

E2.3 Multiple Pathway Exposures

Exposure Parameters
Residential Exposures

		Adults		Children (0-5 years)	
Exposure Parameters	**Units**	**RME**	**References**	**RME**	**References**
Global Parameters					
Exposure Frequency (EF)	days/yr	337	Time spent at home per year	337	Time spent at home per year
Exposure Duration (ED)	yrs	70	enHealth 2002	5	Accidental release occurs once
Body Weight (BW)	kg	70	USEPA 1989, CSMS 1996	13.2	enHealth 2002
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989	25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days	25550	USEPA, 1989	1825	USEPA, 1989
Ingestion of Chemcials in Soil					
Ingestion Rate (IR)	mg/day	25	enHealth value for adults	100	enHealth value for young children
Fraction Ingested (FI)	unitless	1	Assume all soil ingested is from yard	1	Assume all soil ingested is from yard
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = IR*FI*ME*CF*EF*ED	kg/kg/day	3.3E-07	NonThreshold	5.0E-07	NonThreshold
BW*AT		3.3E-07	Threshold	7.0E-06	Threshold
Dermal Contact with Chemicals in Soil					
Skin Surface Area Available for Contact (SA)	cm^2/day	4580	Hands, forearms, and lower legs (average male/female, USEPA 1997)	2100	Hands, legs and feet as per enHealth and NEPM
Soil to Skin Adherence Factor (AF)	mg/cm^2	0.51	CSMS 1996	0.51	CSMS 1996
Fraction of Day Exposed	unitless	0.5	12 hour exposure, CSMS 1991, 1993 and 1998	1	24 hour exposure, CSMS 1991, 1993 and 1998
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = SA*AF*FC*ME*CF*EF*ED	kg/kg/day	1.54E-05	NonThreshold	5.35E-06	NonThreshold
BW*AT		1.54E-05	Threshold	7.49E-05	Threshold
Inhalation of Vapours					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoors at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoors at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	24	Whole day spent at home	24	Whole day spent at home
Fraction Inhaled from Contaminated Source (F	unitless	1	Whole time at home affected by emissions	1	Whole time at home affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	4.25E-01	NonThreshold	6.99E-02	NonThreshold
BW*AT		4.25E-01	Threshold	9.79E-01	Threshold
Inhalation of Particulates					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoos at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoos at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	24	Whole day spent at home	24	Whole day spent at home
Deposition Fraction (DF)	unitless	0.75	enHealth and NEPM	0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless	0.5	enHealth and NEPM	0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless	1	100% inhaled from source	1	100% inhaled from source
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day	1.59E-01	NonThreshold	2.62E-02	NonThreshold
BW*AT		1.59E-01	Threshold	3.67E-01	Threshold
Ingestion of Chemicals in Homegrown Fruit and Vegetables					
Ingestion Rate (IR)	kg/day	0.469	Daily intake for adults	0.202	95% consumption, CSMS 1996
Fraction Ingested (FI)	unitless	0.35	35% homegrown - conservative estimate	0.35	35% homegrown - conservative estimate
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Intake Factor = IR*FI*ME*EF*ED	kg/kg/day	2.17E-03	NonThreshold	3.53E-04	NonThreshold
BW*AT		2.17E-03	Threshold	4.95E-03	Threshold

Exposure Parameters	**Units**		**Infant (0-1 years)**	
Global Parameters				
Exposure Frequency (EF)	days/yr		365	Exposure every day
Exposure Duration (ED)	yrs		1	12 moth exposure to breastmilk
Body Weight (BW)	kg		6	Average weight of 3 month old child
Averaging Time - NonThreshold (ATc)	days		25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days		365	USEPA, 1989
Inhalation of Vapours				
Inhalation Rate (IR)	m^3/hr		0.19	Daily inhalation rate for children less than 1 year
Exposure Time (ET)	hr/day		24	Whole day spent at home
Fraction Inhaled from Contaminated Source (F	unitless		1	Whole time at home affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day		1.07E-02	NonThreshold
BW*AT			7.50E-01	Threshold
Inhalation of Particulates				
Inhalation Rate (IR)	m^3/hr		0.19	Daily inhalation rate for children less than 1 year old as per USEPA 1997.
Exposure Time (ET)	hr/day		24	Whole day spent at home
Deposition Fraction (DF)	unitless		0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless		0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless		1	100% inhaled from source
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day		4.02E-03	NonThreshold
BW*AT			2.81E-01	Threshold
Ingestion of Chemicals in Breastmilk				
Ingestion Rate (IR)	kg/day		0.751	DEH 2004
Fraction of fat/lipids in milk (FM)	unitless		0.037	DEH 2004
Absorption following ingestion (Ab)	unitless		0.9	DEH 2004
Intake Factor = IR*FM*Ab*EF*ED	kg/kg/day		5.95E-05	NonThreshold
BW*AT			4.17E-03	Threshold

Calculation of Concentrations in Soils

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(mg/kg)** ref: Stevens B. (1991)

where:

DR= Particle deposition rate (mg/m^2/year)
K = Chemical-specific soil-loss constant (1/year) = ln(2)/T0.5
T0.5 = Chemical half-life in soil (years)
T = Accumulation time (years)
D = Soil mixing depth (m)
ρ = Soil bulk-density (g/m^3)
1000 = Conversion from g to kg

General Parameters		Surface	Depth
Soil bulk density	g/m^3	1600000	1600000
General mixing depth	m	0.01	0.15
Duration of depositior Chronic	years	30	

Chemical-specific Inputs and calculations

Chemical	**Half-life in soil years**	**Loss constant per year**	**Deposition Rate mg/m^2/year**	**Surface Concentration in Soil mg/kg**	**Depth Concentration in Soil mg/kg**
Hexachlorobutadine (HCBD)	6	0.116	4.67E-05	2.45E-05	1.63E-06
Mercury	2	0.347	1.07E-05	1.93E-06	1.29E-07
Dioxin (TEF)	12	0.058	4.00E-09	3.56E-09	2.37E-10

Calculation of Concentrations in Plants

ref: Stevens B. (1991)

Uptake Due to Deposition in Aboveground Crops

$$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k}$$ (mg/kg plant – wet weight)

where:

DR= Particle deposition rate for accidental release (mg/m^2/day)

F= Fraction for the surface area of plant (unitless)

k= Chemical-specific soil-loss constant (1/years) = ln(2)/T0.5

T0.5= Chemical half-life as particulate on plant (days)

t= Deposition time (days)

Y= Crop yield (kg/m^2)

Uptake via Roots from Soil

$$C_{rp} = C_s \bullet RUF$$ (mg/kg plant – wet weight)

where:

Cs = Concentration of persistent chemical in soil assuming 15cm mixing depth within gardens, calculated using Soil Equation for each chemical assessed (mg/kg)

RUF = Root uptake factor which differs for each Chemical (unitless)

General Parameters	Units	Value
Crop		Edible crops
Crop Yield	kg/m^2	2
Deposition Time	days	70
Plant Interception fraction	unitless	0.051

Chemical-specific Inputs and calculations

Chemical	Half-life on plant days	Loss constant per day	Deposition Rate mg/m^2/day	Aboveground Conentration via Deposition mg/kg	Root Uptake Factor unitless	Soil Concentration mg/kg	Below Ground Concentration mg/kg
Hexachlorobutadine (HCBD)	14.0000	0.05	1.28E-07	6.4E-08	0.013	1.63E-06	2.12E-08
Mercury	14.0000	0.05	2.93E-08	1.5E-08	0.3	1.29E-07	3.86E-08
Dioxin (TEF)	14.0000	0.05	4.99E-10	2.5E-10	0.031	2.37E-10	7.36E-12

Calculation of Concentrations in Breast Milk

ref. USEPA, 1998

$$C_{milk\ fat} = \frac{m \bullet h \bullet f_1}{0.693 \bullet f_2} \text{ (mg/kg milk fat)}$$

where:

m = Average maternal intake of dioxin or HCB (mg/kg/day)

h = Half-life of POP in adults (days)

f_1 = Fraction of ingested stored in fat (unitless)

f_2 = Fraction of mothers weight that is fat (unitless)

General Parameters		
Fraction ingested which is stored as fat	unitless	0.9
Fraction of body fat of mother	unitless	0.35

Chemical-specific Inputs and calculations

Chemical	**Half-life in body days**	**Adult intake from soil, air and plant mg/kg/day**	**Concentration in breastmilk mg/kg milk fat**
Hexachlorobutadine (HCBD)	1095	1.45E-08	5.89E-05
Mercury		3.29E-09	0.00E+00
Dioxin (TEF)	2738	2.26E-12	2.29E-08

Ingestion of Chemcials in Soil
Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	3.3E-07	7.0E-06

Daily Intake from Soil = Concentration in Soil x Intake Factor
NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations for Adults RME			Exposure Calculations for Children (0-5 yrs) RME		
	Non-Threshold Slope Factor (mg/kg-day)⁻¹	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**1.2E-6**			**2.6E-5**
Hexachlorobutadine (HCBD)		8.0E-05	2.44689E-05	8.1E-12	1.0E-7	2.44689E-05	1.7E-10	2.1E-6
Mercury		4.6E-05	1.93179E-06	6.4E-13	1.4E-8	1.93179E-06	1.4E-11	2.9E-7
Dioxin (TEF)		1.1E-09	3.56048E-09	1.2E-15	1.1E-6	3.56048E-09	2.5E-14	2.4E-5

Dermal Contact with Chemicals in Soil

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	1.5E-05	7.5E-05
Daily Intake from Soil = Concentration in Soil x Dermal Absorption x Intake Factor *NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor* *Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)*		

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg-day)⁻¹	Threshold ADI, TDI or RfD (mg/kg/day)	Dermal Absorption (unitless)	Adults: Concentration in Soil (mg/kg)	Adults: Daily Intake from Soil - Threshold Effects (mg/kg/day)	Adults: Hazard Quotient (unitless)	Children: Concentration in Soil (mg/kg)	Children: Daily Intake from Soil - Threshold Effects (mg/kg/day)	Children: Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**2.0E-6**			**9.9E-6**
Hexachlorobutadine (HCBD)		8.0E-05	1.0E-01	2.44689E-05	3.8E-11	4.7E-7	2.44689E-05	1.8E-10	2.3E-6
Mercury		4.6E-05		1.93179E-06			1.93179E-06		
Dioxin (TEF)		1.1E-09	3.0E-02	3.56048E-09	1.6E-15	1.6E-6	3.56048E-09	8.0E-15	7.6E-6

Inhalation of Particulates

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (m^3/kg/day)	1.6E-01	3.7E-01	2.8E-01

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg day)$^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Adults: Concentration of Particulates in Air (mg/m^3)	Adults: Daily Intake from Air - Threshold Effects (mg/kg/day)	Adults: Hazard Quotient (unitless)	Children: Concentration of Particulates in Air (mg/m^3)	Children: Daily Intake from Air - Threshold Effects (mg/kg/day)	Children: Hazard Quotient (unitless)	Infants: Concentration of Particulates in Air (mg/m^3)	Infants: Daily Intake from Air - Threshold Effects (mg/kg/day)	Infants: Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**2.8E-4**			**6.4E-4**			**4.9E-4**
Hexachlorobutadine (HCBD)		8.0E-05	1.75E-08	2.8E-09	3.5E-5	1.75E-08	6.4E-09	8.0E-5	1.75E-08	4.9E-09	6.2E-5
Mercury		5.7E-05	4.02E-09	6.4E-10	1.1E-5	4.02E-09	1.5E-09	2.6E-5	4.02E-09	1.1E-09	2.0E-5
Dioxin (TEF)		1.1E-09	1.54E-12	2.5E-13	2.3E-4	1.54E-12	5.7E-13	5.4E-4	1.54E-12	4.3E-13	4.1E-4

Inhalation of Vapours

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (m^3/kg/day)	4.2E-01	9.8E-01	7.5E-01

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor $(mg/kg\ day)^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Adults: Concentration of Particulates in Air (mg/m^3)	Adults: Daily Intake from Air - Threshold Effects (mg/kg/day)	Adults: Hazard Quotient (unitless)	Children: Concentration of Particulates in Air (mg/m^3)	Children: Daily Intake from Air - Threshold Effects (mg/kg/day)	Children: Hazard Quotient (unitless)	Infants: Concentration of Particulates in Air (mg/m^3)	Infants: Daily Intake from Air - Threshold Effects (mg/kg/day)	Infants: Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**7.5E-4**			**1.7E-3**			**1.3E-3**
Hexachlorobutadine (HCBD)		8.0E-05	1.75E-08	7.4E-09	9.3E-5	1.75E-08	1.7E-08	2.1E-4	1.75E-08	1.3E-08	1.6E-4
Mercury		5.7E-05	4.02E-09	1.7E-09	3.0E-5	4.02E-09	3.9E-09	6.9E-5	4.02E-09	3.0E-09	5.3E-5
Dioxin (TEF)		1.1E-09	1.54E-12	6.5E-13	6.2E-4	1.54E-12	1.5E-12	1.4E-3	1.54E-12	1.2E-12	1.1E-3

Ingestion of Chemicals in Homegrown Fruit and Vegetables

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	2.2E-03	4.9E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data: Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Toxicity Data: Threshold ADI, TDI or RfD (mg/kg/day)	Adults: Concentration in Fruit and Vegetables (mg/kg)	Adults: Daily Intake from Produce - Threshold Effects (mg/kg/day)	Adults: Hazard Quotient (unitless)	Children: Concentration in Fruit and Vegetables (mg/kg)	Children: Daily Intake from Produce - Threshold Effects (mg/kg/day)	Children: Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**4.2E-4**			**9.6E-4**
Hexachlorobutadine (HCBD)		8.0E-05	5.57E-08	1.2E-10	1.5E-6	5.57237E-08	2.8E-10	3.4E-6
Mercury		4.6E-05	1.92E-08	4.2E-11	9.0E-7	1.92022E-08	9.5E-11	2.1E-6
Dioxin (TEF)		1.1E-09	2.03E-10	4.4E-13	4.2E-4	2.03257E-10	1.0E-12	9.6E-4

Ingestion of Chemicals in Breastmilk

Residential Exposures

General Data/ Equations	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (kg/kg/day)	4.2E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data				
	Non-Threshold Slope Factor (mg/kg-day)^{1}	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Fruit and Vegetables (mg/kg)	Daily Intake from Produce - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**9.4E-2**
Hexachlorobutadine (HCBD)		8.0E-05	5.89E-05	2.5E-07	3.1E-3
Mercury		4.6E-05			
Dioxin (TEF)		1.1E-09	2.29E-08	9.6E-11	9.1E-2

Appendix E
Risk Calculations

E3.1 Accidental Release Scenarios

E3.2 Increased Dioxin Emission

Exposure Parameters
Residential Exposures

		Adults		Children (0-5 years)	
Exposure Parameters	**Units**	**RME**	**References**	**RME**	**References**
Global Parameters					
Exposure Frequency (EF)	days/yr	337	Time spent at home per year	337	Time spent at home per year
Exposure Duration (ED)	yrs	1	Duration of increased dioxin release	1	Duration of increased dioxin release
Body Weight (BW)	kg	70	USEPA 1989, CSMS 1996	13.2	enHealth 2002
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989	25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days	365	USEPA, 1989	365	USEPA, 1989
Ingestion of Chemcials in Soil					
Ingestion Rate (IR)	mg/day	25	enHealth value for adults	100	enHealth value for young children
Fraction Ingested (FI)	unitless	1	Assume all soil ingested is from yard	1	Assume all soil ingested is from yard
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = IR*FI*ME*CF*EF*ED	kg/kg/day	4.7E-09	NonThreshold	1.0E-07	NonThreshold
BW*AT		3.3E-07	Threshold	7.0E-06	Threshold
Dermal Contact with Chemicals in Soil					
Skin Surface Area Available for Contact (SA)	cm^2/day	4580	Hands, forearms, and lower legs (average male/female, USEPA 1997)	2100	Hands, legs and feet as per enHealth and NEPM
Soil to Skin Adherence Factor (AF)	mg/cm^2	0.51	CSMS 1996	0.51	CSMS 1996
Fraction of Day Exposed	unitless	0.5	12 hour exposure, CSMS 1991, 1993 and 1998	1	24 hour exposure, CSMS 1991, 1993 and 1998
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = SA*AF*FC*ME*CF*EF*ED	kg/kg/day	2.20E-07	NonThreshold	1.07E-06	NonThreshold
BW*AT		1.54E-05	Threshold	7.49E-05	Threshold
Inhalation of Vapours					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoors at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoors at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	24	Whole day spent at home	24	Whole day spent at home
Fraction Inhaled from Contaminated Source (F	unitless	1	Whole time at home affected by emissions	1	Whole time at home affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	6.07E-03	NonThreshold	1.40E-02	NonThreshold
BW*AT		4.25E-01	Threshold	9.79E-01	Threshold
Inhalation of Particulates					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoos at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoos at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	24	Whole day spent at home	24	Whole day spent at home
Deposition Fraction (DF)	unitless	0.75	enHealth and NEPM	0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless	0.5	enHealth and NEPM	0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless	1	100% inhaled from source	1	100% inhaled from source
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day	2.28E-03	NonThreshold	5.25E-03	NonThreshold
BW*AT		1.59E-01	Threshold	3.67E-01	Threshold
Ingestion of Chemicals in Homegrown Fruit and Vegetables					
Ingestion Rate (IR)	kg/day	0.469	Daily intake for adults	0.202	95% consumption, CSMS 1996
Fraction Ingested (FI)	unitless	0.35	35% homegrown - conservative estimate	0.35	35% homegrown - conservative estimate
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Intake Factor = IR*FI*ME*SS*EF*ED	kg/kg/day	3.09E-05	NonThreshold	7.06E-05	NonThreshold
BW*AT		2.17E-03	Threshold	4.95E-03	Threshold

Exposure Parameters	**Units**			**Infant (0-1 years)**	
Global Parameters					
Exposure Frequency (EF)	days/yr			365	Exposure every day
Exposure Duration (ED)	yrs			1	12 moth exposure to breastmilk
Body Weight (BW)	kg			6	Average weight of 3 month old child
Averaging Time - NonThreshold (ATc)	days			25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days			365	USEPA, 1989
Inhalation of Vapours					
Inhalation Rate (IR)	m^3/hr			0.19	Daily inhalation rate for children less than 1 year
Exposure Time (ET)	hr/day			24	Whole day spent at home
Fraction Inhaled from Contaminated Source (F	unitless			1	Whole time at home affected by emissions
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day			1.07E-02	NonThreshold
BW*AT				7.50E-01	Threshold
Inhalation of Particulates					
Inhalation Rate (IR)	m^3/hr			0.19	Daily inhalation rate for children less than 1 year old as per USEPA 1997.
Exposure Time (ET)	hr/day			24	Whole day spent at home
Deposition Fraction (DF)	unitless			0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless			0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless			1	100% inhaled from source
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day			4.02E-03	NonThreshold
BW*AT				2.81E-01	Threshold
Ingestion of Chemicals in Breastmilk					
Ingestion Rate (IR)	kg/day			0.751	DEH 2004
Fraction of fat/lipids in milk (FM)	unitless			0.037	DEH 2004
Absorption following ingestion (Ab)	unitless			0.9	DEH 2004
Intake Factor = IR*FM*Ab*EF*ED	kg/kg/day			5.95E-05	NonThreshold
BW*AT				4.17E-03	Threshold

Calculation of Concentrations in Soils

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(mg/kg)** ref: Stevens B. (1991)

where:

DR=	Particle deposition rate (mg/m^2/year)
K =	Chemical-specific soil-loss constant (1/year) = ln(2)/T0.5
T0.5 =	Chemical half-life in soil (years)
T =	Accumulation time (years)
D =	Soil mixing depth (m)
ρ =	Soil bulk-density (g/m^3)
1000 =	Conversion from g to kg

General Parameters		Surface	Depth	
Soil bulk density	g/m^3	1600000	1600000	
General mixing depth	m	0.01	0.15	
Duration of depositior Chronic	years	1		Duration of increased dioxin release

Chemical-specific Inputs and calculations

Chemical	**Half-life in soil years**	**Loss constant per year**	**Deposition Rate mg/m^2/year**	**Surface Concentration in Soil mg/kg**	**Depth Concentration in Soil mg/kg**
Hexachlorobutadine (HCBD)	6	0.116		0.00E+00	0.00E+00
Mercury	2	0.347		0.00E+00	0.00E+00
Dioxin (TEF)	12	0.058	2.00E-08	1.21E-09	8.09E-11

Note - concentrations of HCBD and mercury in soil unchanged from that calculated for normal operations

Calculation of Concentrations in Plants

ref: Stevens B. (1991)

Uptake Due to Deposition in Aboveground Crops

$$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k} \quad \text{(mg/kg plant – wet weight)}$$

where:
DR= Particle deposition rate for accidental release (mg/m^2/day)
F= Fraction for the surface area of plant (unitless)
k= Chemical-specific soil-loss constant (1/years) = ln(2)/T0.5
T0.5= Chemical half-life as particulate on plant (days)
t= Deposition time (days)
Y= Crop yield (kg/m^2)

Uptake via Roots from Soil

$$C_{rp} = C_s \bullet RUF \quad \text{(mg/kg plant – wet weight)}$$

where:
Cs = Concentration of persistent chemical in soil assuming 15cm mixing depth within gardens, calculated using Soil Equation for each chemical assessed (mg/kg)
RUF = Root uptake factor which differs for each Chemical (unitless)

General Parameters	Units	Value
Crop		Edible crops
Crop Yield	kg/m^2	2
Deposition Time	days	70
Plant Interception fraction	unitless	0.051

Chemical-specific Inputs and calculations

Chemical	Half-life on plant	Loss constant	Deposition Rate	Aboveground Conentration via Deposition	Root Uptake Factor	Soil Concentration	Below Ground Concentration
	days	per day	mg/m^2/day	mg/kg	unitless	mg/kg	mg/kg
Hexachlorobutadine (HCBD)	14.0000	0.05		0.0E+00	0.013	0.00E+00	0.00E+00
Mercury	14.0000	0.05		0.0E+00	0.3	0.00E+00	0.00E+00
Dioxin (TEF)	14.0000	0.05	2.50E-09	1.2E-09	0.031	8.09E-11	2.51E-12

Note - Concentrations of HCBD and mercury in plants unchanged from that calculated during normal operations

Calculation of Concentrations in Breast Milk

ref. USEPA, 1998

$$C_{milk\ fat} = \frac{m \bullet h \bullet f_1}{0.693 \bullet f_2} \text{ (mg/kg milk fat)}$$

where:

m = Average maternal intake of dioxin or HCB (mg/kg/day)
h = Half-life of POP in adults (days)
f_1 = Fraction of ingested stored in fat (unitless)
f_2 = Fraction of mothers weight that is fat (unitless)

General Parameters		
Fraction ingested which is stored as fat	unitless	0.9
Fraction of body fat of mother	unitless	0.35

Chemical-specific Inputs and calculations

Chemical	**Half-life in body days**	**Adult intake from soil, air and plant mg/kg/day**	**Concentration in breastmilk mg/kg milk fat**
Hexachlorobutadine (HCBD)	1095	1.45E-08	5.89E-05
Mercury		1.42E-08	0.00E+00
Dioxin (TEF)	2738	1.11E-11	1.13E-07

Ingestion of Chemcials in Soil

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	3.3E-07	7.0E-06

Daily Intake from Soil = Concentration in Soil x Intake Factor
NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations for Adults RME			Exposure Calculations for Children (0-5 yrs) RME		
	Non-Threshold Slope Factor (mg/kg-day)[1]	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**5.0E-7**			**1.1E-5**
Hexachlorobutadine (HCBD)		8.0E-05	2.44689E-05	8.1E-12	1.0E-7	2.44689E-05	1.7E-10	2.1E-6
Mercury		4.6E-05	1.93179E-06	6.4E-13	1.4E-8	1.93179E-06	1.4E-11	2.9E-7
Dioxin (TEF)		1.1E-09	1.21373E-09	4.0E-16	3.8E-7	1.21373E-09	8.5E-15	8.1E-6

Dermal Contact with Chemicals in Soil

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	1.5E-05	7.5E-05
Daily Intake from Soil = Concentration in Soil x Dermal Absorption x Intake Factor *NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor* *Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)*		

Chemical	Toxicity Data			Exposure Calculations for Adults RME			Exposure Calculations for Children (0-5 yrs) RME		
	Non-Threshold Slope Factor (mg/kg-day)[1]	Threshold ADI, TDI or RfD (mg/kg/day)	Dermal Absorption (unitless)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration in Soil (mg/kg)	Daily Intake from Soil - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**1.0E-6**			**4.9E-6**
Hexachlorobutadine (HCBD)		8.0E-05	1.0E-01	2.44689E-05	3.8E-11	4.7E-7	2.44689E-05	1.8E-10	2.3E-6
Mercury		4.6E-05		1.93179E-06		--	1.93179E-06		--
Dioxin (TEF)		1.1E-09	3.0E-02	1.21373E-09	5.6E-16	5.3E-7	1.21373E-09	2.7E-15	2.6E-6

Inhalation of Particulates

Residential Exposures

General Data/ Equations			**Exposure Calculations for Adults** **RME**			**Exposure Calculations for Children (0-5 yrs)** **RME**			**Exposure Calculations for Infants** **RME**		
Intake Factor for Threshold Effects (m^3/kg/day)			1.6E-01			3.7E-01			2.8E-01		
Daily Intake from Air = Concentration in Air x Intake Factor *NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor* *Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)*											
Chemical	**Toxicity Data** **Non-Threshold Slope Factor**	**Threshold ADI, TDI or RfD**	**Concentration of Particulates in Air**	**Daily Intake from Air** - Threshold Effects	**Hazard Quotient**	**Concentration of Particulates in Air**	**Daily Intake from Air** - Threshold Effects	**Hazard Quotient**	**Concentration of Particulates in Air**	**Daily Intake from Air** - Threshold Effects	**Hazard Quotient**
	(mg/kg-day) $^{-1}$	(mg/kg/day)	(mg/m^3)	(mg/kg/day)	(unitless)	(mg/m^3)	(mg/kg/day)	(unitless)	(mg/m^3)	(mg/kg/day)	(unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**1.3E-3**			**2.9E-3**			**2.3E-3**
Hexachlorobutadine (HCBD)		8.0E-05	1.75E-08	2.8E-09	3.5E-5	1.75E-08	6.4E-09	8.0E-5	1.75E-08	4.9E-09	1.4E-4
Mercury		5.7E-05	1.75E-08	2.8E-09	4.9E-5	1.75E-08	6.4E-09	1.1E-4	1.75E-08	4.9E-09	1.0E-4
Dioxin (TEF)		1.1E-09	7.70E-12	1.2E-12	1.2E-3	7.70E-12	2.8E-12	2.7E-3	7.70E-12	2.2E-12	2.1E-3

Inhalation of Vapours

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (m^3/kg/day)	4.2E-01	9.8E-01	7.5E-01

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Adults			Children (0-5 yrs)			Infants		
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**3.3E-3**			**7.7E-3**			**5.7E-3**
Hexachlorobutadine (HCBD)		8.0E-05	1.75E-08	7.4E-09	9.3E-5	1.75E-08	1.7E-08	2.1E-4	1.75E-08	1.3E-08	1.4E-4
Mercury		5.7E-05	1.75E-08	7.4E-09	1.3E-4	1.75E-08	1.7E-08	3.0E-4	1.75E-08	1.3E-08	1.0E-4
Dioxin (TEF)		1.1E-09	7.70E-12	3.3E-12	3.1E-3	7.70E-12	7.5E-12	7.2E-3	7.70E-12	5.8E-12	5.5E-3

Ingestion of Chemicals in Homegrown Fruit and Vegetables

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	2.2E-03	4.9E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations for Adults			Exposure Calculations for Children (0-5 yrs)		
	Non-Threshold Slope Factor (mg/kg-day) ^{1}	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Fruit and Vegetables (mg/kg)	Daily Intake from Produce - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration in Fruit and Vegetables (mg/kg)	Daily Intake from Produce - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**2.1E-3**			**4.8E-3**
Hexachlorobutadine (HCBD)		8.0E-05	5.57E-08	1.2E-10	1.5E-6	5.57237E-08	2.8E-10	3.4E-6
Mercury		4.6E-05	5.57E-08	1.2E-10	2.6E-6	5.57237E-08	2.8E-10	6.0E-6
Dioxin (TEF)		1.1E-09	1.01E-09	2.2E-12	2.1E-3	1.00977E-09	5.0E-12	4.8E-3

Ingestion of Chemicals in Breastmilk

Residential Exposures

General Data/ Equations	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (kg/kg/day)	4.2E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg-day)^{1}	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Fruit and Vegetables (mg/kg)	Daily Intake from Produce - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**4.5E-1**
Hexachlorobutadine (HCBD)		8.0E-05	5.89E-05	2.5E-07	3.1E-3
Mercury		4.6E-05			
Dioxin (TEF)		1.1E-09	1.13E-07	4.7E-10	4.5E-1

RISK SUMMARY - Threshold Risk - Dioxins only
Residential Exposures

Pathway	Adults Chronic Hazard Index RME	Children (0-5 yrs) Chronic Hazard Index RME	Infants Chronic Hazard Index RME
Ingestion of Chemcials in Soil	3.8E-7	8.1E-6	
Dermal Contact with Chemicals in Soil	5.3E-7	2.6E-6	
Inhalation of Particulates	1.2E-3	2.7E-3	2.1E-3
Ingestion of Chemicals in Homegrown Fruit and Vegetables	2.1E-3	7.2E-3	5.5E-3
Ingestion of Chemicals in Breastmilk			4.5E-1
TOTAL Dioxin	**3.3E-3**	**9.9E-3**	**4.6E-1**
TOTAL Other Chemicals	**3.1E-4**	**7.2E-4**	**3.6E-3**

E3.3 Thermal Oxidiser Not Operating

Exposure Parameters

Residential Exposures

		Adults		Children (0-5 years)	
Exposure Parameters	**Units**	**RME**	**References**	**RME**	**References**
Global Parameters					
Exposure Frequency (EF)	days/yr	337	Time spent at home per year	337	Time spent at home per year
Exposure Duration (ED)	yrs	1	Event only occurs during 1 year of operation	1	Event only occurs during 1 year of operation
Body Weight (BW)	kg	70	USEPA 1989, CSMS 1996	13.2	enHealth 2002
Averaging Time - NonThreshold (ATc)	days	25550	USEPA, 1989	25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days	365	USEPA, 1989	365	USEPA, 1989
Ingestion of Chemcials in Soil					
Ingestion Rate (IR)	mg/day	25	enHealth value for adults	100	enHealth value for young children
Fraction Ingested (FI)	unitless	1	Assume all soil ingested is from yard	1	Assume all soil ingested is from yard
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = IR*FI*ME*CF*EF*ED	kg/kg/day	4.7E-09	NonThreshold	1.0E-07	NonThreshold
BW*AT		3.3E-07	Threshold	7.0E-06	Threshold
Dermal Contact with Chemicals in Soil					
Skin Surface Area Available for Contact (SA)	cm^2/day	4580	Hands, forearms, and lower legs (average male/female, USEPA 1997)	2100	Hands, legs and feet as per enHealth and NEPM
Soil to Skin Adherence Factor (AF)	mg/cm^2	0.51	CSMS 1996	0.51	CSMS 1996
Fraction of Day Exposed	unitless	0.5	12 hour exposure, CSMS 1991, 1993 and 1998	1	24 hour exposure, CSMS 1991, 1993 and 1998
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Conversion Factor (kg/mg) (CF)	unitless	1.0E-6	USEPA, 1989	1.0E-6	USEPA, 1989
Intake Factor = SA*AF*FC*ME*CF*EF*ED	kg/kg/day	2.20E-07	NonThreshold	1.07E-06	NonThreshold
BW*AT		1.54E-05	Threshold	7.49E-05	Threshold
Inhalation of Vapours					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoors at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoors at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	12	12 hour exposure	12	12 hour exposure
Fraction Inhaled from Contaminated Source (F	unitless	0.00274	Exposure for 1 day only	0.00274	Exposure for 1 day only
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day	8.31E-06	NonThreshold	1.92E-05	NonThreshold
BW*AT		5.82E-04	Threshold	1.34E-03	Threshold
Inhalation of Particulates					
Inhalation Rate (IR)	m^3/hr	1.34	Inhalation rate assuming 20 hours indoos at 1.17 m3/hr and 4 hours outdoors at 2.2 m3/hr	0.58	Inhalation rate assuming 20 hours indoos at 0.45 m3/hr and 4 hours outdoors at 1.25 m3/hr
Exposure Time (ET)	hr/day	12	12 hour exposure	12	12 hour exposure
Deposition Fraction (DF)	unitless	0.75	enHealth and NEPM	0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless	0.5	enHealth and NEPM	0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless	0.00274	Exposure for 1 day only	0.00274	Exposure for 1 day only
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day	3.12E-06	NonThreshold	7.19E-06	NonThreshold
BW*AT		2.18E-04	Threshold	5.03E-04	Threshold
Ingestion of Chemicals in Homegrown Fruit and Vegetables					
Ingestion Rate (IR)	kg/day	0.469	Daily intake for adults	0.202	95% consumption, CSMS 1996
Fraction Ingested (FI)	unitless	0.35	35% homegrown - conservative estimate	0.35	35% homegrown - conservative estimate
Matrix Effect (ME)	unitless	1	Assume 100% bioavailability, CSMS 1996	1	Assume 100% bioavailability, CSMS 1996
Intake Factor = IR*FI*ME*EF*ED	kg/kg/day	3.09E-05	NonThreshold	7.06E-05	NonThreshold
BW*AT		2.17E-03	Threshold	4.95E-03	Threshold
Exposure Parameters	**Units**			**Infant (0-1 years)**	
Global Parameters					
Exposure Frequency (EF)	days/yr			365	Exposure every day
Exposure Duration (ED)	yrs			1	12 moth exposure to breastmilk
Body Weight (BW)	kg			6	Average weight of 3 month old child
Averaging Time - NonThreshold (ATc)	days			25550	USEPA, 1989
Averaging Time - Threshold (ATn)	days			365	USEPA, 1989
Inhalation of Vapours					
Inhalation Rate (IR)	m^3/hr			0.19	Daily inhalation rate for children less than 1 year
Exposure Time (ET)	hr/day			12	12 hour exposure
Fraction Inhaled from Contaminated Source (F	unitless			0.002739726	Exposure for 1 day only
Intake Factor = IR*ET*FI*EF*ED	m^3/kg-day			1.47E-05	NonThreshold
BW*AT				1.03E-03	Threshold
Inhalation of Particulates					
Inhalation Rate (IR)	m^3/hr			0.19	Daily inhalation rate for children less than 1 year old as per USEPA 1997.
Exposure Time (ET)	hr/day			12	12 hour exposure
Deposition Fraction (DF)	unitless			0.75	enHealth and NEPM
Ciliary Clearance factor (CC)	unitless			0.5	enHealth and NEPM
Fraction Inhaled from Contaminated Source (F	unitless			0.002739726	Exposure for 1 day only
Intake Factor = IR*ET*DF*CC*FI*EF*ED	m^3/kg-day			5.50E-06	NonThreshold
BW*AT				3.85E-04	Threshold
Ingestion of Chemicals in Breastmilk					
Ingestion Rate (IR)	kg/day			0.751	DEH 2004
Fraction of fat/lipids in milk (FM)	unitless			0.037	DEH 2004
Absorption following ingestion (Ab)	unitless			0.9	DEH 2004
Intake Factor = IR*FM*Ab*EF*ED	kg/kg/day			5.95E-05	NonThreshold
BW*AT				4.17E-03	Threshold

Calculation of Concentrations in Soils

$$C_s = \frac{DR \bullet \left[1 - e^{-k \bullet t}\right]}{d \bullet \rho \bullet k} \bullet 1000$$ **(mg/kg)** ref: Stevens B. (1991)

where:

DR=	Particle deposition rate (mg/m^2/hour)
K =	Chemical-specific soil-loss constant (1/hour) = ln(2)/T0.5
T0.5 =	Chemical half-life in soil (hours)
T =	Accumulation time (hours)
D =	Soil mixing depth (m)
ρ =	Soil bulk-density (g/m^3)
1000 =	Conversion from g to kg

General Parameters		Surface	Depth	
Soil bulk density	g/m^3	1600000	1600000	
General mixing depth	m	0.01	0.15	
Duration of deposition	hours	12		Duration of release

Chemical-specific Inputs and calculations

Chemical	**Half-life in soil hours**	**Loss constant per hour**	**Deposition Rate mg/m^2/hour**	**Surface Concentration in Soil mg/kg**	**Depth Concentration in Soil mg/kg**
Hexachlorobutadine (HCBD)	52560	1.32E-05	1.89E-04	1.42E-04	9.45E-06
Mercury	12720	5.45E-05	7.77E-08	5.83E-08	3.88E-09
Dioxin (TEF)	105120	6.59E-06	2.45E-11	1.84E-11	1.22E-12

Calculation of Concentrations in Plants

ref: Stevens B. (1991)

Uptake Due to Deposition in Aboveground Crops

$$C_p = \frac{DR \bullet F \bullet \left[1 - e^{-k \bullet t}\right]}{Y \bullet k}$$ (mg/kg plant – wet weight)

where:
DR= Particle deposition rate for accidental release (mg/m^2/day)
F= Fraction for the surface area of plant (unitless)
k= Chemical-specific soil-loss constant (1/years) = ln(2)/T0.5
T0.5= Chemical half-life as particulate on plant (days)
t= Deposition time (days)
Y= Crop yield (kg/m^2)

Uptake via Roots from Soil

$$C_{rp} = C_s \bullet RUF$$ (mg/kg plant – wet weight)

where:
Cs = Concentration of persistent chemical in soil assuming 15cm mixing depth within gardens, calculated using Soil Equation for each chemical assessed (mg/kg)
RUF = Root uptake factor which differs for each Chemical (unitless)

General Parameters	Units	Value
Crop		Edible crops
Crop Yield	kg/m^2	2
Deposition Time	days	1
Plant Interception fraction	unitless	0.051

Chemical-specific Inputs and calculations

Chemical	Half-life on plant	Loss constant	Deposition Rate	Aboveground Conentration via Deposition	Root Uptake Factor	Soil Concentration	Below Ground Concentration
	days	per day	mg/m^2/day	mg/kg	unitless	mg/kg	mg/kg
Hexachlorobutadine (HCBD)	14.0000	0.05	4.54E-03	1.1E-04	0.013	9.45E-06	1.23E-07
Mercury	14.0000	0.05	1.87E-06	4.6E-08	0.3	3.88E-09	1.17E-09
Dioxin (TEF)	14.0000	0.05	5.87E-10	1.5E-11	0.031	1.22E-12	3.79E-14

Calculation of Concentrations in Breast Milk

ref. USEPA, 1998

$$C_{milk\ fat} = \frac{m \bullet h \bullet f_1}{0.693 \bullet f_2} \text{ (mg/kg milk fat)}$$

where:

m = Average maternal intake of dioxin or HCB (mg/kg/day)
h = Half-life of POP in adults (days)
f_1 = Fraction of ingested stored in fat (unitless)
f_2 = Fraction of mothers weight that is fat (unitless)

General Parameters		
Fraction ingested which is stored as fat	unitless	0.9
Fraction of body fat of mother	unitless	0.35

Chemical-specific Inputs and calculations

Chemical	Half-life in body days	Adult intake from soil, air and plant mg/kg/day	Concentration in breastmilk mg/kg milk fat
Hexachlorobutadine (HCBD)	1095	1.04E-06	4.24E-03
Mercury		4.30E-10	0.00E+00
Dioxin (TEF)	2738	1.49E-13	1.52E-09

Ingestion of Chemcials in Soil

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	3.3E-07	7.0E-06

Daily Intake from Soil = Concentration in Soil x Intake Factor
NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor	Toxicity Data Threshold ADI, TDI or RfD	Adults Concentration in Soil	Adults Daily Intake from Soil - Threshold Effects	Adults Hazard Quotient	Children Concentration in Soil	Children Daily Intake from Soil - Threshold Effects	Children Hazard Quotient
	(mg/kg-day) [1]	(mg/kg/day)	(mg/kg)	(mg/kg/day)	(unitless)	(mg/kg)	(mg/kg/day)	(unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**5.9E-7**			**1.3E-5**
Hexachlorobutadine (HCBD)		8.0E-05	0.000141798	4.7E-11	5.8E-7	0.000141798	9.9E-10	1.2E-5
Mercury		4.6E-05	5.82705E-08	1.9E-14	4.2E-10	5.82705E-08	4.1E-13	8.9E-9
Dioxin (TEF)		1.1E-09	1.83561E-11	6.1E-18	5.8E-9	1.83561E-11	1.3E-16	1.2E-7

Dermal Contact with Chemicals in Soil
Residential Exposures

General Data/ Equations				Exposure Calculations for Adults RME			Exposure Calculations for Children (0-5 yrs) RME		
Intake Factor for Threshold Effects (kg/kg/day)				1.5E-05			7.5E-05		
Daily Intake from Soil = Concentration in Soil x Dermal Absorption x Intake Factor *NonThreshold Risk = Daily Intake from Soil for NonThreshold Effects x Slope Factor* *Hazard Quotients = (Daily Intake from Soil for Threshold Effects/Reference Dose)*									
Chemical	**Toxicity Data**								
	Non-Threshold Slope Factor (mg/kg-day) ^{1}	**Threshold ADI, TDI or RfD** (mg/kg/day)	**Dermal Absorption** (unitless)	**Concentration in Soil** (mg/kg)	**Daily Intake from Soil - Threshold Effects** (mg/kg/day)	**Hazard Quotient** (unitless)	**Concentration in Soil** (mg/kg)	**Daily Intake from Soil - Threshold Effects** (mg/kg/day)	**Hazard Quotient** (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals						**2.7E-6**			**1.3E-5**
Hexachlorobutadine (HCBD)		8.0E-05	1.0E-01	0.000141798	2.2E-10	2.7E-6	0.000141798	1.1E-09	1.3E-5
Mercury		4.6E-05		5.82705E-08			5.82705E-08		
Dioxin (TEF)		1.1E-09	3.0E-02	1.83561E-11	8.5E-18	8.1E-9	1.83561E-11	4.1E-17	3.9E-8

Inhalation of Particulates

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (m^3/kg/day)	2.2E-04	5.0E-04	3.9E-04

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg-day) ^{1}	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration of Particulates in Air (mg/m³)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m³)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m³)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**1.5E-3**			**3.5E-3**			**2.7E-4**
Hexachlorobutadine (HCBD)		8.0E-05	5.44E-04	1.2E-07	1.5E-3	5.44E-04	2.7E-07	3.4E-3	5.44E-04	2.1E-07	1.4E-4
Mercury		5.7E-05	2.24E-07	4.9E-11	8.5E-7	2.24E-07	1.1E-10	2.0E-6	2.24E-07	8.6E-11	1.0E-4
Dioxin (TEF)		1.1E-09	8.34E-11	1.8E-14	1.7E-5	8.34E-11	4.2E-14	4.0E-5	8.34E-11	3.2E-14	3.1E-5

Inhalation of Vapours

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (m^3/kg/day)	5.8E-04	1.3E-03	1.0E-03

Daily Intake from Air = Concentration in Air x Intake Factor
NonThreshold Risk = Daily Intake from Air for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Air for Threshold Effects/Reference Dose)

Chemical	Toxicity Data		Exposure Calculations for Adults			Exposure Calculations for Children (0-5 yrs)			Exposure Calculations for Infants		
	Non-Threshold Slope Factor (mg/kg day)$^{-1}$	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)	Concentration of Particulates in Air (mg/m^3)	Daily Intake from Air - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**4.0E-3**			**9.2E-3**			**3.2E-4**
Hexachlorobutadine (HCBD)		8.0E-05	5.44E-04	3.2E-07	4.0E-3	5.44E-04	7.3E-07	9.1E-3	5.44E-04	5.6E-07	1.4E-4
Mercury		5.7E-05	2.24E-07	1.3E-10	2.3E-6	2.24E-07	3.0E-10	5.2E-6	2.24E-07	2.3E-10	1.0E-4
Dioxin (TEF)		1.1E-09	8.34E-11	4.9E-14	4.6E-5	8.34E-11	1.1E-13	1.1E-4	8.34E-11	8.6E-14	8.2E-5

Ingestion of Chemicals in Homegrown Fruit and Vegetables

Residential Exposures

General Data/ Equations	Exposure Calculations for Adults RME	Exposure Calculations for Children (0-5 yrs) RME
Intake Factor for Threshold Effects (kg/kg/day)	2.2E-03	4.9E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg-day)⁻¹	Threshold ADI, TDI or RfD (mg/kg/day)	Adults: Concentration in Fruit and Vegetables (mg/kg)	Adults: Daily Intake from Produce - Threshold Effects (mg/kg/day)	Adults: Hazard Quotient (unitless)	Children: Concentration in Fruit and Vegetables (mg/kg)	Children: Daily Intake from Produce - Threshold Effects (mg/kg/day)	Children: Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**2.5E-3**			**5.7E-3**
Hexachlorobutadine (HCBD)		8.0E-05	9.15E-05	2.0E-07	2.5E-3	9.1471E-05	4.5E-07	5.7E-3
Mercury		4.6E-05	3.78E-08	8.2E-11	1.8E-6	3.78103E-08	1.9E-10	4.1E-6
Dioxin (TEF)		1.1E-09	1.18E-11	2.6E-14	2.4E-5	1.18449E-11	5.9E-14	5.6E-5

Ingestion of Chemicals in Breastmilk
Residential Exposures

General Data/ Equations	Exposure Calculations for Infants RME
Intake Factor for Threshold Effects (kg/kg/day)	4.2E-03

Daily Intake from Produce = Concentration in Produce x Intake Factor
NonThreshold Risk = Daily Intake from Produce for NonThreshold Effects x Slope Factor
Hazard Quotients = (Daily Intake from Produce for Threshold Effects/Reference Dose)

Chemical	Toxicity Data Non-Threshold Slope Factor (mg/kg-day)^{1}	Threshold ADI, TDI or RfD (mg/kg/day)	Concentration in Fruit and Vegetables (mg/kg)	Daily Intake from Produce - Threshold Effects (mg/kg/day)	Hazard Quotient (unitless)
TOTAL (NonThreshold Risk and Hazard Index) for all chemicals					**2.3E-1**
Hexachlorobutadine (HCBD)		8.0E-05	4.24E-03	1.8E-05	2.2E-1
Mercury		4.6E-05			
Dioxin (TEF)		1.1E-09	1.52E-09	6.3E-12	6.0E-3

Consent to Discharge Industrial Trade Wastewater

RISK INDEX: 03

CONSENT NO: 489

CONNECTION NO: 2

PROPERTY NUMBER: 4004456

SYDNEY WATER CORPORATION

and

HUNTSMAN CORPORATION AUSTRALIA PTY LTD
A.C.N. 083 984 187
and
ORICA AUSTRALIA PTY LTD
A.C.N. 004 117 828
and
QENOS PTY LTD
A.C.N. 054 196 771
ACTIVITY: ORGANIC LIQUIDS (DC01)

This **CONSENT** is made on the 14 day of 10 2009
Executed for and on behalf of
Sydney Water Corporation

By

(signature)
Wes Douglass
Manager, Commercial and Industrial Customer Services

In presence of:
Witness

(Signature)

Ruth Fryer
(Print name of witness)

A) HUNTSMAN CORPORATION AUSTRALIA PTY LTD
B) ORICA AUSTRALIA PTY LTD
C) QENOS PTY LTD

A) E. Morritt
(Print name of signatory)

(Signature)

B) PERCY BOTHA
(Print name of signatory)

(Signature)

C) P. BEATTIE
(Print name of signatory)

P Beattie
(Signature)

In the presence of:
Witness

(Signature)

BEN LIM
(Print name of witness)

This consent must be executed by the Customer prior to execution by Sydney Water and submitted by the Customer to Sydney Water for its consideration. Submission of a consent executed by the Customer under no circumstances obliges Sydney Water to enter into or complete the consent. Submission of an executed consent by the Customer constitutes an application for a consent which Sydney Water may in its reasonable discretion reject, or with the consent of the Customer modify any of the proposed terms thereto.

SCHEDULE 1

(SUBJECT TO PUBLIC DISCLOSURE)

TRADE WASTEWATER WHICH MAY BE DISCHARGED

1. Trade wastewater substances

(a) The Customer may discharge trade wastewater into the Sewer in a manner whereby the substance characteristics of the trade wastewater are of a type and discharged at a rate, level or concentration equal to or less than that described in this schedule.

(b) The Customer must not discharge trade wastewater into the Sewer in a manner whereby the trade wastewater discharged;

  (i) contains, possesses or produces a substance characteristic not provided in, or which may be determined as being contrary to that described in this schedule.

  (ii) is at or of a rate, level, or concentration not provided in, or which may be determined as being contrary to, that described in this schedule.

SUBSTANCE	**LTADM (kg/day)**	**MDM (kg/day)**	**Standard (mg/L)**
AMMONIA (AS N)	70.00000	200.00000	100.000
BIOCHEMICAL OXYGEN DEMAND	1200.10000	5000.00000	
SUSPENDED SOLIDS	750.00000	1200.00000	600.000
TOTAL DISSOLVED SOLIDS	50000.00000	75000.00000	10000.000
GREASE	80.00000	200.00000	110.000
SULPHATE	2000.00000	3000.00000	2000.000
ACID/ALKALI DEMAND	60.00000	200.00000	
BARIUM	1.50000	3.55000	5.000
VOLATILE HALOCARBONS	1.00000	3.50000	1.000
CHLORINATED PHENOLICS	0.02000	0.05000	0.050
IRON	50.00000	200.00000	50.000
MERCURY	0.03000	0.17000	0.030
PHENOLIC COMPOUNDS	3.34000	7.00000	1.000
SULPHIDE	6.00000	16.00000	5.000
ZINC	2.70000	5.00000	5.000

RECONCILIATION PROCEDURES:

LONG TERM AVERAGE DAILY MASS:

The Long Term Average Daily Mass is a twelve month arithmetic average of ALL daily mass discharges as calculated for each composite sample. The Daily Mass discharged is to be calculated for each of the above substances, and checked against the above Long Term Average Daily Mass (kg/day) on the basis of average concentrations of substances discharged (mg/L) over any 24 hour period as determined from composite samples, obtained by either the Customer (in accordance with Schedule 2) or Sydney Water, or a combination of sample results by both.

This average concentration (mg/L) is to be multiplied by the total discharge (kL) as recorded by the Customer's discharge flow meter over the 24 hour period in order to calculate the Daily Mass of substances discharged (kg). Exceeding the Long Term Average Daily Mass does not constitute a Breach, but may incur a Critical Mass Charge as detailed in Schedule 3.

ACCEPTANCE STANDARD:

The Composite Sample Concentration is to be determined for each of the above substances, and checked against the above Acceptance Standard (mg/L) for each sample obtained. Exceeding the Acceptance Standard constitutes a Breach and will also incur an increased Quality Charge as detailed in Schedule 3.

The Discrete Sample Concentration is to be determined for each of the substances identified at Schedule 2, 2 (b) and checked against the above Acceptance Standard (mg/L) for each sample obtained. Exceeding the Acceptance Standard constitutes a Breach.

MAXIMUM DAILY MASS:

The Daily Mass discharged is to be calculated for each of the above substances, and checked against the above Maximum Daily Mass (kg/day) on the basis of average concentrations of substances discharged (mg/L) over any 24 hour period as determined from composite samples, obtained by either the Customer (in accordance with Schedule 2) or Sydney Water, or a combination of sample results by both.

This average concentration (mg/L) is to be multiplied by the total discharge (kL) as recorded by the Customer's discharge flow meter over the 24hour period in order to calculate the Daily Mass of substances discharged (kg). Exceeding the Maximum Daily Mass constitutes a Breach.

2. The trade wastewater discharged must at all times have the following properties:

Temperature	-	Not to exceed 38 degrees Celsius.
Colour	-	Determined on a system specific basis
pH	-	Within the range 7.0 to 11.0.
Fibrous material	-	None which could cause an obstruction to Sydney Water's sewerage system.
Gross solids (other than faecal)	-	A maximum linear dimension of less than 20 mm, a maximum cross section dimension of 6 mm, and a quiescent settling velocity of less than 3 m/h.
Flammability	-	Where flammable and/or explosive substances may be present, the Customer must demonstrate to the satisfaction of Sydney Water that there is no possibility of explosions or fires occurring in the sewerage system. The flammability of the discharge must never exceed 5% of the Lower Explosive Limit (LEL) at 25° Celsius.

3. Rate of discharge of waste to sewer:

(a) Instantaneous maximum rate of gravitated discharge 225.00 litres per second

(b) Maximum daily discharge 7500.0 kilolitres

(c) Average daily discharge 5500.0 kilolitres

RECONCILIATION PROCEDURE:

The data obtained from applying these procedures is to be checked by the interface of a chart recorder to the Customer's flow metering equipment, or by the installation of flow metering equipment by Sydney Water, for a minimum of 7 days.

SCHEDULE 2

(SUBJECT TO PUBLIC DISCLOSURE)

SAMPLING, ANALYSIS, FLOW RATES AND VOLUME DETERMINATION

1. The Customer must provide and make available for the purpose of sampling and analysis;
   - (a) Sampling point located at outlet of gauging pit, prior to the point of connection to the Sewer.
   - (b) Equipment necessary to allow collection of composite automatic samples on either a flow proportional or a time basis.
2. The Customer is to undertake collection and analysis of samples in accordance with the schedule detailed below:
   - (a) Composite samples are to be obtained:
     - (i) For Acid Demand, Barium, Ammonia, Biochemical Oxygen Demand, Volatile Halocarbons, Mercury, Sulphide, Sulphate, Grease, Suspended Solids,Total Dissolved Solids, Zinc, Iron, Phenolic compounds and Total Chlorinated Phenolics, Composite samples are to be obtained over one full production day on 25 November 2009 and every 8 days hereafter by combining equal volumes taken at 15 minute intervals. The volumes are to be such that at least 3000 millilitres are obtained over the full day. The reading of the flow meter is to be obtained at the commencement and conclusion of the sampling. If trade wastewater is not discharged on this day, then the sample is to be taken on the next day that trade wastewater is discharged.
     - (ii) For HCB composite samples are to be obtained over one full production day on 24 December 2009 and every 32 days thereafter by combining equal volumes taken at 15 minute intervals. The volumes are to be such that at least 3000 millilitres are obtained over the full day. The reading of the flow meter is to be obtained at the commencement and conclusion of the sampling. If trade wastewater is not discharged on this day, then the sample is to be taken on the next day that trade wastewater is discharged.
     - (iii) Discrete samples are to be obtained as detailed below, to check compliance with the parameters specified:

pH details provided from 24 hour data logger

Volatile Halocarbons at the start and at the finish of each 8th sample day

Ammonia at the start and at the finish of each 8th sample day

(b) The customer is to analyse samples according to the procedures and methods specified in Sydney Water's published analytical methods, or methods otherwise agreed to and detailed hereunder, to determine the concentration or levels of the following substances characteristics

ACID DEMAND
AMMONIA
BIOCHEMICAL OXYGEN DEMAND
GREASE
BARIUM
IRON
MERCURY
PHENOLIC COMPOUNDS
SULPHATE
SULPHIDE
SUSPENDED SOLIDS
VOLATILE HALOCARBONS
TOTAL CHLORINATED PHENOLICS
TOTAL DISSOLVED SOLIDS
ZINC

(c) The Customer, or the laboratory contracted by the customer, is to submit results of analyses to Sydney Water within 21 days from the date the sample was taken. All analysis results are to be submitted on the sample analysis report provided as appendices 1 and 2 to this Consent OR in such format as may be specified from time to time by Sydney Water.

(d) All data requested on the sample analysis report must be provided.

(e) Sydney Water must be notified in writing within 7 days of;

  (i) any failure to obtain samples in accordance with the provisions of Schedule 2; or

  (ii) any loss of any analytical data.

  Where data is unavailable, lost or not provided, the Quality Charge and Critical Substance Charge, as detailed in Schedule 3, will be assessed on the basis of the highest Composite Sample concentration recorded in the 12 months prior to the date of the missing sample data.

3. The volume of wastewater discharged must be obtained from the reading of the total flow on the Customer's flowmetering system.

The rate of waste discharged is to be obtained by the reading of the instantaneous flow rate indicator on the Customer's flowmetering system, or from any chart recorder interfaced to the Customer's flowmetering system.

The flowmetering system is to be calibrated at least annually at the Customer's expense, by a person or company approved by Sydney Water and a copy of the calibration certificate supplied to Sydney Water within one month of such certificate being received by the Customer.

If the Customer's flowmetering system fails to record data for any period, Sydney Water is to be advised in writing by the Customer within 7 days of any such failure becoming known by the Customer. An estimate of any data not recorded is to be made as follows:

Average of the waste discharged, registered for the four weeks before and/or after the failure to record.

SCHEDULE 3

(SUBJECT TO PUBLIC DISCLOSURE)

PAYMENTS

The charges are effective from 1 October 2009 and will continue until otherwise advised by Sydney Water.

All trade waste fees and charges are subject to CPI adjustments from 1 July each year in accordance with Determination No 5, 2005 made by the Independent Pricing and Regulatory Tribunal (IPART).

1. CHARGES FOR TRADE WASTEWATER DISCHARGE

Sydney Water will conduct a reading of the Customer's discharge meter at approximately 90 day intervals. The volume of trade wastewater discharged for the period since the previous reading will be calculated.

Charges are based on the Daily Mass calculated from composite samples and corresponding meter readings for each sampling day in the billing period, and calculated in accord with (c), (d), (e), and (f) below. The charge for each sampling day is then multiplied by a flow weighting factor to give a flow weighted charge. The total charge for each substance for the billing period is equal to the sum of the flow weighted charges for the billing period.

Total Charge = the sum of the flow weighted charges for the billing period

Flow Weighted Charge = (charge for all sample days) x (flow weighting factor) and:

$$\text{Flow Weighting Factor} = \frac{\text{(total volume discharged during billing period)}}{\text{(sum of volumes discharged during all sample days during billing period)}}$$

In this formula volume discharged refers to the volume of trade wastewater discharged.

(a) Mass Discharged:

For each substance, the Mass Discharged is calculated by multiplying the Composite Sample concentration by the Trade Wastewater discharge for that sample day.

(b) Chargeable Trade waste Mass:

(i)For the following substances, the Chargeable Trade waste Mass is equal to the Mass Discharged:

SUBSTANCE
ACID/ALKALI DEMAND
BARIUM
MERCURY
PHENOLIC COMPOUNDS
VOLATILE HALOCARBONS
IRON
TOTAL CHLORINATED PHENOLICS
SULPHIDE
TOTAL DISSOLVED SOLIDS
ZINC

(ii) For the following substances, the Chargeable Trade waste Mass is calculated by subtracting the Equivalent Domestic Mass from the Mass Discharged. The Equivalent Domestic Mass is defined as the Domestic Concentration multiplied by the Trade Wastewater discharge.

SUBSTANCE	DOMESTIC CONCENTRATION mg/L
AMMONIA (AS N)	35.000
BIOCHEMICAL OXYGEN DEMAND	230.000
SUSPENDED SOLIDS	200.000
TOTAL DISSOLVED SOLIDS	450.000
GREASE	50.000
SULPHATE	50.000

If the resulting Chargeable Trade waste Mass is zero or negative, then no Quality or Critical Mass charges will apply for that substance for that sample day.

(ii) Where a Critical Mass Charge applies, the Chargeable Trade waste Mass will be reduced in accord with paragraph (d) (iv), below.

(iii) **Quality Charge:**

(i) For the following substances, the Quality Charge is determined by multiplying the Chargeable Trade waste Mass by the Rate for that substance:

SUBSTANCE	STANDARD MASS CHARGING RATE $ per kg
AMMONIA (AS N)	1.9760
SUSPENDED SOLIDS	0.8450
TOTAL DISSOLVED SOLIDS	0.0057
GREASE	1.1910
BARIUM	13.2470
VOLATILE HALOCARBONS	66.2980
CHLORINATED PHENOLICS	1326.1480
IRON	1.3190
MERCURY	2188.1020
PHENOLIC COMPOUNDS	66.2980
SULPHIDE	13.2470
ZINC	13.2470

(ii) For the following substances, the Quality Charge is determined by multiplying the Chargeable Trade waste Mass by the Rate, where the Rate is a function of the composite sample concentration recorded for that sample day:

SUBSTANCE	STANDARD MASS CHARGING RATE $ per kg
BIOCHEMICAL OXYGEN DEMAND	[[0.11800] + {[0.01755] x (BOD / 600.000)}]
SULPHATE	{[0.13000] x (SO4/2000.000)}

(c) Critical Mass Charge:

(i) Where the customer has been notified that a given substance is Critical or Over Capacity and the Mass Discharged is greater than the 1.5 times the Long Term Average Daily Mass (LTADM) for that substance, then the Chargeable Critical Mass is calculated by subtracting 1.5 times LTADM from the Mass Discharged, except where (ii), below, applies.

(ii) Where the customer has been notified that a given substance is Critical or Over Capacity and the Equivalent Domestic Mass is greater than 1.5 times the LTADM the Chargeable Critical Mass is calculated by subtracting the Equivalent Domestic Mass from the Mass Discharged.

(iii) Where the customer has been notified that a given substance is Critical or Over Capacity and paragraph (i) or (ii) above applies, the Chargeable Trade waste Mass calculated in (b), above, will be reduced by the Chargeable Critical Mass.

(iv) The Critical Mass Charge Rate is a function of the Rate and Mass Discharged and LTADM for that substance:

SUBSTANCE STATUS	CHARGING RATE MULTIPLIER	MASS AFFECTED BY CHARGING RATE MULTIPLIER
Critical	2.00	Mass discharged >1.50 LTADM
Over Capacity	3.00	Mass discharged >1.50 LTADM

(v) The Critical Mass Charge is the product of the Chargeable Critical Mass, the rate for that substance and the charging rate multiplier.

(d) Concentration Breach Charge:

Where the Composite Sample concentration is greater than the Acceptance Standards specified in Schedule 1 (with the exception of sulphate), any charges calculated in (c) or (d) above will be doubled for that sampling day.

(e) Failure to collect required samples:

Where the Customer fails to collect and analyse samples in accord with this consent the above charges will be assessed on the basis of the highest composite concentrations recorded for any billing period within the previous 12 months and the average daily discharge for the current billing period.

2. CHARGES FOR INSPECTIONS

(a) If, in the opinion of Sydney Water, it is necessary for a Customer Service Representative to exercise rights under clause 6.1, the Customer will incur no liability for payment for any such exercise unless Customer Service Representative has already exercised rights under clause 6.1 on 52 occasions within a period of one year.

(b) If it is necessary, in the opinion of Sydney Water, to carry out more than 52 inspections within a period of one year, the additional inspections will be charged. The rate for additional inspections is $74.85 (not including GST) per hour per Sydney Water employee attending, up to a maximum of two employees, with a minimum charge of $37.65 (not including GST).

(c) Any inspection required following up an alleged breach or a default notice will result in a fee payable even if the number of inspections nominated in paragraph 2 (a) has not been exceeded.

(d) For the purposes of 2 (a) and 2 (b), above, one year is defined as the period from 1 July to 30 June the following year.

3. CHARGES FOR ADMINISTRATION OF TRADEWASTE CONSENT

A consent fee of $5536.67 per quarter is payable from 1 October 2009.

4. CHARGES FOR VARIATION OR RENEWAL OF TRADEWASTE CONSENT

Where a Variation is made to the Consent a fee of $327.25 will be payable. There will be no charge for renewal.

5. CHARGES FOR PROCESSING GREASE TRAP WASTE

Charges for processing grease trap waste under the 'Waste safe' Management System are as follows:
Not applicable

6. PAYMENT OF FEES AND CHARGES

An account will be issued for all fees and charges. Any fees or charges payable by the Customer must be paid by the Customer within 30 days of the receipt by the Customer of the account detailing those fees and charges.

SCHEDULE 4

ADDITIONAL REQUIREMENTS

1. EFFLUENT IMPROVEMENT PROGRAM

(a) Supply a detailed project plan by 30th September 2009 on the locations where automatic samplers will be installed .

(b) Install samplers at the point at which each plant discharges effluent into the common effluent system. The samplers will be used to collect composite samples to concide with the 8th day samples collected at the 14th Avenue discharge point. In the event of the 8th day sampling returning an unusually high concentration for any of the measured analytes, the retained plant samples will be analysed to identify the plant responsible for the discharge in question.

2. WASTE MANAGEMENT PLAN

The existing pre treatment will result in the generation of 100.0 tonne per annum of waste substances in the form of a sludge containing generally solids. The waste substances are, and will continue to be disposed of, in compliance with the requirements of the Department of Conservation and Climate Change.

3. ADDITIONAL SAMPLING FOR GROUND WATER TREATMENT PLANT

The customer must collect a composite sample from the reject stream from the GTP over a full production day every 90 days commencing 27 November 2009 and analyse for Aluminium, Arsenic, Cyanide and Manganese.

SCHEDULE 5

APPARATUS, PLANT AND EQUIPMENT

EXISTING: Non GTP Flows:
14th Avenue Diversion

Mercury
chlorine Plant Interceptor Pits
Chlorine Plant effluent diversion tanks
Chlorine Plant effluent equalisation tanks

Suspended Solids
8th Avenue grit pits
Alkathene effluent interceptor pit
Alkatuff effluent interceptor pit
Alkathene API separator
Alkatuff CPI separator
Coal Ash vibrating screen

pH and Acid Demand
pH adjustment at 8th Avenue Effluent Treatment Plant
Demineralisation Plants effluent neutralisation system

Grease
Alkathene effluent interceptor pit
Alkatuff effluent interceptor pit
Alkathene API separator
Alkatuff CPI separator
Surfactants weir pit

Volatile Halocarbons
14th_Avenue Effluent Diversion Basin
Groundwater Treatment Plant, with discrete pipeline discharge to the 14th Avenue gauging pit

On line Monitoring Equipment

Polluntant	Analysis Technique
Acid Demand	Titration to pH with HCL
Sulphate	Spectrophotometric, barium precipitation
Ammonia	Spectrophotometric, salicylate chemistry
Mercury	Cold vapour AFS, acid bromate/bromide scattering
Suspended Solids	Turbidometric, optical absorbtion/ scattering
Chlorinated Hydrocarbons	Headspace GC/FID
TOD	TOD Catalysed thermal oxidation
pH	pH electrode

Operation of on line analysers for non – GTP effluent for day to day management of non GTP effluent including the diversion basin.

Ground Water Treatment Plant On Line Monitoring
Monitoring of flow rate, volume, pH, conductivity, and temperature.

Wet Weather Flows
Signal from Sydney Water's Hale Street Gauging Station 802001 to manage flow during rain events.

Flow Diversion
The diversion of effluent for high TOD, low Ph or high pH is now fully automated.

PROPOSED: N/A

SCHEDULE 6

SPECIAL CONDITIONS

1. DANGEROUS DISCHARGES

In this Schedule, the term "may pose a danger to the environment, the Sewer or workers at a sewage treatment plant";

(a) means an occurrence whereby matter is discharged to the Sewer which either alone or in conjunction with other matter discharged cannot be adequately treated or may cause corrosion or a blockage, explosion or the production of dangerous gases in the Sewer or may adversely affect the operation of a sewer or sewage treatment plant; and

(b) includes, but not so as to restrict the generality of paragraph (a), matter or substances, which is or are

- (i) toxic or corrosive;
- (ii) petroleum hydrocarbons;
- (iii) heavy metals;
- (iv) volatile solvents;
- (v) phenolic compounds;
- (vi) organic compounds.

2. UNINTENDED DISCHARGES

(a) For purposes of avoiding unintended discharges to the Sewer or the stormwater drainage system, all matter and substances on the Premises must be processed, handled, moved and stored in a proper and efficient manner.

(b) Any substance on the Premises which, if discharged to the Sewer, may pose a danger to the environment, the Sewer or workers at a sewage treatment plant or may harm any sewage treatment process must be handled, moved and stored in areas where leaks, spillages or overflows cannot drain by gravity or by automated or other mechanical means to the Sewer or the stormwater drainage system.

3. NOTIFICATION

In the event of a discharge of matter to the sewer that poses or may pose a danger to the environment, the Sewer or workers at a sewage treatment plant the Customer must immediately notify:

(a) MALABAR STP CONTROL ROOM TEL: (02) 9931 8319 FAX: (02) 9931 8366

(b) SITE UTILITIES CONTROL ROOM TEL: (02) 8336 1400 FAX: (02) 8336 1394

(c) COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES
ROCKDALE OFFICE: TEL: (02) 9551 4620 FAX: (02) 9551 4388

COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES EMERGENCY CONTACT
SOUTHERN CATCHMENTS TEL: 0419 277 289

COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES EMERGENCY CONTACT
ALTERNATE CONTACT TEL: 0418 221 516

4. PROVISION OF SAFE ACCESS

The Customer shall provide safe access to Sydney Water employees visiting the site. In the event that unsafe conditions are identified the Customer must take reasonable steps to correct unsafe conditions and create safe access.

5. CALIBRATION AND MAINTENANCE SCHEDULES

The customer must calibrate, validate and maintain on-line analysers for the pollutants listed in Schedule 2 (a) (i) according to the manufacturers instructions and criteria agreed with Sydney Water from time to time. The customer must provide on a quarterly basis commencing 30 November 2009, internal calibration, validation and maintenance records in a format as agreed with Sydney Water.

6. ELECTRONIC REPORTING OF SAMPLE ANALYSIS RESULTS

Sydney Water reserves the right to vary this consent to specify the option of reporting by electronic mail as outlined in Schedule 2, 2 (d).

7. MAINTENANCE SHUTDOWNS

It is acknowledged that periodic maintenance activities must occasionally be conducted in all plants. In some cases, these activities will include effluent treatment devices with the result that standards achieved with all Plants operational may not be attainable for the duration of the maintenance.

Provided that Botany Industrial Park Pty Ltd provides Sydney Water with at least one calendar month notice of a planned maintenance shut down, the parties may negotiate for an increased concentration of pollutants to be discharged to sewer for the duration of the shutdown.

These higher limits shall take into consideration the operational requirements of Sydney Water with respect to, inter alia, the concentration and mass of the substances present in the discharge and the times of discharge.

8. METHODS OF ANALYSIS

Where the customer, or the Customer's laboratory, cannot employ the specified analytical method for a Particular substances, the Customer must notify and seek permission from Sydney Water with respect to the use of an alternate method

9. GENERAL CONDITIONS CLAUSE 11.3

Clause 11.3 on the attached printed folder to this agreement is to be replaced with the following clause 'The Customer must comply with any notice under clause 11.1 or 11.2 subject only to any delay that may be required to safeguard the health and safety of any person or impact on the environment'.

1. **Premises for which Consent is granted**

16-20 BEAUCHAMP RD, MATRAVILLE NSW 2036

Huntsman Plant:
Surfactants

Orica Plants:
Chlorine
Groundwater Treatment Plant Air Stripping of contaminated ground water (EDC)
Steam Stripping of contaminated ground water (EDC)
Former Solvents Plant area (disused, but still retaining active effluent treatment facilities for the removal of HCB from the internal drainage of the HCB storage facility).

Qenos Plants:
Alkathene
Alkatuff
Olefines (Feed Preparation Cooling Tower blowdown only)
Site Utilities

2. **Industrial or other commercial activities for which Consent granted**
Chemical Plant
Groundwater treatment Plant

3. **Discharge point for which Consent granted**
Northern site of SWOOS1 at 14th Avenue

4. **The date for purposes of clause 3.1 is 1 October 2009**

5. **The period for purposes of clause 3.2 is 12 months**

SCHEDULE 8

NOTICES AND COMMUNICATION ADDRESSES

SYDNEY WATER:
CUSTOMER SERVICE REPRESENTATIVE
COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES
77 CHAPEL STREET
ROCKDALE NSW 2216

TEL: (02) 9551 4620
FAX: (02) 9551 4388
A.H: 132 092

CUSTOMER:
DR RICHARD BENSON
SITE OPERATIONS MANAGER
BOTANY INDUSTRIAL PARK
16-20 BEAUCHAMP ROAD
MATRAVILLE NSW 2036

TEL: (02) 83361357
FAX: (02) 83361385

SCHEDULE 9

AUTHORISED OFFICERS

SYDNEY WATER:
MANAGER
COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES
77 CHAPEL STREET
ROCKDALE NSW 2216

TEL: (02) 9350 6274
FAX: (02) 9350 6262
A.H: 132 092

Postal Address:
77 CHAPEL STREET,
ROCKDALE NSW 2216

Email:
Wes.douglass@sydneywater.com.au

CUSTOMER:
BEN LIM
SITE ENVIRONMENT ENGINEER
BOTANY INDUSTRIAL PARK
16-20 BEAUCHAMP ROAD
MATRAVILLE NSW 2036

Email: ben.lim@orica.com

TEL: (02) 93522344
FAX: (02) 93522371

SCHEDULE 10

NOMINATED REPRESENTATIVES

SYDNEY WATER:
BUSINESS MANAGER - SALES & SERVICE
COMMERCIAL AND INDUSTRIAL CUSTOMER SERVICES
77 CHAPEL STREET
ROCKDALE NSW 2216

TEL: (02) 9551 4620
FAX: (02) 9551 4388

CUSTOMER:
DR RICHARD BENSON
OLEFINES ENVIRONMENT ADVISER
QENOS PTY LTD
16-20 BEAUCHAMP RD
MATRAVILLE NSW 2036

TEL: (02) 83361357
FAX: (02) 83361385

APPENDIX 1
SAMPLE ANALYSIS REPORT (COMPOSITE) DISCHARGE METER

Consent Number: 489
Company Name: HUNTSMAN ORICA QENOS PTY LTD
Company Address: 16-20 BEAUCHAMP RD, MATRAVILLE NSW 2036

Sample Type:
☐ 6 (composite, manual time based)
☐ 7 (composite, manual flow proportional)
☐ 8 (composite, automatic time based)
☐ 9 (composite, automatic flow proportional)

Start date: ___/___/___
Finish date: ___/___/___
Start time: ____:____ am/pm
Finish time: ____:____ am/pm

grabs taken in sample period: ________
sample intervals min/kL ________
mL per grab: ________

Initial meter reading: __________kL
Final Meter reading: __________kL
Volume discharged: __________kL

Laboratory:

	Acceptance std	**Measured units**
Substance	Acceptance std **(mg/L)**	**Measured conc.(mg/L)**
AMMONIA (AS N)	100.000	
BIOCHEMICAL OXYGEN DEMAND		
SUSPENDED SOLIDS	600.000	
TOTAL DISSOLVED SOLIDS	10000.000	
GREASE	110.000	
SULPHATE	2000.000	
ACID/ALKALI DEMAND		
BARIUM	5.000	
VOLATILE HALOCARBONS	1.000	
CHLORINATED PHENOLICS	0.050	
IRON	50.000	
MERCURY	0.030	
PHENOLIC COMPOUNDS	1.000	
SULPHIDE	5.000	
ZINC	5.000	

COPY OF ORIGINAL ANALYTICAL LABORATORY REPORT TO BE ATTACHED
NOTE: LABORATORY REPORT MUST CERTIFY NATA REGISTRATION FOR EACH ANALYSIS

Comments: ______________________________________

Customer Signature: ____________________ Date: ___/___/___

Designation: ____________________

OFFICE USE ONLY

TERRITORY: 59

Sample No: ☐☐☐☐☐

PLEASE RETURN TO:
Commercial and Industrial Customer Services
77 Chapel Street
ROCKDALE NSW 2216
DX: 2571W
Fax: (02) 9551 4388

APPENDIX 2
SAMPLE ANALYSIS REPORT (DISCRETE SAMPLE)

Consent Number:	489
Company Name:	HUNTSMAN ORICA QENOS PTY LTD
Company Address:	16-20 BEAUCHAMP RD, MATRAVILLE NSW 2036

Sample Type: DISCRETE
Date
Time

Laboratory:

Substance	Acceptance Std (units or mg/L)	Measured units or conc.
pH at start	6 - 11	
pH at finish	6 - 11	
Ammonia (as N)	100.000	
Volatile Halocarbons	1.000	

COPY OF ORIGINAL ANALYTICAL LABORATORY REPORT TO BE ATTACHED
NOTE: LABORATORY REPORT MUST CERTIFY NATA REGISTRATION FOR EACH ANALYSIS
Comments: ____

Customer Signature: ______________________ Date: ___/___/___
Designation: ______________________________

OFFICE USE ONLY
TERRITORY: 59

Sample No: | | | | | |

PLEASE RETURN TO :
Commercial and Industrial Customer Services
77 Chapel Street
ROCKDALE NSW 2216
DX: 2571W
Fax: (02) 9551 4388

Notice of Clean Up Action

Section 91 Protection of the Environment Operations Act 1997

ORICA AUSTRALIA PTY LTD,
ABN 99 004 117 828,
16-20 BEAUCHAMP ROAD,
MATRAVILLE NSW 2036
STANDARD POST

Attention: Mr. Bruce E GOTTING

Notice Number	1030236
File Number	HO1706/03
Date	26-Sep-2003

NOTICE OF CLEAN-UP ACTION

DEFINITIONS

In this notice:

"the Act" means the *Protection of the Environment Operations Act 1997*;

"*contaminant*" means one or more of the substances as defined in this notice;

"*contaminant containment*" means measures taken that result in the prevention, or reduction to the extent practicable, of the transport of contaminants in groundwater;

"*contaminant plumes*" means contaminated groundwater plumes as described by Figures 2.4 to 2.17 inclusive in the *Orica 2002 Annual Report to the EPA*;

"*defined area*" means the area described as Groundwater Protection Zone 1 on the *Botany Basin Groundwater Management Map [Edition 4]* published by the Department of Infrastructure, Planning and Natural Resources ("DIPNR"), dated August 2003;

"*DNAPL*" means dense non-aqueous phase liquids;

"*hydraulic containment*" means measures taken to lower the potentiometric surface and/or water table and effect hydraulic capture of a contaminant plume;

"Orica 2002 Annual Report to the EPA" means the document *Orica Botany Groundwater Remediation Project Annual Report to the NSW Environment Protection Authority, Document No: EN1591-PPR-10-003*, dated 28 February 2003, and prepared by Orica Engineering Pty Ltd;

"*practicable*" means reasonably practicable having regard, amongst other things, to local conditions and circumstances, and to the current state of technical knowledge;

"*Orica premises*" means the premises described as Botany Industrial Park, including Lots 2, 4 and 8 of DP1016112 and located at 16-20 Beauchamp Road, Matraville, NSW.

"*Orica Southlands premises*" means the Orica-owned vacant land as at the date of this notice, on either side of Nant Street, Banksmeadow and with its southern boundary on McPherson Street, Banksmeadow, being Lot 2 of DP 528680, Lot 1 of DP 85542 and Lot 11 of DP 109505;

"primary containment area" means Lot 2 of DP 528680, being the area known as Block 2 of the Orica Southlands premises;

"secondary containment area" means the location where the EPA approved contaminant containment works upgradient of Botany Bay and Penrhyn Estuary, for the interception and containment of contaminant plumes that have migrated or may migrate beyond the primary containment area, are carried out;

"*substances*" means the following chemical compounds:

Volatile Chlorinated Hydrocarbons	Semi-volatile Chlorinated Hydrocarbons
Chlorinated Methanes:	
Carbon Tetrachloride (CTC)	1,2-Dichlorobenzene
Methylene Chloride	1,3-Dichlorobenzene
Chloroform	1,4-Dichlorobenzene
Chloromethane	1,2,4-Trichlorobenzene
Chlorinated Ethanes:	1,3,5-Trichlorobenzene
1,1,1,2-Tetrachloroethane	1,2,4,5-Tetrachlorobenzene
1,1,1-Trichloroethane	Pentachlorobenzene
1,1,2-Trichloroethane	Hexachlorobenzene
1,1,2,2-Tetrachloroethane (PCA)	Hexachlorobutadiene
1,2-Dichloroethane (EDC)	Hexachlorocyclopentadiene
Chloroethane	Hexachloroethane
Chlorinated Ethenes:	Hexachloropropylene
cis-1,2-Dichloroethene	
Tetrachloroethene (PCE)	
trans-1,2-Dichloroethene	
Trichloroethene (TCE)	
Vinyl Chloride (VC)	

"*voluntary agreement*" means the voluntary investigation and remediation agreement number 19014/26030 #3048 with Orica Australia Pty Ltd under sections 19 and 26 of the *Contaminated Land Management Act 1997*, dated 21 May 2002.

BACKGROUND

A. The Environment Protection Authority ("the EPA") is the appropriate regulatory authority under the Act for the Orica premises and all activities carried on at those premises.

B. The EPA is the appropriate regulatory authority because the Orica premises are subject to a licence under the Act to carry on scheduled activities relating to chemical processing.

C. Orica Australia Pty Ltd (ACN 004 117 828) ("Orica") is the occupier of part of the Orica premises and of the Orica Southlands premises, and is the holder of environment protection licence number 2148. Section 258(2) of the Act effectively provides that the holder of a licence under the Act is taken to be the occupier of those premises. Orica has advised the EPA that it has accepted responsibility, via contracts of sale to other occupiers of the Orica premises, for groundwater contamination by the substances listed in this notice.

D. The EPA reasonably suspects that a series of pollution incidents has occurred and is occurring at the Orica premises and also beyond the Orica premises, including at the Orica Southlands premises. The pollution incidents consist of leaks, spills or other escapes of substances at and from the premises and the continuing pollution of the groundwater by the substances. The EPA reasonably suspects that the location of the leaks, spills or other escapes of the substances to include the following sources on the Orica premises:

- The former Solvent Plant
- The former EDC storage tanks
- The former TCE Plant
- The former CTC/PCE storage tanks
- The former Open Heavy Ends Drums Storage Area
- The former Effluent Treatment Plant overflow area
- The former re-drumming areas adjacent to the Heavy Ends Drums Storage Area

E. The EPA has a voluntary agreement with Orica in relation to contamination of soil and groundwater (including plumes extending beyond the Orica premises) by the substances resulting from pollution at the Orica premises. The work under the most recent agreement (Stage 4) is due to be completed by 31 December 2004.

F. The EPA expects the remediation and investigation actions currently underway or planned for Stage 4 of the voluntary agreement to continue, but issues this notice -

(a) to ensure additional measures are taken for the more immediate containment of the contaminant plumes prior to the implementation of the treatment measure required by this notice and under the voluntary agreement; and

(b) in the light of the results of the more recent monitoring data, to set revised targets for the reduction in the concentrations of the substances in the contaminant plumes.

DIRECTION TO TAKE CLEAN-UP ACTION

1. This notice is issued under section 91 of the Protection of the Environment Operations Act 1997.
2. It is an offence against the Act not to comply with a clean-up notice unless you have a reasonable excuse.

Preparation of groundwater clean-up plan

3. The Environment Protection Authority directs ORICA AUSTRALIA PTY LTD to take the following clean-up action -

A. By 30 September 2003 commence preparation of a groundwater clean-up plan as specified in this notice for the containment and remediation of the substances in the contaminant plumes.

B. By 31 October 2003 prepare and submit the groundwater clean-up plan in writing to the Contaminated Sites Section of the EPA for its consideration and approval. The EPA may require changes to the plan before giving or as part of its approval. The groundwater clean-up plan must include works and strategies to ensure the following matters are carried out within the timeframes specified in condition 4 of this notice –

(a) Contaminant containment within the primary containment area so as to prevent or minimise the further migration of the substances from that area. This must include hydraulic containment;

(b) The identification of the locations of the DNAPL sources of the substances in the subsurface at the Orica premises and the Orica Southlands premises, and removal of such sources to the maximum extent practicable;

(c) The reduction of the concentration of the substances in the groundwater at the primary containment area to the maximum extent practicable. This must include the use of *ex situ* treatment technology;

(d) The preparation of appropriate plans to establish a secondary containment area to intercept and contain any parts of the contaminant plumes that have migrated or may migrate beyond the primary containment area;

(e) The implementation of a comprehensive monitoring program within the defined area to:

  i. monitor changes in concentrations of the substances in the contaminant plumes; and

  ii. monitor changes in the spatial distribution of contaminant plumes in the subsurface; and

  iii. gauge groundwater levels to assess the effectiveness of the hydraulic containment; and

  iv. monitor contaminant concentrations in groundwater and surface water discharges to Botany Bay and Penrhyn Estuary for comparison against the *Australian and New Zealand Guidelines for Marine and Fresh Water (2000)* trigger values for protection for slightly to moderately disturbed ecosystems.

Implementation of groundwater clean-up plan

4. The EPA further directs ORICA AUSTRALIA PTY LTD to take the following clean-up action:

A. Within 14 days of the EPA giving its written approval of the groundwater clean-up plan, commence work on the implementation of the approved plan and at all times ensure the implementation of the plan in accordance with the EPA’s approval;

B. Commence works for contaminant containment in the primary containment area, including hydraulic containment on the southern boundary of that area, within 14 days of obtaining all necessary planning and other statutory approvals, and complete such work within 90 days;

C. Complete the identification of the locations of the DNAPL sources of the substances on the Orica premises and Orica Southlands premises by 31 May 2004;

D. Complete contaminant containment of identified DNAPL sources of the substances on the Orica premises and Orica Southlands premises by 30 November 2004, and remove such sources to the maximum extent practicable by 31 October 2005;

E. Reduce the concentration of the substances in the contaminant plumes within the primary containment area to the maximum extent practicable using *ex situ* treatment by 31 October 2005, with a target of an 80 per cent reduction on the levels set out in the Orica 2002 Annual Report to the EPA;

F. Install all works necessary to establish a secondary containment area for the interception and containment of any parts of the contaminant plumes that have migrated or may migrate beyond the primary containment area by 31 October 2004.

G. Implement the monitoring program referred to in condition 3.B.(e) of this notice, and provide the results of such ongoing monitoring to the EPA at least every 90 days from the date of its giving written approval for the groundwater clean-up plan.

General requirements

5. Without limiting what is required by any other condition of this notice, measures implemented under this notice must ensure that any discharge of the substances whether through groundwater or surface water flows into Botany Bay and Penrhyn Estuary achieve protection for slightly to moderately disturbed ecosystems using the *Australian and New Zealand Guidelines for Marine and Fresh Water (2000).*
6. Any emissions to the environment from works and measures required by this notice must be strictly controlled through the adoption of best practice, including the adoption of specific measures to minimise air emissions. All works and operations must be carried out in a controlled and competent manner at all times.
7. If any works or monitoring is required to be carried out on premises other than those occupied by Orica or its related companies, Orica must make reasonable attempts to obtain the consent of the occupier for such works or monitoring to be carried out on those premises. If consent is refused, the EPA must be notified in writing within 7 days of that refusal being given and be provided with details of the attempts made to obtain consent.

Relationship between this notice and the voluntary agreement

8. The works and measures in the voluntary agreement must be carried out in a way that does not compromise the efficacy of the measures required by this notice. The EPA acknowledges that changes to the voluntary agreement may be needed to take account of actions required under this notice. In particular the location of the iron reactive barrier and bioremediation trial may need to be reconsidered as part of these changes.

FEE TO BE PAID

9. You are required by law to pay a fee of $320 for the administrative costs of issuing this notice.
10. It is an offence not to pay this fee. However you can apply for an extension of time to pay the fee or for the fee to be waived. At the end of this notice there is information about how and when to pay the fee and how to apply for an extension or a waiver of the fee.

....

Ms Carolyn Strange

Director

Contaminated Sites

(By Delegation)

INFORMATION ABOUT THIS NOTICE

- Details provided in this notice will be available on the EPA's Public Register in accordance with section 308 of the Protection of the Environment Operations Act 1997.
- The maximum penalty for a corporation is $250,000 and a further $120,000 for each day the offence continues. The maximum penalty for an individual is $120,000 and a further $60,000 for each day the offence continues.
- If you comply with this clean-up notice but you are not the person who caused the pollution incident to which the notice relates, you have a right to go to court to recover your costs of complying with the notice from the person who caused the incident.
- The fee must be paid by **no later than 30 days after the date of this notice**.
- Any application should be made in writing to the Environment Protection Authority and sent to PO Box A290, Sydney South, NSW, 1232. The application should set out clearly why you think your application should be granted.
- The Protection of the Environment Operations Act allows the Environment Protection Authority to recover from you reasonable costs and expenses it incurs in monitoring action taken under this notice, ensuring the notice is complied with and associated matters. (If you are going to be required to pay these costs and expenses you will later be sent a separate notice called a "Notice Requiring Payment of Reasonable Costs and Expenses").

BOTANY GROUNDWATER CLEANUP PROJECT

Joint Determining Authority Report
Under Section 112
of the Environmental Planning and Assessment Act 1979

Department of Environment and Conservation
Department of Infrastructure, Planning and Natural Resources
NSW Maritime
Sydney Water Corporation
Sydney Ports Corporation

Published by:
Department of Environment and Conservation (NSW)
59–61 Goulburn Street, Sydney
PO Box A290
Sydney South NSW 1232

Phone: (02) 9995 5000 (main switchboard)
Phone: 131 555 (NSW only—information and publication requests)
Sydney Air Pollution Index: 1300 130 520
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DEC 2005/13
February 2005
ISBN 1 7413 7112 0

The EPA is a statutory body with specific powers under environment protection legislation. In September 2003, the EPA became part of the Department of Environment and Conservation (NSW).

DETERMINATION

Environmental Planning and Assessment Act 1979

DECISION OF THE DEPARTMENT OF ENVIRONMENT AND CONSERVATION, DEPARTMENT OF INFRASTRUCTURE, PLANNING and NATURAL RESOURCES, NSW MARITIME, SYDNEY PORTS CORPORATION AND SYDNEY WATER CORPORATION FOR THE BOTANY GROUNDWATER CLEANUP PROJECT

In assessing the proposal for the Botany Groundwater Cleanup project in accordance with Part 5 of the *Environmental Planning and Assessment* (EP&A) *Act 1979* and the EP&A Regulation 2000, the Department of Environment and Conservation, Department of Infrastructure Planning and Natural Resources, NSW Maritime, Sydney Ports Corporation and Sydney Water Corporation have examined and taken into account to the fullest possible extent all matters affecting or likely to affect the environment as a result of the proposal.

In preparation of the determination report under clause 243 of the EP&A Regulation the determining authorities have examined and considered:

a) the Environmental Impact Statement (EIS) for the Botany Groundwater Cleanup project dated November 2004

b) the representations made in relation to the proposed works described in the EIS

c) representations reports prepared by Orica Pty Ltd dated 24 December 2004 and 5 January 2005

d) a letter from Orica to DEC dated 17 December 2004 seeking clarification on additional information in relation to aspects of the EIS

e) a report prepared by Orica Pty Ltd entitled, *Botany Groundwater Cleanup project, A description and assessment of proposed modifications to reduce the detrimental effect on the environment*, dated 27 January 2005

f) a flow chart submitted by Orica to DEC in a facsimile dated 07/02/05 entitled *"Orica Botany GTP Schematic Incorporating Improvements – Draft for Discussion 07/02/05"*

g) the objects and requirements of various statutes including:

    a. *Environmental Planning and Assessment Act 1979*

    b. *Protection of the Environment Operations Act 1997*

    c. *Contaminated Land Management Act 1997*

    d. *Water Act 1912*

    e. *Water Management Act 2000*

    f. *National Parks and Wildlife Act 1974*

    g. *Threatened Species Conservation Act 1995*

    h. *Rivers and Foreshores Improvement Act 1948*

    i. *Sydney Water Act 1994*

    j. Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

h) the EPA Notice of Clean Up Action issued by DEC;

i) an independent review of the project by the United States Environmental Protection Agency dated 20 January 2004

j) an independent review of air emissions, air quality and plant performance capability by John Court & Associates Pty Ltd dated 29 January 2005

k) a letter dated 17 January from Orica to DEC setting out comments on further questions raised by the Department of Environment and Heritage (Commonwealth) on alternate treatment technologies and compliance with the Stockholm Convention on Persistent Organic Pollutants.

l) letters from Department of Environment and Heritage (Commonwealth) to DEC dated 20 December and 2 February 2005 on alternate treatment technologies and compliance with the Stockholm Convention on Persistent Organic Pollutants.

m) the Healthy Rivers Commission *Independent Inquiry into the Georges River–Botany Bay System* and associated *Statement of Joint Intent*

n) the NSW State Groundwater Policy

o) the effect of the proposed activity on the environment

p) the cumulative effect on the environment of the proposed activity with other existing and likely future activities

q) other matters referred to in the determination report.

Following consideration of the above, the Department of Environment and Conservation, NSW Maritime, Sydney Ports Corporation, Sydney Water Corporation and Department of Infrastructure, Planning and Natural Resources have each decided to approve the activity subject to the conditions attached in Appendix B. The reasons for the conditions are to:

- ensure that adequate safeguards are in place to protect the environment and human health
- mitigate the potential environmental impacts of the activity
- ensure compliance with relevant statutes and statutory instruments
- restore the quality of groundwater in and around Botany Industrial Park.

Department of Environment and Conservation

NSW Maritime

Department of Infrastructure, Planning and Natural Resources

Sydney Water Corporation

Sydney Ports Corporation

EXECUTIVE SUMMARY

As a result of historical manufacturing activities at Botany Industrial Park (the former ICI site) there is a legacy of groundwater contamination that must be addressed to ensure adverse impacts to the environment and human health do not occur.

Extensive environmental investigations and groundwater monitoring undertaken by Orica since the 1980s have revealed an extensive and complex distribution of contaminated groundwater in and around Botany Industrial Park. The principal contaminants are volatile chlorinated hydrocarbons, in particular 1,2 dichloroethane (EDC) as well as carbon tetrachloride (CTC), tetrachloroethene (PCE) and trichloroethene (TCE). The groundwater does not contain dioxins or dioxin-related substances. These source areas have led to the creation of multiple overlapping plumes moving generally in a south-west direction towards Penrhyn Estuary and Botany Bay.

On 24 September 2003 the EPA became part of the Department of Environment and Conservation (DEC). However, certain statutory functions and powers, including those in the *Protection of the Environment Operations Act 1997*, continue to be exercised in the name of the EPA.

DEC (and formerly the EPA) has regulated the groundwater remediation in and around Botany Industrial Park for many years. The focus of this work has been on stopping further contamination, fixing up surface drainage, soil remediation works and investigation of groundwater contamination.

In February 2000 the EPA agreed to a Voluntary Investigation and Remediation proposal from Orica under the *Contaminated Land Management Act 1997* to formalise the existing ongoing monitoring, investigation, remediation assessment and communication activities. DEC subsequently issued an EPA Notice of Clean Up Action (NCUA) to Orica under section 91 of the *Protection of the Environment Operations Act 1997* on 26 September 2003. This notice sets a strict framework and timescale for action to contain and reduce the levels of contaminants, to the maximum extent practicable by 31 October 2005, to ensure adverse impacts do not occur.

As an initial response to the Notice's requirement to effect hydraulic containment of the contaminants, Orica implemented use of a steam stripping unit to process extracted groundwater and recover the contaminants (principally EDC) for subsequent treatment/disposal. Orica has also been exploring the feasibility of off-site treatment methods and trialling in situ methods to reduce groundwater contamination, including active and passive bioremediation and the use of reactive iron barriers. While these actions are reducing the amount of contamination reaching Penrhyn Estuary, they will not affect the areas of highest contamination closer to the Botany Industrial Park, which also need to be remediated.

In order to fulfil the EPA Notice of Clean Up Action requirement to contain the plumes, Orica proposed the Botany Groundwater Cleanup project. The key elements of the project include:

- extraction of groundwater from the wells in three containment lines (up to 15 million litres per day)
- transfer of the groundwater via pipelines to the groundwater treatment plant (GTP)
- construction and operation of the GTP
- Discharge of up to 12 million litres per day of treated water from the plant to Bunnerong Canal, although it is expected that approximately half of this treated water will be reused by industry in the Botany Industrial Park (BIP) (or other identified users) ; and
- installation of a discharge point into Bunnerong Canal.

Orica currently holds an EPA environment protection licence (no. 2148) under the *Protection of the Environment (Operations) Act 1997* for a number of existing activities. DEC determined that because the project contains activities likely to significantly affect the environment, an environmental impact statement was required under Part 5 of the *Environmental Planning and Assessment Act 1979* before DEC could vary the existing EPA licence to permit the activity.

In November 2004, Orica submitted an environmental impact statement, also titled *Botany Groundwater Cleanup Project*. The environmental impact statement prepared by Orica proposed a strategy to contain, collect and reduce contaminants in the groundwater in and around the Botany Industrial Park to meet the requirements of the notice and prevent any adverse impacts to the environmental receptors: Penrhyn Estuary, Botany Bay and human health. Orica considers that the implementation of the project will achieve the above objectives. The capital cost of the project is expected to be approximately $102 million for all elements, including the installation of extraction wells, transfer pipelines and treatment plant.

DEC is one of a number of determining authorities whose approval is required for the project to proceed. Other determining authorities are Department of Infrastructure Planning and Natural Resources, NSW Maritime, Sydney Water Corporation, Sydney Ports Corporation and NSW WorkCover. The Minister for Infrastructure and Planning appointed DEC as the nominated determining authority in relation to the environmental impact statement for the project.

DEC, the Department of Infrastructure, Planning and Natural Resources, NSW Maritime, Sydney Water Corporation and Sydney Ports Corporation have prepared this joint determination report in accordance with the *Environmental Planning and Assessment Act 1979* (in particular clauses 228 and 243) and associated Regulation, which require a determining authority to prepare a report on any activity for which an environmental impact statement has been prepared. The purpose of this report is to review the environmental impact statement, the issues raised in representations made in response to its exhibition, the report from Orica on the representations and any other matters relevant to the potential environmental impacts of the proposal.

A total of 19 representations were received in response to the exhibition of the environmental impact statement. These raised issues and concerns related to air, water, flora and fauna and waste as well as compliance with statutory requirements and international conventions on hazardous chemicals and wastes.

A key component of the project is the construction and operation of a groundwater treatment plant (GTP). The plant will be located on Orica-owned land on the Botany Industrial Park. The GTP is designed for continuous operation, treating up to 15 million litres of groundwater per day, 24 hours a day, seven days a week, with a 95% availability for a period of up to 30 years.

The operation of the proposed GTP involves the following steps. Extracted groundwater is collected and combined into a single stream and fed to the plant and conditioned for pH. Volatile organic compounds are then removed by blowing air through the groundwater, transferring them into the air stream (the off-gas stream). Off-gases then move to a thermal oxidiser unit fuelled by natural gas for a sufficient time to enable the destruction of organic compounds to carbon dioxide, water and hydrogen chloride. The off-gases are then passed through a liquid quench to rapidly cool the gas stream and further cleaned in an absorber and scrubber prior to being discharged to the atmosphere via a single stack.

From the air stripper, the cleaned groundwater is further treated through activated carbon to remove non-volatile organic compounds before being forwarded to either of two ways to remove remaining impurities. Stripped groundwater that is to be beneficially reused in industrial processes (up to 10 million litres per day) is treated by a reverse osmosis unit to remove dissolved solids. The remaining stripped water that does not pass through the reverse osmosis unit (up to 5 million litres per day) will be combined with wastewater from the reverse osmosis unit, commonly known as ‘brine’ (up to 2.5 million litres per day) and further treated in a biological treatment unit to remove contaminants. It is then polished to remove ammonia prior to discharge to the Bunnerong Canal.

Since receiving the representations Orica has considered some minor changes to the project. These include replacement of the biological treatment unit with a second reverse osmosis unit, discharging the excess treated water to a stormwater channel (not directly into Bunnerong Canal) and increasing the groundwater treatment plant stack height from 20 metres to 34 metres. The determination of these modifications are included in this report.

If Orica is not able to extract and provide treatment to groundwater at the rates required (up to 15 million litres per day) to contain the plumes it could result in the waters of Penrhyn Estuary and Botany Bay becoming increasingly polluted from contaminants in this groundwater. The project is required to ensure that adverse impacts do not occur and the environment and human health are protected.

A key environmental issue raised in some public representations related to emissions from the groundwater treatment plant as a result of using thermal oxidation to destroy the contaminants in the air stream. These included concerns over the pollutants believed to be discharged to air, in particular dioxins, and the efficacy of the measures in place to ensure impacts to the environment and public health did not occur.

Objections to the use of the thermal oxidation unit and the need for alternatives were received on the grounds that it was contrary to the Stockholm Convention on Persistent Organic Pollutants (POPs). In assessing the project the determining authorities have taken into account the requirements of the Stockholm Convention, in particular, its release reduction measures. The design of the GTP thermal oxidiser adopts all of the internationally recognised safeguards for dioxin minimisation. These include a high thermal oxidiser operating temperature (1000 degrees C), long off-gas residence time in the thermal oxidiser reaction chamber (2 seconds), and a quench to rapidly reduce the temperature of the treated off-gas. These safeguards have been adopted even though the contaminated groundwater does not contain dioxins and Orica has identified that the factors normally required for dioxin formation are absent from the feed stream to the thermal oxidiser, namely carbon structures and metal catalysts due to the very low level of particulate matter in the gas stream. This is supported by successful and well established use of this technology in Japan and the USA.

DEC has required Orica to design, operate and maintain the GTP to achieve international best practice emission concentration limits for dioxins, furans and other air pollutants, in accordance with conditions attached to its EPA licence. Orica is also required to undertake regular monitoring of air emissions to ensure compliance with these limits and demonstrate efficient combustion conditions leading to maximum destruction of contaminants is maintained at all times. The regular monitoring of air emissions will also ensure that the conditions conducive to dioxin and furan formation are minimised at all times.

DEC is, therefore, satisfied that Orica has addressed the requirements of the Stockholm Convention in the design, installation, operation and maintenance of the groundwater treatment system. Consistent with the convention, this will ensure the formation of POPs is prevented or avoided (particularly dioxins and furans) to the greatest extent possible, meeting applicable international standards and guidelines.

Independent assessments of the project were undertaken by John Court & Associates Pty Ltd and the United States Environmental Protection Agency on behalf of DEC. Both supported the project in terms of the appropriateness of the technology selected. The Department of Environment and Heritage (Commonwealth) has also assessed the project and advised that the proposed technology is consistent with the requirements of the Stockholm Convention.

This determination concludes that Orica’s preferred strategy for the collection and treatment of the contaminated groundwater is consistent with accepted best practice and satisfies best international air emission standards. It also maximises the quantity of extracted water that can be recycled for industrial use significantly reducing the demand on potable supplies.

The project is also consistent with the aims and objectives of the NSW State Groundwater Policy and Healthy Rivers Commission Report for the Georges River–Botany Bay System and associated *Statement of Joint Intent*. Fundamentally, the project will allow Orica to comply with the Notice of Clean Up Action issued by the EPA to stop the contamination impacting on Botany Bay and protect the community.

This joint determination report has been prepared by the determining authorities in relation to each of their relevant instruments of approval. It provides the basis for:

- DEC granting a variation to the existing EPA environment protection licence held by Orica
- a permit from NSW Maritime under the *Rivers and Foreshores Improvement Act 1948* for works associated with the construction of the discharge point at Bunnerong Canal
- a water extraction licence from DIPNR
- a variation to the trade waste permit from Sydney Water Corporation
- permission from Sydney Ports Corporation for discharge to Bunnerong Canal.

For Orica to satisfy the requirements of the above legal notice and allow for construction and commissioning of the necessary works, it is seeking a variation to the EPA Environment Protection licence to allow the project to commence in February 2005.

The report concludes that the environmental impacts associated with the project can be mitigated by conditions on the design, construction, operation and maintenance of the project. Accordingly, DEC, the Department of Infrastructure, Planning and Natural Resources, Sydney Ports Corporation, Sydney Water Corporation and NSW Maritime have decided to grant approvals for the project, subject to the relevant conditions.

CONTENTS

1. Introduction

This section introduces the proposed strategy for remediating groundwater contamination as outlined in the Environmental Impact Statement submitted by Orica Australia Pty Ltd to the determining authorities. This section also outlines the key statutory approval requirements, previous regulatory action by the EPA and the assessment process.

On 24 September 2003 the EPA became part of the Department of Environment and Conservation (DEC). However, certain statutory functions and powers, including those in the Protection of the Environment Operations Act 1997*, continue to be exercised in the name of the EPA.*

1.1 Location

The Botany Groundwater Cleanup project incorporates a number of activities on and in the vicinity of Botany Industrial Park. The project area is located on lands largely enclosed within the boundary of the Department of Infrastructure, Planning and Natural Resources (DIPNR) Groundwater Extraction Exclusion Area as shown in Appendix C.

The Botany Industrial Park is located within the Botany/Randwick industrial area to the north-east of Botany Bay, east of Sydney airport and approximately 12 kilometres south of the Sydney Central Business District. Blocks of land owned by Orica, known as Southlands, are located just to the south-west of BIP. The proposed location of the groundwater treatment plant is located within BIP and is owned by Orica.

Land uses in and around the project area largely comprise:

- mixed industrial land uses (including major chemical and food manufacturing sites)
- residential areas of Hillsdale, Matraville, Maroubra, Botany and Eastgardens (including schools and other services) to the north, east and west
- various commercial areas, recreation areas (including parks and golf courses), special uses (including Port Botany to the south) and areas of environmental protection (including Botany Bay and Penrhyn Estuary to the south-west).

The site is located in an area of former sand dunes and coastal swamps within the Botany Basin but has an extensive history of land filling and reclamation. The Botany Sands Aquifer underlies the site.

1.2 Nature of the proposal

Orica submitted an environmental impact statement to DEC entitled *Botany Groundwater Cleanup project*. As a result of historical manufacturing activities at Botany Industrial Park (BIP) (former ICI site) there is a legacy of groundwater contamination in the Botany Sands Aquifer by chlorinated hydrocarbons. The objectives of the project are to meet the requirements of an EPA Notice of Clean Up Action issued by DEC and to stop the movement of contaminated groundwater in and around BIP and collect it for treatment.

The key elements of the project include:

- extraction of groundwater from the wells in three containment lines
- transfer of the groundwater via pipelines to the groundwater treatment plant (GTP)
- construction and operation of the GTP
- transfer of treated water via pipelines for reuse by process plants in the BIP (or other identified users) or discharge to Bunnerong Canal
- installation of a discharge point into Bunnerong Canal.

Orica considers that the implementation of the project will achieve the above objectives and protect the waters of Botany Bay and Penrhyn Estuary. The capital cost of the project is expected to be approximately $102 million for all elements, including the installation of extraction wells, transfer pipelines and treatment plant.

1.3 Background

Extensive environmental investigations and groundwater monitoring undertaken by Orica since the 1980s have revealed an extensive and complex distribution of volatile chlorinated hydrocarbon (CHC) contamination derived from multiple source areas in and around BIP. These source areas are small underground pools of concentrated contaminants referred to as dense non-aqueous phase liquid (DNAPL). As the groundwater flows past these pools it becomes contaminated. The source areas relate to former manufacturing sites and waste disposal areas on parts of the BIP. The principal contaminants are carbon tetrachloride (CTC), tetrachloroethene (PCE), trichloroethene (TCE) and 1,2 dichloroethane (EDC) and a product from the breakdown of these contaminants, vinyl chloride (VC).

These source areas have led to the creation of multiple overlapping plumes moving generally in a south-west direction towards Penrhyn Estuary and Botany Bay:

- The southern plume consists of up to three separate plumes, based on analysis of its composition. The contamination is derived mainly from the former solvents plant and former TCE plant and contamination consists of CTC, PCE and TCE with small amounts of EDC and VC. The front edge of the southern plume has already reached Penrhyn Estuary, resulting in low contaminants concentrations discharging to the estuary.
- The central plume consists of a single plume made up of predominantly EDC and is believed to have originated from the former vinyls manufacturing plant and EDC storage tanks.
- The northern plumes consist of up to five separate dissolved phase plumes and most of the plumes are thought to have derived from the storage of CHC waste in open-air, unpaved drum storage areas. These plumes contain predominantly CTC, PCE and EDC.

In February 2000 the EPA agreed to a Voluntary Investigation and Remediation proposal from Orica under the *Contaminated Land Management Act 1997* to formalise the existing ongoing monitoring, investigation, remediation assessment and communication activities.

As a result of high concentrations of CHCs found to be present in an off-site production bore, together with concerns regarding the movement of the high-concentration central plume and the potential for discharge of contaminants into Botany Bay, DEC issued a Notice of Clean Up Action (NCUA) under section 91 of the *Protection of the Environment Operations Act 1997* on 26 September 2003. This notice sets a strict framework and timescale for action to stop the movement of the contaminated groundwater and collect it for treatment to ensure adverse impacts to the environment do not occur.

The NCUA required the preparation and implementation of a groundwater clean up plan (GCP). Orica prepared a GCP which detailed activities and actions for containment in the short term and remediation in the longer term to achieve the timeframes defined by the NCUA. DEC issued a variation to the NCUA on 17 February 2004 requiring the implementation of the GCP.

One of the initial short-term measures presented in the GCP for hydraulic containment of the contaminants in the groundwater was the recommissioning of the steam stripping unit (SSU) on the BIP to process extracted groundwater and recover the waste CHC concentrate (principally EDC) for subsequent treatment/disposal. The SSU was recommissioned in October 2004 and this short-term measure is currently being implemented. The recovered waste CHC is transferred to Terminals Pty Ltd’s existing bulk liquid storage facility at Port Botany via the existing primary and secondary pipelines. Once the GTP is commissioned, the SSU will cease operation. The recovered waste EDC liquid will be transferred to the

GTP for treatment and destruction. According to Orica's modelling, this action is reducing the amount of contamination reaching Penrhyn Estuary, however this will not reduce the areas of high contamination closer to the Botany Industrial Park, which also need to be remediated.

The EIS states that if the GTP is not able to extract groundwater at the rates required (up to 15 million litres per day) to contain the plumes and provide treatment of this volume of groundwater, it will result in the waters of Penrhyn Estuary and Botany Bay becoming increasingly polluted from contaminants in this groundwater. It further states that the project is required to ensure that adverse impacts do not occur and the environment and human health is protected.

1.4 Statutory Provisions and assessment process

1.4.1 State Environmental Planning Policy 55 — Remediation of Land

State Environmental Planning Policy 55 (SEPP 55) establishes 'best practice' for managing land contamination through the planning and development control process. The objectives of this policy are primarily implemented by planning authorities, particularly local councils.

Under SEPP 55, planning authorities are required to consider, at the development approval and rezoning stage, the potential for contamination to adversely affect the suitability of a site for its proposed use. If the land is unsuitable for the proposed use, remediation must take place before the land is developed.
The policy allows clean-up of contaminated sites by:

- making remediation permissible across the state
- defining when consent is required
- requiring all remediation to comply with standards
- ensuring land that is going through the development consent process is investigated if contamination is suspected (for example, if the site history suggests potentially contaminating land use has occurred in the past)
- requiring councils be notified of all remediation proposals.

SEPP 55 specifies (under Clause 21(2) (a)) that any development or activity carried out for the purpose of complying with a clean up notice may be carried out without development consent.

1.4.2 Environmental Planning and Assessment Act 1979

The proposed activity is permissible without development consent and subject to environmental impact assessment under Part 5 of the *Environmental Planning and Assessment Act* 1979 (EP&A Act), through the provisions of *State Environmental Planning Policy No. 55 – Remediation of Land* (see below). Orica has identified that the following approvals and determining authorities are relevant to the proposed activity:

- a licence from the Environment Protection Authority under the *Protection of the Environment Operations Act* 1997;
- a licence from the Minister for Natural Resources under the *Water Act 1912* and subsequent *Water Management Act* 2000;
- a permit from the Minister for Primary Industries under the *Fisheries Management Act* 1994;
- a permit from the NSW Maritime under the *Rivers and Foreshores Improvement Act* 1948;
- Trade Waste approval from the Sydney Water Corporation under the *Sydney Water Act* 1994; and
- approval to use land owned by the Sydney Ports Corporation.

On 22 November 2004, the Minister for Infrastructure and Planning issued an Order under section 110A of the EP&A Act making the Environment Protection Authority the nominated determining authority for the proposed activity. Notice of this Order was published in the *Sydney Morning Herald* on Friday 3 December 2004.

DEC, through the authority of the EPA and in consultation with the other determining authorities for the proposed activity, formed the view that the activity is likely to significantly affect the environment. As a consequence, an EIS was required for the activity, in accordance with section 112(1) of the EP&A Act. The delegate for the Director General of the Department of Infrastructure, Planning and Natural Resources (DIPNR) issued requirements for the preparation of the EIS on 23 July 2004, and updated those requirements on 1 November 2004. The EIS requirements were prepared in consultation with the determining authorities for the activity, relevant government agencies and the City of Botany Bay Council. DIPNR has reviewed the EIS and considers that it has been prepared substantially in accordance with the Director General's requirements.

In accordance with section 113 of the EP&A Act, the DEC as nominated determining authority caused the proposed activity and accompanying EIS to be publicly exhibited and notified. The EIS was publicly exhibited from Tuesday 16 November 2004 until Friday 17 December 2004 (31 days), with public notifications being made through the *Sydney Morning Herald* and local newspapers. A total of 19 submissions were received in response to the exhibition of the EIS. Issues raised in submissions are considered in more detail in later sections of this report, and were the subject of a Representations Report prepared by Orica.

1.4.3 Contaminated Land Management Act 1997

The EPA has determined that elevated concentrations of contaminants in groundwater in and around BIP are present in such a way as to present a significant risk of harm (SRoH) in accordance with section 9 of the *Contaminated Land Management Act 1997* (CLM Act). Subsequently the EPA agreed to a series of Voluntary Investigation and Remediation proposals from Orica between 2000 and 2004 to address the contamination.

In conjunction with requiring works through the NCUA and environment protection licence, the EPA proposes to declare approximately 200 hectares of land affected by the contamination as a remediation site under section 21 of the CLM Act. A declaration serves to 'tag' contamination as presenting a SRoH. A copy of the declaration is included in the CLM Act public register and its presence noted on planning certificates under the EPA&A Act (s149(2)).

Copies of the proposed declaration have been sent to all affected land owners and other key stakeholders. Once the declaration is made, it will be published in the *NSW Government Gazette* and advertised in the *Sydney Morning Herald* and *Southern Courier* giving all interested parties the opportunity to make submissions to DEC on matters concerning the 'remediation site', including whether or not an order should be issued or a Voluntary Remediation Agreement be entered into.

Only when DEC is satisfied that the SRoH caused by the contamination has been addressed, can the declaration be removed.

1.4.4 Protection of the Environment Operations Act 1997

The project is required as a result of a Notice of Clean Up Action issued by the EPA, under section 91 of the *Protection of the Environment Operations Act 1997*. The key elements of the notice require Orica to;

- prepare a groundwater clean-up plan for approval by the EPA by 31 October 2003
- implement the approved plan
- contain and reduce the levels of contaminants to the maximum extent practicable by 31 October 2005. This must include the use of *ex situ* treatment technology.

Orica Australia Pty Ltd currently holds an EPA environment protection licence (no. 2148) under the Protection of the Environment Operations Act.

Schedule 1 of the Act requires that Orica holds this licence for a number of existing scheduled activities:

- chemical storage facilities
- waste activities
- chemical industries or works
- waste facilities (Hazardous, Industrial, Group A or Group B wastes processing).

It is an offence against Section 120 of the Act if a person carries out an activity which pollutes waters other than in accordance with the conditions of an existing environment protection licence.

The groundwater treatment plant is a key component of the project to meet the requirements of the NCUA. It constitutes a scheduled activity within the meaning of the 'waste facility' category in schedule 1 of the Act. There is no requirement to vary the quantity or types of waste identified for processing in the existing licence. However, the project will require the installation of a new water discharge point into Bunnerong Canal and this will trigger the need for Orica to submit an application to vary the licence to permit the discharge, subject to conditions issued by the EPA.

Section 45 of the Protection of the Environment Operations Act requires the EPA to take a number of relevant issues into consideration when exercising licensing functions. The EPA must consider, among other things, the pollution caused or likely to be caused by the carrying out of the activity concerned, the impact of this pollution on the environment, and any practical measures that could be taken to prevent, control or mitigate this impact.

Other relevant considerations for the EPA are any documents that accompany the application to vary the licence, in this case the environmental impact statement as well as public submissions.

1.4.5 Rivers and Foreshores Improvement Act 1948

A permit under Part 3A of the *Rivers and Foreshores Improvement Act 1948* is required for works in or within 40 metres of a waterway. Orica will be required to obtain a Part 3A permit prior to the commencement of any works associated with the construction of the discharge from the outlet of the Groundwater Treatment Plant to Bunnerong Canal. Since Bunnerong Canal is owned by Sydney Ports Corporation, permission from Sydney Ports Corporation must also be obtained prior to issuing the Part 3A permit. Responsibility for issuing the permit will rest with NSW Maritime.

1.4.6 Sydney Water Act 1994

Orica must comply with the requirements of the *Sydney Water Act 1994*. This includes obtaining a Section 73 Compliance Certificate. In seeking the Compliance Certificate, Orica must supply to Sydney Water all information necessary for Sydney Water to assess the impacts from the proposal on Sydney Water assets and operations. Orica must comply with the requirements of Sydney Water issued as a Notice of Requirements, under Section 74 of the Act, prior to the Completion Certificate being issued. Such requirements may include, for example, relocation of existing sewer lines, payment of developer charges and adjustments to the trade waste agreement.

1.4.7 Water Act 1912 and Water Management Act 2000

The rights to control, manage and use groundwater in NSW is regulated under the *Water Act 1912*, and subsequently the *Water Management Act 2000.* The extraction of groundwater is regulated through a licensing system administered by DIPNR. A licence is required by Orica from DIPNR under Part V (Section 116) of the Water Act to authorise the extraction of groundwater for containment of contamination and groundwater remediation purposes.

The Water Management Act was passed in December 2000 and, apart from the licensing provisions, supersedes the Water Act. The principal objective of the Water Management Act is to provide for the sustainable and integrated management of the state's waters for the benefit of both present and future generations.

The Water Management Act introduces measures that:

1. provide for improved environmental health of the State's waters through equitable sharing provisions, which require water to be provided for the environment as the highest priority. The Act also allows for the regulation of activities that threaten waters and their dependent ecosystems
2. provide for shared government and community responsibility for water management, through the establishment of a comprehensive community-based planning framework
3. provide greater economic benefits for individuals and communities by clarifying and strengthening access rights, establishing water markets and introducing improved compliance tools.

Once a Water Management Plan is developed for the Botany Sand Beds groundwater source (See Section 4), the licensing provisions in the Water Management Act will be activated. This will allow licences currently issued under the Water Act to be made compliant with the provisions of the Water Management Act.

1.5 Preparation and exhibition of the EIS

1.5.1 Director General's requirements

Orica wrote to the Director General of the Department of Infrastructure Planning and Natural Resources seeking advice on requirements for the form and content of an environmental impact statement for the proposal. The Director General's requirements were issued to Orica in a letter dated 23 July 2004. Orica prepared an environmental impact statement for the project which addresses these requirements.

Orica undertook extensive consultation with relevant government agencies and the community during the environmental impact assessment development process. This included planning focus meetings and workshops.

1.5.2 Exhibition of the environmental impact statement

The Minister for Infrastructure and Planning appointed DEC as the nominated determining authority for the project. In accordance with this role, DEC advertised and placed the EIS on exhibition, received public submissions and ensured compliance with other requirements under the environmental planning legislation.

The environmental impact statement was exhibited from 16 November to 17 December 2004 inclusive. The environmental impact statement includes a certificate stating that it was prepared in accordance with clauses 230 and 231 of the Environmental Planning and Assessment Regulation 2000. The company that prepared the environmental impact statement was URS Australia Pty Ltd.

Advertisements identifying public display locations and times were published in the *Sydney Morning Herald* and in local newspapers. The advertisements also indicated that copies of the environmental impact statement were available for purchase and that the EPA would receive submissions up to the close of exhibition.

DEC forwarded copies of all representations to the Department of Infrastructure, Planning and Natural Resources and determining authorities on 22 December 2004.

Orica also provided reports to the determining authorities dated 24 December 2004 and 5 January 2005 addressing the issues raised in the representations from the public exhibition of the EIS. These reports may be obtained from Orica.

1.6 Purpose of the Determining Authority Report

Under the EP&A Act and Regulation, each determining authority must prepare a determination report. The report (under clause 243 of the EP&A Regulation) must give full particulars of the decision on the proposal and, if approval is granted, any conditions imposed.

The purpose of this Determining Authority Report is to consider:

- the environmental impact statement that set out Orica's measures to stop the movement of contaminated groundwater and remove the groundwater for treatment
- the issues raised in representations made in response to the exhibition of the environmental impact statements
- the effects of the proposed activity on the environment
- the proponent's proposals to mitigate any adverse effects of the activity on the environment.

It also provides the determining authorities' determination relating to the activity and any conditions or modifications imposed or required by the authorities in connection with the carrying out of the activity.

This joint determination report has been prepared in accordance with this requirement by the determining authorities relating to each of their relevant instruments of approval. It provides the basis for:

- DEC granting a variation to the existing EPA environment protection licence for the project
- a permit from NSW Maritime under the *Rivers and Foreshores Improvement Act 1948* for works associated with the construction of the discharge point at Bunnerong Canal for the project
- a water extraction licence from DIPNR
- defining and responding to Sydney Water's Section 73 requirements, such as a variation to the trade waste permit; and
- permission from Sydney Ports Corporation for the discharge of treated groundwater to Bunnerong Canal.

It also includes advice from NSW WorkCover, NSW Health and Department of Primary Industries.

For Orica to satisfy the requirements of the above legal notice and allow for construction and commissioning of the necessary works, it is seeking a variation to the EPA Environment Protection licence to allow the project to commence in February 2005.

2 Development Proposal

This section describes Orica's proposed strategy as outlined in the environmental impact statement.

2.1 Description of proposal

2.1.1 The EIS proposal

Orica proposed a strategy to prevent and minimise the environmental impact of contaminated groundwater in and around Botany Industrial Park. Orica's strategy has five key components:

- extraction of groundwater from the wells in three containment lines
- transfer of the groundwater via pipelines to the groundwater treatment plant
- construction and operation of the GTP
- transfer of treated water via pipelines for reuse by process plants in the Botany Industrial Park (or other identified users) or discharge to Bunnerong Canal
- Installation of a discharge point into Bunnerong Canal.

Orica has stated that treatment of contaminated groundwater is expected to cease after approximately 30 years.

Extraction of groundwater from the wells in three containment lines

The EIS describes the extensive network of groundwater wells that has been or will be installed by Orica within the Botany Sands Aquifer to extract contaminated groundwater. These form three hydraulic containment lines: along Foreshore Road, on Southlands and on BIP.

The EIS characterises the composition of the contaminated groundwater. Contaminants in the groundwater include chlorinated hydrocarbons, for example 1,2 dichloroethane (also known as EDC) and carbon tetrachloride). No dioxins are present in the groundwater.

Transfer the groundwater via pipelines to the groundwater treatment plant

The contaminated groundwater will be pumped out of the extraction wells and transferred to the groundwater treatment plant via dedicated transfer pipelines, at a maximum rate of 15 million litres per day. Three main pipelines are in existence or will be constructed, one for each of the containment lines.

Construction and operation of the GTP

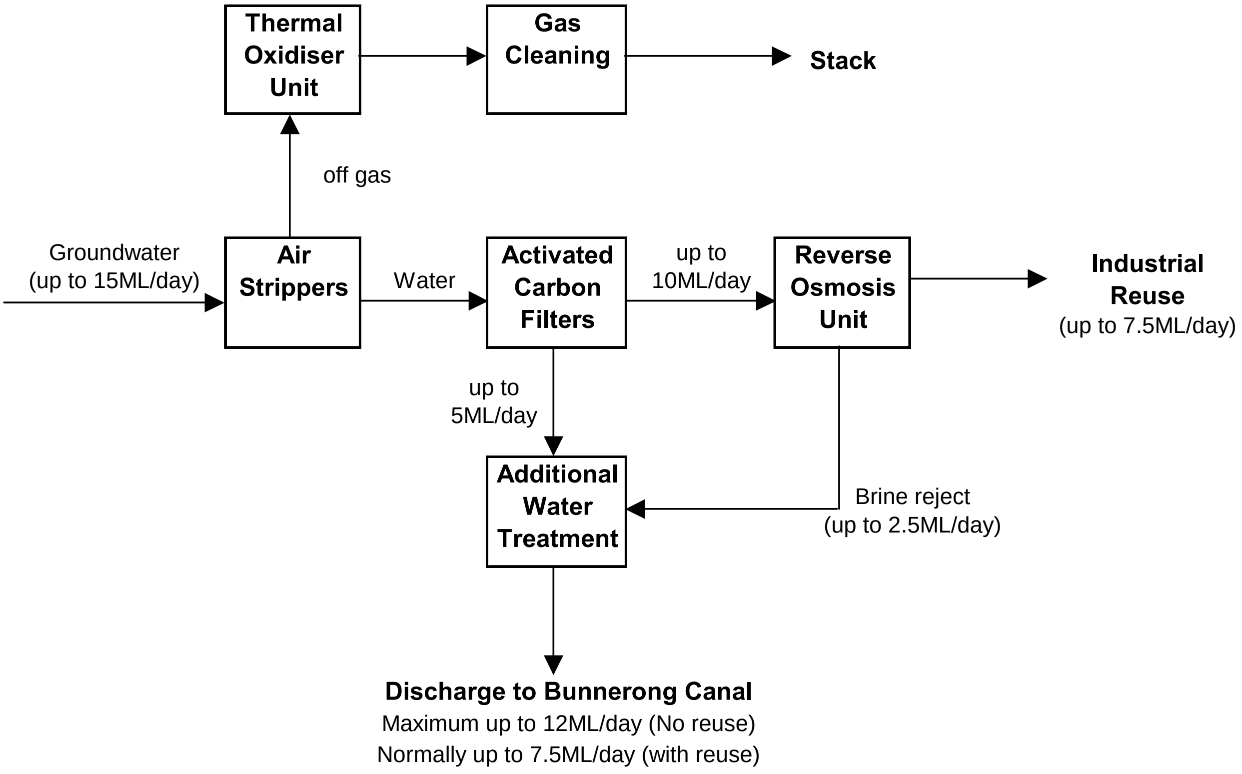
The extracted groundwater will be combined into a single stream and fed to the groundwater treatment plant on Orica-owned land on the Botany Industrial Park. The GTP is designed for continuous operation, treating up to 15 million litres of groundwater per day, 24 hours a day, seven days a week, with a 95% availability for a period of up to 30 years. The EIS describes the proposed GTP and it is outlined in the figure below. It will comprise the following steps:

- **Groundwater feed handling**. Groundwater from the containment areas (up to 15 million litres per day) is collected and combined in a feed tank prior to treatment. The pH is then adjusted with acid to prevent the precipitation of iron and biofouling.
- **Air stripping**. Volatile organic compounds are removed by blowing air through the groundwater and transferring them into the air stream (the off-gas stream).
- **Off-gas treatment (thermal oxidation).** Off-gases then move to a thermal oxidiser unit fuelled by natural gas for a sufficient time to enable the destruction of organic compounds to carbon dioxide, water and hydrogen chloride. Condensate collected from the existing steam stripping unit (around 500 tonnes)

as part of the interim containment measures will also be fed into the unit for destruction in a controlled manner.

- **Off-gas treatment (quench).** Following thermal oxidation and heat recovery the treated off-gas temperature is reduced very rapidly from about 500 °C to 100 °C by spraying weak acid through the gas stream. The rapid quench minimises the potential for the formation of dioxin.
- **Off-gas treatment (gas scrubbing).** Off-gas is further treated in an acid absorber recovery system and caustic scrubber to remove traces of hydrogen chloride and chlorine. The treated off-gases are then discharged to the atmosphere via a single 20-metre-high stack.
- **Stripped water treatment (iron removal).** From the air stripper, the groundwater is treated to remove iron.
- **Stripped water treatment (removal of non-volatile organics, such as phenol)**. The groundwater is passed through activated carbon to remove any organic compounds.
- **Stripped water treatment (reverse osmosis ie dissolved solids removal**). The stripped groundwater that it to be reused is treated by reverse osmosis unit to remove dissolved solids.
- **Treated water reuse and discharge**. The treated water from the reverse osmosis unit (up to 7.5 million litres per day) will be for industrial reuse. The remaining stripped water that does not pass through the reverse osmosis unit (up to 5 million litres per day) will be combined with wastewater from the reverse osmosis unit, commonly known as 'brine' (up to 2.5 million litres per day) and treated in a biological reactor with further polishing to remove ammonia, prior to discharge to the environment.

Groundwater Treatment Plant



Transfer of treated water via pipelines for reuse by process plants in the Botany Industrial Park

Orica has entered into agreements with other industries in the Botany Industrial Park for reuse of the treated groundwater. Orica has stated that it will provide sufficient reverse osmosis capacity and treated water distribution network for up to 10 million litres per day. Orica will also seek to identify other potential users of this water on an ongoing basis.

Installation of a discharge point into Bunnerong Canal.

Treated water that is not recycled will transferred by an existing pipeline and discharged into Bunnerong Canal. Up to 12 million litres per day (equivalent to 0.14 m^3 per second) will be discharged and approval is being sought for this amount from the determining authorities. This amount is based on the maximum hydraulic capacity of this pipeline. This canal flows to Brotherson Dock and Botany Bay. The objective however is to maximise the reuse of this high quality water (initially up to 7.5 million litres per day) and minimise discharge to waters.

2.1.2 Possible modifications to the proposal

Subsequent to the EIS exhibition and public representations Orica suggested some modifications to the proposal. These amendments were submitted in a report dated 27 January 2005. These suggestions mostly reflect the results of detailed design and consideration of representations. The proposed key changes are as follows and have also been considered by the authorities in this determination report for the project.

Replacement of biological treatment unit with second reverse osmosis unit

Orica proposes to remove the biological treatment unit and final ammonia unit from the circuit and install a second reverse osmosis (RO) unit. This will generate up to 13.5 million litres of treated water. Orica states that this will increase the robustness, reliability and effectiveness of the groundwater treatment system. It will avoid the need for solid waste management (generated by the biological treatment unit). It will also enhance opportunities to reuse wastewater and utilise the sewerage system to dispose of wastewater under trade waste agreements (see below).

Salty water discharge to sewer, not Bunnerong canal

Brine from the reverse osmosis units was to be discharged to Bunnerong Canal. Orica now propose to discharge the ‘brine’ from the reverse osmosis units (approximately 1.5 million litres per day) to sewer under an amended trade waste agreement with Sydney Water. This will reduce the quantity of treated water that will be required to be discharged to waters. It will also result in less salt being discharged to waters.

Excess water to stormwater channel, not directly into Bunnerong Canal

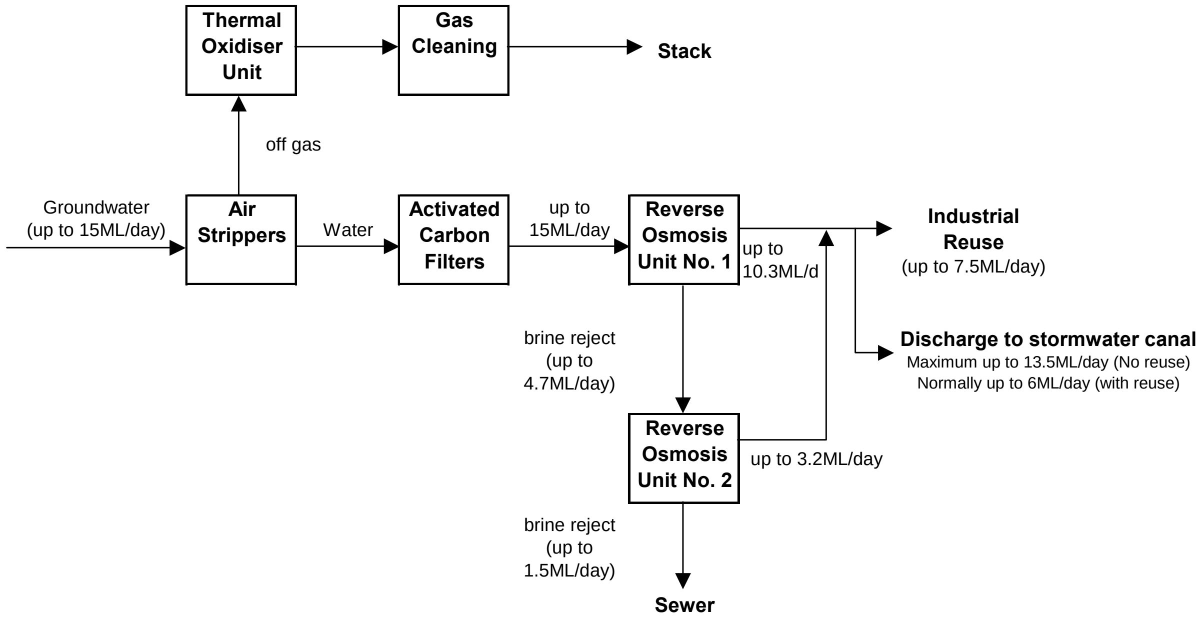
Orica proposes to modify the project to transport excess treated water via an existing disused pipe which feeds into the Amcor freshwater ponds (known as Long Dam) for reuse. Any excess water not reused will be discharged to the Sydney Water Bunnerong Channel. The channel continues to Brotherson Dock (and Botany Bay). Orica states that this will eliminate the need for any direct discharge to Bunnerong Canal.

Increase groundwater treatment plant stack height from 20 metres to 34 metres

Orica proposes to increase the height of the GTP stack from 20 metres (as described in the EIS) to 34 metres. There will be no additional or increased emissions from the stack. It will result in a significant reduction in ground-level concentrations. In addition Orica will introduce plume suppression. Under certain weather conditions the water vapour in the plume was predicted to create a visible plume. Plume suppression will involve slightly cooling the caustic scrubber and heating the discharge steam using recovered energy from the thermal oxidation unit. This will require no additional energy or production of greenhouse gases.

The proposed treatment process is summarised in the following diagram.

Groundwater Treatment Plant - Amended Proposal



2.2 Project timing and cost

Orica has stated that construction of the project will take an estimated nine months. A target completion date of August 2005 for the construction of the groundwater treatment plant has been indicated by Orica as necessary to enable it to be commissioned and operational by 31 October 2005, to meet the requirements of the EPA notice. Within this timeframe, all other works including pipelines and groundwater wells will be constructed, commissioned and operational.

The EIS states the capital cost of the project is expected to be approximately $102 million for all elements including the installation of extraction wells, transfer pipelines and treatment plant.

2.3 Need, benefit, project justification and consequences of not proceeding

2.3.1 Proposal objectives

The environmental impact statement states that the primary objective of the project is to stop further migration of contaminated groundwater and collect it for treatment to ensure the protection of the ecological, recreational and aesthetic values of both the terrestrial and aquatic environments of Botany Bay and Penrhyn Estuary.

2.3.2 Justification of the proposal

The environmental impact statement justifies Orica’s preferred strategy by outlining the outcomes that would be achieved by implementing the strategy. These are:

- achieve the required level of groundwater containment in both the Primary Containment Area and the Secondary Containment Area and prevent the discharge of contaminants at levels greater than ANZECC (2000) trigger levels into Penrhyn Estuary and Botany Bay

- achieve a reduction by 31 October 2005 in the concentration of contaminants in the groundwater at the Primary Containment Area to the maximum extent practicable, with a target of an 80% reduction in levels, as set out in the Orica 2002 Annual Report to the EPA
- clean up the contaminated plumes (by removal and treatment of the contaminants) by
    - preventing further contaminant migration through containment lines, allowing gradual clean up of up gradient areas
    - assisting DNAPL removal projects by containing potentially increased concentrations of mobilised contaminants.
- minimise air emissions and generation of waste according to best-practice design standards
- undertake monitoring to assess the effectiveness of the hydraulic containment.

2.3.3 Consequences of not proceeding

The existing steam stripping unit can process up to 2 million litres of contaminated groundwater per day. DEC has indicated to Orica that use of the SSU beyond 31 October 2005 would necessitate an upgrade to best practice with respect to air emissions. This is a requirement of the current licence. According to Orica's modelling, this action is reducing the amount of contamination reaching Penrhyn Estuary, however it will not reduce the areas of high contamination closer to the Botany Industrial Park, which also need to be remediated.

The environmental impact statement identifies the consequence of not proceeding with Orica's preferred strategy. Orica would not be able to extract groundwater at the rates required (up to 15 million litres per day) to contain the plumes and treat the groundwater to remove the contamination. As a result the identified chlorinated contaminants in the groundwater plumes would be expected to discharge into Penrhyn Estuary and Botany Bay at increasing concentrations.

The EIS states that such discharges would be likely to result in a number of unacceptable outcomes including:

- impacts on the terrestrial and marine flora and fauna in the Foreshore Beach and Penrhyn Estuary ecosystems, including migratory shorebirds identified for protection by Commonwealth legislation and international treaties
- increased risk to human health for recreational users of the foreshore and within Botany Bay
- diminished quality of life for residents and workers in the area
- failure to achieve the requirements of the EPA clean up notice and associated Groundwater Clean Up Plan through failure to contain and treat the contaminated groundwater as stated in the notice.

The EIS states that if no action is taken to contain, recover and treat the contaminants in the groundwater they will increasingly pollute Penrhyn Estuary and possibly Botany Bay. Orica states that, based on most recent monitoring, it estimates that higher concentrations of contaminants could reach the upper extent of Penrhyn Estuary in the first half of 2006. These higher levels would be likely to kill or injure marine life as well as affect the protected migratory shorebirds either directly or indirectly, for example due to a lack of food. It is also possible these high levels would present potential risks to the recreational users in that area and also potentially workers. Orica concludes that the project is urgently needed to stop this happening.

2.3.4 Alternatives considered

The notice mandates the use of 'pump and treat' technology (ie *ex situ* treatment) to treat groundwater contamination within the primary containment area and form the basis for this project. Consequently in situ processes, for example bioremediation, were not considered as part of the project. Orica is however currently trialling in situ methods to reduce groundwater contamination in other areas of the Botany Industrial Park and its Southlands site, including active and passive bioremediation and the use of reactive iron barriers.

The environmental impact statement includes a review of available treatment options, locations and emission requirements taking into account the project objectives and the requirements of the EPA Notice of Clean Up Action. An independent assessment of available groundwater treatment technologies was also undertaken by consultants engaged by Orica and included in the EIS. A summary of the treatment options considered by Orica in the EIS is provided below. These options were based on two main approaches: (1) treating the contaminants in the groundwater or (2) removing the contaminants from the water and then destroying them.

Summary of treatment technologies considered by Orica (from EIS)

Approach 1	Technique	Description	Comments
Treat Contaminants in water	Biological treatment	Similar to sewage treatment plant but using mixed culture of microbes. Variety of methods considered.	Concerns over robustness of system to handle contaminants and long lead time in developing microbe cultures. Residual biosolids (contaminated) need disposal.
	Advanced oxidation	UV light, ozone or hydrogen peroxide used to destroy contaminants.	Can suffer from fouling.
	Activated carbon	Pass water through activated carbon.	Proven technology, but requires large volumes of carbon and that carbon would still require contaminant destruction.

Approach 2	Technique	Description	Comments
Remove contaminants from groundwater …	Air stripping	Contaminants removed by blowing air stream through it.	Robust and well-developed technology. Once in off-gas, the contaminants cannot be further collected and are destroyed as a dilute mixture in air, usually by thermal oxidation (see below).
	Steam stripping	Contaminants removed by blowing low pressure steam blown through it. Steam is condensed and contaminants separate from water as a condensate.	Currently used by Orica (up to 2 ML/day) Condensate must still be destroyed. Wide range of destruction techniques available (see below).
… then destroy removed contaminants.	Gas phase chemical reduction	Treat waste using high pressure and temperature with hydrogen gas. Does not form dioxins etc due to reducing atmosphere.	Significant safety hazards (inherent safety is low in engineering classification schemes due to the danger posed by high temperature hydrogen atmosphere), poor reliability and online availability, currently no operational facilities world wide. Not achievable in required timeframe.
	Base catalysed decomposition	Treat in a reactor using high temperature, caustic soda and oil.	Not suited to destruction of EDC, a principal contaminant. Inherent safety concerns, generates significant volumes of wastes for subsequent disposal.
	Plasma arc	Pass through a high temperature plasma arc in an inert atmosphere.	Commercially available, limited throughput capacity requiring multiple units and regular operator attention. Limited reliability. High electricity consumption.
	Gas phase thermal oxidation	Use high temperature and oxygen. Can form dioxins etc but can be minimised with design.	Well proven technology and Orica's preferred option.

	Other processes	Included super critical water, molten salt oxidation and molten metal oxidation	Experimental, not proven or commercially available.

The EIS concludes that Orica's preferred strategy for the collection and treatment of the contaminated groundwater is air stripping followed by thermal oxidation.

2.3.5 Contingency measures

The EIS describes the measures that would be adopted by Orica if the groundwater treatment plant could not be operated in a proper and efficient manner and failed to meet statutory requirements. The plant, including the thermal oxidation unit, would be shutdown and groundwater treatment would cease. The system is designed to incorporate a contingency shutdown of around two weeks per year to enable maintenance and repairs. The EIS states that this length of shutdown will not adversely affect the hydraulic containment of the contaminant plumes, due to the hydraulic gradient of the groundwater and the length of time required for it to re-equilibrate after pumping.

Orica will maintain the steam stripping unit in standby mode, for recommissioning in a controlled and timely manner in the event of a long term shutdown (for example, catastrophic failure of key equipment). This unit would be used to provide ongoing containment of the highest concentration contaminated groundwater and protection of receiving environments while GTP operational issues are rectified.

3 Summary of representations

3.1 Summary of representations received

A total of 19 representations were received from the exhibition of the environmental impact statement. The category types of representations are summarised below.

Type	Number
NSW Government departments	5
Members of Parliament	1
Local council	2
Non-government organisations	7
Individuals	4
TOTAL	**19**

3.2 Overview of key issues raised in representations

3.2.1 Introduction

The general range of issues raised in representations and addressed in this report is summarised below. A more detailed summary is provided at Appendix A.

As an overall observation, representations supported the need to take action to stem the movement of the contaminated groundwater towards Botany Bay. However, a number of the representations did not support the proposal for treatment of the contaminated groundwater: issues were raised in relation to the consideration of alternatives (including storage until more appropriate treatment techniques can be determined) and in relation to the health risk potential of the proposed treatment process.

Other points raised relate to the legal position in view of Australia's ratification of the Stockholm Convention on Persistent Organic Pollutants (POPs), the need for a financial assurance (or bond), impacts of wastewater discharge and water quality impacts generally, the regulatory regime to be imposed in terms of on-going monitoring requirements, the brevity of the consultation process/lateness of regulatory clean up action, and energy use and greenhouse gas generation.

3.2.2 Overview of key issues

The issues raised most frequently in submissions related to the proposal to extract and thermally oxidise the groundwater contaminants and the assessment of potential alternative methodologies. Specifically, the key issues raised were:

- the location of an 'incinerator' for toxic chemicals in proximity to residences, schools and hospitals. A number of submissions addressed the nature of potential emissions from the proposed plant and dealt with the nature and impact of these potential emissions in considerable detail.
- the question of alternative treatment technologies and the consideration given to these alternative options in the EIS and throughout the consultation process. Several submissions raised the issue of

storage capacity on site and the ability to use this capacity to take a more considered approach to the treatment technology that might be applied. Consideration of alternatives to thermal oxidation, such as gas phase chemical reduction, were also raised in this context. The concept of establishing a waste precinct where all such wastes, including other wastes from the Orica Botany site, might be treated, was also raised in this context.

- the statutory/legal implications of the proposal. A number of the submissions raised this in the context of Australia's obligations under the Stockholm Convention on Persistent Organic Pollutants and the intent and spirit of that treaty.
- the air quality assessment and air emissions from the proposed treatment facility. In particular, submissions addressed the potential for emissions of dioxins and furans as a result of the treatment process. As noted above, this was often in the context of the proximity to local schools and residences. The issue of air quality monitoring in Banksmeadow school was also raised in this respect.
- the risk hazard analysis in the context of air emissions, but also in relation to treated water discharge. Several submissions asked what safeguards were in place to protect the community and environment in the event that the proposed treatment process failed. The particular vulnerability of children to toxic chemicals was raised in this context in several submissions. The DIPNR submission noted that a number of the assumptions on which the preliminary hazard analysis was based would need to be reviewed once the design of the facility had been finalised. Cumulative impacts and the issue of bioaccumulation were raised also in several submissions.
- The need for a bond or some form of surety to be provided by Orica (a $50 m bond was mentioned in several submissions).
- water quality and wastewater discharge was raised in a number of submissions in the context of the impact on fauna and flora and in particular, the impact on sensitive sea grass and salt marsh habitats in the locality. This was also raised in the context of the application of the *Threatened Species Conservation Act 1995* and the need to evaluate the impact.
- land use, future regulation and socio-economic considerations. These included the issue of long-term responsibility for continued compliance with the requirements of the clean up. Other submissions raised the issue of the disposal by Orica of parcels of land in order to pay for the clean up and that this should not be allowed. Another issue was the need for independent review, not self-monitoring by Orica.
- the impact of the restriction on the use of bores by residents in the affected area. This was generally raised in the context of Orica's proposal to sell treated wastewater to other industrial users. Submissions proposed Orica compensate affected residents in various ways, including by providing the treated water to the residents by way of replacement for the loss of the use of their bore, and by meeting the cost of installation of rainwater tanks.

3.3 Independent reviews and additional sources of advice

In making this determination, independent reviews of the project and advice on the technology selected were also sought by DEC. These organisations and their brief are summarised in the following table.

Organisation	**Brief**
United States Environmental Protection Agency	Independent peer review of Botany Groundwater Cleanup project
John Court & Associates Pty Ltd	Review of air emissions, air quality and the capability of the proposed plant to achieve the performance claimed.
Department of Environment and Heritage (Commonwealth)	Advice on alternate technologies and compliance with the Stockholm Convention on Persistent Organic Pollutants.

4 Strategic context and project justification

4.1 Strategic context

4.1.1 Environmental Planning and Assessment Act a related planning instruments

Under the *Environmental Planning and Assessment Act 1979* (EP&A Act), the following environmental planning instruments apply and are relevant to the proposed activity:

- *State Environmental Planning Policy No. 55 – Remediation of Land*
- *State Environmental Planning Policy No*. 33 – *Hazardous and Offensive Development*
- *Botany Local Environmental Plan 1995*
- *Randwick Local Environmental Plan 1998*.

State Environmental Planning Policy No. 55 – Remediation of Land (SEPP 55) is the key and overarching environmental planning instrument that applies to the proposed activity. The SEPP was amended and published in the Government Gazette on 31 July 2004, making specific provisions applicable to the proposed activity. In particular, clause 21 of SEPP 55 dictates that any works subject to a Notice under the Protection of the Environment Operations Act are permissible without development consent if the Notice is listed in Schedule 1 of the SEPP. In this case, the proposed activity is subject to such a Notice (No 1030236 dated 26 September 2003 and addressed to Orica Australia Pty Ltd) and therefore does not require development consent. The proposed activity does, however, still require assessment under Part 5 of the EP&A Act. It is also important to note that clause 19 of SEPP 55 provides that the SEPP prevails over local environmental plans *inter alia* to the extent of any inconsistency. Therefore, where the *Botany Local Environmental Plan 1995* would otherwise require development consent for aspects of the proposal, SEPP 55 prevails and provides that the proposal is permissible without development consent.

Clause 21 of SEPP 55 also calls up clauses 17(1)(a) and 17(1)(b), which require that the proposed remediation be carried out in accordance with the contaminated land planning guidelines and any guidelines in force under the *Contaminated Land Management Act 1997*. In this regard, the relevant guideline document is *Managing Land Contamination: Planning Guidelines: SEPP 55 – Remediation of Land* (DUAP & EPA, 1998). The proposed activity has been assessed against the relevant aspects of this guideline and determined to be consistent. Firstly, the land is known to be contaminated and the nature and extent of that contamination is generally well known from previous investigations over a number of decades. Where there is any doubt (for example, in the exact extent of some areas of free-phase contamination), it is possible to conservatively estimate the worst-case situation so as to ensure an appropriately conservative environmental planning outcome. Generally, the EIS and historical data for the land provide sufficient information for an informed merit assessment of the proposed activity. This assessment is detailed in this report, and focuses on the key question posed through the guidelines – whether the consequences of not carrying out the remediation outweigh the environmental impacts of carrying out the work.

As detailed in this report, it has been demonstrated that the proposed activity could be undertaken within acceptable environmental and public health standards, and that residual risks and environmental impacts can be reduced to as low as reasonably possible through the imposition of stringent conditions on relevant approvals, particularly the EPA licence. Furthermore, it can be concluded that the proposed activity has been assessed as having environmental, as well as human health and amenity impacts, which can be managed to meet or be more stringent than acceptable standards. In contrast, contaminated groundwater in its current state continues to pose an ecological risk, and a potential human health risk. Comparison of the risks, although not easily quantifiable, suggests that the controllable above-ground risks associated with the proposed remediation works outweigh the uncontrolled and on-going risks posed by not addressing the contamination. This balance is considered in more detail in other sections of this report, but it is apparent that a clear outcome of SEPP 55 will be achieved through the proposed activity – the consequences of not remediating the contaminated groundwater outweigh the acceptable and manageable impacts attributable to the remediation works.

State Environmental Planning Policy No. 33 – Hazardous and Offensive Development (SEPP 33) is framed to apply to assessment of potentially hazardous and potentially offensive industry under Part 4 of the EP&A Act. SEPP 33 is therefore not directly relevant to assessment under Part 5, and there may even be some question as to whether the proposed activity could be characterised as 'industry' (noting the definition in the *Model Provisions 1980*). Notwithstanding, the principles of SEPP 33 have been applied to the proposal, with the activity established as 'potentially hazardous' as it would exert a significant off-site risk impact in the absence of all risk-mitigating measures. As would be required for assessment of a development application for potentially hazardous industry, a Preliminary Hazard Analysis (PHA) was prepared and included in the EIS for the activity. Through that PHA, Orica has demonstrated that land use planning risk could be reduced to within acceptable levels for surrounding land uses with the application of a suite of proposed risk-mitigating measures. As a consequence, the proposed activity would not be defined as 'hazardous' and, in the context of land use planning, the risk is considered acceptable. Consideration of hazards and risk issues is provided in more detail in Section 5 of this report.

The provisions of the *Botany Local Environmental Plan 1995* (Botany LEP) are largely inapplicable to the proposed activity, given that the majority of these provisions are generally phrased to apply to a consent authority's consideration of development applications under Part 4 of the EP&A Act. As the activity is subject to assessment under Part 5 of the EP&A Act, the determining authorities are not bound by the heads of consideration dictated for a consent authority. Nonetheless, it is apparent that the proposed activity would not be inconsistent with the objectives of the Botany LEP, being:

a) to recognise the importance of the local government area of Botany as a gateway to Sydney, given its proximity to Sydney (Kingsford-Smith) Airport and Port Botany
b) to ensure, as far as practicable, that land uses are compatible with each other in terms of environmental and aesthetic amenity
c) to make the local government area of Botany a more attractive and pleasant place in which to live, work and visit
d) to improve the image of the local government area of Botany by ensuring that developments are of a good standard of design, form and function
e) to protect areas from inappropriate development and to ensure that, in particular, residential amenity, health and safety is maintained or improved, where necessary
f) to provide for an appropriate balance and distribution of land for residential, commercial, retail, industrial, advanced technology enterprises, tourism, port-related and airport-related development and recreation, entertainment and community facilities.

The proposed activity would not in itself contribute directly to the achievement of the objectives of the Botany LEP, but would indirectly provide for the on-going viability of parts of the local government area for development and attainment of LEP objectives. In particular, objectives specified under b), c) and d) would be indirectly assisted by the proposed activity through removal of an existing, and expanding, threat to the local environment attributable to contaminated groundwater. In the short-term, the activity would restrict the expansion of groundwater contamination that would otherwise potentially detract from local amenity, the attractiveness of the area and the image of Botany. The longer-term result would be ultimate removal of the aspects of the existing groundwater contamination that detract from these outcomes. The objectives of the Botany LEP also provide for avoidance of potential land use conflicts, and in this regard, the proposed activity would have a positive indirect effect. Through removal of contaminant loads in groundwater, potential existing and future conflicts between contaminated groundwater and incompatible land uses would be removed, thereby permitting a more diverse (and less restricted) suite of possible land uses, consistent with the Botany LEP.

As noted above, it may not be strictly correct to characterise the proposed development as 'industry', particularly given the definition of industry in the *Model Provisions 1980* (which includes reference to a manufacturing process and similar concepts). Notwithstanding, in terms of the nature and perception of the activity, common, everyday interpretations would suggest that the proposal constitutes industry (or industry-like works), rather than commercial, residential or other distinct land use categories. In this context, it is appropriate to consider the proposal against the Botany LEP objectives for industry, which are:

a) to restrict industrial uses to defined zoned areas
b) to encourage new developments with a high standard of design and form that are compatible with adjoining developments, whilst ensuring a high level of environmental amenity
c) to minimise the adverse environmental effects of industries
d) to restrict the development and expansion of hazardous and offensive industries
e) to improve the environmental quality of the local government area of Botany by minimising disturbances caused by any form or type of pollutant
f) to ensure that industries conform to strict hazard minimisation and environmental guidelines
g) to ensure adequate buffers between industries and other land uses, particularly residential, are provided.

In the context of objectives a) and g) above, the groundwater treatment plant component of the activity is proposed to be located on land zoned for industrial purposes. The activity is therefore consistent with the nature of other existing developments in the direct vicinity and any future development that may occur on that land. In fact, the treatment plant is located well within what is identified as the Botany Industrial Park, and is therefore not only distanced from the nearest residential and sensitive land uses, but is buffered from those land uses by an established industrial area. The proposed activity itself would not generate any land use conflict with residential or other non-industrial land uses, and is considered compatible with adjacent land uses as required by objective b).

As noted above and further considered in section 5.1.5.1 of this report, Orica has demonstrated that the proposed activity would not defined as ‘hazardous’ within the meaning of SEPP 33. In a preliminary sense, Orica has applied appropriate hazard minimisation measures, which have been complemented with the recommended imposition of conditions requiring additional hazards investigations at the detailed design and implementation stage. The proposal is also not considered to be ‘offensive’ within the meaning of SEPP 33, with the activity assessed as being able to comply with relevant environmental and human health criteria. The combination of mitigation measures proposed by Orica, and the recommended additional measures outlined in this report for imposition through the relevant approvals (particularly the Environment Protection Licence) are considered to represent all reasonable and feasible measures for minimisation of impacts to as low as reasonably possible. The proposed activity is therefore consistent with objectives c) to f).

In industrial zones, the consent authority for a development application under Part 4 of the EP&A Act is required to take certain matters into account before granting development consent. While the proposed activity is subject to assessment under Part 5 of the EP&A Act, the following heads of consideration remain relevant to the proposal:

a) a maximum floor space ration of 1:1 (clause 12)
b) the development provides adequate off-street parking (clause 17)
c) the development provides an efficient and safe system for the manoeuvring, loading and unloading of vehicles (clause 17)
d) the operations of the development will not have an adverse impact on the functions of the surrounding road network (clause 17)
e) any goods, plant, equipment and other material resulting from the operations of the development will be stored within a building or wholly within the site and screened suitably from public view (clause 17)
f) there is sufficient area on-site for the storage and parking of vehicles associated with the operations of the development (clause 17)
g) landscaping will be provided that is integral to the design and function of the building and the site to improve the appearance of the development, enhance the streetscape and add to the amenity of the adjoining area (clause 17)

h) the development is of a height, scale and design that is sympathetic to adjoining land uses and built form (clause 17)
i) the building design and finishes are sympathetic and complementary to the built form, the streetscape and the public domain in the vicinity (clause 17)
j) the design and operation of the development will protect the visual and aural amenity of adjoining non-industrial uses (clause 17)
k) any noise generated from the operation of the development is minimised (clause 17)
l) any risk to human health, property or the natural environment arising from the operation of the development is minimised (clause 17)
m) the provisions of *State Environmental Planning Policy No 55 - Remediation of Land* will be complied with in relation to the land (clause 17)
n) whether adequate water and sewerage services will be available to the land it is proposed to develop (clause 38)
o) adequate provision has been made for the disposal of stormwater from the land it is proposed to develop (clause 38).

The above matters are addressed in detail in the relevant sections of this report, however, there are a number of these heads of consideration that require specific comment. Firstly, the proposed activity has been assessed as having a floor space ratio within the limits specific under the Botany LEP (point a) above), and in the context of the immediate industrial setting, is characterised with appropriate urban design and landscaping [points e), g), h), i) and j)]. Given the nature of the proposal, it will not be associated with significant traffic generation, and as such, is considered to pose minimal potential for impact on the surrounding road network. The internal design of the activity has been assessed to be generally consistent with relevant codes and standards for parking, manoeuvring and vehicle access arrangements [points b), c) and f)]. Specific environmental impacts, including in relation to noise, land use safety planning, human health risk, and stormwater are considered in the relevant sections of this report and have been demonstrated as meeting acceptable environmental and amenity criteria.

Depending on the final detailed design of the proposed activity, off-site pipework associated with the groundwater treatment plant is likely to affect a number of different land use zones in the Botany local government area, and potentially within the Randwick area. Neither the Botany LEP nor the *Randwick Local Environmental Plan 1998* provide any requirements specific to the installation and operation of pipework in any zone. Consistency with zone objectives in each circumstance would be achieved through compliance with acceptable environmental standards during construction of the pipework, and design of this infrastructure to avoid alienation or sterilisation of land from its permitted development potential. Consideration of pipework and associated water management infrastructure suggests that these measures are minimal in both scale and impact, with well-established practices and standards available for both installation and operation. Proposed locations/routes for these aspects of the proposed activity are unlikely to affect developable land or to detract from attainment of the development potential of land in either the Botany or the Randwick local government areas.

In summary, the proposed activity is considered to be consistent with all relevant environmental planning instruments. Notwithstanding that the proposal is subject to assessment under Part 5 of the EP&A Act, and not bound to compliance with the requirements for developments under Part 4, the activity has been reviewed against the heads of consideration dictated for assessment of development applications. This consideration demonstrates that the proposal is generally consistent with the zoning requirements, planning objectives and environmental planning specifications relevant to the land and local government areas affected by the proposal.

4.1.2 NSW State Groundwater Policy

Groundwater is an essential resource for human activities and the environment. However, the quality of groundwater will influence the types of activities it can be used for. The groundwater resource of the Botany

Sand Beds is of a naturally high water quality. One public representation noted that it was once used as a source of drinking water for Sydney. Groundwater quality has deteriorated significantly over the years due to human activities, in particular historical manufacturing activities in and around the Botany area.

The government's aim is to manage the state's groundwater resources so that it can sustain environmental, social and economic uses for the people of NSW. State Government policy is to encourage the ecologically sustainable management of the state's groundwater resources, so as to:

- slow, halt or reverse any degradation of groundwater resources
- ensure sustainability of groundwater-dependent ecosystems
- maintain the full range of beneficial uses of these resources
- maximise economic benefit to the region, State and nation.

In 1997 the NSW Government released the *State Groundwater Policy Framework Document*, which aims to achieve efficient and sustainable management of groundwater resources (NSW Government, 1997). Three component policies have been written to support the framework document. To date the *NSW Groundwater-dependent Ecosystems Policy* (NSW Government, 2002a) and the *NSW Groundwater Quality Protection Policy* (NSW Government, 1998b) have been published. The *NSW Groundwater Quantity Management Policy* is still in draft stage and will provide management approaches to control groundwater extraction to within the assessed sustainable yield of a resource.

The *NSW Groundwater Quality Protection Policy* establishes four basic concepts as the foundation of groundwater management:

Beneficial use and water quality objectives: The beneficial use of groundwater systems can be one or more of: ecosystem protection, recreation and aesthetics, raw water for drinking, agricultural water and industrial water.

Groundwater vulnerability: This recognises that risks of pollution from an activity vary according to natural geological conditions including soil types, depth to groundwater and transmitting capacity of the aquifer.

The conduit effect: Aquifers not only store water, they transmit it down a hydraulic gradient. An individual particle of water will move along a flow path from the point of recharge to the point of discharge. The aquifer is in effect a conduit for carrying water. If it becomes polluted at some point then the polluted water will be transported to the discharge site.

Groundwater compatibility: When groundwater is extracted and used for irrigation, proper consideration must be given to the compatibility of the water with respect to soil and crops onto which it is to be applied. If the groundwater has excessive salt content, for example, it could cause a breakdown in soil structure, salinisation of the root zone, leaching of salts into underlying groundwater and ultimately, the movement of salts into creeks and rivers.

The policy also contains a set of principles that require management activities and plans to:

- maintain the most sensitive beneficial use of the groundwater system
- ensure town water supplies are protected against contamination
- ensure groundwater pollution is prevented so that remediation is not required
- ensure groundwater-dependent ecosystems are protected from contamination
- ensure the quality of pumped groundwater is compatible with soil, vegetation and/or receiving water
- rehabilitate degraded areas where practical
- consider the cumulative impacts of activities on groundwater quality
- consider the links between groundwater quantity and groundwater quality management.

The *NSW State Groundwater-dependent Ecosystems Policy* is a whole-of-government policy, developed by the NSW State Groundwater Policy Working Group (consisting of government and non-government representatives). This policy recognises the shared goals of government and the community in promoting the sustainable use and management of groundwater resources in New South Wales and the need for all stakeholders to work together in the protection of groundwater-dependent ecosystems. It is specifically designed to protect our valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored, for the benefit of present and future generations.

The Orica Groundwater Cleanup project is in accordance with the goals and principles of the NSW State Groundwater Policy and supporting component policies. The determining authorities consider that, given the nature of the contamination present in the sand bed aquifer's groundwater system, its extent beneath and down gradient from the Botany Industrial Park as well as the high concentration levels of chlorinated hydrocarbons that occur in the system, hydraulic containment using pump and treat technology is an appropriate course of action to address the situation. This approach to an environmental problem, as presented, must be taken where it is too difficult to treat the groundwater in situ. It is also vital to stop the contaminated groundwater from further spreading while the cleanup of the groundwater resource is undertaken. It will also work towards ensuring environmentally degraded areas are rehabilitated and their ecosystem support function restored.

4.1.3 Water Act 1912 and Water Management Act 2000

The rights to control, manage and use groundwater in NSW is regulated under the *Water Act 1912* (Water Act), and subsequently, the *Water Management Act 2000* (Water Management Act). The extraction of groundwater is regulated through a licensing system administered by DIPNR.

In response to the detection of contaminants in groundwater, DIPNR established a groundwater Extraction Exclusion Area around the known contamination plumes originating from historical activity in and around Botany Industrial Park. This was undertaken as an Order under Section 113A of the Water Act, in August 2003 (refer Appendix C for locality plan). DIPNR issued notices to licensees in this area under the Water Act,1912 that instructed them to cease extracting groundwater.

DIPNR is currently working with DEC, NSW Department of Health and local government to develop a groundwater strategy for the Botany Sand Beds. The preparation of the strategy is in accordance with a recommendation of the *Healthy Rivers Commission Statement of Intent for the Georges River - Botany Bay system* (2002).

The strategy will set rules for granting licences, identify the sustainable water yield and aim to protect the environmental and economic values of the groundwater system. In particular, the strategy will stress the need for protection of groundwater-dependent ecosystems and aim to ensure that industry and the public accord higher values to protection and use of the aquifer. The Botany Groundwater Strategy will subsequently be incorporated into a Water Management Plan under the Water Management Act. It is envisaged that this will be accomplished through the Macro Water Sharing Plan process that is presently being developed by DIPNR. Macro Water Sharing Plans, once completed and endorsed by the government, will enable the Water Management Act to be announced state-wide.

The Healthy Rivers Commission *Independent Inquiry into the Georges River–Botany Bay System* (HRC, 2001) identified the need to define 'broadscale pollution risk zones' based on current knowledge of former potentially contaminating activities, current potential pollution sources and known aquifer water quality. The strategy will provide a better understanding of the groundwater system and a framework for dealing with any newly discovered contamination. It will also define broad scale 'groundwater pollution risk zones' which, when implemented, will preclude extraction from some areas and provide warnings on risks to groundwater users in other areas.

DIPNR also imposed an embargo on accepting any further applications for groundwater supply licences under Part V of the Water Act in a large area of the Botany Basin (Northern Zone) in August 2003 (see Appendix D). This embargo area was gazetted to proactively manage other sites with potential contamination, in addition to the contaminant plume from the Orica site, by restricting new access to groundwater. The restriction placed on this area precludes any new bore licences for the extraction of groundwater from being issued, with the exception of temporary dewatering for building construction, groundwater monitoring and bores for purposes of groundwater remediation. The intent of the embargo is to not issue new licences until further assessment of the groundwater system occurs through the Botany Groundwater Strategy.

A licence is required by Orica from DIPNR under Part V (section 116) of the Water Act to authorise the extraction of groundwater for containment of contamination and groundwater remediation purposes. The lands to be authorised by the licence relate to locations at Banksmeadow, generally bounded by Foreshore Road, Botany Road and Beauchamp Road to the south, Denison Road to the East, Floodvale drain to the west and to the north in part by Ampol Terminals, Anderson Street and Corish Circuit.

The existing and proposed bore locations are within the hydraulic containment lines specified in the Notice of Clean Up Action (NCUA) issued to Orica Australia Pty Ltd by DEC and outlined in Section 2. DIPNR has already issued test bore licences under the Water Act for the works in the Primary Containment Line as well as the Secondary Containment Line to enable preliminary field testing by Orica.

At least three (3) production bore licence applications must be submitted to DIPNR for processing, commensurate with the intended licence conditions as set out in Appendix B. These licences will authorise the production water supply borefields in each containment area. The contaminated groundwater pumped out in the extraction bores is proposed to be transferred to the GTP via dedicated transfer pipelines at a total rate of up to 15 million litres per day.

The determining authorities consider that the proposed extraction borefields, once commissioned for production purposes (to deliver 15 million litres per day to the groundwater treatment plant), will achieve hydraulic containment of the plumes.

The intended conditions of the licence are set out in Appendix B, subject to a formal application being received from Orica. General and specific conditions for management of groundwater resources and dependent ecosystems in the area of the proposed groundwater clean up development are included. This includes, but is not limited to, requiring Orica to carefully monitor groundwater level behaviour with pumping, minimise any potential adverse environmental impacts and report the effectiveness of the clean up.

4.1.4 Contaminated land management

The NSW Government recognises the importance of managing contaminated sites in NSW. The *Contaminated Land Management Act 1997* (CLM Act) enables DEC to respond to contamination that is causing a significant risk of harm to human health or the environment, and sets out criteria for determining whether such a risk exists. The Act gives the EPA power to:

- declare an investigation site and order an investigation
- declare a remediation site and order remediation to take place and
- agree to a voluntary proposal to investigate or remediate a site.

The EPA has determined that the contaminants in the groundwater at Botany sourced from the Orica site present a significant risk of harm (SRoH) in accordance with section 9 of the CLM Act. The EPA proposes to declare approximately 200 hectares of land affected by the contamination as a remediation site in accordance with section 21 of the CLM Act. A declaration means that the contamination of the land is ‘tagged’ as presenting a SRoH. The copy of the declaration is placed on the CLM Act public record. Only when DEC is satisfied that the SRoH caused by the contamination has been addressed, can the declaration be removed.

The EIS states that if no action is taken to contain, recover and treat the contaminants in the groundwater at the rates required (up to 15 million litres per day) they will increasingly pollute Penrhyn Estuary and possibly Botany Bay. Such discharges would be likely to result in a number of unacceptable outcomes including:

- impacts (such as effects on growth, reproduction, abundance and diversity) on the terrestrial and marine flora and fauna in the Foreshore Beach and Penrhyn Estuary ecosystems, including migratory shorebirds identified for protection by Commonwealth legislation and international treaties
- increased risk to human health for recreational users of the foreshore and within Botany Bay
- diminished quality of life for residents and workers in the area
- increased loads of volatile organic compounds to the atmosphere which are precursors for smog formation
- failure to achieve the requirements of the EPA clean up notice and associated Groundwater Control Plan through failure to contain and treat the contaminated groundwater as stated in the notice.

DEC believes that significant adverse impacts on the environment and potentially human health will result if the project does not proceed. For these reasons the project is vital in terms of Orica's ability to meet its obligations under this legislation.

4.1.5 Protection of the Environment Operations Act

The *Protection of the Environment Operations Act 1997* supports government priorities for protecting and restoring the environment by reducing to acceptable levels the discharge of substances likely to cause harm to the environment. Recognising the potentially significant impact of chemical manufacturing and storage and waste activities on the environment, Orica is required to have an environment protection licence under the Act.

An environment protection licence issued under the Protection of the Environment Operations Act contains conditions that ensure effective and efficient management of these sorts of activities. An environment protection licence requires the licensee to operate activities competently, as well as maintain systems in such a way as to ensure ongoing environmental improvement.

Licenses also include nominated discharge points for the purposes of setting limits to, and the monitoring of, the emission of pollutant discharges to air, water and land. Limit conditions may apply to loads, concentration, volume or mass, and frequency of discharges. Conditions may also relate to waste and noise. Monitoring conditions are an important aspect of an environment protection licence. A licence also requires recording of pollution complaints, as well as reporting on licence compliance on an annual basis to the EPA. The Protection of the Environment Operations Act requires the EPA to be notified as soon as practicable of incidents that cause or threaten material harm to the environment.

Pollution reduction programs are another important component of environment protection licences. They provide the EPA with a means of requiring ongoing and progressive environmental improvements to the way in which licensed activities are undertaken. Pollution reduction programs identify activities or processes that should be prioritised for improvement, setting milestones and deliverables to be achieved. Capital works may be involved in such programs, where required to alleviate public health and environmental impacts in sensitive areas.

Environment protection licences remain in force until surrendered by the licence holder or until suspended or revoked by the EPA or the Minister for the Environment. A licence may only be surrendered with the written approval of the EPA. A licensee may request a variation to the licence, and the EPA may also vary the licence at any time.

The Act also requires the EPA to keep a public register of details and decisions of the EPA in relation to, for example, licence applications, licence conditions and variations and statements of compliance. In addition monitoring data submitted to the EPA is available to the public.

Regulating this project and other activities under the Act provides an ongoing framework for DEC to require integrated and progressive improvements to the environmental performance of Orica's operations at Botany Industrial Park.

4.2 Strategic issues raised in submissions

Representations responding to the environmental impact statement raised a range of concerns relating to the strategy as proposed by Orica. These included:

- selection of preferred technology, namely the thermal oxidation unit
- minimising dioxins formation
- compliance with International Conventions on Hazardous Chemicals and Waste
- timetable for clean up
- system maintenance
- environmental monitoring
- waste precinct
- fishing ban
- need for a financial assurance

The determining authorities have noted these concerns and have also considered whether Orica's strategy would deliver the anticipated environmental and public health benefits. These concerns are discussed below.

4.2.1 Selection of preferred technology, in particular the thermal oxidation unit

Several representations opposed the use of the thermal oxidation unit and recommended that steam stripping be used to treat the groundwater (up to 15 mega litres per day). The recovered condensate (approximately 3 tonnes per day) would be stored until an appropriate site for disposal could be found using "*non-incineration*" (sic). This would accumulate at a rate of approximately 1000 tonnes per year, noting the proposal is for treatment over 30 years. Orica has potential for some 10 years' storage capacity.

Orica is currently using a steam stripping unit to treat contaminated groundwater (up to 2 million litres per day). The collected condensate is currently being stored at a rate of around 500 kilograms a day. Since it was recommissioned in October 2004, there is an estimated 6.5 tonnes of condensate, principally 1,2 dichloroethane (EDC), stored to date and awaiting destruction.

While providing an important interim measure the use of a steam stripping unit to treat the required quantity of groundwater (up to 15 million litres per day) was ruled out in the EIS because it does not result in destruction of the contaminants. Some representations objected to any further storage of wastes at the site and raised concerns about the ongoing risks of existing stockpiled waste. For example, they cited concerns over a current stockpile of 10,500 tonnes of hexachlorobenzene wastes at the site that was awaiting determination on its disposal. Orica has funds set aside for the construction of the plant to collect and treat the contaminated groundwater. The determining authorities do not consider alternate options that concentrate, contain and store the contaminants are environmentally responsible. This is because of the legacy this approach would leave for future generations to deal with and the lack of financial certainty that it would be able to be treated later. There are also inherent safety risks associated with the storage and management of concentrates, for example accidents and spills, especially in the longer term.

A representation encouraged the use of bioremediation as an alternative to the use of the groundwater treatment plant and thermal oxidation unit. The EPA notice mandates the use of 'pump and treat' technology (ie *ex situ* treatment) to treat groundwater contamination as it is proven to be effective within the required clean-up timeframe. There are doubts over the effectiveness of the treatment of groundwater in the ground (ie *in situ* processes) and consequently this approach was not considered as part of the project. Orica, however, continues to trial *in situ* methods, including active and passive bioremediation and the use of reactive iron barriers.

Other alternate ‘pump and treat’ technologies were evaluated in the EIS, summarised in Section 2.3.4 of this report. These include gas phase chemical reduction, base catalysed decomposition and the use of plasma arcs. Some public representations recommended the adoption of gas phase chemical reduction (for example ‘Eco-Logic’). These were not selected by Orica because they are not able to deal with volatile chlorinated hydrocarbons but were actually designed for the treatment of POPs. There are no dioxins in the groundwater, however there is the risk that dioxins may be formed from the destruction of volatile chlorinated compounds in the thermal oxidation unit. The relevant technology must destroy volatile chlorinated hydrocarbons as well as minimising or eliminating the production of POPs. Furthermore, while appearing to be able to further minimise the potential for the unintentional production of POPs, these methods have not been successfully trailed on an industrial scale, nor do they minimise the possibility of accidents or ensure occupational health and safety to the same extent as the preferred design.

DEC considers it vital that an integrated and holistic approach be adopted for the collection, treatment and disposal of contaminants in the groundwater. DEC and other determining authorities concur that the technology proposed by Orica (air stripping/thermal oxidation) is consistent with accepted best practice and satisfies stringent international air emission standards. The pump and treat technology selected by Orica is a proven and available technology that can process the required quantity of contaminated groundwater (up to 15 million litres per day). It will reduce to a minimum the amount of POPs, including dioxins, that might be formed from the treatment of the groundwater, any releases to the environment and the associated risks. It consumes few raw materials as it is focused on destroying the contaminants in the groundwater and will be as energy efficient as possible. It is designed to minimise the possibility of accidents or failures and ensures that occupational health and safety is protected. It meets the project time constraints and is the one technology evaluated that has been tried with success on an industrial scale. It also maximises the quantity of extracted water that can be recycled for industrial use significantly reducing the demand on potable supplies.

In making this determination, an independent assessment of the technology and air emissions was undertaken by John Court & Associates Pty Ltd (on behalf of DEC). The assessment concluded that Orica’s preferred technology constitutes a combination of well-known and well-proven technology. Pumping and *ex-situ* treatment of groundwater to remove contaminants has been employed at many locations in North America and Europe for clean up of contaminated groundwater. Air stripping is a well established and characterised chemical engineering process. Thermal oxidation of organic impurities in gas streams before discharge to atmosphere has been a widely used technique in air pollution control technology for over 40 years. The technology and science involved in each of these components have been refined and developed over the long period of their use, so there is no lack of experience in the technology combination proposed by Orica. Each component continues to be extensively used internationally, in jurisdictions with demanding, strict and up-to-date environmental requirements.

The assessment by Court & Associates also indicated concerns regarding gas-phase reduction process as a viable alternative treatment process. Sulfides and organic acids are present in the groundwater and processing of the groundwater by treating the organochlorine compounds with hydrogen in reducing conditions would generally result in production of more odorous materials than those already in the groundwater, due to the formation of odorous organic sulfides and aldehydes. It would be necessary to collect and withdraw a stream containing the odorous, non-condensable materials and treat them through a thermal oxidiser for discharge to atmosphere. These emission concerns, together with the hazards and difficulties associated with handling hydrogen, were also taken into account in reaching the above determination.

Independent assessments of the project undertaken by John Court & Associates Pty Ltd and the United States Environmental Protection Agency on behalf of DEC supported the project in terms of the appropriateness of the technology selected.

The Department of Environment and Heritage (Commonwealth) has also assessed the project. It advised that alternate technologies (in particular gas phase chemical reduction and the base catalysed decomposition processes) would not be appropriate for the destruction of the stripped chemicals and accepts that the thermal oxidation treatment plant appears to be the most appropriate technology for destroying these chemicals. The US EPA also concluded that the treatment technology was reasonable based on its reliability and proven capability to meet emission standards. Both agencies provided advice on elements that should be included during the implementation of this technology. These elements, including operational and monitoring requirements, have subsequently been taken into account in DEC's requirements for the project.

In summary, the determination concludes that the technology selected by Orica is consistent with accepted best practice and satisfies stringent international air emission standards and Australia's obligations for the minimisation of persistent organic pollutants under the Stockholm Convention on Persistent Organic Pollutants. It also maximises the quantity of extracted water that can be recycled for industrial use, significantly reducing the demand on potable supplies.

4.2.2 Minimising dioxin formation

The proposed design of the GTP includes a thermal oxidiser to treat the off-gas from the air strippers. Numerous representations raised objection to the thermal oxidation unit. Many stated that it was an ”incinerator” and stated that the “incineration” of chlorinated compounds is widely recognised as a primary source of dioxins, furans and other toxic by-products.

The reactions that can result in the formation of dioxins and furans are complex and *de novo* synthesis is the dominant mechanism. In the *de novo* mechanism, dioxins are formed by the reaction of chlorine and macromolecular carbon structures. The EIS has identified the following necessary conditions for *de novo* formation of dioxins:

1. solid phase material containing suitable carbon structures (eg soot, charcoal)
2. organic or inorganic chlorine
3. metal catalysts (also solid particles incorporated with 1. above)
4. excess oxygen
5. a temperature window of 250 to 450 °C.

The design of the GTP thermal oxidiser adopts all of the safeguards for dioxins minimisation: high temperature of the oxidiser (1000 ^{o}C), long residence time (2 seconds), and a quench by spraying weak acid through the gas stream to rapidly reduce the temperature of the treated off-gas from 500 ^{o}C to 100 ^{o}C. A rapid quench minimises the potential for *de novo* formation of dioxins by rapidly cooling the gas stream through the optimal formation temperature range of 250 to 450 ^{o}C. These standard safeguards have been adopted even though Orica has identified that the feed stream to the thermal oxidiser is inherently less prone to *de novo* synthesis reactions. Two of the factors normally required for *de novo* dioxins formation, carbon structures and metal catalysts, are absent due to the very low level of particulate matter in the gas stream. Orica expects the contaminated air stream from the groundwater stripping columns to be free of solid particles.

As independent assessment of these design elements was conducted by John Court & Associates Pty Ltd on behalf of DEC. It states there has been extensive research and study of polychlorinated dioxins/furan formation in combustion and industrial processes over the last 20 years. A technical consensus has emerged from this research which concludes that where dioxins are not present in the materials being oxidised, the *de-novo* formation of dioxins occurs primarily in the post combustion-zone where **all** of the following conditions apply:

- chlorine is present
- carbon and/or some form of organic precursor is present
- the gas temperature is in the range 250 to 450 ^oC
- there is a surface on which the reaction can be catalysed, eg particles in the gas or the surface of heat exchange or gas cleaning equipment
- there is a catalyst for the reaction, such as copper or some other metals.

The maximum dioxin formation rate occurs at about 300 ^oC. The assessment by Court & Associates concluded that the design features adopted by Orica meet the requirements for avoiding dioxins formation after the combustion chamber. This is because:

- Combustion of an air stream with low concentrations of organic contaminants at 1000 ^oC for 2 seconds with excess oxygen and turbulent flow should leave no residual gaseous organic materials (dioxin forming ‘precursors’) unconverted to CO_2 or CO and should not generate sooty carbon, given the gaseous flame, good mixing, preheating of combustion air and the high amount of excess air for combustion.
- Generation of the organic materials by air stripping (volatilisation) ensures that solid and inorganic materials in the groundwater will not be transferred to the gas stream, thereby eliminating the potential for solid particles formation as a surface for dioxins formation.
- Efficient mist elimination in the air strippers will effectively prevent carry-over of liquid droplets containing non-volatile material to the thermal oxidiser, thereby ensuring no inorganic solid particle formation as a surface for dioxins formation.
- Metals that are known to catalyse dioxins formation, such as copper and zinc (present in municipal waste), are unlikely to be present: the copper content of groundwater is 0.00129 mg/L and zinc 0.017 mg/L and these will not be volatilised in the stripper or carried over.
- The temperature window for dioxins formation (250-450 ^oC) will be rapidly traversed in the quench tower.

These conditions should avoid dioxins formation beyond trace quantities, ie well less than the internationally accepted design standard of 0.1 ng TEQ/m^3 that has been adopted for the groundwater treatment plant. One nanogram is equal to 10^{-12} grams.

Court & Associates also indicates that this is further supported by published and peer reviewed literature on the performance of catalytic and thermal oxidisers treating dilute chlorinated vapours, drawing on results from emission testing of plants operating in California desorbing vapours from contaminated soils. For thermal oxidisers the principal cogener formed was octachloro dibenzo-dioxin (OCDD), the least toxic on the TEF scale. The oxidisers operated from 773 to 927 ^oC and with residence times of 0.5 to 1 second, less intense than the oxidising conditions proposed for the Orica unit (1000 ^oC for 2 seconds). The emission rates reported for the thermal oxidiser were very low at 0.005 ng TEQ/m^3, or, expressed as a molar conversion, 10^{-12} of the feed organochlorine. For 500 ppm EDC entering the Orica thermal oxidiser this would correspond to an emission from the unit of well less than 0.01 ng TEQ/m^3. These results for thermal oxidisers are from closely comparable situations to the Orica proposal and give confidence that the manufacturer’s assurances and the conclusion drawn from the engineering principles above are sound.

The independent review by Court & Associates also concluded that the predicted levels of dioxins exposure from emissions from the groundwater treatment plant are very low. The maximum predicted ambient concentration is 0.19 fg TEQ/m3 (annual average). One fentogram is equal to 10^{-15} grams or a millionth trillionth of a gram. This is several orders of magnitude lower than typical reported values in Australian urban areas of 10 to 20 fg TEQ/m3. The Victorian EPA design criteria for a 3 minute average is 3700 fg TEQ/m3. Allowing for a very conservative factor between the 3 minute average and the corresponding average, there would still be a wide margin of safety for the predicted emission for the groundwater treatment plant, namely 19 fg TEQ/m3 against 3700 fg TEQ/m3 allowed on a 3 minute average.

The determination has concluded that Orica can design and operate the GTP to achieve international best practice emission concentration limits for dioxins and furans and all air pollutants. DEC has attached conditions to the licence that require Orica to meet these best-practice emission concentration limits as never to be exceeded (100th percentile limits). The conditions also require regular monitoring of dioxins and furans in the emissions from the groundwater treatment plant. The continuous monitoring of other pollutants, (for example carbon monoxide and oxygen) and thermal oxidation operating parameters (for example temperature and residence time) will ensure maximum destruction of contaminants and conditions conducive to the formation of dioxins and furans are minimised at all times.

As a further safeguard, DEC has also required Orica as a licence requirement to:

- Regularly validate the predictions and conclusions in the EIS and demonstrate that the groundwater treatment plant can meet or perform better than the internationally recognised design standard of 0.1 ng TEQ/m^3
- Implement a Dioxin Minimisation Program to:
    - investigate technical options and scientific developments which would allow continuous monitoring and/or sampling of any dioxin that may be emitted from the groundwater treatment plant.
    - investigate chemical and/or physical parameters that are likely to correlate with the actual or potential formation of dioxins and could be used as a surrogate indicator of dioxins formation in the groundwater treatment plant; and
- regularly review monitoring programs, including substances monitored and frequency of monitoring to ensure dioxins can be detected and effective measures are in place to ensure their formation is minimised at all times.
- Undertake a Thermal Oxidation Unit Validation Program to ensure the performance of the thermal oxidation unit to ensure it achieves its stated performance and the formation of dioxins is minimised at all times.

4.2.3 Compliance with International Conventions on Hazardous Chemicals and Wastes

Several submissions objected to the project on the grounds that it was contrary to the Stockholm Convention on Persistent Organic Pollutants (POPs), particularly as the plant includes a thermal oxidation unit. Some submissions referred to the unit as a “waste incinerator” and believed it would be a significant source of dioxins.

The Stockholm Convention seeks the elimination or restriction of production and use of all intentionally produced POPs (Article 3). It requires parties to take measures to reduce or feasibly eliminate releases of by-product POPs that are produced unintentionally (Article 5). It also requires that stockpiles and wastes containing POPs are managed in a manner protective of human health and the environment (Article 6). The convention obliges parties to develop strategies for identifying POP wastes and to manage these in an environmentally sound manner. Where the POP content of wastes is to be destroyed or irreversibly transformed or otherwise disposed of, it must be done in an environmentally sound manner (Article 6). It is important to note that the contaminated groundwater does not contain dioxins, so only Article 5 and Annex C directly relate to the Orica groundwater cleanup project.

Additional information in Annex C of the Convention about aspects to be addressed when considering the possibility of unintentional production in any newly-proposed facility provides guidance to DEC in its consideration of Orica’s proposal. Part II of this Annex identifies industry source categories that have the potential for comparatively high formation and release of these chemicals, in particular dioxins and furans, to the environment. One of those source categories is waste incinerators, including co-incinerators of municipal, hazardous or medical waste or of sewage sludge. With regards to the Orica project, however, it should be noted that air stripping of contaminants from water results in a much cleaner input to the thermal oxidation unit than does thermal desorption of contaminants in soils or the direct oxidation of wastes.

Part V of this Annex provides general guidance on best available techniques and best environmental practices to be considered when establishing a facility where dioxins may be unintentionally produced, such as a waste incinerator, identified as a source category in Part II. It provides a list of general prevention measures and guidance for determining what constitutes best available techniques. When considering what constitutes best available technique, the convention states that no specific technique or technology is prescribed or precluded, indicates that issues to be evaluated include:

- the technical characteristics of the installation concerned
- its geographical location
- the local environmental conditions
- the nature and size of the source of unintentional POPs
- how urgently the facility is required
- whether there are comparable processes or methods of operations that have been tried with success on an industrial scale
- technological advances and changes in scientific knowledge
- the need to prevent or reduce the overall impact of the releases to the environment and the risks.

Consideration of all these factors needs to occur, bearing in mind the likely costs and benefits of the measure and consideration of precaution and prevention. Priority should always be given to processes, techniques or practices that avoid the formation and release of unintentional POPs.

This part of the Annex goes on to provide a list of release reduction measures to be applied wherever possible for the source categories listed in Part II, which include:

- use of improved methods for flue gas cleaning, such as thermal and catalytic oxidation, dust precipitation or adsorption
- treatment of wastes and wastewaters, for example by thermal treatment, rendering them inert or chemical processes that detoxify them
- process changes that lead to the reduction or elimination of releases, such as moving to closed systems
- modifications of process designs to improve combustion and prevent formation of the chemicals listed, through the control of parameters such as incineration temperature and residence time.

The EIS included an assessment of possible technologies, which allow all of these issues to be evaluated for the project.

The groundwater treatment plant is being proposed to enable the collection and treatment of a large volume of contaminated groundwater as part of Orica’s commitment to meeting an EPA Notice of Clean Up. This places constraints on the location of the facility and the urgency with which the facility needs to be established. It also means some of the general prevention/avoidance measures listed in the Stockholm Convention and raised in the submissions are not triggered. For example, it is not possible to use less hazardous substances or institute reuse and recycling of these waste materials or to replace feed materials with less problematic ones. As a result, the focus of the evaluation has to be on which technology best complies with the guidance on best available techniques rather than on doing something other than destroying the contaminants in the groundwater.

The plant design proposed by Orica will reduce to a minimum the amount of POPs, including dioxins, that might be formed from the treatment of the groundwater, any releases to the environment and the associated risks. It consumes few raw materials, as it is focused on destroying the contaminants in the groundwater, and will be as energy efficient as possible. It is designed to minimise the possibility of accidents or failures and ensures that occupational health and safety is protected. It meets the timing constraints for the operation and is the one technology evaluated that has been tried with success on an industrial scale, incorporating recent advances in chemical engineering and scientific knowledge.

The plant design proposed by Orica has also incorporated all relevant release reduction measures listed in Annex C to the Stockholm Convention. The plant is using thermal oxidation as a flue gas cleaning method to destroy the chemicals in the air stream prior to discharge. The process includes measures to reduce formation and release of POPs, such as operating the thermal oxidiser at 1000 °C and holding the off-gases for at least 2 seconds at this temperature to ensure efficiency of combustion. It also includes a quench to minimise the potential for *de novo* formation of dioxins by rapidly reducing the temperature of the treated off-gas exiting the thermal oxidation unit through the optimal formation temperature window of 250 to 450 ºC.

Other technologies that were evaluated in the EIS fail the above evaluation in a number of ways. Some of the alternate technologies do not result in destruction of the contaminants, but instead store the condensate for a later time leaving legacy issues for future generations. Several public representations objected strongly to these ‘concentrate and contain’ options. Some of the alternate technologies are not able to deal with volatile chlorinated hydrocarbons but were actually designed for the treatment of other POPs, in particular polychlorinated biphenyls. The focus of this project is the destruction of the volatile chlorinated hydrocarbons so any relevant technology needs to be able to destroy these chemicals as well as minimising or eliminating the production of POPs. Some of the alternative technologies, while appearing to be able to further minimise the potential for the unintentional production of POPs, have not been successfully trialled on an industrial scale, do not provide treatment of groundwater at the required capacity and do not minimise the possibility of accidents or ensure occupational health and safety to the same extent as the preferred design.

In finalising this position DEC also sought advice from the Department of Environment and Heritage (Commonwealth). Initial advice recommended Orica further explore all alternatives for collection and treatment of groundwater contaminants, further justify the selected technology and demonstrate that it was consistent with the Stockholm Convention. DEC sought further advice from Orica and John Court & Associates Pty Ltd in relation to these recommendations and provided it to Environment and Heritage. Environment and Heritage has advised that, provided the thermal oxidation treatment plant operates in accordance with the above requirements, it holds the view that the operation would not present a problem in terms of Australia’s obligations under the Stockholm Convention on Persistent Organic Pollutants.

On the basis of the above, DEC is confident that the EIS has addressed the requirements of the Stockholm Convention in the design, installation, operation and maintenance of the groundwater treatment system. Consistent with the convention, this will ensure the formation of dioxins is prevented or avoided to the greatest extent possible, taking into account applicable international standards and guidelines.

The convention states that guidance is being prepared on best environmental practices. The EIS refers to a draft document currently being developed. Some representations objected to Orica’s reliance on these draft guidelines to justify the selected technology in the EIS. In assessing and determining this proposal DEC has focused on the implementation of the existing and ratified Convention, in particular Article 5 and Annex C. DEC can review and if necessary vary its licensing requirements should new information come to light following the release of the final version of these guidelines or receipt of any other relevant technical or environmental data.

One submission referred to the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal* and the *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*. It states that these conventions are inadequate in their omission of any discussion of the issues related to the destruction of hazardous wastes by any method in populated areas. These conventions relate to ensuring that the transport of hazardous wastes between countries is done safely and in an informed way. Regulation of destruction of hazardous wastes within a country are subject to the legislative framework of that country. Orica does not intend to move the wastes they have generated to another country so these conventions do not apply. The Basel Convention (Article 4) does however require each party to minimise waste generation and to ensure, to the extent possible, the availability of disposal facilities within its own territory.

4.2.4 Timetable for clean up

Some representations raised concerns over perceived delays in DEC issuing a notice of Clean Up Action and that this resulted in a lack of duty of care by the government to address the contamination issue.

DEC (and formerly the EPA) has regulated groundwater remediation in and around Botany Industrial Park for many years. The focus of this work has been on stopping further contamination, fixing up surface drainage, soil remediation works and investigation of groundwater contamination. The Notice of Clean Up Action, while a key component, is only one aspect of these regulatory activities. Further information on DEC action to date is provided in Section 2.

Some representations stated that the amount of time (30 days) provided by DEC for public exhibition of the EIS was inadequate. Part V of the EPA and A Act requires EIS to be exhibited for 30 days. Orica undertook extensive consultation with relevant government agencies and the community during the environmental impact assessment process. This is detailed in the EIS and included planning focus meetings and numerous workshops.

Some representations raised concerns about the tight timeframe for the assessment and determination of the project. The government’s priority is to ensure that the migration of contaminated groundwater is stopped and remediated as quickly as possible, subject to an adequate level of assessment and the necessary approvals being obtained. In order to satisfy the requirements of the DEC Notice of Clean Up Action and allow for construction and commissioning of the necessary works to protect the sensitive marine ecosystems of Penrhyn Estuary and Botany Bay, Orica must obtain a variation to the existing environment protection licence to allow the project to commence in February 2005.

4.2.5 System maintenance

Orica has indicated in the EIS that collection and treatment of the plume may take up to 30 years. A number of representations raised concerns about the ability of the government and Orica to maintain the system over this time and questioned who would be accountable for its reliability and ensuring its safe and effective operation.

The environment protection licence provides an ongoing framework for DEC to require integrated and progressive improvements to the environmental performance of Orica’s operations at Botany Industrial Park. As part of its determination DEC has included conditions in the environment protection licence for the project that require the effective and efficient management and competent operation of the groundwater treatment system and ensure it is maintained to achieve ongoing environmental improvement.

This determination also took into account comments from John Court & Associates Pty Ltd, US EPA and the Department of Environment and Heritage on the importance of the integrity of the groundwater treatment plant, especially in the longer term. Given the anticipated long life of the plant and the importance of it operating at a high level of performance throughout its life, DEC has included a requirement in its licence for Orica to undertake periodic engineering audits to ensure the performance of the plant will not deteriorate in the longer term. These audits must occur with increasing frequency as the plant continues to operate.

4.2.6 Environmental monitoring.

Several submissions raised concerns about the adequacy of existing monitoring programs and called for a comprehensive monitoring program.

Orica has proposed extensive monitoring for the construction as well as the operational phase of the project, in particular parameters that indicate the effectiveness of the operation of the groundwater treatment plant. This includes monitoring stack emissions, water discharges and a range of other parameters to ensure proper operation of the GTP.

The determination concludes that ensuring the development of monitoring programs that can adequately demonstrate proper operation of the GTP is a critical aspect of the project and forms an important part of its approval. Consequently, conditions have been attached to the instruments of approval that require the development and implementation of comprehensive monitoring programs for both the groundwater collection and treatment system and receiving environment zones.

Representations also called for independent monitoring programs. Some expressed concern over reliance on industry self-monitoring. Monitoring by industry is required because industry has a responsibility to ensure the ongoing verification of the environmental performance of its activities. The determining authorities support measures that enhance independent audit systems. DEC has required the development and implementation of validation audits of the performance of the groundwater treatment plant by an independent expert.

Orica has indicated that it is committed to establishing an independent technical panel, which would have access to all monitoring data for the operation of the groundwater treatment plant. Orica intends to discuss the establishment of this panel with the Community Liaison Committee in early 2005. DEC has required the formation of this independent panel as a condition of its environment protection licence for the project. The panel must include community representatives and be consulted in the selection of the independent auditor to conduct the validation audits.

Some representations requested ambient air quality environmental monitoring be carried out, in particular at Banksmeadow Primary School. DEC’s focus is on ensuring the groundwater treatment plant and associated infrastructure does not result in air emissions that could cause adverse impacts to the environment or human health. Our priority is to ensure stringent air emission limits and monitoring regimes at the source of potential pollution. This is because there are limitations in the effectiveness of ambient (off-site) monitoring programs to detect changes in the environmental performance of plant and equipment.

As conditions of licence DEC has required Orica to comply with strict source emission limits monitoring and reporting requirements and undertake an air, water and noise emission validation program. This program requires Orica to demonstrate that the strict emission and discharge limits of the licence have been complied with so that any discharges do not cause off-site impacts in adjoining residential or other sensitive locations.

In arriving at this position DEC has taken into account independent advice from Court & Associates. Because of this very low level of predicted contribution to ambient dioxins from the plant, it is not feasible to undertake meaningful ambient monitoring to track exposure, as desirable as this might be from the perspective of public concern. Nor is it possible to identify a marker emission from the process. The other emissions considered (CO, PM_{10}, SO_2, Cl_2, HCl and VOC) would all be present from other sources in higher concentrations at Botany. The most feasible approach for monitoring the plant is emission monitoring coupled with background odour observation and auditing.

4.2.7 Fishing ban

In September 2003, DEC collected oysters from Penrhyn Estuary. None of the solvents in the plume were expected to be accumulated by the oysters and the analysis confirmed this, however, they were found to contain mercury and hexachlorobenzene. Orica was asked to do a more thorough study of fish and shellfish, which it presented in mid 2004. DEC, NSW Health, NSW Food Authority and the Department of Primary Industries reviewed the information and decided to formalise a fishing ban in the estuary. Prior to this there were advisory signs warning the public not to swim or fish there. The fishing ban was gazetted in November 2004. The contaminants found in the fish and shellfish are believed to be from historic contamination of the sediments of Penrhyn estuary.

4.2.8 Waste precinct

Some submissions called for the establishment of a ‘Hazardous Waste Precinct’, along the lines of those being established by the Western Australia EPA. These submissions stated that in Western Australia the State Government has approved tougher criteria for establishing precincts containing new and better hazardous waste treatment facilities in Western Australia. This is based upon detailed technology suitability criteria and site selection criteria developed by the Core Consultative Committee (3C) on Waste. The 3C has members from community and environmental organisations, industry, union and local government.

It is important to understand the context in which the 3C and their criteria were developed. The 3C were established by the WA Waste Management Board in 2002 to promote advice and open discussion about waste management issues. During 2003 the role of the 3C was expanded to give greater attention and priority to stakeholder concerns regarding the management of hazardous waste in the state. The main trigger for this was a major fire at the waste control site in Bellevue, where hazardous wastes were inappropriately stored and managed. The 3C and the WA government saw the establishment of a specific hazardous waste treatment precinct (or a number of smaller precincts) as an opportunity for both more transparent regulation and public engagement in monitoring the management and regulation of hazardous waste treatment. The 3C’s role is to facilitate stakeholder involvement to advise government on establishing new and better hazardous waste facilities in WA. The 3C has been involved in a broader framework of minimising hazardous waste generation and regulating hazardous waste more effectively. The 3C has facilitated stakeholder consultation on a technology suitability criteria and a site selection criteria.

Many submissions received referred to the 3C site and technology selection criteria. In particular, the site selection criterion, which includes a minimum three-kilometre buffer from the nearest sensitive land use, with a desirable buffer distance of six kilometres. DEC notes that the buffer zones are not areas devoid of all human activity, but areas from which sensitive land uses will be excluded. ‘Sensitive land uses’ are defined as “areas zoned residential, motels and hotels, caravan parks, hospitals and nursing homes, schools and other educational establishments, shopping centres and some public buildings”. The 3C recommended buffer distances that are large by world standards and are larger than those routinely recommended by the WA EPA and Department of Planning and Infrastructure approvals and planning processes. This is not achievable in or around the Botany Industrial Park.

It is also important to note that the Orica project is in response to a Notice of Clean Up Action for collection and treatment of contaminated groundwater in and around Botany Industrial Park. For this reason the groundwater treatment plant must be located where the groundwater remediation will occur. The Botany project will be treating only contaminated groundwater from the site, and this is an additional plant within the facility, not an application for a new facility. The Orica example is in distinct contrast to the establishment of a new hazardous waste treatment facility where the 3C site selection criteria can be more readily and appropriately applied.

While maximising buffer distances as far as practicable is encouraged, DEC's focus is on minimising risks to the environment and human health from the source of pollution.

4.2.9 Financial Assurance

Some submissions requested DEC require the collection of a financial assurance to be maintained during the operation of the facility and thereafter until such time as all parties are satisfied that the groundwater has been appropriately remediated and is environmentally secure. These calls arise from a concern that Orica may withdraw from or not have the financial capacity to meet its responsibilities to address the contamination issues, especially in the longer term. Amounts of $50 million were suggested in some representations.

Orica has made major and public commitments to the government and community regarding the clean up of the groundwater contamination. The Orica Board of Directors has committed $167 million (before tax) of shareholders funds to the project. These funds have been allocated to the project in the statutory accounts of the company, which have been signed off by its auditors and announced to the Australian Stock Exchange. Orica is required to publish details of expenditure in its annual report (including auditor comment). For these reasons Orica did not support the lodgement of a financial assurance.

DEC has maintained a strong regulatory approach with respect to Orica to ensure groundwater is appropriately remediated. It regulates the site through an existing EPA licence and Notice of Clean Up Action issued under the POEO Act. These publicly available statutory instruments are legally binding on Orica. Should Orica fail to comply with these requirements DEC has a range of powers available to take appropriate regulatory action in accordance with the EPA Prosecution Guidelines.

The contamination is also regulated under the Contaminated Land Management Act. As stated in Section 1, the EPA agreed to a series of voluntary investigation and remediation proposals under the CLM Act and proposes to declare land affected by contamination a remediation site. This declaration serves to tag contamination as presenting a significant risk of harm (as defined under the Act). Only when DEC is satisfied that the SRoH caused by the contamination has been addressed, can the declaration be removed.

Under the POEO Act (Section 70 and Part 9.4)*,* DEC can require a financial assurance to secure or guarantee funding for or towards remediation or pollution reduction programs from the occupier of a scheduled (licensed) premises. DEC needs to be satisfied that it is justified having regards to:

- the degree of risk of environmental harm associated with the activities under the licence
- the remediation work that may be required because of activities under the licence
- the environmental record of the holder of the licence or former holder of the licence, or proposed holder of the licence, or
- any other matters prescribed by the regulations (under the Act).

While DEC is satisfied that Orica has the funds set aside for the treatment plant, it cannot be certain about, for example, the commercial or economic factors which may affect Orica's financial or legal capacity to operate the plant for the entire period of up to 30 years. Therefore, DEC has included a condition to the licence requiring the establishment of a financial assurance to cover the operation of the plant through to completion of the required remediation. It will not cover the initial construction of the plant. The final amount will be determined by the EPA following its consideration of reports from an independent expert and may be reviewed from time to time in line with the remaining works to complete the groundwater remediation.

5 Consideration of key environmental issues

This section outlines the determining authorities' consideration of key environmental issues relating to the current proposal, having regard to information presented in the environmental impact statement and other additional information obtained. Where appropriate, conditions attached to the determining authority approvals reflect action taken to address particular issues.

It should be noted that private individuals who made representations to the environmental impact statement have not been identified in order to maintain their privacy.

5.1 Introduction

The determining authorities have reviewed the EIS and supporting information for the project and duly considered the submissions from government agencies, councils and the public. As a result, the determining authorities have identified the following key environmental issues. A full consideration of each of the issues listed is provided in sections 5.1 to 5.10 of this report.

Issues:
- air quality impacts
- surface and wastewater
- soil and groundwater contamination
- impacts on flora, fauna and heritage
- hazard and risk
- waste management
- noise impacts
- traffic and transport impacts
- socio-economic impacts
- cumulative impacts.

5.1.1 Air quality impacts

5.1.1.1 Sources of emissions.

The EIS has identified the groundwater treatment plant (GTP) as the main source of air emissions from the project. The GTP includes a 20-metre-high stack through which the air stream from the treatment process will be exhausted. DEC requested additional information on fugitive air emissions associated with the GTPt and transfer pipelines to ensure these emissions will be minimised. The EIS has identified each source of fugitive air emissions associated with the GTP and transfer pipeline and provided an assessment of the potential for fugitive emissions to atmosphere from each source. The potential for fugitive air emissions from the GTP and transfer pipelines is considered in the EIS to be negligible.

The EIS has proposed a leak detection and repair (LDAR) program as a mitigation measure for monitoring and minimising fugitive emissions. DEC considers a LDAR Program fundamental to ensure fugitive Volatile Organic Compound (VOC) emissions are minimised and has consequently attached conditions to the licence that requires a LDAR program be conducted over the lifetime of the project.

5.1.1.2 Characterisation of emissions.

Numerous representations raised a range of issues relating to emissions from the GTP as a result of using thermal oxidation to destroy the contaminants in the air stream. These included concerns over the pollutants likely to be discharged to air and a clear need for them to be fully identified and characterised. Of particular interest were pollutants known to be harmful to human health including VOCs, dioxins, furans and polycyclic aromatic hydrocarbons (PAHs).

The EIS has identified the key pollutants to the atmosphere from the proposal will include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulates (PM_{10}), carbon monoxide (CO), chlorine (Cl_2), hydrogen chloride (HCl), hydrogen sulfide (H_2S), dioxins and furans, and the following volatile organic compounds (VOCs): 1-2 dichloroethane (also known as ethylene dichloride or EDC), vinyl chloride, trichloroethene, benzene, 1,1,2 trichloroethane, 1,1,2,2 tetrachloroethane, chloroform, carbon tetrachloride, cis-1,2 dichloroethene, tetrachloroethene and phenol.

5.1.1.3 Stack emission limits

The proposed stack emission concentration limits for the GTP are provided in Table 1 together with the corresponding 100th percentile and 97th percentile emission limits from the European Directive on the incineration of waste (European Directive 2000/76/EC). DEC considers the proposed emission concentration limits to reflect the adoption of best practice, as required by Condition 6 of the Notice of Clean Up Action, as they are equivalent to, or more stringent than, the European Directive 2000/76/EC 100th percentile limits. For pollutants not included in the European Directive 2000/76/EC, such as Cl_2 and vinyl chloride, the proposed emission concentration limits are equivalent to other international standards.

Orica has suggested that the proposed emission concentration limits are 90th percentile for pollutants that will be continuously monitored and 100th percentile for pollutants that are monitored manually. DEC does not accept this proposal and has determined that all air emission concentration limits for the GTP in the EPA licence will be set as 100th percentile, regardless of the type of monitoring. The proposed emission concentration limits are equivalent to the European Directive 2000/76/EC 100th percentile limits and were assessed as 100th percentile limits in the air quality impact assessment. DEC has set GTP stack emission concentration limits in the licence for each pollutant based on the information in Table 1.

Table 1 Summary of emission concentration limits

Pollutant	**EIS Proposed**			**European Directive 2000/76/EC**			**EPA Licence**
	Limit	**Percentile**	**100th percentile 30 minute average**	**97th percentile 30 minute average**	**Averaging period**	**100th percentile 30 minute average**	**100th percentile**
NO_X	400 mg/m^3 @ 11% O_2	100th	400 mg/m^3 @ 11% O_2	200 mg/m3 @ 11% O_2	1 hour	400 mg/m^3 @ 11% O_2	400 mg/m3 @ 11% O_2
SO_2	100 mg/m^3 @ 11% O_2	100th	200 mg/m^3 @ 11% O_2	50 mg/m^3 @ 11% O_2	1 hour	200 mg/m^3 @ 11% O_2	100 mg/m^3 @ 11% O_2
CO	100 mg/m^3 @ 11% O_2	**90th**	100 mg/m^3 @ 11% O_2	-	1 hour	100 mg/m^3 @ 11% O_2	100 mg/m^3 @ 11% O_2

Particulates	20 mg/m^3 @ 11% O$_2$	100th	30 mg/m^3 @ 11% O$_2$	10 mg/m^3 @ 11% O$_2$	1 hour	30 mg/m^3 @ 11% O$_2$	20 mg/m^3 @ 11% O$_2$
HCl	30 mg/m^3 @ 11% O$_2$	**90th**	60 mg/m^3 @ 11% O$_2$	10 mg/m^3 @ 11% O$_2$	1 hour	60 mg/m^3 @ 11% O$_2$	30 mg/m^3 @ 11% O$_2$
Cl$_2$ [1]	30 mg/m^3 @ 11% O$_2$	100th			1 hour		30 mg/m^3 @ 11% O$_2$
Dioxins/ furans [2]	0.1 ng/m^3 @ 11% O$_2$	100th	0.1 ng/m^3 @ 11% O$_2$		1 hour	0.1 ng/m^3 @ 11% O$_2$	0.1 ng/m^3 @ 11% O$_2$
VOCs	10 mg/m^3 @ 11% O$_2$	**90th**	20 mg/m^3 @ 11% O$_2$	10 mg/m^3 @ 11% O$_2$	1 hour	20 mg/m^3 @ 11% O$_2$	10 mg/m^3 @ 11% O$_2$
H$_2$S	2 mg/m^3 @ 11% O$_2$	100th	-	-	1 hour	-	2 mg/m^3 @ 11% O$_2$
Vinyl chloride monomer [3]	10 ppm @ 11% O$_2$, <50 g/hr	**90th**	-	-	3 hours	-	10 ppm @ 11% O$_2$,
1,2 Dichloroethane (ethylene dichloride)	-	**-**	-	-	-	-	8 mg/m^3 @ 11% O$_2$,

Notes:

1. Cl$_2$ limit is a significant reduction on the requirements under the Clean Air (Plant and Equipment) Regulation 1997 (200 mg/m^3) and is equivalent to the Japanese value.
2. ng/m^3 = nanograms per cubic metre. One nanogram is 10^{-9} grams
3. Vinyl chloride limit of 10 ppm is equivalent to the US limit in the National Emission Standard for Vinyl Chloride for control systems serving vents in vinyl chloride service. An emission limit for vinyl chloride of 50 g/hr is equivalent to the limit in the Californian South Coast Air Quality Management District Rule 11163 Control of Vinyl Chloride Emissions.
4. 100th percentile air emission concentration limit for ethylene dichloride based on the results of the air quality impact assessment

5.1.1.4 Assessment of air emissions and potential impacts

A large number of representations raised concerns about the impact of emissions from the GTP on ambient air quality as a result of using thermal oxidation to destroy the contaminated air stream. These concerns were heightened by the proximity of the proposed plant (and stack) to residences and other sensitive receivers, like child care facilities. Representations raised concerns about potential harmful emissions from the plant, for example dioxins and VOCs, in particular during plant upsets.

Orica has undertaken an air quality impact assessment for the project. In particular, Orica has assessed the air quality impact of the following scenarios:

- normal operation of the GTP for all key air pollutants;
- abnormal operation of the GTP for VOC key air pollutants and H$_2$S
- normal operation of the GTP and current Botany Industrial Park emissions for NO$_2$, SO$_2$, PM$_{10}$, CO, HCl and Cl$_2$.

Two abnormal operating scenarios for the GTP have been identified by Orica for which the event occurrence is estimated at once per 50,000 years:

- maximum dioxins concentration increases to 0.5 ng/m^3 due to a fault with the temperature control at the same time as a failure of automatic shutdown system linked to low temperature monitor and failure of other indicators of incorrect operation or not responded to by operator
- effective destruction of the contaminants minimal due to low temperatures in the thermal oxidiser at the same time as a failure of automatic shutdown system linked to low temperature monitor and failure of other indicators of incorrect operation or not responded to by operator.

DEC is generally satisfied that the air quality impact assessment has been conducted in accordance with the requirements of the *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW*. For each scenario, Orica has predicted ground-level concentrations of the key pollutants at 14 discrete receptors and outside the boundary of the premise using the CALMET/CALPUFF atmospheric dispersion model. The discrete receptors include schools, a childcare centre, retirement village, sporting venues and residences.

Predicted ground-level concentrations are compared with DEC's impact assessment criteria as specified in the *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW*. DEC also compared the predicted ground-level concentrations for the VOC key pollutants against the impact assessment criteria in DEC's *Draft Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW, 2004*. These updated impact assessment criteria were derived from the Victorian EPA's ground-level concentration criteria, based on more up-to-date information regarding the health effects of pollutants. The results of the impact assessment for each scenario are summarised in Table 2 together with the DEC and Draft DEC impact assessment criteria.

Table 2 Summary of air quality impact assessment results

Pollutant	**DEC Impact assessment criteria**		**Draft DEC impact assessment criteria ($\mu g/m^3$)**	**Maximum predicted ground-level concentration**		
	Averaging period	**Concentration ($\mu g/m^3$)**		**Normal operation of GTP ($\mu g/m^3$)**	**Abnormal operation of GTP ($\mu g/m^3$)**	**Normal operation of GTP and current BIP emissions [1] ($\mu g/m^3$)**
Nitrogen dioxide	1 hour	246	N/A	63	N/A	144 [2]
	annual	62	N/A	0.8	N/A	27 [2]
Sulfur dioxide	10 minutes	712	N/A	22	N/A	671
	1 hour	570	N/A	15.6	N/A	469
	24 hours	228	N/A	2	N/A	85
	annual	60	N/A	0.2	N/A	26
PM_{10}	24 hours	50	N/A	0.5	N/A	37
	annual	30	N/A	0.04	N/A	19
Carbon monoxide	1 hour	30 mg/m^3	N/A	15.6	N/A	111
	8 hour	10 mg/m^3	N/A	4.6	N/A	37
Chlorine	3 minute		N/A	3.7	N/A	15
Hydrogen chloride	3 minute		N/A	3.7	N/A	19
Hydrogen sulfide [3]	nose response	1.38	N/A	1.2	73 [4]	
Ethylene dichloride [5]	3 minute	6700	130	3.72	6426	N/A
Vinyl chloride [5]	3 minute	100	43	0.13	227	N/A
Trichloroethene [5]	3 minute	NA	900	0.16	274	N/A
Benzene [5]	3 minute	100	53	0.02	31	N/A
1,1,2 Trichloroethane [5]	3 minute	1500	1800	0.02	31	N/A
1,1,2,2 Tetrachloroethane [5]	3 minute	NA	NA	0.03	55	N/A
Chloroform [5]	3 minute	1590	1600	0.11	190	N/A
Carbon tetrachloride [5]	3 minute	1100	21	0.35	599	N/A
cis-1,2 Dichloroethene [5]	3 minute	NA	26300	0.03	49	N/A
Tetrachloroethene [5]	3 minute	NA	11200	0.30	516	N/A
Phenol [5]	3 minute	36	36	$5.1x10^{-5}$	-	N/A

Notes:
1. Concentrations are based on predicted ground-level concentrations in the EIS and so does not include the revised GTP stack design. Revised design of the GTP includes a higher stack and increased stack exit velocity, which will result in a greater dispersion of pollutants.
2. NO_2 concentrations are maximum predicted at a nearest sensitive receptor.

3. H_2S concentrations are maximum 99th percentile predicted at the nearest sensitive receptor and do not include revised GTP stack design.
4. The H_2S impact assessment criteria of 1.38 $\mu g/m^3$ is not appropriate for atypical operation of the groundwater treatment plant. Odour threshold for H_2S is 6.3 $\mu g/m^3$ and health effects (eye irritation) occur at 42,000 $\mu g/m^3$.
5. Predicted concentrations are 99.9th percentile.

The results of the impact assessment indicate:

- Normal Operation of GTP:
  - all predicted ground-level concentrations comply with DEC and Victorian EPA impact assessment criteria
  - most significant GTP air emission is hydrogen sulfide and the maximum H_2S ground-level concentration at a sensitive receptor is 87% of the assessment criterion
  - based on DEC's draft impact assessment criteria, the most significant VOC emission from the GTP is ethylene dichloride, being 3% of criterion. The air quality impact assessment in the EIS concluded that vinyl chloride was the most significant VOC emission from the GTP based on DEC's impact assessment criteria.
- Abnormal Operation of GTP:
  - predicted ground-level concentrations of vinyl chloride exceed the DEC and draft DEC impact assessment criteria
  - predicted ground-level concentrations of ethylene dichloride and carbon tetrachloride exceed the draft DEC impact assessment criteria
  - H_2S odours are likely to be detected at the discrete receptors, however, no adverse health effects would be expected.
- Normal Operation of GTP and current BIP emissions:
  - all predicted ground-level concentrations comply with DEC impact assessment criteria.

DEC is generally satisfied that Orica has undertaken an appropriate air impact assessment for the proposed development and adequately demonstrated the project can achieve DEC's environmental outcomes for air quality.

This determination is also supported by independent assessments of the air emissions by John Court & Associates Pty Ltd and the US EPA. Court & Associates states that the air quality impact has been appropriately and adequately assessed in the EIS by dispersion modelling and all relevant pollutants are within ambient guidelines and/or health criteria during normal operations.

As stated in Section 4.2.2 of this report, predicted dioxins ambient concentrations from the plant operation are very low in comparison to urban dioxins levels and ambient guidelines. The US EPA also states that the proposed selection of air stripping and thermal oxidation is based on reliable technology and a proven capability to meet emission standards. Both also provided advice on operational and monitoring requirements that have subsequently been taken into account in DEC's requirements for the project.

DEC has attached licence conditions such as emission concentration limits for the GTP stack and either continuous or periodic monitoring for all key pollutants. These conditions will ensure the plant is continually performing at or exceeding international best practice and not resulting in adverse local air quality impacts. The basis for the licence conditions are specified below:

- GTP stack 100th percentile air emission concentration limits for Cl_2, HCl, NO_X, solid particles, total VOCs, dioxins and furans, CO, SO_2, H_2S and vinyl chloride based on the proposed limits in Table 1;
- GTP stack 100th percentile air emission concentration limit for ethylene dichloride based on the results of the air quality impact assessment
- continuous HCl, total VOCs, CO, vinyl chloride and 1,2-dichloroethane monitoring to ensure the GTP is continually achieving the stated performance for these pollutants. Continuous monitoring of total VOCs and CO is also a surrogate for continuous monitoring of combustion performance and hence destruction of contaminants

- quarterly monitoring for Cl_2 , H_2S, NO_2 to ensure the GTP is achieving the stated performance for chlorine
- monthly monitoring for the first six months then quarterly thereafter for solid particles and SO_2 to ensure the GTP is achieving the stated performance for these pollutants
- monthly monitoring for the first six months and then bimonthly afterwards for dioxins and furans to ensure the GTP is achieving the stated performance for these pollutants
- Meteorological monitoring (wind speed and direction) at a representative location in accordance with recognised standards.
- lower limits on the residence time and operating temperature of the thermal oxidation unit to maximise the destruction of VOCs and related substances based on the stated operating conditions in the EIS
- continuous monitoring of thermal oxidiser operating temperature and flow rate of exhaust stream (residence time) to ensure the destruction of VOCs is maximised at all times
- implementation of a VOC leak detection and repair (LDAR) program to ensure fugitive emissions are minimised
- air emission validation program to ensure the GTP is achieving the stated performance during processing of all contaminated streams.

5.1.1.5 Preventing odours

The EIS has assessed the potential for odour formation. The raw groundwater is odorous due to the presence of sulfur compounds and organic acids. The EIS states that the off-gas treatment (thermal oxidation plus scrubbing) will remove sulfur compounds below the odour threshold. The organic acids will not be stripped out of the groundwater into the off-gas stream to any significant extent and would be treated in the groundwater treatment system, in particular capture in the activated carbon circuit.

In assessing this information DEC has taken into account an independent review by Court & Associates of the odour potential for the project. It states that the raw groundwater has considerable odour potential. While the thermal oxidiser, quench or scrubber train should not generate odour problems, care will still be needed in managing odours at every stage of pumping, processing and subsequent treatment and management of the treated groundwater. Some of the aspects that will need careful consideration include:

- minimising and testing for flange leakage
- minimising and containment of pump seal leakage
- controlling vapour and gas venting from all holding and processing vessels
- a mechanism for containing liquids and gases from maintenance operations when pipe and plant containing odorous liquids are opened
- monitoring the odour level of treated water finally released to surface waters.

The determination has concluded that the groundwater treatment system can be designed and operated to ensure it does not cause off-site odours. This performance requirement is also a condition of the current EPA licence for Orica. DEC has attached a condition requiring the odour predictions for the project to be validated after plant commissioning to demonstrate compliance with this requirement.

As a further safeguard, DEC has also attached conditions to the licence in relation to this project, including a requirement for Orica to undertake a VOC leak detection and repair program to detect and minimise fugitive VOC emissions from the groundwater treatment plant and associated plant and equipment. In addition an overall odour detection program has been required to identify and prevent unanticipated odour sources.

5.1.1.6 Greenhouse gases

Several submissions from the public raised issues associated with increases in the emission of greenhouse gases, principally carbon dioxide. This results mainly from electricity consumption required from groundwater extraction (pumping) and the operation of the natural gas burners within the thermal oxidation unit.

The EIS has assessed greenhouse emissions for the project and explored mechanisms whereby the emission of greenhouse gases could be managed and/or mitigated. This includes improvements in energy efficiency at its Botany plant and other plants in Australia, optimising pumping rates and using energy efficient lighting. The primary objective of the project is to achieve hydraulic containment and to maximise the destruction capacities of the contaminants. Orica has stated it will continue to investigate and implement measures to balance greenhouse gas savings against the requisite destruction efficiencies.

5.1.2 Surface and Waste Water Impacts

Some representations indicated concerns about the impact of discharges from the groundwater treatment plant on Bunnerong Canal, Penrhyn Estuary and Botany Bay. This included its effect on recognised environmental values like recreational water quality (Botany Bay), protection of aquatic ecosystems (Penrhyn Estuary) and resource potential (groundwater). Orica has identified a number of potential impacts during the construction and operation of the GTP.

5.1.2.1 Construction

The determination has concluded the EIS adequately identifies the potential impacts and mitigation measures to minimise the construction phase impacts to surface waters. This includes the preparation and implementation of a construction environmental management plan.

5.1.2.2 Discharge from GTP

5.1.2.2.1 Discharge to waters

Orica’s preferred option for the water treatment post-air stripping, as outlined in the EIS, consists of an iron removal step; an organics polishing step; a reverse osmosis step for part of the water stream and an ammonia/organics acid removal step for the other part of the water stream.

Treated water that is not recycled (up to 7.5 million litres per day) will be transferred by an existing pipeline and discharged into Bunnerong Canal. This canal flows to Brotherson Dock and Botany Bay. The pipeline has a maximum hydraulic capacity of up to 12 million litres per day (equivalent to 0.14 metres cubed per second (m^3)). While the objective is to maximise the reuse of this high quality water, if this is not possible, Orica is seeking approval to discharge up to this capacity. There will be no discharges from the groundwater treatment plant to Penrhyn estuary.

Appropriately detailed construction drawings and associated management measures will need to be provided on the discharge. The agreement of Sydney Ports Corporation (as the affected landowner) to the design and operation of the discharge will be required. This will specify the terms and conditions by which Orica can use the canal. A permit will also be required from NSW Maritime under the *Rivers and Foreshores Improvement Act 1948* for works associated with the construction of the discharge point at Bunnerong Canal.

The EIS details the quality of water expected to be discharged to Bunnerong Canal. Both water quality modelling and monitoring studies were used to establish existing and future water quality conditions to assess the potential impacts of the plant. The predicted conditions were compared against community expectations for these waterways, using the 2000 ANZECC water quality guidelines to establish appropriate water quality objectives.

The determining authorities consider it is important to establish links between the system performance (eg discharge limits) and environmental performance (receiving water quality) so that the system can be adaptively managed for optimal performance. The following table (Table 3) lists the values DEC will establish as licence limits to meet recognised water quality guidelines.

Table 3 Water Discharge limits for EPA licence

Parameter	Water discharge licence limits (mg/L unless otherwise specified)
pH	7-8.5
1,2-dichloroethane	1.9
Carbon tetrachloride	0.24
Tetrachloroethene	0.07
Trichloroethene	0.33
Vinyl chloride	0.10
Benzene	0.95
Toluene	0.18
Arsenic (total)	0.023
Cadmium	0.0007
Chromium (total)	0.0044
Copper	0.0013
Iron	0.3
Lead	0.0044
Mercury	0.0001
Nickel	0.007
Zinc	0.015
Ammonia as N	0.015 (see note below)
Total Phosphorous	0.01 (see note below)
BOD	10
Turbidity	5 NTU (see note below)
Manganese	0.08
Chloroform	0.37
Total N	0.1 (see note below)
Oxidised nitrogen	0.015 (see note below)
Free reactive phosphorus	0.005 (see note below)
Temperature	15 to 25 degrees Celsius

Note These are the ANZECC ambient guidelines which should be met after the final discharges mixes with the receiving waters. Once final details on the treatment technology and the design of the discharge structure are received these will be converted to discharge limits on the EPA licence.

The EPA licence limits are based on ANZECC marine water quality guidelines, which are designed to protect aquatic ecosystems from both physical and chemical stressors. This includes Physical and Chemical Stressors (Section 3.3 of ANZECC) and Water Quality Guidelines for Toxicants (Section 3.4 of ANZECC)

With respect to nutrients the licence limits listed also take into account the relevant water quality objectives in the *Healthy Rivers Commission Statement of Intent for the Georges River - Botany Bay system* (2002).

Concentration limits for each specified pollutant have been included in the environment protection licence based on the above. DEC has also included a requirement for Orica to undertake a water discharge validation program. The program is intended to ensure that Orica demonstrate that the plant is capable of achieving the limits specified in the licence and the range of water pollutants monitored is continually reviewed and modified where necessary to ensure that Orica is capable of detecting the presence of pollutants not already specified in the licence. The program must be developed and implemented by Orica in consultation with the determining authorities.

In addition to the source monitoring outlined above, the determining authorities have required Orica to undertake ambient environmental monitoring. The program will include ambient water quality and sediment quality and distribution, including initial baseline measurements in and around Bunnerong Canal, Brotherson Dock, Penrhyn Estuary and adjacent areas of Botany Bay. The program must be developed and implemented by Orica in consultation with the determining authorities.

While the discharge flow rate is expected to be 7.5 million litres per day with reuse, the EIS states Orica is seeking approval for discharge of up to 12 million litres per day, if full reuse is not possible in and around Botany Industrial Park. The figure of 12 million litres is based on the maximum hydraulic capacity of the pipeline from the groundwater treatment plant to Bunnerong Canal. This determination concludes that approval be given for a discharge of up to 12 million litres per day (equivalent to 0.14 m^3 per second) however the objective must be to maximise reuse of this high quality water at all times (see Section 5.1.2.2.3 below). Flow limits will be included in the EPA environment protection licence and permission from Sydney Ports Corporation.

The determination has required as a condition of approval that the discharge structure and location (including initial dilution of the discharge) as well as discharge frequency and timing be designed and optimised to achieve the best environmental performance in consultation with the determining authorities. This is to ensure that discharge will result in minimal environmental impacts, for example scouring of sediments. Orica will be required to cease any discharge into the canal if it is essential for the determining authorities to conduct maintenance on the canal, maintain port operations or respond to emergencies; or in the event of pollution incidents.

DEC may vary the limit and monitoring requirements on the EPL subject to the findings and recommendations of the above program. Should this monitoring indicate adverse impacts to the environment, Orica will be required to develop appropriate mitigation and/or management measures in consultation with the determining authorities and implement these within an agreed timeframe.

The determination has concluded that the water impact assessment for the proposed development has enabled decisions to be made on the specific discharge limits for water pollutants and a water discharge validation program to ensure that the plant can be operated within the appropriate ambient environmental limits.

5.1.2.2.2 Trade waste

All industrial and commercial customers discharging trade waste into Sydney Water wastewater systems must obtain written permission from Sydney Water. Trade waste requirements help to ensure that Sydney Water can discharge or reuse wastewater in a way that protects employee safety and the environment, and complies with regulatory requirements. Depending on the type of business and trade waste, Sydney Water will either issue a trade waste permit or enter into a trade waste agreement.

Orica currently has approval to discharge 6 ML per day of trade wastewater to sewer from the Botany Industrial Park. Sydney Water has provided Orica with preliminary approval to discharge an additional 1.5 ML per day during dry weather conditions only, to be confirmed in light of any potential future demand on the carrier. Any proposals for adjustments to the trade wastewater discharges from the Orica site will be assessed by Sydney Water, in terms of wastewater quality and quantity, and its impact on the limited capacity of the Malabar Sewage Treatment System. Any adjustments to the current Sydney Water trade waste requirements will need to be met by Orica.

The EIS identifies wastes that will be discharged to the sewerage system operated by Sydney Water, principally spent caustic solution from the wet scrubbers on the GTP. Orica will need to apply to Sydney Water for a variation to this agreement to allow this project to proceed.

5.1.2.2.3 Reuse of treated water

Sydney Water and Orica are discussing options available for the potential reuse of treated groundwater from the site. Orica has advised that it has received in-principle government support for the sale of recycled water and is in the process of investigating potential markets for its use. Sydney Water has provided Orica with detailed information regarding potential recycled water options in the Botany area, including likely future demand. Further discussions between Sydney Water and Orica are anticipated on matters including timing, and the quality, volume and price of the recycled water.

Given the high quality of the treated effluent from the GTP, the determining authorities view this as a resource for utilisation rather than a waste for disposal. We encourage the reuse of this wastewater where it is safe and practicable to do so and provides the best environmental outcome. DEC has attached a condition on the licence which requires the preparation of a GTP water reuse strategy. This strategy must include investigations to beneficially reuse waters from the GTP and reduce the amount of water discharged to Botany Bay.

5.1.2.2.4 Stormwater

The determination has concluded that, on the basis of the information provided in the EIS, the proposed development would not significantly alter the quantity or nature of surface water runoff from BIP. A first flush stormwater system will be installed, designed to catch the first 15 mm of rain over the relevant hard surfaced areas. Soil and erosion control measures during construction will be addressed in more detail in the construction environmental management plan.

5.1.3 Soil and groundwater contamination

5.1.3.1 Groundwater

The project allows for the enhanced ability of Orica to clean up contaminated groundwater and meet the requirements of the EPA Notice of Clean Up and ensure the protection of human health and the environment.

Extensive environmental investigations and groundwater monitoring undertaken by Orica since the 1980s have revealed an extensive and complex distribution of volatile chlorinated hydrocarbon (CHC) contamination derived from multiple source areas. Further information is provided in Section 2. Orica has commissioned hydrogeological and surface water modelling and assessment, the findings of which are presented in the EIS. This includes Hydraulic Containment of Groundwater and Hydraulic Assessment of Bunnerong Canal (Appendices D and E of the EIS)

The determining authorities have reviewed the EIS and supporting studies including the report, *Optimal Groundwater Abstraction Rates For Hydraulic Containment Of Contaminant Plumes and Source Areas* dated October 2004 and prepared by Dr N P Merrick from the National Centre for Groundwater Management (University of Technology, Sydney). It is noted that this latter report also has been independently peer reviewed. The peer review report strongly endorses the findings of the hydraulic containment groundwater simulation study undertaken by Dr Merrick.

The primary aim of modelling was to assist in the design of the remediation system by providing best estimates for required extraction rates, bore locations and screen intervals. It also assisted in determining the capacity requirement of any treatment option. The modelling was adequate in relation to all these objectives.

The determining authorities consider that the proposed extraction borefields, once commissioned for production purposes (to deliver 15 million litres per day to the groundwater treatment plant), should achieve hydraulic containment of the plumes. Intended conditions for a licence under the Water Act have been prepared (Appendix B). They require Orica to carefully monitor groundwater level behaviour with pumping and to minimise any potential adverse environmental impacts, as well as reporting the effectiveness of the cleanup. The determining authorities consider that groundwater monitoring to determine the applicability of models to reality is critical and a comprehensive monitoring program will be an integral component water of the water extraction permit issued by DIPNR.

Some representations raised concerns about saltwater (sea water) intrusion resulting from the extraction of groundwater and its resultant impact on sensitive habitats such as Penrhyn Estuary. Orica has evaluated potential impacts of saltwater intrusion and stated they will not be significant. While the determining authorities have accepted these findings it is recognised that saltwater intrusion is difficult to estimate and model. For this reason the determining authorities have requested that saltwater intrusion be carefully monitored. The groundwater simulation study undertaken by Dr Merrick indicates that some saline intrusion into the sand bed aquifer is likely, due to pumping from the secondary containment line. This will be particularly the case when the nearby drains are dry and for any prolonged interception pumping. The deeper aquifer system is likely to be impacted due to migration and upconing of the saline interface that occurs near Botany Bay as a consequence to intensive pumping. However, careful optimisation of pumping rates will mitigate the negative impacts of saline intrusion. Monitoring of saline intrusion will be required as a condition of the Water Act licence.

The determining authorities consider that failure to contain and remediate the polluted groundwater would cause a far more serious environmental impact than any negative saline intrusion effects to the Botany Sands Aquifer that may be induced by pumping from the containment line borefields. Moreover, the impact of any saline intrusion is likely to diminish once pumping is no longer necessary.

5.1.3.2 Soils

Some submissions raised issues relating to the need for careful management of contaminated soil, in particular on the site of, and during the construction of the groundwater treatment plant.

Orica undertook a soil investigation program to collect of samples from the proposed GTP site. Contaminants assessed were those associated with historical activities on and around that part of the site, including 1,2- dichloroethane; vinyl chloride; carbon tetrachloride; tetrachlorothane; trichloroethane; hexachloroethane and hexachlorobutadiene. In addition to these chlorinated hydrocarbons, metals such as mercury and chromium as well as total petroleum hydrocarbons (TPH) were also investigated. In undertaking this assessment, Orica used the EPA's *Guidelines for Assessing Service Station Sites,* NEPM (Assessment of Contamination) Schedule B1 – *Guideline on the Investigation Levels for Soil and Groundwater, Health Investigation Level (HIL) F (Commercial/Industrial)* and the EPA's *Assessment, Classification and Management of Liquid and Non-liquid Wastes* (EPA 1999) where relevant. No contaminants were identified above the guideline value in any of the soil samples for the proposed groundwater treatment plant plot. In all cases concentrations of identified contaminants were below the appropriate investigation levels.

It is important to note that conservative assumptions apply within these guidelines. For example, the *Guidelines for Assessing Service Station Sites* (EPA Guideline) identifies TPH concentrations for sensitive land uses such as residential development, which are therefore considered conservative for commercial/industrial land uses. The *Assessment, Classification and Management of Liquid and Non-liquid Wastes* describes the values of contaminants in materials allowed to be disposed of.

Orica states that, with appropriate dust suppression measures, potential migration of the contaminants off-site would be minimised and would not be expected to result in any significant off-site impacts. All excavated material is proposed to be tested for contamination. DEC has requested that this include hexachlorobenzene. While it is not proposed to take any soils from the site during construction, should the need arise the material would need to be tested further to ensure it met the inert classification of waste, prior to off-site disposal, in accordance with the conditions of the Orica's existing Environment Protection Licence. These aspects will be addressed in more detail in the construction environmental management plan to ensure all contaminated material is appropriately identified and managed.

5.1.3.3 Acid sulfate soils

Some submissions raised issues relating to acid sulfate, in particular in regard to Penrhyn Estuary, and the need for testing to ensure acid drainage does not occur from this project. Investigations by Orica indicate that acid sulfate soil conditions are not expected to be present. This is because the estuary was formed artificially through land reclamation in the 1970s for the port development. The EIS states acid sulfate soils are possibly present in and around Botany Industrial Park, although this is expected to be limited on the proposed groundwater treatment plant site.

The determination concludes that, as recommended in the EIS, an acid sulfate soil management plan be prepared and implemented to provide an approach for the management of acid sulfate soils during construction. As a further safeguard, Orica will maintain regular inspection of disturbed soil and groundwater quality, and inspection procedures are detailed within the construction and operational environmental management plans.

5.1.3.4 Subsidence

Some representations raised concerns about subsidence from the extraction of groundwater. The issue of groundwater pumping affecting residential properties or infrastructure was addressed in the EIS. This included a groundwater simulation report. This included the base case (ignoring prior consolidation) as well as likely and worst case scenarios (taking into account prior consolidation).

Most areas in the vicinity of the extraction borefields area are expected to have experienced consolidation of the sand bed aquifer due to prior groundwater level fluctuation, particularly in the 1960s and 1970s due to heavy groundwater pumping in the Botany area in those years. Very minor subsidence is identified in the scenarios that take account of prior consolidation.

The likely case prediction indicates a maximum of 0.9 mm on Foreshore Road and 0.1 mm on Botany Industrial Park. Hence, risk of subsidence (also termed settlement in geotechnical reports) impacting on structures including residential properties is considered to be negligible or very low.

Notwithstanding, Orica will be required as a condition under the DIPNR water extraction licence to install suitably located settlement monitoring stations to validate these predictions and ensure adverse impacts do not occur.

5.1.4 Impacts on flora, fauna and heritage

5.1.4.1 Threatened species

An assessment of terrestrial flora and fauna was included in the EIS. Additional studies were also conducted on groundwater modelling and behaviour in and around Penrhyn Estuary and the adjoining salt marsh communities to better understand the physical and chemical conditions that would be present in subtidal sand, intertidal sediments and saltmarsh and mangrove communities during the extended period of groundwater extraction. An eight-part test for the saltmarsh community at Penrhyn Estuary was also undertaken. Significant areas in the study area included:

- Botany Wetlands, including Lachlan swamps to the north and west of BIP;
- Penrhyn Estuary, including saltmarsh to the south-west of BIP
- Foreshore Beach to the west of BIP.

The potential impacts on these areas included changes to the groundwater flows from the operation of the groundwater extraction and treatment system.

There are a number of endangered ecological communities (EECs) listed under the *Threatened Species Conservation Act 1995* (TSC Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) located near BIP, however no EECs were found on the BIP or the proposed site of the groundwater treatment plant.

Thirteen species of terrestrial flora listed under the TSC Act and the EPBC Act have been recorded in the study area. However, Orica identifies that no plants would be expected to occur on the site of the proposed groundwater treatment plant and associated infrastructure, due to the lack of suitable habitat.

There are 86 species of terrestrial fauna listed under the TSC Act and the EPBC Act that have been previously recorded in the vicinity of the study area or have been predicted to occur within the study area. Of particular significance is the shorebird habitat at Penrhyn Estuary. Twenty four species of resident and migratory shorebirds listed under the TSC Act and EPBC Act are known to occur or have previously been recorded at Penrhyn Estuary. Of these seven are listed as vulnerable and one, the Little Tern, as endangered under the TSC Act.

In addition, 22 shorebird species found in the study area have been listed under international agreements (the Japan-Australia Migratory Bird Agreement and the China Australia Migratory Bird Agreement) and 23 under the Bonn Convention of Migratory Animals.

The above studies indicate that none of the listed species would be expected to occur on the site of the groundwater treatment plant and associated infrastructure due to the lack of suitable habitat, and that there are no threatening processes listed under the various Acts at the site. The determination considers that the methodology applied enabled conclusions to be made on the conservation value of the area, the extent of likely impacts associated with the proposal and the appropriate mitigation measures.

Orica concludes that the proposal would not directly impact terrestrial flora or fauna within the Botany Industrial Park due to the absence of native vegetation and suitable habitat for fauna on site. It is understood that no significant vegetation is located along the pipeline routes and existing or proposed borefields. The determination concludes that the site for the proposed groundwater treatment plant is well within the boundary of the existing Botany Industrial Park as well as being highly disturbed, so its construction will not cause any significant impacts on flora or fauna nearby to the BIP.

Several submissions raised issues associated with impacts to the flora and fauna in nearby habitats and saltwater (sea water) intrusion resulting from the extraction of groundwater extraction. The effects of groundwater extraction and risk of saltwater intrusion was assessed in the EIS and supporting documents.

It is understood that Penrhyn Estuary, the associated areas of saltmarsh and Foreshore Beach are dominated by tidal water exchange and rainwater infiltration. As such these communities are predicted to be unaffected by groundwater interception. In reaching this position, the determination has taken into account an eight-part test undertaken for the saltmarsh and Penrhyn Estuary which concluded that it would be unlikely for the works to have an adverse impact on these EECs.

The determination concludes that extracting polluted groundwater will remove the current risk of contaminant discharge to Penrhyn Estuary and the potential negative impacts on commercial, recreational and ecological activities within Penrhyn Estuary and Botany Bay.

One submission indicated the need for the proposal to be referred to Department of Environment and Heritage (Commonwealth) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This issue has been addressed in the EIS and supporting information. No species listed under international agreements would be sufficiently significantly affected to warrant a formal referral to the Department of Environment and Heritage with regard to the species listed under the EPBC Act. In reaching this view, the determination has also noted that Orica referred the proposed activity to the DEH for comment. DEH has responded in writing and it is not a ‘controlled action’ and therefore will not require approval under the EPBC Act.

The mitigation measures proposed in the EIS to protect sensitive areas from groundwater extraction are considered appropriate for the proposed activity to ensure the potential environmental impacts are appropriately managed and that no significant impact arises. The determination recognises that salinity intrusion can be difficult to estimate due to the complex nature of these systems, and there are limitations to the models used and assumptions made. As recommended in the EIS, it is important that an extensive monitoring program be developed and implemented to enable detection of changes in the ecology of estuarine communities due to groundwater interception or saltwater (sea) intrusion, to determine the applicability to reality of the model and to ensure adaptive management so that any unforeseen environmental impacts can be prevented. This is supported by a number of submissions that encouraged regular groundwater monitoring.

The determination concludes that a comprehensive ambient environmental monitoring program and groundwater monitoring program will be an integral component of the EPA environment protection licence and water extraction permit issued by DIPNR. These programs must be developed and implemented by Orica in consultation with the nominated authorities. The monitoring programs must also take into account the potential cumulative impacts of Orica's proposal on the works proposed by Sydney Ports as part of the proposed Port Botany Expansion. Should this monitoring identify issues that require addressing appropriate management and/or mitigation measures will be developed in consultation with these agencies as required.

While the DEC consider that there are a range of management options available, for example, the refinement of groundwater extraction rates at individual extraction bores, all works should stop immediately should the project result in an unexpected and previously unidentified disturbance to a threatened species listed under the *Threatened Species Conservation Act 1995* and the DEC should be consulted immediately. Works must only proceed once DEC is satisfied that all appropriate measures have been undertaken to minimise impacts to threatened species

5.1.4.2 Aboriginal and cultural heritage

An archaeological and cultural heritage assessment for the project was undertaken and included in the EIS. No Aboriginal sites are recorded as occurring within the development site. Orica therefore asserts that, due to the extensive disturbance as a result of industrial activities and landfilling, the potential for the area to include Aboriginal archaeological sites or objects is predicted to be low.

The proposed development is expected to have a negligible impact on the industrial heritage significance of the site, as the industrial character would be maintained.

The determination has concluded that the methodology applied to undertake the Aboriginal and cultural heritage assessment for the EIS enable the above conclusions to be made.

If any Aboriginal objects are uncovered during the proposed activity, through excavation or disturbance of the area, all work likely to affect the site is to stop immediately and the DEC is to be informed.

If any evidence of previously unidentified non-indigenous heritage items and/or archaeological objects are found, all work likely to affect the site(s) must cease immediately and, in accordance with section 146(a) of the *Heritage Act 1977* the Heritage Council be notified within a reasonable time of the discovery or location of any objects.

5.1.5 Hazard and risk

5.1.5.1 Land use safety planning

The EIS for the proposed development includes a Preliminary Hazard Analysis (PHA), consistent with the requirements of *State Environmental Planning Policy No. 33 – Hazardous and Offensive Development* (SEPP 33). The requirement for a PHA was triggered by characterisation of the proposed activity as ‘potentially hazardous’ within the meaning of SEPP 33. That is, in the absence of all risk-mitigating measures (including separation of the proposal from other land uses), the proposed activity has the potential to exert a significant risk to human health, life or property, or to the biophysical environment generally. The purpose of the PHA was to demonstrate that sufficient risk-mitigating measures exist, and are proposed to be implemented, to reduce this potential risk to an acceptable level, thereby ensuring that the activity would not be considered ‘hazardous’ within the meaning of SEPP 33.

The PHA presents a screening of potential hazards on the site, and identifies that key hazards are associated with stored volumes of class 8 dangerous goods (hydrochloric acid and sodium hydroxide), the storage and handling of ethylene dichloride waste (class 3, subsidiary class 6) and the use of natural gas within the activity (only process inventories proposed). A hazard identification process is presented to consider, in a qualitative sense, the likely significance of possible incidents on the site. Of all credible incidents considered, fifteen were established as representing significant potential for off-site consequences:

- emission of dioxins from the thermal oxidiser
- failure of thermal oxidiser piping
- natural gas jet fires impinging on stored EDC
- failure of natural gas piping
- explosion within the thermal oxidiser
- incorrect operation of the thermal oxidiser
- release of EDC from the stack
- inadequate scrubber operation
- full or partial scrubber failure
- release of recovered EDC
- pipework corrosion and material release
- boiling liquid expanding vapour explosion (BLEVE)
- exposure to EDC
- sabotage/terrorism
- knock-on effects from incidents at adjacent development.

Where the above incidents posed the potential for chronic risks (human health), such as the emission of dioxins from the activity, consideration was carried forward for assessment as part of the human health risk assessment in the EIS. In the case of acute risks (those associated with a short-term event, with immediate or near-immediate effects), incidents were carried forward for further assessment in the PHA.

The off-site consequence of each of the incidents identified above is considered further in the PHA, with quantification where relevant, to establish which scenarios have the potential to generate a significant impact. In general, the PHA demonstrates that incidents involving natural gas fires and explosions would not generate a significant off-site consequence, either through heat radiation or explosion overpressure effects. In the case of scrubber failure scenarios, the most credible mode of consequence effect is fatality, injury or irritation from the release of hydrogen chloride. However, this mode of action is demonstrated to pose little consequence within the Botany Industrial Park or at the closest residential receptors.

There is potential for a BLEVE involving ethylene dichloride on the site to affect other land uses within the Botany Industrial Park through human fatality, but the heat and overpressure effects of such an event are considered unlikely to affect structural integrity. Effects out-site the Botany Industrial Park are demonstrated to have negligible consequence in terms of fatality, injury or irritation.

The most significant incidents identified through the PHA relate to leaks/releases of materials between the thermal oxidiser and the stack for the development. Under these circumstances, hot gases are released near to ground level, containing irritants including ethylene dichloride and hydrogen chloride. Consequence analysis in the PHA suggests that hydrogen chloride, in particular, would generate a significant consequence at the boundary of the Botany Industrial Park in such an event, primarily through injury or irritation. Fatality consequences are demonstrated to be negligible, as are the consequences of EDC effects at the park boundary.

Potential incidents with significant off-site consequences are considered further in the PHA through analysis of potential incident frequencies, from which ultimate risk impacts are calculated. From this analysis, the PHA demonstrates that land use safety planning criteria stipulated in *Hazardous Industry Planning Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning* (HIPAP 4) are met. In this regard, fatality, injury and irritation risk criteria are met for surrounding land uses, including residential and sensitive receptors. Fatality risk is estimated to be in the order of 1×10^{-7} at the boundary of the Botany Industrial Park (well below the most stringent criterion of 0.5×10^{-6} for sensitive receptors) and negligible at the closest off-site receptors. Fatality risk within the Botany Industrial Park is 500 times below the acceptable industrial land use criterion. Injury risks are similarly well below acceptable levels, with heat injury effects demonstrated to be negligible and toxic injury risk in the order 1×10^{-6} (one-tenth of the acceptable residential criterion). Toxic irritation is less than half the residential criterion, estimated at 21×10^{-6}.

The PHA also considers and demonstrates that risks associated with knock-on effects, property damage, societal effects, cumulative effects and transport are all negligible.

A number of submissions raise issues of concern in relation to hazards and risk impacts, and for the most part these matters concern chronic risks/human health effects and contingency risks in the event that the proposed activity is unsuccessful in halting the spread of contaminated groundwater. A single public submission raises issues associated with ‘acute’ land use safety planning risks, particularly:

- the risk assessment methodology generally, and the acceptability of the risk assessment and land use safety guidelines developed by DIPNR
- the acceptability of assumptions in the risk assessment, rather than actual data
- the need for independent review of the PHA by an expert chosen by the community.

The Preliminary Hazard Analysis included in the EIS was assessed by the Major Hazards Unit of DIPNR. The unit is the peak land use planning team within the NSW Government, and has provided independent technical review of land use safety risks to inform the decision-making process for the determining authorities.

The unit considers that the PHA has been completed in accordance with DIPNR's relevant risk assessment guidelines, particularly *Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis* and *Multi-Level Risk Assessment*. The assumptions and methodology applied to the PHA are considered both robust and appropriate for the derivation of likely land use safety planning implications. While concerns raised in public submissions over the application of assumptions in the PHA are appreciated, the assumptions themselves are the result of considerable engineering and scientific experience. In particular, the assumptions applied in respect of heat and overpressure effects, the toxicity/ irritation potential of combustion products and the failure rates for common plant and equipment are well known. Although no development has been completed with exactly identical features to that proposed by Orica, the distinct components of the proposal (pipes, pumps, scrubbers, thermal oxidisers) and the effects of various hazardous incidents (fires, explosions, toxic effects) are not new. Further, the risk assessment approach applied by Orica through the PHA and advocated by DIPNR is well-known and well-developed as a result of several decades of international engineering experience.

It is noted that the proposed activity would meet relevant land use safety criteria, and in most cases by a significant degree. The dominant risk contribution relates to toxic irritation effects from certain accidental hydrogen chloride release scenarios, however this impact would be less than half of what would be considered acceptable. In the context of strategic land use safety planning, the Major Hazards Unit has assessed the proposed activity against the recommendations and findings of the *Botany/Randwick Industrial Area Land Use Safety Study* (DUAP, 2001) and considers that the proposal is consistent in that regard. In particular, it is highlighted that the proposal would exacerbate current consultation regions for the future case (2001) illustrated in the Study.

Although the proposed activity has been demonstrated as meeting relevant risk criteria, it is important that potential risks are managed in an on-going context. Particularly at the detailed design stage, it is important to fully review and consider the design and implementation of risk-mitigating measures to ensure that the predictions from the PHA are achieved. To this end, the DIPNR Major Hazards Unit has recommended that Orica undertake both a Hazard and Operability Study and a Final Hazard Analysis for the groundwater treatment plant. Both of these measures are commonly applied to potentially hazardous developments to manage risk considerations through detailed design and implementation of a proposal. The Final Hazard Analysis, in particular, provides a mechanism to confirm predictions from the PHA and establish final design for risk mitigation techniques and infrastructure to constrain potential risk impacts to as low as reasonably possible.

As the proposed activity would be implemented within an active industrial area, the Unit has also recommended the preparation of a Construction Safety Study. This Study would ensure that construction and commissioning risks are identified up front and appropriate measures implemented to ensure safe implementation of the proposal.

As a final measure, the unit has also recommended regular hazard auditing of the activity throughout its life to ensure on-going safe operation and identify issues of potential risk as the remediation process progresses. This measure is considered particularly important given the likely timeframe over which the proposal is to be implemented, and the need to ensure public safety and amenity at all times during operation.

5.1.5.2 Human health risk assessment

The EIS includes a human health risk assessment. Several submissions raised questions about the adequacy of the health risk assessment.

The HHRA is generally in accordance with the nationally accepted framework and guidelines published by enHealth in June 2002 (*Environmental Health Risk Assessment : Guidelines for assessing human health risks from environmental hazards*).

The HHRA is based on modelling the expected emission rates of various chemicals of potential concern from the GTP under normal and worst-case conditions. Calculations have been undertaken for worst-case scenarios both in terms of chemical concentration and toxicity and for potential human exposure. The modelled maximum ground-level concentrations of emitted chemicals occur within the BIP, but are used in calculating residential exposure and risk. Given this, the risk assessment is considered to be conservative.

In issuing its licence requirements for the project, DEC took into account the human health risk assessments undertaken by Orica. DEC has required Orica, as part of the notice, to validate the findings of the HHRA based on comprehensive emissions data and emissions validation programs required under the licence. This will include using representative data collected under worst-case scenario operating conditions.

5.1.6 Waste management

Several submissions raised concerns about waste management at the premises and resulting from the proposed development. Some raised concerns about the hexachlorobenzene (HCB) waste currently stored on the Orica premises and awaiting appropriate disposal. Others strongly objected to the creation of any further waste stockpiles on the site.

Key wastes that are generated as a result of the on-going operation of the proposal are provided in the EIS. DEC notes that Orica has existing waste management requirements under the environment protection licence which requires all wastes to be managed appropriately. All wastes must be managed in accordance with the EPA guidelines *Assessment, Classification and Management of Liquid and Non-liquid Wastes*. All wastes will also need to be assessed and transported in accordance with the *NSW Road and Rail Transport (Dangerous Goods) Act 1997* (which adopts the Australian Dangerous Goods Code).

If the wastes are dangerous goods, Orica will also have to comply with the NSW Road and Rail Transport (Dangerous Goods) Act and its Regulations. For example, Regulations made under the NSW Road and Rail Transport (Dangerous Goods) Act require any dangerous goods transport to be in accordance with an emergency plan required under Regulation 14.5(3) of the Road Transport Reform (Dangerous Goods) (NSW) Regulations.

5.1.7 Noise impacts

No submissions raised issues relating to noise impacts from this project.

With regard to construction noise, construction activity is to occur in the area of the proposed groundwater treatment plant (GTP) and in areas near the wells and pipelines to and from the GTP. Orica has assessed these noise impacts and indicated that these facilities are located reasonably far away from residential receivers and that noise levels from construction activities is not likely to be excessive and will meet the background plus five decibel criteria suggested in the Construction Noise Guideline, Chapter 171, *Environmental Noise Control Manual* (ENCM).

DEC has recommended that standard construction noise hours recommended in the guideline be applied, notably construction should occur between:

- 7:00 am until 6:00 pm Monday to Friday
- 8:00 am until 1:00 pm Saturdays

- no construction should occur on Sundays or public holidays.

The existing EPA licence for the premises requires Orica to not exceed a limit of 65 dB(A) daytime, 55 dB(A) evening and 50 dB(A) night-time (measured as Laeq, 15 min).

Orica has conducted a noise impact assessment for the project and it is generally consistent with the DEC Industrial Noise Policy. In particular, Orica has identified potentially affected noise-sensitive receivers at the residential areas surrounding the proposed development, identified background noise levels, determined noise criteria and assessed the predicted noise emissions from the project against these criteria.

Orica has modelled noise impacts, taking into account meteorological noise level enhancement. DEC has attached conditions to account for inversions and wind blowing from source to receiver to account for these effects.

Orica adopted a design goal of 35 dB(A) (measured as an LAeq,15 min) for the facility. DEC has concluded that the goal is reasonable and will not result in an exceedence of the current noise limits specified on the EPA licence. The level also takes into account reported ambient noise levels for other development proposals in the area, Visy Recycling at Banksmeadow and the Port Botany Container Terminal Expansion.

DEC has included the above goal as a licence limit for the project. It has also required Orica to undertake noise compliance monitoring following commissioning of the groundwater treatment plant to demonstrate that the plant it is complying with the above limits.

5.1.8 Traffic and transport impacts

Orica has predicted that the additional traffic associated with the construction and operation of the facility is likely to be minimal and that additional traffic from this development is not likely to significantly impact on the environment surrounding the proposed facility. DEC agrees with the conclusions reached by Orica. No submissions raised issues relating to traffic impacts of the proposed development.

5.1.9 Socio-economic impacts

The project allows for the ongoing ability of Orica to clean up contaminated groundwater and meet the requirements of the EPA Notice of Clean Up.

The EIS states that, while it does not include any new employment positions, it represents a major capital investment by Orica to clean up contaminated groundwater and ensure the protection of human health and the environment.

The determining authorities note the principal benefits of the project are associated with remediation of a valuable groundwater resource. As a result there are likely to be environmental benefits associated with reduced levels of contaminants in the Botany Sands and receiving systems.

There were no representations received relating to socio-economic impacts of the proposed project.

5.1.10 Cumulative impacts

Several public representations raised issues associated with the cumulative impact of the project, in particular air emissions (including dioxins and VOCs) and the project's relationship to the proposed port expansion (and vice versa).

The potential cumulative impacts of the project have been reviewed and considered as part of the EIS. These include impacts the project may have on existing and proposed developments (including the Port Botany Expansion) in and around the Botany area. They include hydrogeology, water use, hydrology, traffic and transportation, noise, flora and fauna, air quality, hazard and risk assessment and human health risk assessment. Overall the EIS concludes that the cumulative impact of the project with other developments in the area is expected to be low.

The EIS states that the predicted air emissions from the groundwater treatment plant will not be significant in comparison to current existing background levels and will meet recognised air quality goals. A cumulative health risk assessment was also completed for persistent and bioaccumuative chemicals (such as mercury, hexachlorobutadiene, dioxins and furans) associated with the groundwater treatment plant, which concluded that there was negligible incremental risk due to these emissions at the modelled receptor locations.

An independent review of air emissions information was undertaken by John Court & Associates Pty Ltd (on behalf of DEC). This review concluded that the predicted levels of dioxins exposure from emissions from the groundwater treatment plant are very low. The maximum predicted ambient concentration is 0.19 fg TEQ/m3 (annual average). This is orders of magnitude lower than typical reported values in Australian urban areas of 10 to 20 fg TEQ/m3. The Victorian EPA design criteria for a 3 minute average is 3700 fg TEQ/m3. Allowing for a very conservative factor between the 3 minute average and the corresponding average, there would still be a wide margin of safety for the predicted emission for the groundwater treatment plant, namely 19 fg TEQ/m3 against 3700 fg TEQ/m3 allowed on a 3 minute average.

The determination has taken into account the information in the EIS, representations and the design, installation, operation and management of the project itself as outlined in section 5 above. It concludes that the cumulative impacts associated with the project can be managed through the mitigation measures proposed in the EIS and subject to conditions outlined in Appendix B.

The determining authorities acknowledge that in contrast to most EIS, for a new proposal or activity, this project differs significantly in that it relates to clean up and remediation. Contaminated groundwater is already present and impacting on the environment. Therefore the consequences of not proceeding with the project or delaying its commencement are significant.

6 Consideration of possible modifications to proposal

Orica has suggested a number of modifications to the exhibited proposal which are discussed in Sections 4 to 6 of this report. These modifications have been included within the scope of this determination report for the project.

The suggestion, made by Orica subsequent to the EIS exhibition, mostly reflects the results of detailed design and consideration of representations. A summary of the changes and the determining authorities' evaluation are set out below. The key changes are:

- replacement of biological treatment unit with second RO unit
- salty water discharge to sewer, not Bunnerong canal
- excess water to Bunnerong Stormwater Channel not directly into Bunnerong Canal
- increased groundwater treatment plant stack height from 20 metres to 34 metres

Project Changes	**Reasons presented by Orica**
Replacement of biological treatment unit with second RO unit	• will further improve reliability and robustness of groundwater treatment system • increases volume of treated wastewater available for reuse • increases the suitability of discharges for direction to sewer • removes the need for dewatered solid waste management
Salty water discharge to sewer, not Bunnerong canal	• discharge of 'brine' from second RO is acceptable for discharge to sewer • discharge of 'brine' reject to Bunnerong Canal not required • reduces the volume of treated wastewater discharged to Bunnerong canal
Excess water to another stormwater channel, not directly into Bunnerong Canal	• provides an opportunity for Amcor to reuse treated wastewater.
Increase groundwater treatment plant stack height from 20 metres to 34 metres	• permits plume suppression using recovered energy from steam produced by the thermal oxidiser • further reduces ground-level concentrations from stack emissions • prevents stack plume visibility under most weather conditions.

The determination has concluded that the proposed changes are generally consistent with the existing proposal and its objectives.

On the basis of a review of the information provided by Orica and the representations on the exhibited EIS, the following determination has been made.

- The groundwater treatment plant stack height be increased from 20 metres to 34 metres. The plume suppression will reduce the visibility of the stack plume and require no additional energy or production of greenhouse gases. While the mass emission of pollutants will not change from those assessed in the EIS, reheating the plume and raising the discharge stack height will improve dispersion by increased plume buoyancy and height of discharge. This will further reduce ground-level concentrations of pollutants. Reductions of four to eight times are predicted. It will also work towards meeting the Victorian EPA ambient air quality goal for ethylene dichloride during abnormal operations of the groundwater treatment plant, even though the human health risk assessment indicated adequate protection with a 20 metre stack.

- Replacement of the biological treatment unit with a second RO unit be supported in principle, subject to compliance with an amended trade waste requirements to be finalised by SWC. It is consistent with the groundwater treatment plant reuse strategy, which has been required as a condition of the EPA licence for the project. It will enhance opportunities to reuse treated water and utilise the sewerage system to dispose of wastewater under trade waste agreements. It will generate additional treated water for reuse and reduce the quantity of treated water that will be required to be discharged to waters. This will reduce the amount of salt being discharged to waters and solid waste management. It is also expected to improve the robustness and reliability of the groundwater treatment plant.

- The discharge of excess treated water to the Bunnerong Stormwater Channel operated by Sydney Water be supported in principle, subject to:
  - further investigations into this discharge by Orica in consultation with the relevant authorities. These authorities include but are not limited to Sydney Ports Corporation, DEC, Sydney Water, DIPNR and NSW Maritime. These investigations would include but not be limited to the channels hydraulic capacity to accept the water, flooding and sediment scouring ; and
  - Any necessary approvals being obtained prior to the commencement of this discharge.

Discharge to this channel provides an opportunity to increase the amount of treated water that can be re-used by industry, for example Amcor. It relies on existing infrastructure and reduces the disturbances that would otherwise be required. If approvals for this discharge cannot be obtained prior to the commencement of operation of the groundwater treatment plant, then the project should proceed in accordance with the EIS proposal (namely discharge directly to Bunnerong Canal) and the conditions of approval provided for this determination in Appendix B.

7 Conclusions and recommendation

It is important that all environmental matters associated with this clean-up project are properly assessed and statutory requirements satisfied as quickly as possible. This is because, unless enhanced measures are taken to collect and treat the groundwater plume, the contamination may continue to migrate towards Penrhyn Estuary and Botany Bay. In order to fulfil the EPA Notice of Clean Up Action, Orica proposed the Botany Groundwater Cleanup project.

Orica currently holds an EPA environment protection licence (no. 2148) under the *Protection of the Environment (Operations) Act 1997* for a number of existing activities. DEC determined that, because the project contains activities likely to significantly affect the environment, an environmental impact statement was required under Part 5 of the *Environmental Planning and Assessment Act 1979* before DEC could vary the existing EPA licence to permit the activity.

In November 2004, Orica submitted an environmental impact statement entitled Botany Groundwater Cleanup project. The environmental impact statement prepared by Orica proposed a strategy to contain, collect and reduce contaminants in the groundwater in and around the Botany Industrial Park to meet the requirements of the notice and prevent any adverse impacts to the environmental receptors: Penrhyn Estuary, Botany Bay and human health. Orica considers that the implementation of the project will achieve the above objectives. The capital cost of the project is expected to be approximately $102 million for all elements, including the installation of extraction wells, transfer pipelines and treatment plant.

DEC, the Department of Infrastructure, Planning and Natural Resources, NSW Maritime, Sydney Water Corporation and Sydney Ports Corporation have prepared this joint determination report in accordance with the Environmental Planning and Assessment Act (in particular clauses 228 and 243) and associated Regulation, which requires a determining authority to prepare a report on any activity for which an environmental impact statement has been prepared. The purpose of this report is to review the environmental impact statement, the issues raised in representations made in response to its exhibition, the report from Orica on the representations and any other matters relevant to the potential environmental impacts of the proposal.

This joint determination report has been prepared by the determining authorities in relation to each of their relevant instruments of approval for the project. It provides the basis for:

- DEC granting a variation to the existing EPA environment protection licence held by Orica.
- a permit from NSW Maritime under the *Rivers and Foreshores Improvement Act 1948* for works associated with the construction of the discharge point at Bunnerong Canal for the project.
- a water extraction licence from DIPNR
- a variation to the trade waste permit from Sydney Water Corporation.
- permission from Sydney Ports Corporation to discharge treated groundwater to Bunnerong Canal.

If Orica is not able to extract groundwater at the rates required (up to 15 million litres per day) to contain the plumes and provide treatment of this volume of groundwater, it could result in the waters of Penrhyn Estuary and Botany Bay becoming increasingly polluted from contaminants in this groundwater. The project is required to ensure that adverse impacts do not occur and the environment and human health are protected.

Independent assessments of the project were undertaken by John Court & Associates Pty Ltd and the United States Environmental Protection Agency on behalf of DEC. Both supported the project in terms of the appropriateness of the technology selected. The Department of Environment and Heritage (Commonwealth) has also assessed the project and advised that the proposed technology is consistent with the requirements of the Stockholm Convention.

This determination concludes that Orica's preferred strategy for the collection and treatment of the contaminated groundwater is consistent with accepted best practice and satisfies best international air emission standards. It also maximises the quantity of extracted water that can be recycled for industrial use significantly reducing the demand on potable supplies.

The project is also consistent with the aims and objectives of the NSW State Groundwater Policy and *Healthy Rivers Commission Report for the Georges River–Botany Bay System* and associated Statement of Joint Intent. Fundamentally, the project will allow Orica to comply with the Notice of Clean Up Action issued by the EPA to stop the contamination impacting on Botany Bay and protect the community.

The determination has concluded that the Department of Environment and Conservation, NSW Maritime, Sydney Ports Corporation, Sydney Water Corporation and Department of Infrastructure, Planning and Natural Resources have each decided to approve the activity, subject to the conditions attached in Appendix B. The reasons for the conditions are to:

- ensure that adequate safeguards are in place to protect the environment and human health
- mitigate the potential environmental impacts of the activity
- ensure compliance with relevant statutes and statutory instruments
- restore the quality of groundwater in and around Botany Industrial Park.

Appendix A Issues raised in submissions

Submission	***Primary issues raised in submission***
Private submitter	• The lower quality of the product proposed to be discharged to Bunnerong Canal and the Bay is difficult to justify. • Contaminated groundwater should be treated in such a way as to restore its original quality. • Project should produce an outcome that could reuse the treated groundwater.
Private submitter	• What evidence is there that subsidence will not occur and negatively impact surrounding properties? • Will there be a Dilapidation Survey undertaken prior to extraction commencing? • What guarantees, compensation or bonds are required to ensure any negative impacts are rectified? • What will be the impact if the process fails to stop the toxic plume reaching the Bay? • What safeguards are there for residents and users of the Bay? • If Orica plans to sell treated greywater, it should offer it for free to residents who have lost the use of their bores.
Private submitter	• Siting a hazardous waste incinerator in Sydney is unacceptable. • There is sufficient liquid storage that can be used until a dedicated Hazardous Waste Precinct is established for the management and destruction of toxic wastes for all of NSW. • Australia's ratification of the Stockholm Convention requires minimisation and where possible elimination of dioxins, furans, and other hazardous by-product emissions. • EIS has not fully considered alternatives. • The proposed incinerator will emit many other pollutants to which vulnerable groups such as children will be exposed.
National NGO	• Incineration of chlorinated groundwater contaminants in an area surrounded by residences, schools, hospital is unacceptable and out of line with Australia's international obligations. • Incineration particularly of chlorinated waste is acknowledged as a priority source of dioxins, furans and other toxics by US EPA and international community. • It is inconsistent with Australia's obligations under the Stockholm Convention. • Dioxins and furans bioaccumulate, are toxic to humans and wildlife and persist. • Effects of dioxin include immune system, reproductive, development disorders and cancers. • Do not accept "bushfire argument" in EIS that uncontrolled combustion is the largest source of dioxins. • Other pollutants like VOCs, PAHs are also of major concern. • EIS does little to mitigate opposition to siting an incinerator emitting persistent bioaccumulative toxins approximately 300 metres from residents. • Orica has failed its obligations to the community and the EIS process to fully consider the alternatives to building a hazardous waste incinerator in Sydney, in particular Gas Phase Chemical Reduction (Ecologic). • Reliance by Orica on using draft Best Available Techniques guidelines (Stockholm Convention) to support preferred option is unacceptable because they have not been finalised. • The health risk assessment is meaningless because it does not include body burden testing, air monitoring data and examination of all exposures. • There is capacity to store the waste for up to a decade and ample time to locate an appropriate waste management precinct and construct a non-incineration facility – this could be combined with an appropriate destruction site for Orica's existing HCB waste stockpile.
Private submitter	• Life cycle engineering should be achieved. • All contaminated fill should be stored until an acceptable treatment technology is found. • Sewer should not be used as a receptacle for waste. • Needs a waste management plan. • Need to monitor the plume to see if it is stable or receding. • Who will decide on what ammonia treatment unit will be used? A technical committee should be developed and consulted here, including representatives from EPA, universities, local government and community etc.

Submission	Primary issues raised in submission
Local representative NGO	• Assessment of alternatives should have included Germany which is recognised as a leader in dealing with dioxins and furans emissions. • Self monitoring by Orica should cease. • Over a 30 year period how will consistency and accountability be maintained? • EIS does not state what is the best available thermal oxidiser and who is the best vendor for it? USA and Japan thermal oxidiser plants may not be good enough. • How would other chemicals discharged into Bunnerong Canal react with proposed discharges? How much monitoring and testing is undertaken? • What control systems are in place? Is a daily diary kept by operators. Who will operators report to? • Once the treatment of contaminated groundwater is complete the GTP must be decommissioned and removed. • Public comment period was insufficient; there has been a lot of public consultation but due to technical complexities the public is disadvantaged – Orica should fund an independent expert chosen by the community to assist it in understanding technologies etc. • Thorough review is required of the management plan and an update of the international and national chemical emission standards. Constant review of the procedures is required which could be antiquated in 10 years or less. • The current hazard/risk analysis is inadequate and should be reviewed by an independent expert chosen by the community and funded by Orica. • Where has the final selection been seen in operation? Has it operated for 30 years? Does it perform the same in the Australian climate? • Periodic checks of the pipe conditions must be made for leaks etc. • Recommendations made by Dr Peggy O'Donnell and Dr Marcus Lincolm Smith must be implemented in the estuary monitoring programs. • Orica should place a security bond of $50m against satisfactory clean up (first payment to be in Public Trustees). • An independent expert chosen by community members and funded by Orica must be appointed to assist community members of CLG as required. • The standards for dioxin emissions as quoted in the EIS for USA and Japan may not be good enough. Standards for Germany must be investigated. • All areas surrounding the clean up facility must be cleaned (inc Botany Industrial Park). • There is to be no stockpile remaining of chemicals used or unused or wastes resulting from the clean up stockpiles. • All compensations are to be finalised wherever necessary. • Orica's Board of Directors is to be held accountable for all mishaps, non-compliance etc. • Every section of the clean up plant is to be decommissioned, dismantled and removed from the regions of Botany Bay.
Local representative NGO	• Emissions of dioxins and furans within proximity of homes and schools are unacceptable • Not demonstrated that the levels of salinity in discharges will not impact ecology of the immediate area and beyond, particularly seagrasses. • EIS fails to examine impact on seagrass beds or salt marsh or study bird, mammal, reptile ingestion of toxins from drinking water near plume sites. • Within Botany Bay there are recognised sites and issues under Australian Oceans Policy, Ramsar Convention, marine parks, aquatic reserves, intertidal protected areas – need to clearly demonstrate that discharges will not impact these areas. • Timing of exhibition and period for comment unsatisfactory. • EIS has very little information on impacts on ecology of the bay or health of community using estuary at the discharge interface: in event proposal fails, what back up? Precautionary Principle should be applied and both containment and destruction systems should have support systems in place prior to approval. • Little or no investigation has been made of the long term issues for movement of contaminants in the aquifer beneath the Bay itself – test on fish caught in Botany Bay should be identified and NSW Fisheries should make results public. Most fish that visit Penrhyn Estuary also visit other extremes of the bay. • Dredging 7.5m m^3 sand from immediately adjacent to Penrhyn Estuary will have some effect on toxic plumes. • Orica is responding to DEC's demands as top priority but this doesn't excuse DEC delay in requiring clean up. • Support the call for a $50m security bond and the holding of Orica management responsible for mishaps.

Submission	***Primary issues raised in submission***
Global NGO	• Decision to clean up groundwater supported but not the proposal that will result in generation and release to the environment of POPs. • Other alternatives for containment and treatment need to be considered: it appears the least cost option has been chosen without due consideration of health and environmental impacts from incineration – EIS gives little consideration to VOCs and PAHs that can arise from incineration. • Orica should be seeking to reduce emissions from site not increasing them. • The proposal is inconsistent with Australia's obligations under the Stockholm Convention.
State government agency [DIPNR]	• The Preliminary Hazard Analysis is based on a number of assumed conditions due to limited design information – all these assumptions should be reviewed after finalisation of design and updated in the Final Hazard Analysis. • Impact of toxic fumes is defined as local – reasons for this conclusion should be clarified. • Statement in Consequence Analysis that groundwater is non-hazardous contradicts other information and should be clarified. • Consideration should be given to the proximity of storage tanks to the thermal oxidiser in the event of explosion. • Further information is required on the influent gas concentration to the thermal oxidiser. • Clarification of the methods used to achieve stated concentrations for Arsenic and Chromium in the treated reuse water is required.
Global NGO	• Use of incineration technology to destroy groundwater contamination is opposed when viable closed loop non-incineration technologies are available. • By own admission Orica has 10 years' storage capacity for contaminant using pumping and stream stripping – rejecting the incineration proposal will not threaten the Bay – current pumping allows time for a solution that does not negatively impact the local community. • The proposal is inconsistent with the Stockholm Convention and Australia's obligations thereunder. • The human health risk assessment is problematic re treatment of dioxins: firstly, there is no safe level for dioxins intake; secondly, ignores the fact that some segments of Australian population already receive far in excess of Australian standard tolerable daily intake. • Accepting certain levels of dioxins intake as tolerable inconsistent with rationale of Stockholm Convention; lack of endpoint analysis for endocrine disruption renders value of risk calculations questionable
State government agency [NSW Health]	• Human health risk assessment in EIS broadly in accordance with nationally accepted framework and guidelines • Estimated emissions of chemicals of potential concern under best/worst scenarios need to re-confirmed as accurate; operational status of emissions need continuous monitoring and reporting
State government agency [Sydney Water]	• Any proposals for adjustments to trade wastewater discharges from the Orica site will be assessed in terms of wastewater quality and quantity and impact on the limited capacity of the Malabar Sewage Treatment Facility
Local NGO	• The proposed treatment method will release dioxins and increase the VOCs emitted from Orica – any increase in emissions is of concern particularly with respect to the vulnerability of our children • Because of the urgency of preventing contamination reaching the Bay, there should be an alternative plan if the proposal proves unacceptable which should be activated if contamination breaches the containment lines • Not happy with current emissions from the site, much less future emissions. • Supports proposals in other submissions for alternative technologies • Resents being required to comment on the proposal in a situation of such urgency to act – the lateness of the compulsory clean up action places unconscionable pressure on the Government and community to accept whatever is proposed • The DNAPL sites are on-going sources of contamination likely to impact our grandchildren when the liner fails – consideration should be given also to the clean up of these sites • Effects of the plume on the Penrhyn Estuary not included in the EIS – these are of concern • The effect of current levels of emissions on Banksmeadow school are unacceptable, and future emissions will be much less so: there should be ambient air quality and dust monitoring at the school • Support calls for a $50m bond and moratorium on any sale of land by Orica

Submission	***Primary issues raised in submission***
Local government [Randwick City]	• Extraction and treatment of contaminated groundwater should be undertaken as soon as possible and hydraulic containment and groundwater treatment plant construction strongly supported, subject to concerns with thermal oxidation, emissions and the risk assessment process • A rigorous independent assessment of alternative technologies should be conducted – mechanisms should be put in place that ensure best practice technologies are included at a later date when suitable new destruction technology that avoids incineration and release of dioxins is developed • Purchase of GTP equipment by Orica pre-approval seems to pre-empt the consultation and EIS process outcome: it appears Orica proposal based on time and money rather than holistic environmental, social, economic assessment, especially when alternatives like biotreatment still under investigation • Use of the GTP should be restricted to the current proposal. • Contaminated water passed Foreshore Road containment is reaching Penrhyn Estuary but there doesn't appear to be a mechanism to address this: actions such as the fencing need to be clearly articulated; containment at Foreshore Road will result in salt water being drawn into the aquifer – potential ecological, environmental and infrastructural effects of this are unclear • EIS fails to have regard to the sensitive salt marsh and sea grass habitat. • Need for incineration as a treatment process is questioned, as there may still be better yet-to-be-investigated alternatives, which would be more in keeping with the Stockholm Convention • Recommended that accurate background levels be obtained to information health risk assessment process especially regarding cumulative impacts. • Recommended that an ongoing health risk assessment process be formalised with independent expert overview re bioaccumulation of contaminants in water, and re dioxins emission to air. • There should be an independent review of alternative technologies over the 30 year period with a requirement for best practice to supersede the GTP once technologies are developed. • There should be independent expert monitoring of the process at the cost of Orica.
Local government [City of Botany Bay]	• Not enough effort is being put into addressing and managing the DNAPL source areas. • Use of the GTP beyond clean up of the contaminated groundwater should be subject to extensive discussion with the community and key stakeholders. • Containment along Foreshore Road will impact the interface between freshwater and marine water – EIS does not propose any measures to continuously evaluate or mitigate. • Plant should be run on a minimum of 10% green power to mitigate greenhouse emissions. • EIS fails to recognise coastal saltmarsh communities as listed endangered ecological community under NSW Threatened Species Act – detailed monitoring regime should be implemented to ensure changes to this community are monitored, identified, reported and communicated. • Ambient air quality monitoring in Randwick LGA provides less accurate representation than monitoring in Botany; buffer distance to residences not significant compared to other sites in Australia; dioxin emissions are a concern for the local community so monitoring and reporting needs to be accessible, easily read and understood by the community.
State government agency [Department of Primary Industries]	• Return the treated water through the estuary rather than discharge through Brotherson Dock – this appears to have been treated in a cursory fashion as being too hard or too expensive. • Potential impacts on the benthic communities in Penrhyn Estuary due to changes in flow in Springvale and Floodvale Drains – reduction in freshwater inputs to the estuary has the potential to greatly influence the community structure of the aquatic community in the estuary and have a flow effect for wading bird populations. • There is a lack of specific information on the toxicity or bioaccumulation potential of the chemicals in the groundwater in the benthic organisms, fish populations and wading birds that feed on them. • There should be a monitoring program to determine the abundance and special distribution of benthos and sampling before, during and after groundwater interception. • There should also be toxicological studies using a range of indicator species.
State government agency [NSW Maritime]	• There appears to be no specification given for the salinity level of discharge water. • Water quality monitoring should be undertaken at the discharge point, namely the pipeline where it enters Bunnerong Canal in addition to at Brotherson Dock as proposed. • There is minimal detail regarding the discharge point at Bunnerong Canal – the design of the diffuser should be provided and the nature of the works required to construct and install the diffuser should be provided.

Submission	***Primary issues raised in submission***
Local State MP	• Orica should conduct Dilapidation Surveys for residents concerned about potential structural damage to their properties. • What consideration has been given to impacts if assumptions made in the EIS concerning the application of the Environmentally Hazardous Chemicals Act, Water Act, Road and Rail transport (Dangerous Goods) Act and Soil Conservation Act prove to be incorrect. • It is unclear from the EIS how the Community Relations Activities and public input will be incorporated into the project. • Orica should consider how it can alleviate the inconvenience to community and residents e.g. for those who have lost the use of bores, by meeting the cost of installation, operation and maintenance of rainwater tanks. • Orica should enter a Community Contract that goes beyond DA conditions and includes a commitment to consultation, reporting a lodgement of a security bond. • Conclusions drawn re HCB detected in oysters and fish seem inconsistent with the testing results and HCB in marine organisms is not mentioned in the Executive Summary. • The most efficient destruction technology will mean higher greenhouse gas emissions – a GHG management/offset strategy will be required. • The EIS does not mention the impact of emissions on ambient air temperature and impacts for local weather and bird flight paths.
Private Submitter	• Government and industry have a responsibility to ensure that risks are properly managed and that they are negligible compared to the risks faced during the course of everyday life. • DEC's detailed EIS guidelines and Orica's fulfilment of them are commendable • Orica has been accessible and generous with resource information. • Ongoing consultation opportunities include monitoring methods, recording and reporting to community on air emissions, groundwater, transport of chemicals, storage of chemicals, bioremediation, community emergency alarm procedures, guidelines for local developments. • There is a window of opportunity for positive proactive stakeholders to be part of a model consultative process. • Success in avoiding contingent liabilities, in this case contaminating Botany Bay, will be achieved if the persons responsible possess both the ability and the will to build the groundwater treatment plant and continue research on clean up.

Appendix B Conditions of Approval

Introduction

The Department of Environment and Conservation, NSW Maritime, Sydney Ports Corporation, Sydney Water Corporation and Department of Infrastructure, Planning and Natural Resources have each decided to approve the activity subject to the following conditions.

- General Conditions
- Conditions to vary Environment Protection Licence No. 2148
- Conditions under Part V (section 116) of the Water Act
- Conditions from DIPNR regarding land use safety planning
- Conditions for Part 3A permit under Rivers and Foreshore Act
- Conditions from Sydney Water
- Conditions from Sydney Ports Corporation for approval for discharge into Bunnerong Canal

The reasons for the conditions are to:

- ensure that adequate safeguards are in place to protect the environment and human health
- mitigate the potential environmental impacts of the activity
- ensure compliance with relevant statutes and statutory instruments
- restore the quality of groundwater in and around Botany Industrial Park.

General Conditions

1. The proposed works must be carried out generally in accordance with:
   1.1. the procedures, safeguards and mitigation measures identified in the EIS
   1.2. an environmental protection licence under the *Protection of the Environment Operations Act 1996*
   1.3. a licence under the *Water Act 1912*
   1.4. an approval under the *Rivers and Foreshores Act 1994*
   1.5. an approval under the *Sydney Water Act 1994*
   1.6. any permission from Sydney Ports Corporation; and
   1.7. this determination report and conditions of this approval.

2. 2. All necessary approvals as stated in section 1 must be obtained by Orica.

3. As far as practicable, the Environmental Management Plan for the project should combine and cover the conditions of the relevant approvals required for the project including the conditions of this approval.

Conditions to vary Environment Protection Licence No. 2148

Orica currently holds an EPA environment protection licence (no. 2148) under the *Protection of the Environment Operations Act 1997*. A copy of this licence can be accessed via the EPA Public Register at www.environment.nsw.gov.au.

This licence contains existing conditions including but not limited to:

- limits in regard to controlling air, noise, water pollution and waste

- requirements for maintaining plant and equipment in a proper manner and operating plant and equipment in a competent manner
- monitoring and reporting environmental performance
- submitting a statement of compliance with respect to licence conditions
- reporting incidents that may cause harm to DEC.

DEC has determined that it is able to vary the existing EPA licence held by Orica to incorporate the following new licence conditions for the proposed development.

NEW CONDITIONS

Discharges to air and water and applications to land

P1 Location of monitoring/discharge points and areas

P1.1 The points referred to in the following table are identified in this licence for the purposes of monitoring and/or setting limits for the emission of pollutants to the air from the point.

Air

EPA identification no.	Type of monitoring point	Type of discharge point	Description of location
9	Air emissions monitoring/ Discharge to air	Air emissions monitoring/ Discharge to air	Stack serving GTP labelled “Monitoring Point 9 (GTP stack)” on drawing number B94744 submitted to the EPA on 25 January 2005.
10	Parameter monitoring		Thermal oxidation unit labelled “Monitoring Point 10 (Thermal Oxidation Unit)” on drawing number B94744 submitted to the EPA on 25 January 2005
12	Weather monitoring		Weather monitoring station labelled “Monitoring Point 12 (Weather Station)” on drawing number B94744 submitted to the EPA on 25 January 2005.

P1.2 The points referred to in the following table are identified in this licence for the purposes of monitoring and/or setting limits for discharges of pollutants to water from the point.

P1.3 The utilisation areas referred to in the following table are identified in this licence for the purposes of monitoring and/or setting limits for any application of solids or liquids to the utilisation area.

Water and land

EPA identification no.	**Type of monitoring point**	**Type of discharge point**	**Description of location**
11	Discharge to waters Effluent quality and volume monitoring	Discharge to waters Effluent quality and volume monitoring	Drain outlet serving the GTP labelled “Monitoring Point 11 (GTP discharge to waters)” on drawing number B94744 submitted to the EPA on 25 January 2005.

Limit conditions

L3 Concentration limits

L3.1 For each monitoring/discharge point or utilisation area specified in the table(s) below (by point number), the concentration of a pollutant discharged at that point, or applied to that area, must not exceed the concentration limits specified for that pollutant in the table.

L3.2 Where a pH quality limit is specified in the table, the specified percentage of samples must be within the specified ranges.

L3.3 To avoid any doubt, this condition does not authorise the pollution of waters by any pollutant other than those specified in the tables.

Air

POINT 9

Pollutant	**Unit of measure**	**100th percentile concentration limit**
1,2-Dichloroethane	mg/m3	8
Chlorine	mg/m3	30
Nitrogen oxides	mg/m3	400
Volatile organic compounds	mg/m3	10
Hydrogen sulfide	mg/m3	2
Dioxins and Furans [1]	ng/m3	0.1
Hydrogen chloride	mg/m3	30
Sulfur dioxide	mg/m3	100
Vinyl chloride	Ppm	10
Solid particles	mg/m3	20
Carbon monoxide	mg/m3	100

Note: The above limits apply to the stack emissions prior to the addition of any re-heat air.

1. Polychlorinated-dibenzo-p-dioxins (PCDD) and polychlorinated-dibenzofurans (PCDF) as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalent calculated in accordance with the procedures included in Part 9, Clause 19 of the Clean Air (Plant and Equipment) Regulation 1997.

POINT 11

Pollutant	Unit of measure	50th percentile concentration limit	90th percentile concentration limit	3DGM concentration limit	100th percentile Concentration Limit
1,2-Dichloroethane	mg/L				1.9
Arsenic	mg/L				0.0023
Cadmium	mg/L				0.0007
Carbon tetrachloride	mg/L				0.24
Copper	mg/L				0.0013
Iron	mg/L				0.3
Lead	mg/L				0.0044
Manganese	mg/L				0.08
Mercury	mg/L				0.0001
Nickel	mg/L				0.007
Oxidised nitrogen	mg/L				0.015 Note 1
pH	pH				7-8.5
Reactive phosphorus	mg/L				0.005
Tetrachloroethene (tetrachloroethylene)	mg/L				0.07
Nitrogen (total)	mg/L				0.1 Note 1
Trichloroethene (trichloroethylene)	mg/L				0.33
Turbidity	NTU				5 Note 1
Zinc	mg/L				0.015
Benzene	mg/L				0.95
Toluene	mg/L				0.18
Vinyl chloride	mg/L				0.1
Biochemical oxygen demand	mg/L				10
Total phosphorus	mg/L				0.01 Note 1
Chromium (total)	mg/L				0.0044
NH3-N	mg/L				0.015 Note 1
Chloroform	mg/L				0.37
Temperature	°C				15-25

For the purposes of the table above Note 1 means that concentration limits may be subject to review and change once the final details are received on the treatment technology and the design of the discharge structure.

L3.4 Reference condition

For the concentration limits specified for Point 9 (above), the following reference conditions also apply:

Pollutant	Unit of measure	100th percentile concentration limit	Reference Conditions	Averaging Period
1,2-Dichloroethane	mg/m3	8	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 1 hour average
Chlorine	mg/m3	30	Dry, 273 K, 101.3 kPa, 11% O_2	As per test method
Nitrogen oxides	mg/m3	400	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 1 hour average
Volatile organic compounds	mg/m3	10	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 1 hour average
Hydrogen sulfide	mg/m3	2	Dry, 273 K, 101.3 kPa, 11% O_2	As per test method
Dioxins and furans[1]	ng/m3	0.1	I-TEQ, Dry, 273 K, 101.3 kPa, 11% O_2	As per test method
Hydrogen chloride	mg/m3	30	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 1 hour average
Sulfur dioxide	mg/m3	100	Dry, 273 K, 101.3 kPa, 11% O_2	As per test method
Vinyl chloride	ppm	10	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 3 hour average
Solid particles	mg/m3	20	Dry, 273 K, 101.3 kPa, 11% O_2	As per test method
Carbon monoxide	mg/m3	100	Dry, 273 K, 101.3 kPa, 11% O_2	Rolling 1 hour average

Note

1. Polychlorinated-dibenzo-p-dioxins (PCDD) and polychlorinated-dibenzofurans (PCDF) as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalent calculated in accordance with the procedures included in Part 9, Clause 19 of the Clean Air (Plant and Equipment) Regulation 1997.

L3.5 Thermal oxidation unit lower limits

For each monitoring/discharge point or utilisation area specified in the tables below (by point number), the parameter must be equal to or greater than the lower limits specified for that parameter in that table.

Point 10

Parameter	Unit of measure	Lower Limit	Averaging period
Residence time	s	2	Instantaneous
Temperature	°C	850	Instantaneous

L3.6 The air stripping and thermal oxidiser plant must shut down and cease all emissions as soon as safely possible, but in no case later than 10 minutes, if there is a combustion failure in the thermal oxidiser.

L4 Volume and mass limits

L4.1 For each discharge point or utilisation area specified below (by point number), the volume/mass of:

(a) liquids discharged to water or

(b) solids or liquids applied to the area,

must not exceed the volume/mass limit specified for that discharge point or area.

Point	Unit of measure	Volume/mass limit
11	kL/day	12000

Noise limits

L6.4 Noise generated by activities associated with the Groundwater Cleanup Project, other than those accepted by DEC as being 'construction' at the premises, must not exceed the noise goal level presented in Table 6.4 below:

Table 6.4 - Noise Design Goal Limits (dB(A))

Location	Day	Evening	Night
	$L_{Aeq(15\ minute)}$	$L_{Aeq(15\ minute)}$	$L_{Aeq(15\ minute)}$
Nearest affected receivers surrounding the Groundwater Cleanup Project	*35 dB(A)*	*35 dB(A)*	*35 dB(A)*

L6.5 For the purpose of Condition(s) L6.1; L6.2 and L6.4:

- Day is defined as the period from 7 am to 6 pm Monday to Saturday and 8 am to 6 pm Sundays and public holidays.
- Evening is defined as the period from 6 pm to 10 pm.
- Night is defined as the period from 10 pm to 7 am Monday to Saturday and 10 pm to 8 am Sundays and public holidays.

L6.6 Noise from the premises is to be measured at the most affected point on or within the residential boundary to determine compliance with the LAeq(15 minute) noise limits in condition L6.4.

Where it can be demonstrated that direct measurement of noise from the premises is impractical, the EPA may accept alternative means of determining compliance. See Chapter 11 of the *NSW Industrial Noise Policy*.

The modification factors presented in section 4 of the *NSW Industrial Noise Policy* shall also be applied to the measured noise level where applicable

L6.7 The noise emission limits identified in condition L6.4 apply under meteorological conditions of:

- wind speeds up to 3 m/s at 10 metres above ground level, or
- temperature inversion conditions of up to 3 ^{o}C/100 m and wind speeds up to 2 m/s at 10 metres above ground level.

Hours of operation – construction

L6.8 All construction work at the premises must only be conducted between 7:00 am and 6:00 pm Monday to Friday, 8:00 am and 1:00 pm Saturdays, with no construction activities on Sundays or public holidays. Construction is permitted at any time if it is not audible at the nearest affected receivers. Audible means that it can be heard by a person at the nearest affected receivers.

L6.9 Activities at the premises, other than construction work, that meet the noise goal provided in L6.4 may be conducted on a continuous basis.

L6.10 The following activities may be carried out at the premises outside the hours specified in condition L6.8:

- the delivery of materials as requested by Police or other authorities for safety reasons
- emergency work to avoid the loss of lives, property and/or to prevent environmental harm.

Monitoring conditions

M2 Requirement to monitor concentration of pollutants discharged

M2.1 For each monitoring/discharge point or utilisation area specified below (by point number), the licensee must monitor (by sampling and obtaining results by analysis) the concentration of each pollutant specified in Column 1. The licensee must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns.

POINT 9

Pollutant	Unit of measure	Frequency	Sampling method
1,2-Dichloroethane	mg/m3	Continuous	CEM-8
Carbon monoxide	mg/m3	Continuous	CEM-4
Chlorine	mg/m3	Quarterly	TM-7 and 8
Dioxins and furans	ng/m3	Special frequency 2	TM-18
Dry gas density	kg/m3	Quarterly	TM-23
Hydrogen sulfide	mg/Nm3	Quarterly	TM-5
Hydrogen chloride	mg/m3	Continuous	Method approved in writing by the EPA
Moisture content	%	Continuous	TM-22
Molecular weight of stack gases	g/g-mole	Quarterly	TM-23
Nitrogen oxides	mg/m3	Quarterly	TM-11
Oxygen (O2)	%	Continuous	CEM-3
Solid particles	mg/m3	Special frequency 3	TM-15
Sulfur dioxide	mg/m3	Special frequency 3	TM-4
Temperature	K	Continuous	TM-2
Velocity	m/s	Continuous	CEM-6
Vinyl chloride	ppm	Continuous	CEM-8
Volatile organic compounds	mg/m3	Continuous	CEM-8
Volumetric flowrate	m3/s	Continuous	CEM-6

M2.5 For the purposes of the table(s) above:

Special Frequency 2 is defined as monitoring monthly for the first 6 months and bimonthly thereafter. This monitoring frequency could be reviewed after 2 years.

Special Frequency 3 is defined as monitoring monthly for the first 6 months and quarterly thereafter. This monitoring frequency could be reviewed after 2 years.

POINT 11

Pollutant	Unit of measure	Frequency	Sampling Method
1,2-Dichloroethane	mg/L	weekly	Grab sample
Arsenic	mg/L	weekly	24 hour composite
BOD	mg/L	weekly	24 hour composite
Benzene	mg/L	weekly	grab sample
Cadmium	mg/L	weekly	24 hour composite
Carbon tetrachloride	mg/L	weekly	Grab sample
Chromium (total)	mg/L	weekly	24 hour composite
Copper	mg/L	weekly	24 hour composite
Iron	mg/L	weekly	24 hour composite
Lead	mg/L	weekly	24 hour composite
Manganese	mg/L	weekly	24 hour composite
Mercury	mg/L	weekly	24 hour composite
Nickel	mg/L	weekly	24 hour composite
Nitrate + Nitrite (oxidised nitrogen)	mg/L	weekly	24 hour composite
Nitrogen (ammonia)	mg/L	weekly	24 hour composite
Nitrogen (total)	mg/L	weekly	24 hour composite
Phosphorus (total)	mg/L	weekly	24 hour composite
Reactive Phosphorus	mg/L	weekly	24 hour composite
Tetrachloroethene (tetrachloroethylene)	mg/L	weekly	Grab sample
Toluene	mg/L	weekly	Grab sample
Trichloroethene (Trichloroethylene)	mg/L	weekly	Grab sample
Turbidity	NTU	weekly	24 hour composite
Vinyl chloride	mg/L	weekly	Grab sample
Zinc	mg/L	weekly	24 hour composite
pH	pH	weekly	24 hour composite
conductivity	uS/cm	continuous	in line instrumentation
temperature	C	continuous	in line instrumentation

M2.5 In relation to monitoring requirements at point 9, a performance specification test must be conducted for all continuous emission monitoring systems at the time of installation, or soon after, and thereafter on a quarterly basis. The quarterly tests must be conducted at least two months apart for each continuous emission monitoring system and in accordance with the requirements of the applicable CEMS protocol. The results of all performance specification tests must be submitted to the EPA within one month of completion of the tests.

M3 Testing methods - concentration limits

M3.2 Subject to any express provision to the contrary in this licence, monitoring for the concentration of a pollutant discharged to waters or applied to a utilisation area must be done in accordance with the Approved Methods Publication, unless another method has been approved by the EPA in writing before any tests are conducted.

M6 Requirement to monitor volume or mass

M6.1 For each discharge point or utilisation area specified below, the licensee must monitor

(a) the volume of liquids discharged to water or applied to the area
(b) the mass of solids applied to the area
(c) the mass of pollutants emitted to the air.

at the frequency and using the method and units of measure specified below.

POINT 11

Frequency	Unit Of Measure	Sampling Method
Daily during any discharge	kL/day	Method approved in writing by the EPA

M7 Requirement to monitor thermal oxidation unit parameters

M7.1 For each monitoring/discharge point or utilisation specified in the tables below (by point number), the licensee must monitor (by sampling and obtaining results by analysis) each parameter specified in column 1. The licensee must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns.

Air

POINT 10

Parameter	Unit of measure	Frequency	Averaging period
Volumetric flow rate	m^3/s	Continuous	CEM-6
Temperature	°C	Continuous	TM-2

M8 Weather monitoring

M8.1 For each monitoring point specified below (by a point number), the licensee must monitor (by sampling and obtaining results by analysis) the parameter specified in column 1. The licensee must use the sampling method, units of measure, averaging period and sample at the frequency specified opposite in the other columns.

POINT 12

Parameter	Unit of measure	Averaging period	Frequency	Sampling Method
Wind speed @ 10 m	m/s	15 min	Continuously	AM-2 and AM-4
Wind direction @ 10 m	°	15 min	Continuously	AM-2 and AM-4
Sigma theta @ 10 m	°	15 min	Continuously	AM-2 and AM-4
Additional requirements				

Parameter	Unit of measure	Averaging period	Frequency	Sampling Method
Siting				AM-1 and AM-4
Measurement				AM-2 and AM-4

General conditions

Signage

G2.1 The location of EPA point number(s) 3,4,7,8,9,10,11 and 12 must be clearly marked by signs that indicate the point identification number used in this licence and be located as close as practical to the point.

Special conditions

E9 Audits and reviews

The objective of this condition is:

- to conduct a series of ongoing independent audits to validate the predictions included in the EIS and compliance with this licence, and to the extent required by any other approval, compliance with those approval conditions relating to the project
- to conduct environmental reviews with the aim of optimising performance
- to conduct engineering audits to ensure the performance of the plant will not deteriorate in the longer term
- to identify remedial measures that can be implemented in the event an audit shows a discrepancy between actual and predicted performance.

This condition comprises two parts:

- Part A – Validation audit and Environmental review
- Part B – Engineering audit

PART A - VALIDATION AUDIT AND ENVIRONMENTAL REVIEW

General

The licensee must undertake comprehensive validation audits and environmental reviews of the works undertaken in accordance with the EIS.

The auditor must prepare a written report on the validation audit and environmental review for submission to the DEC, DIPNR, Sydney Ports Corporation, Sydney Water Corporation, NSW Maritime, City of Botany Council and the Independent Monitoring Committee and make this report available for public inspection on request.

A single report must be submitted that includes all the validation audit and environmental review requirements of this licence and to the extent required by any other approval, compliance with those approval conditions relating to the project.

The report must be submitted with each Annual Return for the first two reporting periods during which the groundwater treatment plant has commenced operation. The ongoing necessity for this requirement will be reviewed in consultation with the Independent Monitoring Committee and taking into account the performance of the groundwater treatment plant.

The EPA may require the licensee to undertake works to address the findings or recommendations presented in the report as a requirement of this licence. Any such works must be completed within such time as agreed to by the EPA.

Each Validation audit and Environmental review must include the following components:

- Validation audit
- Environmental review

E9.1 VALIDATION AUDIT

The licensee must engage (and bear the full cost of) an independent and suitably qualified auditor to undertake comprehensive validation audits of the project.

The auditor must:

- be a certified environmental auditor who has gained certification from a certification body (such as Registrar Accreditation Board and Quality Society of Australasia international (RABQSA) formerly known as (QSA) who have been accredited by the Joint Accreditation Services Australia and New Zealand (JAS/ANZ);
- have Lead Environmental Auditor certification; and
- have held lead environmental certification for at least 2 years.

The licensee must consult with the Independent Monitoring Committee in the selection of the auditor.

The validation audit must:

(a) be carried out in accordance with ISO 19011:2003: Guidelines for Quality and/or Environmental Management Systems Auditing
(b) take into account representative operating conditions, including worst-case scenarios, which relate to the groundwater treatment plant
(c) assess compliance with the requirements of this licence, and to the extent required by any other approval, compliance with those approval conditions relating to the project
(d) assess the project against the predictions made and conclusions drawn in the EIS and supporting documents prepared by the licensee
(e) include the following components
  - air emission validation program
  - water discharge validation program
  - noise validation program
  - thermal oxidation unit validation program

E9.1.1 Air emission validation program

The licensee must conduct an air emissions validation program, which includes but is not be limited to the following:

(a) Ensures the range of all air pollutants monitored are continually reviewed and modified where necessary to ensure the licensee is capable of detecting the presence of all significant air pollutants not already specified in the licence.
(b) make recommendations about changes to existing monitoring, including substances monitored and

frequency of monitoring

(c) validate the conclusions of the human health risk assessment that was undertaken as part of the EIS using emissions monitoring data collected under this licence

(d) validate the conclusions of the air quality impact assessment undertaken as part of the EIS using emissions monitoring data collected under this licence

(e) prepare and implement of a comprehensive odour detection program. This must include but not be limited to:

- A leak detection and repair (LDAR) program to detect and minimise fugitive VOC emissions from the groundwater treatment plant and associated plant and equipment, in accordance with US EPA Method 21 – Determination of Volatile Organic Compound Leaks (40 CFR Part 60, Appendix A, Method 21) or such other method agreed in writing by the EPA
- An overall odour detection program, including representative off-site observations by independent and suitably qualified persons to identify and prevent unanticipated odour sources.

E9.1.2 Water discharge validation program

The licensee must conduct a water discharge validation program, which must include but not be limited to the following:

(a) Ensures the range of all water pollutants monitored are continually reviewed and modified where necessary to ensure the licensee is capable of detecting the presence of all significant water pollutants not already specified in the licence, make recommendations about changes to existing monitoring, including substances monitored and frequency of monitoring.

E9.1.3 Noise validation program

The licensee must conduct a noise validation program, which must include but not be limited to the following:

(a) identification and ranking by sound power level all significant noise sources on the premises (in 1/3 octave bands for any source with potentially undesirable noise character)

(b) identification of all noise sensitive receivers that may be affected by the operation of the groundwater treatment plant, and select an appropriate number of representative receiver locations to represent all sensitive receivers

(c) the results of all noise measurements undertaken to assess compliance with Condition L6.4 of the licence

(d) a statement of whether noise levels from all activities at the licensed premises comply with the specified noise limits at the representative receiver locations. The statement must take into account tonal, impulsive and short duration noises originating from the groundwater treatment plant

(e) where noise levels have been assessed as exceeding allowable licence limits, a statement explaining the reason why this has taken place

(f) a statement of what feasible and reasonable additional measures may be implemented to further reduce noise levels below those specified in the licence.

E9.1.4 Thermal oxidation unit validation program

The licensee must conduct an thermal oxidation unit Validation program which includes but is not be limited to the following:

(a) Ensures that all parameters monitored comply with the Thermal Oxidation Unit lower limits specified in Condition L3.5 in the licence.

(b) Reports the fraction of time the lower temperature limit specified in Condition L3.5 is not achieved within ±50°C.

(c) Correlates all dioxin air emissions data monitored at Point 9 in accordance with Condition M2.1 with temperature and flow rate data monitored at Point 10.

(d) Quantitatively assess dioxin air emissions at Point 9 with the thermal oxidiser operating at or near 850°C.

(e) Where there are increases in dioxin air emissions at the lower temperature limit set at Point 10 (as investigated in (d) above), make recommendations to change the lower temperature limit set at Point 10 and associated operational procedures to prevent dioxin concentration increases at the recommended lower temperature limit.

Note: Quantitative assessment of dioxin at Point 9 is to be undertaken in accordance with the *Approved Methods for the Sampling and analysis of Air Pollutants in NSW, 2000, unless otherwise agreed in writing by the EPA.*.

E9.2 ENVIRONMENTAL REVIEW

The licensee must conduct an Environmental review, which must include but not be limited to the following:

(a) a review of complaints received and action taken by the licensee
(b) summary of environmental monitoring required under the licence and to the extent required by any other approval, compliance with those approval conditions relating to the project
(c) identification of trends in all monitoring data collected since the commencement of operation of the groundwater treatment plant
(d) a statement on the effectiveness of the overall environmental management and performance of the project
(e) the following programs:
  - dioxin minimisation and management program
  - groundwater treatment plant water
  - reuse groundwater monitoring program
  - ambient environmental monitoring program

E9.2.1 Dioxin minimisation program

The licensee must conduct a program that includes, but is not limited to the following:

(a) an investigation into technical options and scientific developments that would allow continuous monitoring and or sampling of any possible dioxin emissions from the groundwater treatment plant
(b) an investigation of chemical and/or physical parameters that are likely to correlate with the actual or potential formation of dioxins and could be used as a surrogate indicator of dioxin formation in the groundwater treatment plant
(c) make recommendations about changes to existing monitoring, including substances monitored and frequency of monitoring.

E9.2.2 Groundwater treatment plant (GTP) water reuse strategy

The Licensee must conduct a program that investigates opportunities to maximise the reuse of treated water from the groundwater treatment plant and reduce the amount of treated water discharged to waters provided the reuse or reduction can be achieved in a safe and practical manner and it will provides the best environmental outcome, in the circumstances.

The program must include but need not necessarily be limited to the following:

- characterisation of the treated water in terms of quality and quantity
- identification of potential sues for this treated water, taking into account relevant and recognised environmental and human health guidelines or standards to ensure it is appropriate for this use
- identification of options to beneficially reuse treated waters to minimise the amount of treated water being discharged
- assessment of the feasibility and cost of these options
- selection of options for implementation
- timetable for implementation of the selected options
- inclusion of any of potential uses of this treated water, taking into account relevant and recognised
- other relevant recommendations relating to treated water reuse.

The licensee must consult with the DEC, NSW Health Department, Sydney Water Corporation, Sydney Ports Corporation, Botany Bay Council, DIPNR and NSW Maritime on the development of the program.

E9.2.3 Groundwater monitoring program

The licensee must conduct a Groundwater monitoring program which must include but not be limited to the following:

(a) monitor groundwater to assess whether the extraction of groundwater will result in any actual or potential impacts to surface waters or habitats in the locality
(b) review the conclusions of the groundwater assessments and modelling that was undertaken as part of the EIS, including using all monitoring data collected under this licence or other approvals for this project
(c) include a mechanism to regularly review the effectiveness of the monitoring program to ensure it is effective in detecting the presence of actual or potential impacts not already identified
(d) make recommendations about changes to existing monitoring and frequency of monitoring.

The program must be prepared and implemented in consultation with the DEC, DIPNR, DPI, Sydney Ports Corporation, Sydney Water Corporation, NSW Maritime and City of Botany Council.

E9.2.4 Ambient environmental monitoring program

The licensee must conduct an Ambient environmental monitoring program which must include but not be limited to the following

(a) develop and implement a program to monitor ecological health of habitats in the locality and water quality in the receiving environment, including specification of sampling locations, sampling frequencies and parameters to be tested
(b) include quality control elements
(c) include monitoring sites at Penrhyn Estuary, Botany Bay and Bunnerong Canal as well as other relevant off-site locations
(d) assess whether the project will result in any actual or potential impacts to surface waters or habitats in the locality from the operation of the groundwater treatment plant and associated plant and equipment
(e) review the conclusions of the ecological and ambient water quality assessments that were undertaken as part of the EIS, including using monitoring data collected under this licence or other approvals for this project
(f) include a mechanism to regularly review the effectiveness of the monitoring program to ensure it is effective in detecting the presence of actual or potential impacts not already identified
(g) make recommendations about changes to existing monitoring, including substances monitored and

frequency of monitoring.

The program must be prepared and implemented in consultation with the DEC, DIPNR, DPI, Sydney Ports Corporation, Sydney Water Corporation, NSW Maritime and City of Botany Council.

E9.3 PART B - ENGINEERING AUDIT

The licensee must make arrangements for, and bear the full cost of, an independent auditor to undertake engineering audits of the groundwater treatment plant and associated plant and equipment (including all control systems) to ensure it is maintained in a proper and efficient condition and operated in a proper and efficient manner with respect to its environmental and safety capability and performance.

Matters to be addressed in the audits must include but not be limited to

(a) review of the frequency of inspections and maintenance programs to ensure they are effective in detecting actual or potential changes in the environmental and safety performance
(b) review of procedures for detecting changes to the equipment that could impact on performance, including corrosion and wear
(c) review of results of internal inspections of all equipment, using video techniques where appropriate.

The licensee must consult with the Independent Monitoring Committee in the selection of the auditor.

The engineering audits must generate a report for submission to the EPA, DIPNR, Sydney Water Corporation, City of Botany Council, Community Liaison Group and available for public inspection on request.

The report must be submitted with each Annual Return

- at end of every 5th reporting period, for the first 15 years of operation of the groundwater treatment plant and then
- every 2nd reporting period in which the plant remains in operation.

The EPA may require the licensee to undertake works to address the findings or recommendations presented in the report as a requirement of this licence. Any such works shall be completed within such time as the EPA may agree.

E10 Independent Monitoring Committee

E10.1 The licensee must establish and service an Independent Monitoring Committee with technical and community representatives. The licensee must provide monitoring information and reports and consult with this Committee as required by the relevant conditions of this licence.

Note: The Independent Monitoring Committee may be formed by the licensee by expanding the existing Community Liaison Group currently established and serviced by the licensee.

E11 Financial Assurance

Requirement for works

The licensee must construct and operate the groundwater treatment plant referred to, and required by, the EPA Notice of Clean-up Action issued on 26 September 2003 as subsequently varied, and this licence.

Purpose of financial assurance

This licensee requires construction and operation of the groundwater treatment plant to complete the Botany groundwater clean-up project. The purpose of this project is to undertake remediation work to address groundwater contamination caused by historical manufacturing activities undertaken at the Botany Industrial Park (former ICI site). The objective of this condition is to secure or guarantee funding for or towards the ongoing operating costs of the project, following construction of the groundwater treatment plant.

Due date for financial assurance

The licensee must lodge a financial assurance in the form of a bank guarantee, a bond, or in another manner acceptable to the EPA by 30 November 2006.

The financial assurance must be maintained during the operation of the groundwater treatment plant and thereafter until such time as the EPA notifies the licensee in writing that it is satisfied that the contaminated groundwater has been appropriately remediated.

Expert advice to be provided to the EPA

The licensee must engage (and bear the full cost of) independent and suitably qualified experts to:

- Review and confirm the estimated annual and total remaining net operating and maintenance costs of the groundwater treatment plant and the associated monitoring and reporting costs over the life of the project; and
- Review and advise on the risks associated with the licensee's ability and commitment to meet those costs during the life of the project and the probabilities of those risks ; and
- Review and advise on the technical and environmental risks if the licensee is unable to meet the operating costs during the life of the project and the probability of those risks.

The licence must provide the expert reports to the EPA, together with any written comments from the licensee about the appropriate form or amount of the financial assurance, by 30 June 2006.

Determination of financial assurance

The form and amount of the financial assurance will be determined by the EPA (and imposed by a subsequent licence condition), following the EPA's consideration of the expert reports on costs and risks and probabilities, and the licensee's submission on the appropriate form and amount of the financial assurance.

The EPA may require the financial assurance to be adjusted so that it keeps pace with inflation for so long as the EPA requires the financial assurance to remain in place. The EPA may review the financial assurance from time to time in light of the remaining works required to complete the remediation.

Conditions under Part V (Section 116) of the Water Act

Pursuant to Part V of the *Water Act 1912* the Department of Infrastructure, Planning and Natural Resources (DIPNR), having reviewed the documentation associated with the proposal as described in a report titled *Botany Groundwater Cleanup Project – Environmental Impact Statement* (EIS) dated November 2004 and submitted to the Department by Orica Australia Pty Ltd, proposes to grant a Licence subject to a formal application being received from the proponent for such.

In addition to the licence, DIPNR proposes general and specific conditions for management of groundwater resources and dependent ecosystems in the area of the proposed groundwater clean up development.

The general terms of approval are set out below.

A. General conditions - Water Licence (Part V Water Act)

1. Under the provisions of Part V (s116) of the Water Act, this licence shall be valid for the period of ten (10) years and may be renewed upon application.

2. The licensee shall allow the Department of Infrastructure, Planning and Natural Resources, or its authorised representatives, subject to appropriate occupational health and safety provisions, full and free access to the works (ie groundwater extraction bores and groundwater investigation/monitoring bores), during or after construction, for the purpose of undertaking inspection or test of works and its fittings, and shall carry out any work or alterations deemed necessary by DIPNR to ensure the protection and maintenance of the works, or the control of the water extracted and for the protection of the quality and the prevention from pollution/contamination of surface and subsurface water.

3. The licensee shall notify DIPNR if the works (ie groundwater extraction bores, investigation/monitoring bores) are to be abandoned and, contingent with safety requirements, seal off the works by:
    (a) backfilling the work to ground level with clay or cement, or
    (b) other methods agreed to or directed by DIPNR.

4. Prior to the construction of any bore for purposes of groundwater extraction, investigation and/or groundwater monitoring, a bore licence application shall be submitted and a licence obtained from DIPNR. Completion details (Form A - Particulars of completed bore) of all bores are required to be forwarded to DIPNR within three (3) months of completion of construction.

5. Any drilling contractor engaged to construct a groundwater extraction, investigation and/or monitoring bore must hold a current NSW Water Bore Drillers Licence, with appropriate endorsements for the proposed work, that has been issued under the Water Act by DIPNR.

6. All groundwater extraction, investigation and/or monitoring bores shall be constructed in accordance with bore construction requirement given in *Minimum Construction Requirements for Water Bores in Australia* – Land and Water Biodiversity Committee Edition No 2, September 2003.

7. Appropriate occupational health and safety provisions required by NSW WorkCover must be observed during the construction of all water bores for the project.

8. Any licence granted that authorises pumping from the specified extraction areas viz Primary Containment Area on Southlands, Secondary Containment Area along Foreshore Road and DNAPL Containment line on the Botany Industrial Park is to be used for containment of contamination and groundwater remediation purposes only.

9. All groundwater extracted for containment and remediation shall be transferred to the GPT via dedicated transfer pipelines, which should be monitored to ensure pipeline failure does not occur.

10. Works used for the purpose of conveying water taken by means of the licensed work shall not be constructed or installed so as to obstruct the reasonable passage of flood water flowing into or from a water course.

Specific conditions – groundwater management

1. The licensee shall maintain records of the gross and individual volume of groundwater extracted from all bores utilised for containment of contamination and groundwater remediation and provide this information to DIPNR on an annual basis or upon request from the Department.

2. The licensee shall install and maintain groundwater monitoring bores as part of the Environmental Monitoring Plan (EMP) and obtain the endorsement of DIPNR for the location, design and technical data to be obtained from the monitoring bore network

3. The licensee shall install automatic water-level recording devices with provision for downloading and archiving groundwater level data for the endorsed groundwater monitoring network.

4. DIPNR reserves the right to request an audit of the groundwater monitoring data and archiving quality assurance/quality control (QA/QC) procedures and request the licensee take corrective measures if found to be necessary as a consequence of the audit findings.

5. The licensee shall prepare interpreted reports on a schedule endorsed in the EMP that provides technical information about the groundwater level behaviour for the area impacted by the extraction borefields, with reference to previous groundwater simulation predictions cited in the EIS.

6. The licensee shall install and maintain a settlement monitoring network in accordance with the EMP endorsed by DIPNR.

7. The licensee shall obtain as part of the EMP groundwater quality data from both the production borefields and monitoring bore network and provide technical reports on this information, with reference to performance indicators for groundwater clean up, in accordance with the endorsed EMP.

Groundwater monitoring program

1. Orica must, as a component of the Environmental Monitoring Plan, prepare and implement a groundwater monitoring program by 30 June 2005 and prior to commencement of operation of the groundwater treatment plant.

   The objectives of this monitoring program are:

   (a) to detect groundwater flow and direction at depths relevant to the proposed extraction points
   (b) to document the effectiveness of the groundwater pumping containment activity
   (c) to assess the remediation of the sand beds aquifers groundwater system by reference to performance indicators.

   The groundwater monitoring program must be developed in consultation with DIPNR, DEC, the Department of Primary Industries and Sydney Ports Corporation.

   The groundwater monitoring program must include details on but need not necessarily be limited to the following:

   (a) location of monitoring bore holes - including the depth at which they are screened to enable access of groundwater
   (b) monitoring of the reduced level (m AHD)
   (c) monitoring the groundwater gradient and determination the direction of groundwater flow
   (d) monitoring methodologies and standards to be employed
   (e) reporting and assessment of results
   (f) opportunities to integrate the monitoring program with other monitoring requirements in the vicinity
   (g) monitoring frequency
   (h) representativeness of the sampling.

The applicant must submit a pre-extraction baseline groundwater monitoring report to DIPNR and any other relevant government agencies by 30 September 2005 for the operation of the groundwater treatment plant.

Conditions from DIPNR regarding land use safety planning

Preconstruction

1. At least one month prior to the commencement of construction of the proposed activity (except for construction of those preliminary works that are outside the scope of the hazard studies), or within such further period as the Director General may agree, Orica shall prepare and submit for the approval of the Director General the studies set out under subsections (a) to (c) (the pre-construction studies). Construction, other than of preliminary works, must not commence until approval has been given by the Director General.

    (a) HAZARD AND OPERABILITY STUDY

    A Hazard and Operability Study for the proposed activity, chaired by an independent qualified person approved by the Director General prior to the commencement of the study. The study shall be carried out in accordance with the DIPNR's Hazardous Industry Planning Advisory Paper No. 8, *HAZOP Guidelines*. The study report must be accompanied by a program for the implementation of all recommendations made in the report. If the Applicant intends to defer the implementation of a recommendation, justification must be included.

    (b) FINAL HAZARD ANALYSIS

    A Final Hazard Analysis of the proposed activity prepared in accordance with DIPNR 's Hazardous Industry Planning Advisory Paper No. 6, *Guidelines for Hazard Analysis*.

    (c) CONSTRUCTION SAFETY STUDY

    A Construction Safety Study prepared in accordance with DIPNR's Hazardous Industry Planning Advisory Paper No. 7, *Construction Safety Study Guidelines*. If the construction period exceeds six (6) months, the commissioning portion of the Construction Safety Study may be submitted two months prior to the commencement of commissioning.

Ongoing

2. INCIDENT REGISTER

    The Applicant shall maintain a register of accidents, incidents and potential incidents with actual or potential significant off-site impacts on people, property or the biophysical environment. The register shall be made available for inspection at any time by the independent Hazard Auditor and the Director General.

3. HAZARD AUDIT

    Twelve months after the commencement of operations of the proposed development, or within such further period as the Director General may agree, the applicant shall carry out a comprehensive Hazard Audit of the proposed development and within one month of the audit submit a report to the Director General. The hazard audit may be incorporated in the overall hazard audit for Orica.

The audit shall be carried out at the applicant's expense by a duly qualified independent person or team approved by the Director General prior to commencement of the audit. Further audits shall be carried out every three years or as determined by the Director General and a report of each audit shall within a month of the audit be submitted to the Director General. Hazard Audits shall be carried out in accordance with DIPNR's Hazardous Industry Planning Advisory Paper No. 5, *Hazard Audit Guidelines*.

The audit shall include a review of elements of the site Safety Management System and a review of all entries made in the incident register since the previous audit.

The audit report must be accompanied by a program for the implementation of all recommendations made in the audit report. If the applicant intends to defer the implementation of a recommendation, justification must be included.

4. The conditions of consent imposed on the BIP (DA No 30/98, approved on 16/1/1998) include the review and update, if necessary, of BIP and Orica Site Safety Management Systems, Site Fire Safety Study and Site Emergency Plan. Any revisions of the above studies should be submitted to the Director General for approval.

5. In these conditions "Director General" means Director General of the Department of Infrastructure Planning and Natural Resources or delegate.

Conditions for Part 3A Permit under Rivers and Foreshore Act

1. Physical works at Bunnerong Canal are not to commence until such time as a Part 3A Permit under the *Rivers and Foreshores Improvement Act 1948* has been issued by NSW Maritime.

2. The permission of the relevant landowner on which the works will be undertaken is to be obtained prior to lodgement of any Part 3A Permit application with NSW Maritime.

3. Suitably dimensioned plans and elevations showing the pipeline and outlet to Bunnerong Canal in relation to Bunnerong Canal and surrounds are to be provided to NSW Maritime prior to issue of any Part 3A Permit for the works.

4. A suitable plan to manage any acid sulfate material that may be encountered during the works associated with the Bunnerong Canal discharge point is to be prepared and submitted to NSW Maritime prior to the issue of the Part 3A permit.

5. Water quality monitoring should be undertaken at the discharge point, being the pipeline where it enters Bunnerong Canal.

6. Within 2 months of achieving practical completion of the construction activities at Bunnerong Canal, the proponent must submit a report outlining its compliance with the conditions of the Part 3A Permit. The report must also outline details of environmental incidents, near incidents and remedial actions undertaken to repair any environmental damage.

7. Prior to lodgement of any Part 3A Permit application with NSW Maritime the proponent must submit in writing to Sydney Ports Corporation and NSW Maritime a Bunnerong Canal Discharge Optimisation Plan. The objective of this plan is to ensure that the discharge in Bunnerong Canal is optimised to minimise scouring of sediments and maximise the mixing of the discharge with the receiving waters. The plan must include but not be limited to:

   - a detailed design of the discharge structure demonstrating how the potential for scouring is minimised and how mixing with receiving waters is optimised.

- a description of how the operation of the discharge will be optimised (ie flow rate limitations and timing of discharge).

- protocols for handling emergency situations.

- a monitoring proposal, including initial base line measurements of the sediment levels and distribution within the canal and Orica's proposed ongoing sediment distribution monitoring program.

The plan must be developed in consultation with DEC, DIPNR, Sydney Ports Corporation and the NSW Maritime.

Conditions from Sydney Water

1. Orica must comply with the requirements of the *Sydney Water Act 1994*. This includes obtaining a Section 73 Compliance Certificate. In seeking the Compliance Certificate, Orica must supply to Sydney Water all information necessary for Sydney Water to assess the impacts of the proposal on Sydney Water assets and operations. Orica must also comply with the requirements of Sydney Water issued as a Notice of Requirements, under Section 74 of the Act, prior to the Completion Certificate being issued. Such requirements will include adjustments to the trade waste agreement.

2. In relation to the discharge of excess treated water to Sydney Water's Bunnerong stormwater channel, Orica must conduct further technical investigations (eg potential impacts on flooding and the structural integrity of the channel) and obtain appropriate agreement with Sydney Water, prior to the commencement of any discharge.

Conditions from Sydney Ports Corporation for approval to discharge into Bunnerong Canal

1. Subject to the finalisation of a formal instrument of agreement between Sydney Ports Corporation and Orica, approval shall be granted for the discharge of water into Bunnerong Canal (the Canal) at a rate not to exceed 12 ML per day, and at a flow rate not to exceed 0.14 cubic metres per second.

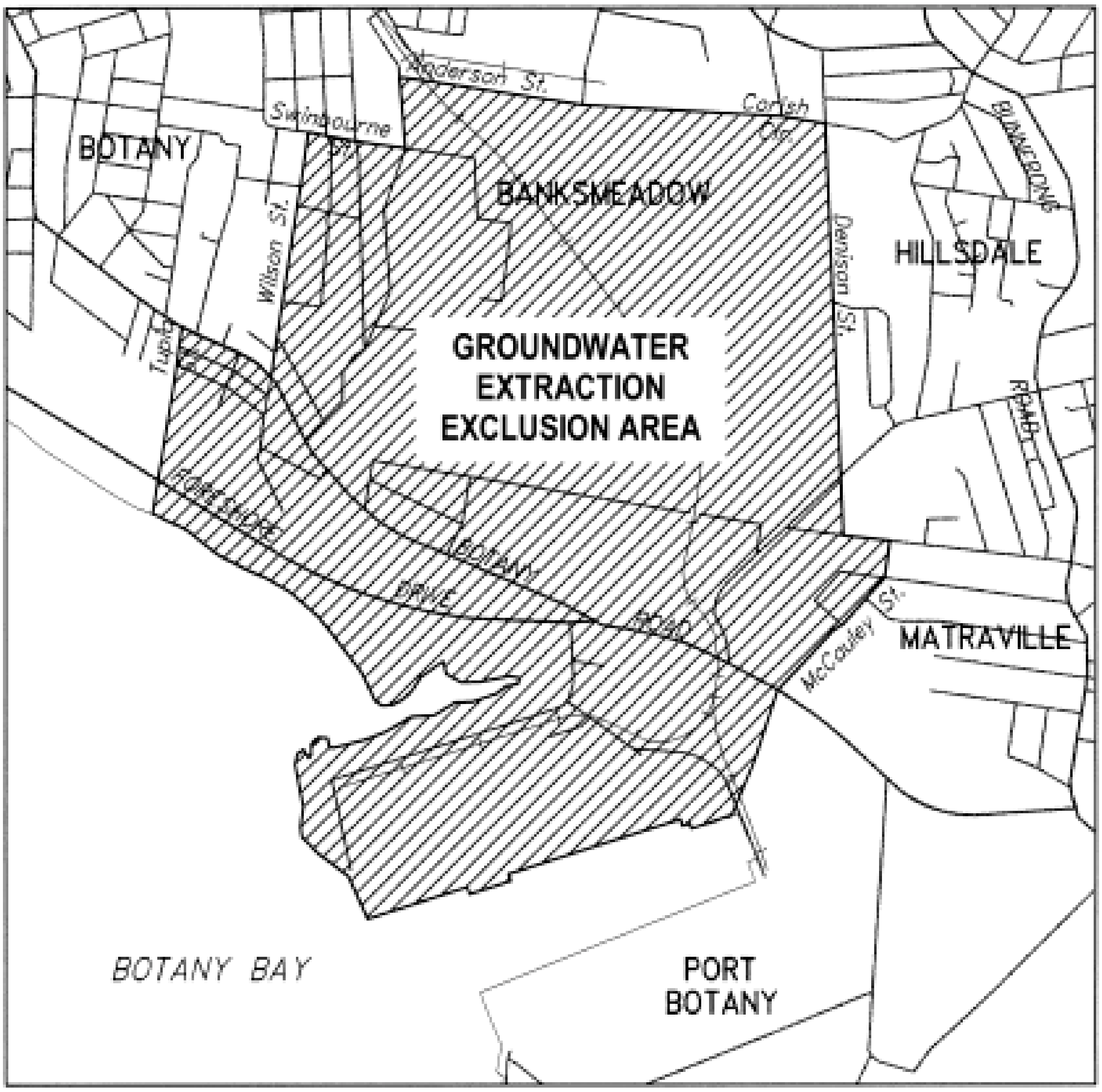
2. Prior to the commencement of any discharge into the canal, and the finalisation of the formal instrument of agreement, Orica shall submit – for Sydney Ports Corporation approval - a *Bunnerong Canal Discharge Optimisation Plan*. This plan shall contain (but is not limited to) details of the discharge structure to be installed, initial baseline measurements of the sediment levels and distribution within the Canal and Orica's proposed ongoing sediment distribution monitoring program.

3. Should monitoring indicate sediment movement to an extent that is unacceptable to Sydney Ports Corporation, Orica will be required to develop appropriate mitigation and/or management measures for Sydney Ports Corporation approval and implement these within an agreed timeframe.

4. Orica will be required to cease discharge in the canal as directed by Sydney Ports Corporation, if it is essential to conduct maintenance on the canal, maintain port operations, respond to emergencies or in the event of a pollution incident.

5. The quality of the water being discharged must meet all relevant requirements for discharge into stormwater systems. Orica is to monitor and document for Sydney Ports Corporation pollutant levels within the water to be discharged. In the event of discharge waters containing pollutant levels in excess of relevant requirements, Orica will:
   (a) immediately notify Sydney Ports Corporation
   (b) undertake appropriate action to cease the generation of the pollution and undertake appropriate clean up actions
   (c) at its expense, promptly comply with any notice, order, direction or requirement of Sydney Ports Corporation and/or of any other relevant Authority.

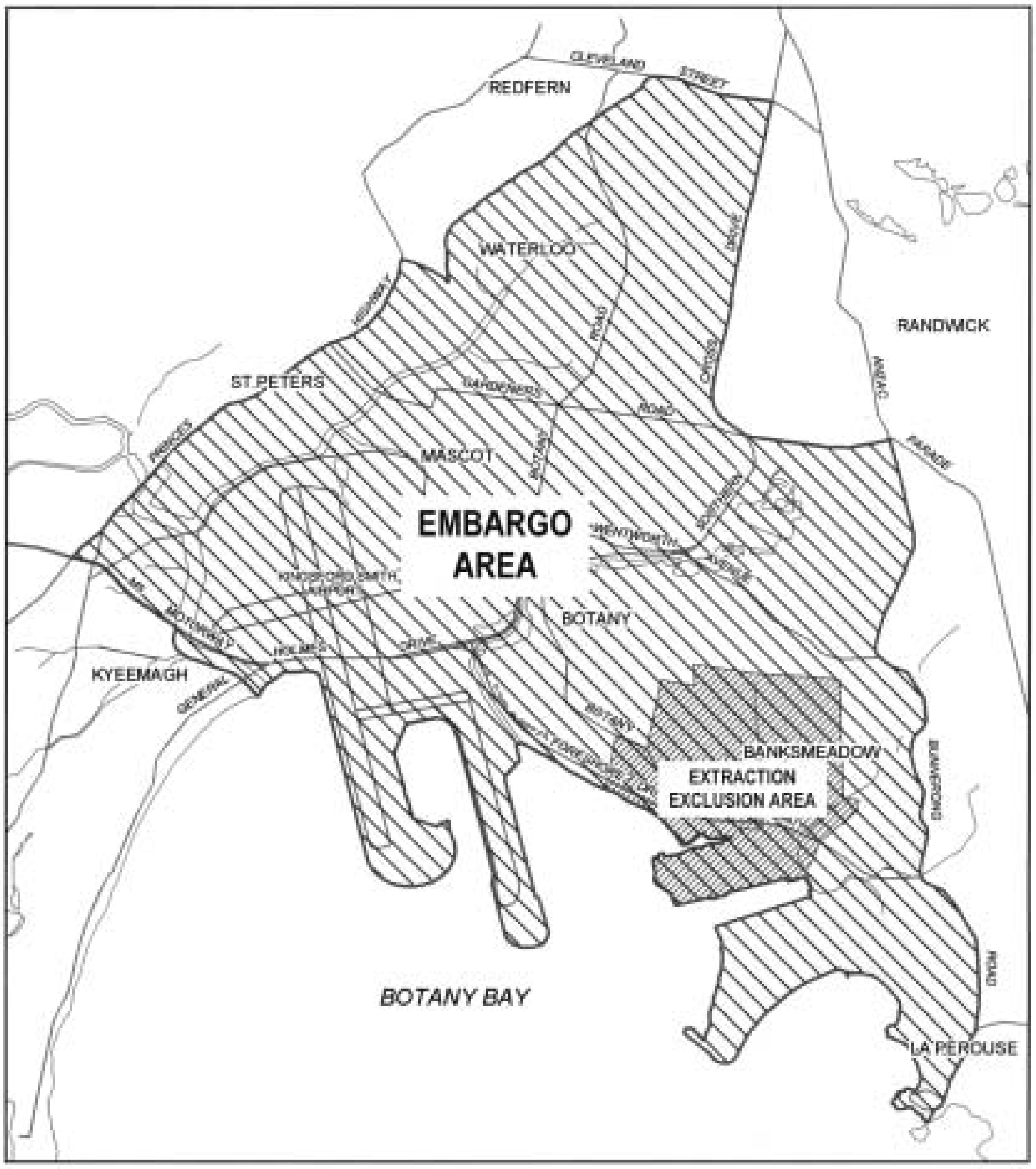
Appendix C Botany Sand Beds Groundwater Extraction Exclusion Area



The Groundwater Extraction Exclusion Area (previously Groundwater Protection Zone 1) is an area around the known contamination plumes originating from historical activity at the former ICI Petrochemical Complex (now Orica). The exclusion area has been implemented in response to the detection of contaminants in groundwater downgradient of the Orica Complex.
This area occupies parts of East Botany and Banksmeadow, and is defined by cultural features as follows: Tupia Street, Botany Road, Wilson Street, Swinbourne Street, Stephen Road, Anderson Street, Corish Circle, Denison Street and McCauley Street.

In the Groundwater Extraction Exclusion Area, the Department of Infrastructure, Planning and Natural Resources has issued notices to licensees under the *Water Act 1912* not to extract groundwater. Unlicensed bore owners are advised not to extract groundwater within this area.

Appendix D Botany Sand Beds Groundwater Embargo Area



The Groundwater Embargo Area This embargo area was gazetted to proactively manage sites with potential contamination by restricting new access to groundwater.

The area incorporates parts of the western half of the Botany Sand Beds Northern Zone, where it is known that historic industrial activity has occurred. The area is bounded by Anzac Parade, Bunnerong Road, Gardeners Road, Southern Cross Drive, South Dowling Street, Cleveland Street, Princes Highway and M5 tunnel alignment. The restriction placed on this area precludes any new bore licences for the extraction of groundwater from being issued with the exception of temporary dewatering, groundwater monitoring and remediation bores. The intent of the embargo is to not issue new licences until further assessment of the groundwater system occurs through the Botany Groundwater Strategy.

Environment Protection Licence

Licence Details	
Number:	2148
Anniversary Date:	21-July
Review Due Date:	29-May-2014

Licensee

ORICA AUSTRALIA PTY LTD
16-20 BEAUCHAMP ROAD
MATRAVILLE NSW 2036

Licence Type

Premises

Premises

ORICA AUSTRALIA PTY LTD
16-20 BEAUCHAMP ROAD
MATRAVILLE NSW 2036

Scheduled Activity

- Chemical storage
- Chemical production - other
- Waste storage
- Waste processing (non-thermal treatment)
- Waste disposal (thermal treatment)
- Contaminated groundwater treatment

Fee Based Activity	**Scale**
Dangerous goods production	> 25000 - T produced
General chemicals storage	> 5000 - 100000 kL of active storage capacity
Non-thermal treatment of hazardous and other waste	0 - All
Thermal treatment of hazardous & other waste - Sydney Basin	0 - All
Waste storage - Hazardous, restricted solid, liquid, clinical & related waste & Asbestos waste	0 - All
Contaminated groundwater treatment	0 - All (T)

Region

Metropolitan
Level 3, NSW Govt Offices, 84 Crown Street
WOLLONGONG NSW 2500
Phone: 02 4224 4100
Fax: 02 4224 4110

PO Box 513 WOLLONGONG EAST
NSW 2520

Information about this licence

Dictionary

A definition of terms used in the licence can be found in the dictionary at the end of this licence.

Responsibilities of licensee

Separate to the requirements of this licence, general obligations of licensees are set out in the Protection of the Environment Operations Act 1997 ("the Act") and the Regulations made under the Act. These include obligations to:

- ensure persons associated with you comply with this licence, as set out in section 64 of the Act;
- control the pollution of waters and the pollution of air (see for example sections 120 - 132 of the Act); and
- report incidents causing or threatening material environmental harm to the environment, as set out in Part 5.7 of the Act.

Variation of licence conditions

The licence holder can apply to vary the conditions of this licence. An application form for this purpose is available from the EPA.

The EPA may also vary the conditions of the licence at any time by written notice without an application being made.

Where a licence has been granted in relation to development which was assessed under the Environmental Planning and Assessment Act 1979 in accordance with the procedures applying to integrated development, the EPA may not impose conditions which are inconsistent with the development consent conditions until the licence is first reviewed under Part 3.6 of the Act.

Duration of licence

This licence will remain in force until the licence is surrendered by the licence holder or until it is suspended or revoked by the EPA or the Minister. A licence may only be surrendered with the written approval of the EPA.

Licence review

The Act requires that the EPA review your licence at least every 5 years after the issue of the licence, as set out in Part 3.6 and Schedule 5 of the Act. You will receive advance notice of the licence review.

Fees and annual return to be sent to the EPA

For each licence fee period you must pay:

- an administrative fee; and
- a load-based fee (if applicable).

The EPA publication "A Guide to Licensing" contains information about how to calculate your licence fees.

The licence requires that an Annual Return, comprising a Statement of Compliance and a summary of any monitoring required by the licence (including the recording of complaints), be submitted to the EPA. The Annual Return must be submitted within 60 days after the end of each reporting period. See condition R1 regarding the Annual Return reporting requirements.

Usually the licence fee period is the same as the reporting period.

Transfer of licence

The licence holder can apply to transfer the licence to another person. An application form for this purpose is available from the EPA.

Public register and access to monitoring data

Part 9.5 of the Act requires the EPA to keep a public register of details and decisions of the EPA in relation to, for example:

- licence applications;
- licence conditions and variations;
- statements of compliance;
- load based licensing information; and
- load reduction agreements.

Under s320 of the Act application can be made to the EPA for access to monitoring data which has been submitted to the EPA by licensees.

This licence is issued to:

ORICA AUSTRALIA PTY LTD
16-20 BEAUCHAMP ROAD
MATRAVILLE NSW 2036

subject to the conditions which follow.

1 Administrative conditions

A1 What the licence authorises and regulates

A1.1 Not applicable.

A1.2 This licence authorises the carrying out of the scheduled activities listed below at the premises specified in A2. The activities are listed according to their scheduled activity classification, fee-based activity classification and the scale of the operation.

Unless otherwise further restricted by a condition of this licence, the scale at which the activity is carried out must not exceed the maximum scale specified in this condition.

Scheduled Activity
Chemical storage
Chemical production - other
Waste storage
Waste processing (non-thermal treatment)
Waste disposal (thermal treatment)
Contaminated groundwater treatment

Fee Based Activity	Scale
Dangerous goods production	> 25000 - T produced
General chemicals storage	> 5000 - 100000 kL of active storage capacity
Non-thermal treatment of hazardous and other waste	0 - All
Thermal treatment of hazardous & other waste - Sydney Basin	0 - All
Waste storage - Hazardous, restricted solid, liquid, clinical & related waste & Asbestos waste	0 - All
Contaminated groundwater treatment	0 - All (T)

A1.3 Not applicable.

A2 Premises to which this licence applies

A2.1 The licence applies to the following premises:

Premises Details
ORICA AUSTRALIA PTY LTD

Premises Details
16-20 BEAUCHAMP ROAD
MATRAVILLE
NSW
2036
LOTS 2,4 DP 1016112, LOTS 2,5 DP 206413, LOT 11 DP 1039919, LOT 1 DP 85542, LOT 11 DP 109505, LOT 1 DP1078077, LOT 1 DP 740704
As defined in drawing No B97290 RevA, titled "Botany Industrial Park Site - Orica Land Areas" and dated 29/01/07

A3 Other activities

A3.1 Not applicable.

A4 Information supplied to the EPA

A4.1 Works and activities must be carried out in accordance with the proposal contained in the licence application, except as expressly provided by a condition of this licence.

In this condition the reference to "the licence application" includes a reference to:
(a) the applications for any licences (including former pollution control approvals) which this licence replaces under the Protection of the Environment Operations (Savings and Transitional) Regulation 1998; and
(b) the licence information form provided by the licensee to the EPA to assist the EPA in connection with the issuing of this licence.

2 Discharges to air and water and applications to land

P1 Location of monitoring/discharge points and areas

P1.1 The following points referred to in the table below are identified in this licence for the purposes of monitoring and/or the setting of limits for the emission of pollutants to the air from the point.

Air

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Description of Location
3	Discharge to air Air emissions monitoring	Discharge to air Air emissions monitoring	Vent from the hypochlorite backing tower marked "monitoring point 3" on Drawing No. B78323 submitted as an attachment to the letter to the EPA dated 21 March 2003.
4	Discharge to air Air emissions monitoring	Discharge to air Air emissions monitoring	Vent duct from the absorption tail tower marked "monitoring point 4" on Drawing No. B78323 submitted as an attachment to the letter to the EPA dated 21 March 2003.
7	Discharge to air Air emissions monitoring	Discharge to air Air emissions monitoring	Emergency chlorine vent marked "monitoring point 7" on Drawing No. B78323 submitted as an attachment to the letter to the EPA dated 21 March 2003.
9	Discharge to air Air emissions monitoring	Discharge to air Air emissions monitoring	Stack serving GTP labelled "Point 9 - Discharge to air" on drawing number B96283 Rev2 submitted to the EPA on 20 June 2006.
10	Parameter monitoring		Thermal oxidation unit labelled "Point 10 - Parameter monitoring temperatue" on drawing number B96283 Rev2 submitted to the EPA on 20 June 2006.
12	Weather monitoring		Weather monitoring station labelled "Point 12 - Weather Monitoring" on drawing No B96283 Rev2 submitted to the EPA on 20 June 2006
13	Parameter monitoring		Pipe serving the GTP thermal oxidiser, labelled "Point 13 - Thermal Oxidiser Flow (Residence Time) Monitoring Point" on drawing number B96283 Rev2 submitted to the EPA on 20 June 2006
25	Discharge to air Air emission monitoring	Discharge to air Air emission monitoring	Stack serving the vapour extraction system labellled as "Exhaust to atmosphere (single, short stack, approx. 3m above ground)" on drawing No B96878 RevB submitted to the EPA on 26 June 2006

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Description of Location
26	Discharge to air. Air emissions monitoring	Discharge to air. Air emissions monitoring	Common stack from building housing HCB repackaging plant and new Store J
27	Discharge to air. Air emissions monitoring.	Discharge to air. Air emissions monitoring.	Stack from temporary enclosure of Store G/H
28	Discharge to air. Air emissions monitoring	Discharge to air. Air emissions monitoring	Stack from temporary enclosure of Store E
29	In-pipe monitoring	In-pipe monitoring	Store J interstage point between the two activated charcoal filters on extraction pipe 1.
30	In-pipe monitoring	In-pipe monitoring	Store J interstage point between the two activated charcoal filters on extraction pipe 2.
31	In-pipe monitoring	In-pipe monitoring	Store G/H interstage point between the two activated charcoal filters on the extraction pipe.
32	In-pipe monitoring		Store E interstage point between the two activated charcoal filters on the extraction pipe.
33	In-pipe monitoring		Store J interstage point between the two activated charcoal filters on the extraction pipe. (Note - this is the same as Point 29).
34	In-pipe monitoring		Store J interstage point between the two activated charcoal filters on the extraction pipe. (Note - this is the same as Point 30).
35	In-pipe monitoring		Store G/H interstage point between the two activated charcoal filters on the extraction pipe. (Note - this is the same as Point 31).
36	In-pipe monitoring		Store E interstage point between the two activated charcoal filters on the extraction pipe. (Note - this is the same as Point 32).

P1.2 The following points referred to in the table are identified in this licence for the purposes of the monitoring and/or the setting of limits for discharges of pollutants to water from the point.

P1.3 The following utilisation areas referred to in the table below are identified in this licence for the purposes of the monitoring and/or the setting of limits for any application of solids or liquids to the utilisation area.

Water and land

EPA identi-fication no.	Type of monitoring point	Type of discharge point	Description of location
11		Discharge to waters	Drain outlet serving the GTP labelled "Point 11- Water Discharge Point" on drawing number B96284 Rev0 submitted to the EPA on 14 September 2005
14	Effluent quality monitoring		Drain outlet serving the GTP labelled "Point 14 - Water Discharge Composition" on drawing No B96284 Rev1 submitted to the EPA on 14 Sep 2007
15	Effluent quality monitoring		Drain outlet serving the GTP labelled "Point 15 - Water Discharge Conductivity" on drawing No B96283 Rev2 submitted to the EPA on 20 June 2006
16	Effluent quality and volume monitoring		Drain outlet serving the GTP labelled "Point 16 - Water Discharge Temperature & Flow" on drawing No B96284 Rev0 submitted to the EPA on 14 September 2005

3 Limit conditions

L1 Pollution of waters

L1.1 Except as may be expressly provided in any other condition of this licence, the licensee must comply with section 120 of the Protection of the Environment Operations Act 1997.

L2 Load limits

L2.1 The actual load of an assessable pollutant discharged from the premises during the reporting period must not exceed the load limit specified for the assessable pollutant in the table below.

Note: An assessable pollutant is a pollutant which affects the licence fee payable for the licence.

L2.2 The actual load of an assessable pollutant must be calculated in accordance with the relevant load calculation protocol.

Assessable Pollutant	Load limit (kg)
Arsenic (Air)	2.98
Benzene (Air)	59.03
Benzo(a)pyrene (equivalent) (Air)	0.15
Fine Particulates (Air)	5352
Lead (Air)	7.83
Mercury (Air)	0.06
Nitrogen Oxides (Air)	172445
Nitrogen Oxides - Summer (Air)	43111
Sulfur Oxides (Air)	5306

L3 Concentration limits

L3.1 For each monitoring/discharge point or utilisation area specified in the table\s below (by a point number), the concentration of a pollutant discharged at that point, or applied to that area, must not exceed the concentration limits specified for that pollutant in the table.

L3.2 Where a pH quality limit is specified in the table, the specified percentage of samples must be within the specified ranges.

L3.3 To avoid any doubt, this condition does not authorise the pollution of waters by any pollutant other than those specified in the table/s.

Air

POINT 3

Pollutant	Units of measure	100 percentile concentration limit
Chlorine	milligrams per cubic metre	200

POINT 4

Pollutant	Units of measure	100 percentile concentration limit
Hydrogen chloride	milligrams per cubic metre	30

POINT 9

Pollutant	Units of measure	100 percentile concentration limit
1,2-Dichloroethane	milligrams per cubic metre	8 Note 1
Chlorine	milligrams per cubic metre	30
Nitrogen Oxides	milligrams per cubic metre	400
Volatile organic compounds	milligrams per cubic metre	10 Note 1
Hydrogen Sulfide	milligrams per cubic metre	2
Dioxins & Furans	nanograms per cubic metre	0.1 Note 2
Hydrogen chloride	milligrams per cubic metre	30
Sulphur dioxide	milligrams per cubic metre	100
Vinyl chloride	parts per million	10
Solid Particles	milligrams per cubic metre	20
Carbon monoxide	milligrams per cubic metre	100

POINT 25

Pollutant	Units of measure	100 percentile concentration limit
Mercury	micrograms per cubic metre	30

POINTS 26,27,28

Pollutant	Units of measure	100 percentile concentration limit
Cadmium	milligrams per cubic metre	0.1
Hexachlorobenzene	milligrams per cubic metre	0.002
Mercury	milligrams per cubic metre	0.1
Volatile organic compounds	milligrams per cubic metre	10
Dioxins & Furans	nanograms per cubic metre	0.1
Hazardous substances	milligrams per cubic metre	0.5
Total solids	milligrams per cubic metre	10
Hexachlorobutadiene	milligrams per cubic metre	0.21
Hexachloroethane	milligrams per cubic metre	9.7

POINT 29

Pollutant	Units of measure	100 percentile concentration limit
Tetrachloroethene (tetrachloroethylene)	milligrams per cubic metre	340

POINT 30

Pollutant	Units of measure	100 percentile concentration limit
Tetrachloroethene (tetrachloroethylene)	milligrams per cubic metre	340

POINT 31

Pollutant	Units of measure	100 percentile concentration limit
1,2-Dichloroethane	milligrams per cubic metre	40

Water and Land

POINT 11

Pollutant	Units of Measure	50 percentile concentration limit	90 percentile concentration limit	3DGM concentration limit	100 percentile Concentration Limit
1,2-Dichloroethane	milligrams per litre				1.9
Arsenic	milligrams per litre				0.013
Cadmium	milligrams per litre				0.001
Carbon tetrachloride	milligrams per litre				0.24
Copper	milligrams per litre				0.01
Iron	milligrams per litre				0.3
Lead	milligrams per litre				0.0034
Manganese	milligrams per litre				1.9
Mercury	milligrams per litre				0.0005
Nickel	milligrams per litre				0.011
pH	pH				6.5-8.5
Reactive Phosphorus	milligrams per litre				0.05
Temperature	degrees Celsius				10-30
Tetrachloroethene (tetrachloroethylene)	milligrams per litre				0.07
Nitrogen (total)	milligrams per litre				5 Note 4
Phosphorus (total)	milligrams per litre				0.1Note 3
Trichloroethene (Trichloroethylene)	milligrams per litre				0.33
Turbidity	nephelometric turbidity units				10 Note 3
Zinc	milligrams per litre				0.01
Nitrate + nitrite (oxidised nitrogen)	milligrams per litre				0.1Note3
Benzene	milligrams per litre				0.95
Chloroform	milligrams per litre				0.37
Toluene	milligrams per litre				0.18
Vinyl chloride	milligrams per litre				0.1
Biochemical oxygen demand	milligrams per litre				10
Chromium (total)	milligrams per litre				0.01
Total residual chlorine	milligrams per litre				0.1
NH3-N	milligrams per litre				4.6Note 4

Note: The above air pollutant concentration limits apply to the stack emissions prior to the addition of any re-heat air.

Note 1: Expressed as total organic carbon. This should be determined by summing all individual components after being analysed by FTIR.

Note 2: Polychlorinated-dibenzo-p-dioxins (PCDD) and polychlorinated-dibenzofurans (PCDF) as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalent calculated in accordance with the procedures included in Part 9, Clause 19 of the POEO (Clean Air) Regulation 2002.

Note 3: For the purposes of the table(s) above, Note 3 means that concentration limits may be subject to review and change once the final details are received on the treatment technology and the design of the discharge structure.

Note 4: For the purposes of the table above, Note 4 means that this concentration limit will be subject to review and change once the licensee has submitted the report as required in Condition U2 (Ammonia Concentration Reduction Strategy).

L3.5 **Reference Condition**

For the concentration limits specified for Point 9 (above), the following reference conditions also apply:

Pollutant	**Units of measure**	**100 percentile concentration limit**	**Reference Conditions**	**Averaging Period**
1,2-Dichloroethane[1]	mg/m3	8	Dry, 273K, 101.3kPa, 11% O_2	Rolling 1 hour average
Chlorine	mg/m3	30	Dry, 273K, 101.3kPa, 11% O_2	As per test method
Nitrogen Oxides	mg/m3	400	Dry, 273K, 101.3kPa, 11% O_2	Rolling 1 hour average
Volatile organic compounds[1]	mg/m3	10	Dry, 273K, 101.3kPa, 11% O_2	Rolling 1 hour average
Hydrogen Sulfide	mg/m3	2	Dry, 273K, 101.3kPa, 11% O_2	As per test method
Dioxins & Furans[2]	ng/m3	0.1	I-TEQ, Dry, 273K, 101.3kPa, 11% O_2	As per test method
Hydrogen chloride	mg/m3	30	Dry, 273K, 101.3kPa, 11% O_2	Rolling 1 hour average
Sulfur dioxide	mg/m3	100	Dry, 273K, 101.3kPa, 11% O_2	As per test method
Vinyl chloride	ppm	10	Dry, 273K, 101.3kPa, 11% O_2	Rolling 3 hour average
Solid Particles	mg/m3	20	Dry, 273K, 101.3kPa, 11% O_2	As per test method
Carbon monoxide	mg/m3	100	Dry, 273K, 101.3kPa, 11% O_2	Rolling 1 hour average

Note The above limits apply to the stack emissions prior to the addition of any re-heat air.

[1] Expressed as total organic carbon.

[2] Polychlorinated-dibenzo-p-dioxins (PCDD) and polychlorinated-dibenzofurans (PCDF) as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalent calculated in accordance with the procedures included in the Protection of the Environment Operations (Clean Air) Regulation 2002.

L3.6 **Reference conditions for Points 26, 27 and 28.**

For the concentration limits specified for Points 26, 27 and 28 (above), the following reference conditions also apply:

Pollutant	**Units of measure**	**100 percentile concentration limit**	**Reference Conditions**
Total solids	mg/m^3	10	Dry, 273K, 101.3kPa
Hazardous substances (aggregate of Sb, As, Be, Cd, Cr, Co, Pb, Mn, Hg, Ni, Se, Sn and V)	mg/m^3	0.5	Dry, 273K, 101.3kPa
Volatile Organic Compounds	mg/m^3	10	Dry, 273K, 101.3kPa
Cadmium	mg/m^3	0.1	Dry, 273K, 101.3kPa
Mercury	mg/m^3	0.1	Dry, 273K, 101.3kPa
Hexachlorobenzene (HCB)	mg/m^3	0.002	Dry, 273K, 101.3kPa
Hexachlorobutadiene (HCBD)	mg/m^3	0.21	Dry, 273K, 101.3kPa
Hexachloroethane (HCE)	mg/m^3	9.7	Dry, 273K, 101.3kPa
Dioxins and Furans	ng/m^3	0.1	I-TEQ, Dry, 273K, 101.3kPa

Note: For the purpose of monitoring and determining compliance with this condition, 'Dioxins and Furans' are polychlorinated-dibenzo-p-dioxins (PCDD) and polychlorinated-dibenzofurans (PCDF) as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) equivalent and calculated in accordance with the procedures included in the Protection of the Environment Operations (Clean Air) Regulation 2002.

L3.7 Thermal Oxidiser Lower Limits

For each monitoring/discharge point or utilisation area specified in the tables below (by point number), the parameter must be equal to or greater than the lower limits specified for that parameter in that table.

Point 10

Parameter	Units of measure	Lower Limit	Averaging period
Temperature	°C	875	Instantaneous

Point 13

Parameter	Units of measure	Lower Limit	Averaging period
Residence time	s	2	Instantaneous

L3.8 Whenever a combustion failure occurs in the thermal oxidiser, both the Air Stripping Unit and the Thermal Oxidiser must be shut down and all emissions must cease as soon as safely possible, but in no case later than 10 minutes after the start of the failure.

L3.9 Exemptions from concentration limits for Point 9 and temperature limit for Point 10

The concentration limits specified for Point 9 (above) and temperature limit for Point 10 (above) do not apply during the following periods:

(a) a start-up period – that is, while the thermal oxidiser is being brought up to normal operation following a period of inactivity; or

(b) a shutdown period – that is, while the thermal oxidiser is being taken out of service from normal operation to inactivity.

Note 1: While the concentration limits specified for Point 9 (above) do not apply, the licensee is subject to the requirements of section 128 (2) of the Protection of the Environment Operations Act in relation to the prevention and minimisation of air pollution.

Note 2: Condition O9.1 requires that only uncontaminated off-gas feed is processed by the thermal oxidiser when the temperature at the thermal oxidiser unit (Point 10) is below 875°C.

L4 Volume and mass limits

L4.1 For each discharge point or utilisation area specified below (by a point number), the volume/mass of:

(a) liquids discharged to water; or;

(b) solids or liquids applied to the area;

must not exceed the volume/mass limit specified for that discharge point or area.

Point	Unit of measure	Volume/Mass Limit
11	kilolitres per day	13500

L5 Waste

L5.1 The licensee must not cause, permit or allow any waste to be received at the premises, except the wastes expressly referred to in the column titled “Waste” and meeting the definition, if any, in the column titled “Description” in the table below.

Any waste received at the premises must only be used for the activities referred to in relation to that waste in the column titled “Activity” in the table below.

Any waste received at the premises is subject to those limits or conditions, if any, referred to in relation to that waste contained in the column titled “Other Limits” in the table below.

Condition L5.1 does not limit any other conditions in this licence.

Code	Waste	Description	Activity	Other Limits
B100	Acidic solutions or acids in solid form		Storage and processing (non-thermal treatment)	B100 waste is limited t ferrous chloride (pickle liquor)
D120	Mercury; mercury compounds		Storage	
NA	General or Specific exempted waste	Waste that meets all the conditions of a resource recovery exemption under Clause 51A of the *Protection of the Environment Operations (Waste) Regulation 2005*	As specified in each particular resource recovery exemption.	NA
NA		Any waste received on site that is below licensing thresholds in Schedule 1 of the POEO Act, as in force from time to time		NA

L5.2 The licensee is permitted to receive and treat extracted groundwater, the substances therein, and associated free phase contaminants originating from Orica’s (formerly ICI Australia) activities at the Botany Industrial Park (BIP). This includes but is not limited to groundwater from:

1. The BIP, primary and secondary hydraulic containment lines;

2. Environmental investigation, monitoring and remediation activities conducted by, or on behalf of, Orica within areas impacted by Orica / ICI Australia's historic activities within the Groundwater Extraction Exclusion Area (GEEA); and

3. Short-term third party dewatering activities (for construction, pipe repairs, etc.) within the GEEA, in instances in which those waters have been affected by contaminants associated with Orica/ICI Australia’s historic BIP operations.

For the purposes of licensing and the liquid waste levy, this material is deemed to have been generated onsite.

L6 Noise Limits

L6.1 For the area known as ‘Southlands’ and the associated wells and reticulation system for the primary containment area the noise limit conditions L6.1.1 to L6.1.4 inclusively, apply:

L6.1.1 The operation of all plant and equipment must not give rise to an equivalent continuous (L_{Aeq}) sound pressure level at any point on any residential property greater than 5dB(A) above the existing background L_{A90} level (in the absence of the noise under consideration).

L6.1.2 The operation of all plant and equipment must not give rise to an LA1, 1minute or LAMax sound pressure level at any point on any residential property greater than 15dB(A) above the existing background LA90 level (in the absence of the noise under consideration) during night time.

L6.1.3 The operation of all plant and equipment when assessed on any residential property must not give rise to a sound pressure level that exceeds LAeq 50dB(A) day/evening time, and LAeq 40 dB(A) night time.

L6.1.4 The operation of all plant and equipment when assessed on any neighbouring commercial/industrial premises must not give rise to a sound pressure level that exceeds LAeq 65dB(A) day/evening time and night time.

Note 1: For assessment purposes, the above L_{Aeq} sound levels must be assessed over a period of 10-15 minutes. The modification factors presented in Section 4 of the NSW Industrial Noise Policy must be applied to the measured noise levels where applicable.

Note 2: The area known as ‘Southlands’ and the associated wells and reticulation system is defined by Lot 2 DP 528680; Lot 11, DP 109505; and Lot 1 DP85542 as shown on drawing titled “Botany Site Plan Sub-division Boundary Plots”, drawing no. B87201 Rev 12 4/03 and the reticulation layout shown on drawing B96310 RevA dated 15.10.05 submitted to the EPA on 4 November 2005.

L6.2 For the operation of plant and equipment located at Botany Industrial Park (BIP) premises the following conditions L6.2.1 to L6.2.3 inclusively, apply:

L6.2.1 Noise emissions emanating from all active Plants in the BIP premises, including loading and unloading of material in or above the premises and when determined as a sound level contribution, shall not exceed the following amenity LAeq criteria when measured or computed at any point within one metre of the nearest boundary of any residence in the vicinity of the premises, using the "FAST" response on the sound level meter.

Time of Day	LAeq
Day	65
Evening	55
Night	50

L6.2.2 The intrusive noise criterion for all active plants in the BIP shall be that the LAeq15 minute noise levels shall not exceed the amenity LAeq noise levels by more than 5 dB(A) when measured or computed at any point within one metre of the nearest boundary of any residence in the vicinity of the premises, using the "FAST" response on the sound level meter.

L6.2.3 Each existing BIP Plant shall ensure that new or replacement equipment is selected and/or installed so that no increase in noise emissions is thereby created when measured or computed at any point within one metre of the nearest boundary of any residence in the vicinity of the premises, using the "FAST" response on the sound level meter.

L6.3 A report for all BIP Licences (L7494 Huntsman Corporation; L 2148 Orica Pty Ltd and L10000 Qenos Pty Ltd) demonstrating compliance with the noise conditions listed at Condition L6.1 to L6.2 must be appended to the Annual Return for Qenos L10000.

L6.4 Noise generated by activities associated with the Groundwater Cleanup Project, other than those accepted by the EPA as being “construction” at the premises must not exceed the noise goal level presented in the Table 6.4 below:

Table 6.4 - Noise Design Goal Limits (dB(A))

Location	Day	Evening	Night
	$L_{Aeq(15\ minute)}$	$L_{Aeq(15\ minute)}$	$L_{Aeq(15\ minute)}$
Nearest affected receivers surrounding the Groundwater	*35 dB(A)*	*35 dB(A)*	*35 dB(A)*

Cleanup Project			

L6.5 For the purpose of Condition L6.1, L6.2 and L6.4:

- Day is defined as the period from 7am to 6pm Monday to Saturday and 8am to 6pm Sundays and Public Holidays,
- Evening is defined as the period from 6pm to 10pm, and
- Night is defined as the period from 10pm to 7am Monday to Saturday and 10pm to 8am Sundays and Public Holidays

L6.6 Noise from the premises is to be measured at the most affected point on or within the residential boundary to determine compliance with the LAeq(15 minute) noise limits in condition L6.4.

Where it can be demonstrated that direct measurement of noise from the premises is impractical, the EPA may accept alternative means of determining compliance. See Chapter 11 of the NSW Industrial Noise Policy.

The modification factors presented in Section 4 of the NSW Industrial Noise Policy shall also be applied to the measured noise level where applicable

L6.7 The noise emission limits identified in condition L6.4 apply under meteorological conditions of:

- wind speeds up to 3 m/s at 10 metres above ground level; or
- temperature inversion conditions of up to 3^{o}C/100m and wind speeds up to 2m/s at 10 metres above ground level.

L6.8 **Hours of operation – Construction**

All construction work at the premises must only be conducted between 7:00am to 6:00pm Monday to Friday, 8:00am to 1:00pm Saturdays, with no construction activities on Sundays or Public Holidays. Construction is permitted any time if it is not audible at the nearest affected receivers. Audible means that it can be heard by a person at the nearest affected receivers.

L6.9 Activities at the premises, other than construction work, that meet the noise goal provided in L6.4 may be conducted on a continuous basis.

L6.10 The following activities may be carried out at the premises outside the hours specified in conditions L6.8:

(a) the delivery of materials as requested by Police or other authorities for safety reasons; and
(b) emergency work to avoid the loss of lives, property and/or to prevent environmental harm.

L7 Polychlorinated Biphenyls (PCBs)

Note: The licensee must comply with the conditions as specified in this licence or where no specific conditions are outlined in this licence, the licensee must comply with the "Chemical Control Order in Relation to Materials and Wastes Containing Polychlorinated Biphenyl, 1997".

4 Operating conditions

O1 Activities must be carried out in a competent manner

O1.1 Licensed activities must be carried out in a competent manner.

This includes:

(a) the processing, handling, movement and storage of materials and substances used to carry out the activity; and

(b) the treatment, storage, processing, reprocessing, transport and disposal of waste generated by the activity.

O2 Maintenance of plant and equipment

O2.1 All plant and equipment installed at the premises or used in connection with the licensed activity:

(a) must be maintained in a proper and efficient condition; and

(b) must be operated in a proper and efficient manner.

O3 Emergency Response

O3.1 The licensee must maintain emergency response plans which document the procedures to deal with all types of incidents (eg spill, explosions or fire) that may occur at the premises or outside of the premises (eg during transfer) which are likely to cause harm to the environment.

O4 Processes and management

O4.1 The licensee must ensure that any waste received and/or generated at the premises is assessed and classified in accordance with the DECC Waste Classification Guidelines as in force from time to time.

O4.2 The licensee must ensure that waste identified for recycling is stored separately from other waste.

O4.3 All above ground tanks containing material that is likely to cause environmental harm must be bunded or have an alternative spill containment system in-place.

O4.4 The licensee must ensure that suitable measures (e.g. high/low alarms, control valves with interlock control, one way valves) are installed on all tanks, ponds or clarifiers and associated pipes and hoses to prevent the spillage of waste.

O5 Asbestos Wastes

O5.1 The licensee must manage any asbestos or asbestos-contaminated materials that may be uncovered during the construction, commissioning and operation of all activities undertaken at the premises strictly in accordance with the requirements under the *Protection of the Environment Operations (Waste) Regulation 2005* and any guidelines or requirements issued by the EPA in relation to those materials.

O6 Odour

O6.1 The licensee must not cause, permit or allow the emission of offensive odour beyond the boundary of the premises.

O6.2 No condition of this licence identifies a potentially offensive odour for the purposes of Section 129 of the Protection of the Environment Operations Act 1997.

O7 Not applicable.

O8 Dust

O8.1 Activities occurring at the premises must be carried out in a manner that will minimise emissions of dust from the premises.

O8.2 Loaded trucks must be covered at all times, except during loading and unloading of material.

O9 Thermal Oxidiser Operating Conditions

O9.1 The licensee must ensure that only uncontaminated off-gas feed is sent to the thermal oxidiser when the temperature at the thermal oxidiser unit (Point 10) is below 875°C, subject to L3.8.

5 Monitoring and recording conditions

M1 Monitoring records

M1.1 The results of any monitoring required to be conducted by this licence or a load calculation protocol must be recorded and retained as set out in this condition.

M1.2 All records required to be kept by this licence must be:
(a) in a legible form, or in a form that can readily be reduced to a legible form;

(b) kept for at least 4 years after the monitoring or event to which they relate took place; and
(c) produced in a legible form to any authorised officer of the EPA who asks to see them.

M1.3 The following records must be kept in respect of any samples required to be collected for the purposes of this licence:
(a) the date(s) on which the sample was taken;
(b) the time(s) at which the sample was collected;
(c) the point at which the sample was taken; and
(d) the name of the person who collected the sample.

M2 Requirement to monitor concentration of pollutants discharged

M2.1 For each monitoring/discharge point or utilisation area specified below (by a point number), the licensee must monitor (by sampling and obtaining results by analysis) the concentration of each pollutant specified in Column 1. The licensee must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns:

POINT 3

Pollutant	Units of measure	Frequency	Sampling Method
Chlorine	milligrams per cubic metre	Continuous	In line instrumentation

POINT 4

Pollutant	Units of measure	Frequency	Sampling Method
Hydrogen chloride	milligrams per cubic metre	Quarterly	Method approved in writing by the Authority

POINT 7

Pollutant	Units of measure	Frequency	Sampling Method
Chlorine	milligrams per cubic metre	Continuous	In line instrumentation

POINT 9

Pollutant	Units of measure	Frequency	Sampling Method
1,2-Dichloroethane	milligrams per cubic metre	Special Frequency 13	CEM-10
Carbon monoxide	milligrams per cubic metre	Special Frequency 13	CEM-4
Chlorine	milligrams per cubic metre	Yearly	TM-7 & TM-8
Dioxins & Furans	nanograms per cubic metre	Yearly	TM-18
Dry gas density	kilograms per cubic metre	Quarterly	TM-23
Hydrogen Sulfide	milligrams per normalised cubic metre	Yearly	TM-5
Hydrogen chloride	milligrams per cubic metre	Yearly	Special Method 8
Moisture content	percent	Quarterly	TM-22
Molecular weight of stack gases	grams per gram mole	Quarterly	TM-23
Nitrogen Oxides	milligrams per cubic metre	Quarterly	TM-11
Oxygen (O2)	percent	Continuous	CEM-3
Solid Particles	milligrams per cubic metre	Special Frequency 3	TM-15
Sulphur dioxide	milligrams per cubic metre	Yearly	TM-4
Temperature	degrees Celsius	Continuous	TM-2
Velocity	metres per second	Continuous	CEM-6
Vinyl chloride	parts per million	Special Frequency 13	CEM-10
Volatile organic compounds	milligrams per cubic metre	Quarterly	Other Approved Method 1
Volumetric flowrate	cubic metres per second	Continuous	CEM-6

POINT 10

Pollutant	Units of measure	Frequency	Sampling Method
Temperature	degrees Celsius	Continuous	TM-2

POINT 13

Pollutant	Units of measure	Frequency	Sampling Method
Volumetric flowrate	cubic metres per second	Continuous	CEM-6

POINT 14

Pollutant	Units of measure	Frequency	Sampling Method
1,2-Dichloroethane	milligrams per litre	Monthly	Special Method 2
Arsenic	milligrams per litre	Monthly	24 hour composite sample
Benzene	milligrams per litre	Monthly	Special Method 2
Biochemical oxygen demand	milligrams per litre	Monthly	24 hour composite sample
Cadmium	milligrams per litre	Monthly	24 hour composite sample
Carbon tetrachloride	milligrams per litre	Monthly	Special Method 2
Chloroform	milligrams per litre	Monthly	Special Method 2
Chromium (total)	milligrams per litre	Monthly	24 hour composite sample
Copper	milligrams per litre	Monthly	24 hour composite sample
Iron	milligrams per litre	Monthly	24 hour composite sample
Lead	milligrams per litre	Monthly	24 hour composite sample
Manganese	milligrams per litre	Monthly	24 hour composite sample
Mercury	milligrams per litre	Monthly	24 hour composite sample
Nickel	milligrams per litre	Monthly	24 hour composite sample
Nitrate + nitrite (oxidised nitrogen)	milligrams per litre	Monthly	24 hour composite sample
Nitrogen (ammonia)	milligrams per litre	Monthly	24 hour composite sample
Nitrogen (total)	milligrams per litre	Monthly	24 hour composite sample
Phosphorus (total)	milligrams per litre	Monthly	24 hour composite sample
Reactive Phosphorus	milligrams per litre	Monthly	24 hour composite sample
Tetrachloroethene (tetrachloroethylene)	milligrams per litre	Monthly	Special Method 2
Toluene	milligrams per litre	Monthly	Special Method 2
Total residual chlorine	milligrams per litre	Monthly	Special Method 7
Trichloroethene (Trichloroethylene)	milligrams per litre	Monthly	Special Method 2
Turbidity	nephelometric turbidity units	Monthly	24 hour composite sample
Vinyl chloride	milligrams per litre	Monthly	Special Method 2
Zinc	milligrams per litre	Monthly	24 hour composite sample
pH	pH	Monthly	24 hour composite sample

POINT 15

Pollutant	Units of measure	Frequency	Sampling Method
Conductivity	microsiemens per centimetre	Continuous	In line instrumentation

POINT 16

Pollutant	Units of measure	Frequency	Sampling Method
Temperature	degrees Celsius	Continuous during discharge	In line instrumentation

POINT 25

Pollutant	Units of measure	Frequency	Sampling Method
Mercury	micrograms per cubic metre	Daily	24 hour composite sample

POINTS 26,27,28

Pollutant	Units of measure	Frequency	Sampling Method
Cadmium	milligrams per cubic metre	Special Frequency 14	TM-14
Dioxins & Furans	nanograms per cubic metre	Special Frequency 15	TM-18
Hazardous substances	milligrams per cubic metre	Special Frequency 14	TM-12 & TM-13
Hexachlorobenzene	milligrams per cubic metre	Special Frequency 14	TM-34
Hexachlorobutadiene	milligrams per cubic metre	Special Frequency 14	TM-34
Hexachloroethane	milligrams per cubic metre	Special Frequency 14	TM-34
Mercury	milligrams per cubic metre	Special Frequency 14	TM-14
Total solids	milligrams per cubic metre	Special Frequency 14	TM-15
Volatile organic compounds	milligrams per cubic metre	Special Frequency 14	TM-34

POINTS 29,30,31,32

Pollutant	Units of measure	Frequency	Sampling Method
Volatile organic compounds	milligrams per cubic metre	2 times daily during discharge	Special Method 6

POINTS 33,34,35,36

Pollutant	Units of measure	Frequency	Sampling Method
Volatile organic compounds	milligrams per cubic metre	Special Frequency 14	TM-34

M2.2 For the purpose of the table(s) above:

- Emission monitoring for hydrogen chloride in point 4 must be undertaken when the burner is on line at such a steady rate as will facilitate sampling in accordance with the EPA's letter dated 20 August 2002.

- Emission monitoring for hydrogen chloride is TM 7 & TM 8 using site specific variations as outlined in the EPA's letter dated 20 August 2002 or any other methods approved in writing by the EPA.

- **Other Approved Method 1** means In-house Method 04-010 consistent with USEPAm18.

  - Minor variations to those sampling methods as specified in the DECC's *'Approved Methods for the Sampling and Analysis of Air Pollutants in NSW'* and *'Approved Methods for the Sampling and Analysis of Water Pollutants in NSW'* , as approved by the National Association of Testing Authorities' (NATA) endorsement of Laboratories, are deemed to be appropriate. As per DECC's letter to licensee dated 13 September 2007 permitting the use of in-house methods and standards as an interim measure, pending NATA accreditation.

- **Special Frequency 1** means samples must be collected and analysed continuously and reference samples must also be collected and analysed on a quarterly basis.

- **Special Frequency 3** is defined as monitoring monthly for the first 6 months and quarterly thereafter. This monitoring frequency could be reviewed after 2 years of normal operations of the plant.

- **Special Frequency 4** is defined as monitoring continuously for the first two weeks. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 5** is defined as monitoring daily for first two weeks then weekly thereafter. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 6** is defined as monitoring continuously for the first two weeks only. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 7** is defined as monitoring daily for the first week then twice during the second week. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 8** is defined as monitoring daily for the first two weeks only. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 9** is defined as conducting a study (prepared using 5 individual samples) on one day prior to commencing discharge and then another 2 studies (prepared using 5 individual samples for each) during discharge. The two later studies would be conducted on a day in both the first and second weeks of discharge to Springvale drain.

- **Special Frequency 10** is defined as monitoring daily for the first two weeks only. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 11** is defined as monitoring daily for the first week and then twice in the second week. This monitoring frequency could be reviewed following assessment of results of the first two weeks.

- **Special Frequency 12** is defined as monitoring during the initial transfer of material to the storage tank.

- **Special Frequency 13** is defined as monitoring continuously at all times except when the Fourier Transform Infrared Spectrometer (FTIR) is taken off-line for service, repair, maintenance and/or calibration purposes only. During this off-line period, monitoring must be carried out on a daily basis for 1-hour composite samples in accordance with the EPA's Approved Methods. In these exceptional circumstances, the licensee may use the in-house laboratory for analysis of these samples.

- **Special Frequency 14**

a) **For Store J**, is defined as monitoring every quarter.

b) **For Store E,** is defined as monitoring on every 5th working day of operation for Points 28, 32 and 36. Special frequency 14 may be reviewed by the EPA from time to time based on the results of monitoring of parameters for Store E.

c) **For Store G & H**, is defined as monitoring every quarter.

- **Special Frequency 15**

d) **For Store J**, is defined as monitoring once annually.

e) **For Store E**, is defined as monitoring on every 5th working day of operation for Points 28, 32 and 36. Special frequency 15 may be reviewed by the EPA from time to time based on the results of monitoring of parameters for Store E.

f) **For Store G & H**, is defined as monitoring once annually.

- **Special Method 1** means continuous monitoring and analysis for 1,2-dichloroethane and vinyl chloride is CEM-10 while the quarterly method for 1,2-dichloroethane is OM-2 and the quarterly method for vinyl chloride is OM-2 or USEPA Method 106

- **Special Method 2** means taking three (3) grab samples in any 24-hour period once per week. The result will be obtained by mathematically averaging the results of three grab samples after being analysed individually.

- **Special Method 3** means weekly analysis of a prepared composite sample obtained from 3 grab samples taken over a 24-hour period.

- **Special Method 4** means is defined as conducting a study (prepared using 5 individual samples) on one day prior to commencing discharge and then another 2 studies (prepared using 5 individual samples for each) during discharge. The two later studies would be conducted on a day in both the first and second weeks of discharge to Springvale drain.

- **Special Method 5** means that a single sample is taken in the centre of the stack, but with the sampling velocity adjusted to match the stack velocity. This special method should align as close as practicable with the test method TM-8.

- **Special Method 6** means CEM-8, CEM-9 or CEM-10 (as defined in *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW. EPA 2005*), or a continuous monitoring method otherwise approved by the EPA.

- **Special Method 7** means taking three (3) grab samples in any 24-hour period once per week. Each grab sample must be analysed on-site within minutes of the sample being collected as per Approved Methods. The result will be obtained by mathematically averaging the individual results of three grab samples.

- **Special Method 8** means testing in accordance with USEPAm26A

M2.3 At Point 4, the licensee is required to take a grab sample during 4 startups and shutdowns to determine the concentration of HCl emissions during startup or shutdown conditions. In these circumstances, the licensee may use the in-house HCl sampling method.

M3 Testing methods - concentration limits

M3.1 Monitoring for the concentration of a pollutant emitted to the air required to be conducted by this licence must be done in accordance with:

(a) any methodology which is required by or under the Act to be used for the testing of the concentration of the pollutant; or

(b) if no such requirement is imposed by or under the Act, any methodology which a condition of this licence requires to be used for that testing; or

(c) if no such requirement is imposed by or under the Act or by a condition of this licence, any methodology approved in writing by the EPA for the purposes of that testing prior to the testing taking place.

Note: The Protection of the Environment Operations (Clean Air) Regulation 2002 requires testing for certain purposes to be conducted in accordance with test methods contained in the publication "Approved Methods for the Sampling and Analysis of Air Pollutants in NSW".

M3.2 Subject to any express provision to the contrary in this licence, monitoring for the concentration of a pollutant discharged to waters or applied to a utilisation area must be done in accordance with the Approved Methods Publication unless another method has been approved by the EPA in writing before any tests are conducted.

Note: Testing methods - load limit

Note: Clause 18 (1), (1A) and (2) of the Protection of the Environment Operations (General) Regulation 1998 requires that monitoring of actual loads of assessable pollutants listed in L2.1 must be carried out in accordance with the testing method set out in the relevant load calculation protocol for the fee-based activity classification listed in condition A1.2.

M4 Recording of pollution complaints

M4.1 The licensee must keep a legible record of all complaints made to the licensee or any employee or agent of the licensee in relation to pollution arising from any activity to which this licence applies.

M4.2 The record must include details of the following:

(a) the date and time of the complaint;
(b) the method by which the complaint was made;
(c) any personal details of the complainant which were provided by the complainant or, if no such details were provided, a note to that effect;
(d) the nature of the complaint;
(e) the action taken by the licensee in relation to the complaint, including any follow-up contact with the complainant; and
(f) if no action was taken by the licensee, the reasons why no action was taken.

M4.3 The record of a complaint must be kept for at least 4 years after the complaint was made.

M4.4 The record must be produced to any authorised officer of the EPA who asks to see them.

M5 Telephone complaints line

M5.1 The licensee must operate during its operating hours a telephone complaints line for the purpose of receiving any complaints from members of the public in relation to activities conducted at the premises or by the vehicle or mobile plant, unless otherwise specified in the licence.

M5.2 The licensee must notify the public of the complaints line telephone number and the fact that it is a complaints line so that the impacted community knows how to make a complaint.

M5.3 Conditions M5.1 and M5.2 do not apply until 3 months after:
(a) the date of the issue of this licence or
(b) if this licence is a replacement licence within the meaning of the Protection of the Environment Operations (Savings and Transitional) Regulation 1998, the date on which a copy of the licence was served on the licensee under clause 10 of that regulation.

M6 Requirement to monitor volume or mass

M6.1 For each discharge point or utilisation area specified below, the licensee must monitor:

(a) the volume of liquids discharged to water or applied to the area;
(b) the mass of solids applied to the area;
(c) the mass of pollutants emitted to the air;

at the frequency and using the method and units of measure, specified below.

POINT 16

Frequency	Unit Of Measure	Sampling Method
Continuous during discharge	kilolitres per day	Wedge Flow Meter

M7 Weather monitoring

M7.1 For each monitoring point specified below (by a point number), the licensee must monitor (by sampling and obtaining results by analysis) the parameter specified in Column 1. The licensee must use the sampling method, units of measure, averaging period and sample at the frequency, specified opposite in the other columns:

POINT 12

Parameter	Units of measure	Averaging period	Frequency	Sampling Method
Wind speed @ 10 m	m/s	1 hour	Continuously	AM-2 & AM-4
Wind direction @ 10 m	°	1 hour	Continuously	AM-2 & AM-4
Sigma Theta @ 10 m	°	1 hour	Continuously	AM-2 & AM-4
Additional Requirements				
Siting				AM-1 & AM-4
Measurement				AM-2 & AM-4

Note: Due to technical and topographical difficulties associated with the installation of the weather monitoring station, the licensee is required to align as close as possible to the sampling methods included in this condition for point 12.

6 Reporting conditions

R1 Annual return documents

What documents must an Annual Return contain?

R1.1 The licensee must complete and supply to the EPA an Annual Return in the approved form comprising:
(a) a Statement of Compliance; and
(b) a Monitoring and Complaints Summary.
A copy of the form in which the Annual Return must be supplied to the EPA accompanies this licence. Before the end of each reporting period, the EPA will provide to the licensee a copy of the form that must be completed and returned to the EPA.

Period covered by Annual Return

R1.2 An Annual Return must be prepared in respect of each reporting period, except as provided below.

Note: The term "reporting period" is defined in the dictionary at the end of this licence. Do not complete the Annual Return until after the end of the reporting period.

R1.3 Where this licence is transferred from the licensee to a new licensee:
(a) the transferring licensee must prepare an Annual Return for the period commencing on the first day of the reporting period and ending on the date the application for the transfer of the licence to the new licensee is granted; and
(b) the new licensee must prepare an Annual Return for the period commencing on the date the application for the transfer of the licence is granted and ending on the last day of the reporting period.

Note: An application to transfer a licence must be made in the approved form for this purpose.

R1.4 Where this licence is surrendered by the licensee or revoked by the EPA or Minister, the licensee must prepare an Annual Return in respect of the period commencing on the first day of the reporting period and ending on:
(a) in relation to the surrender of a licence - the date when notice in writing of approval of the surrender is given; or

(b) in relation to the revocation of the licence - the date from which notice revoking the licence operates.

Deadline for Annual Return

R1.5 The Annual Return for the reporting period must be supplied to the EPA by registered post not later than 60 days after the end of each reporting period or in the case of a transferring licence not later than 60 days after the date the transfer was granted (the 'due date').

Notification where actual load can not be calculated

R1.6 Where the licensee is unable to complete a part of the Annual Return by the due date because the licensee was unable to calculate the actual load of a pollutant due to circumstances beyond the licensee's control, the licensee must notify the EPA in writing as soon as practicable, and in any event not later than the due date. The notification must specify:

(a) the assessable pollutants for which the actual load could not be calculated; and
(b) the relevant circumstances that were beyond the control of the licensee.

Licensee must retain copy of Annual Return

R1.7 The licensee must retain a copy of the Annual Return supplied to the EPA for a period of at least 4 years after the Annual Return was due to be supplied to the EPA.

Certifying of Statement of Compliance and signing of Monitoring and Complaints Summary

R1.8 Within the Annual Return, the Statement of Compliance must be certified and the Monitoring and Complaints Summary must be signed by:
(a) the licence holder; or
(b) by a person approved in writing by the EPA to sign on behalf of the licence holder.

R1.9 A person who has been given written approval to certify a certificate of compliance under a licence issued under the Pollution Control Act 1970 is taken to be approved for the purpose of this condition until the date of first review of this licence.

R2 Notification of environmental harm

Note: The licensee or its employees must notify the EPA of incidents causing or threatening material harm to the environment as soon as practicable after the person becomes aware of the incident in accordance with the requirements of Part 5.7 of the Act.

R2.1 Notifications must be made by telephoning the Environment Line service on 131 555.

R2.2 The licensee must provide written details of the notification to the EPA within 7 days of the date on which the incident occurred.

R3 Written report

R3.1 Where an authorised officer of the EPA suspects on reasonable grounds that:
(a) where this licence applies to premises, an event has occurred at the premises; or
(b) where this licence applies to vehicles or mobile plant, an event has occurred in connection with the carrying out of the activities authorised by this licence,
and the event has caused, is causing or is likely to cause material harm to the environment (whether the harm occurs on or off premises to which the licence applies), the authorised officer may request a written report of the event.

R3.2 The licensee must make all reasonable inquiries in relation to the event and supply the report to the EPA within such time as may be specified in the request.

R3.3 The request may require a report which includes any or all of the following information:
(a) the cause, time and duration of the event;
(b) the type, volume and concentration of every pollutant discharged as a result of the event;
(c) the name, address and business hours telephone number of employees or agents of the licensee, or a specified class of them, who witnessed the event;
(d) the name, address and business hours telephone number of every other person (of whom the licensee is aware) who witnessed the event, unless the licensee has been unable to obtain that information after making reasonable effort;
(e) action taken by the licensee in relation to the event, including any follow-up contact with any complainants;
(f) details of any measure taken or proposed to be taken to prevent or mitigate against a recurrence of such an event; and
(g) any other relevant matters.

R3.4 The EPA may make a written request for further details in relation to any of the above matters if it is not satisfied with the report provided by the licensee. The licensee must provide such further details to the EPA within the time specified in the request.

General conditions

G1 Copy of licence kept at the premises

G1.1 A copy of this licence must be kept at the premises to which the licence applies.

G1.2 The licence must be produced to any authorised officer of the EPA who asks to see it.

G1.3 The licence must be available for inspection by any employee or agent of the licensee working at the premises.

G2 Signage

G2.1 Each monitoring and discharge point, located within the premises as defined in this licence, must be clearly marked by a sign that indicates the EPA point identification number used in this licence and be located as close as practical to the point.

Pollution studies and reduction programs

Pollution Reduction Programs (PRPs) Completed

PRP No	Description	Completed Date
1	Noise Pollution Reduction Program	December 2001
2	Stormwater Pollution Reduction Program	**Ongoing**
3	Steam Stripper Unit Optimisation Plan	30/09/04
4	Steam Stripper Unit Optimisation	24/12/04
5	Best Practice Benchmarking for Steam Stripper Unit	24/12/04
6	Measures to achieve world’s best practice for Steam Stripper Unit	29/03/05
7	Requirement to achieve world’s best practice	Completed
8	Air Stripping Unit	24/03/05
9	Ammonia Concentration Reduction Strategy	**Ongoing**
10	Requirement to determine dilution (at Point 11)	06/05/08

U1 Stormwater Pollution Reduction Program

U1.1 A continuous improvement program must be implemented to address issues associated with the stormwater system on any part of the premises. The stormwater improvement program must be consistent with the Botany Industrial Park stormwater improvement plan.

U1.2 **A report must be forwarded to the EPA annually as an attachment to the Qenos P/L (Environment Protection Licence No. 10000) annual return**, that details the following:

a) Issues associated with the stormwater system
b) Programs that have been and will be implemented to address areas requiring attention
c) Progress made towards the goals outlined in the stormwater improvement plan.

U2 Ammonia Concentration Reduction Strategy

U2.1 Objective

The objective of this Pollution Reduction Program (PRP) is to reduce ammonia concentrations in the treated effluent of the Groundwater Treatment Plant at Point 11 to achieve the protection of aquatic ecosystems (95 percent species protection) in both the Perry Street Canal System and Botany Bay based on the ANZECC and ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* ('the ANZECC Guidelines').

For the purposes of this condition, the Perry Street Canal System is defined as the stormwater drainage system from the point near the intersection of Flack Avenue and Beauchamp Road Hillsdale (UBD Map Ref 276 M16) downstream to Brotherson Dock (including all associated formed channel structures, weirs and culverts) and the drainage system downstream of Discharge Point 11.

U2.2 Ammonia Concentration Reduction Progress Report

On or before 1 July 2009, the licensee must submit an Ammonia Concentration Reduction Progress Report to the Manager Sydney Industry at PO Box 668 Parramatta NSW 2124.

This report must include, but not be limited to, the following:

a) details of the status of works proposed in the report titled 'Ammonia Concentration Reduction Pollution Reduction Program. 30 August 2007' which was submitted by the licensee on 30 August 2007;
b) details of proposed strategies to achieve the objective set out in Condition U2.1; and
c) timeframes for the implementations of the above works and strategies to achieve the objectives set out in Condition U2.1.

Note 1: Following the receipt of the above Ammonia Concentration Reduction Progress Report, additional licence conditions may be added to the licence to require implementation of the options to achieve the objective in condition U2.1.
Note 2: On 12 December 2008 the licensee submitted one progress report required by the above condition. The condition has been amended to require a second progress report by a 1 July 2009..

U3 Treated water discharge - temperature reduction strategy.

U3.1 Objective

The objective of this Pollution Reduction Program (PRP) is to reduce the temperature of the treated effluent of the Groundwater Treatment Plant at Point 11 to achieve the temperature limits specified in condition L3.

U3.2 By 31 December 2009 the licensee must implement option 1 as described in the document titled "Treated Water Discharge Temperature Reduction Strategy Progress Report" dated 27 August 2009. The licensee must notify the EPA's Manager Sydney Industry PO Box 668 Parramatta 2124 within two weeks of completion of the works.

Special conditions

CPWE Special Conditions

Preamble

a) The timeline provided in E1 is based on remediation of the Car Park Waste as described in the project Environmental Assessment and Remediation Action Plan (final amended) submitted by Orica to the NSW Department of Planning.

b) Should the results of the current monitoring program indicate that more timely attention is required by Orica, the timeline provided for the remediation works may be modified.

c) For the purposes of all special condition(s) in Section E:

- ‘Impacted materials’ is defined as: any materials contaminated by hexachlorobutadiene (HCBD) and/or associated compounds, within the immediate vicinity of the Car Park Waste Encapsulation cell.
- ‘Car Park Waste Encapsulation (CPWE)’ or ‘HCB encapsulation cell’ is defined as: the encapsulation cell that lies beneath the car park on the North East boundary of the Botany Industrial Park (BIP) as shown on map Fig 4.1 from “HCB Encapsulation Groundwater Monitoring Report No 7” dated 28 August 2003.
- ‘Car Park Waste’ is defined as: Approximately 45 000 cubic metres of a mixture of sand and coal ash containing hexachlorobenzene (HCB) and other chlorinated materials including HCBD, interred under a paved car park area containing approximately 0.18% of HCB and other chlorinated materials (Ref.: Hexachlorobenzene Waste Management Plan, Australian and New Zealand Environment Conservation Council (ANZECC), 1996).
- ‘Remediation’ is defined as:

(a) preparing a long-term management plan (if any) for the land, and

(b) removing, destroying, reducing, mitigating or containing the contamination of the land, and

(c) eliminating or reducing any hazard arising from the contamination of the land (including by preventing the entry of persons or animals on the land).

Reference: Contaminated Land Management Act 1997 No 140

Note: (i) in this context “land” includes the Car Park Waste and Impacted Materials; (ii) the Scheduled Chemical Waste Chemical Control Order (CCO) does not permit ‘dispersion’ to meet limits; and (iii) the aim of these works also includes protection of groundwater.

E1 Timetable for Remediation of Car Park Waste and Impacted Materials

E1.1 Once the Construction and Site Establishment Works (Stage 2 in EPA's recommended Approval conditions) have physically commenced, the licensee must ensure the Car Park Waste and Impacted Materials are remediated and/or disposed of within a maximum period of two years from the date of commencement of the works unless otherwise agreed to in writing by the EPA. The licensee must notify the EPA in writing the date of commencement of Construction and Site Establishment. The remediation activity must include treatment of waste and demobilisation of site equipment. The licensee must also submit a report to the EPA by 1 February and 1 July each year until the commencement of Construction and Site Establishment Works to provide an update on the progress towards remediation of Car Park Waste and Impacted Materials.

E2 Progress reporting on remediation works to remove the source of hexachlorobutadiene (HCBD) and associated compounds

E2.1 Every six months after commencement of the Construction and Site Establishment Works, the licensee must submit a report to Manager Sydney Industry, EPA, PO Box 668, Parramatta 2124 containing the following information:

a) Progress report on the remediation works;

b) Confirmation that the works have been undertaken in accordance with the EPA's waste guidelines and POEO Waste Regulation 2005;

c) Results of any additional monitoring or alternative works to demonstrate as far as practical that this action has been effective in removing the source that led to the detection of HCBD in groundwater at the groundwater monitoring point at WG95S;

d) An interpretive report on the results of groundwater and/or soil monitoring and an assessment of the effectiveness of the remediation works to achieve an HCBD groundwater concentration not greater than 0.04µg/L at the boundary of the CPWE part of Lot 11 in DP1039919; and

e) Any revisions to the project timetable (as a Gantt Chart or equivalent).

Note: the above concentration is a low reliability trigger value taken from ANZECC and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000 water quality guidelines. Exceedances of such levels trigger further investigation.

E3 Ongoing groundwater monitoring around the Car Park Waste Encapsulation (CPWE)

E3.1

a) On a six monthly basis until the commencement of the Construction and Site Establishment Works the licensee must conduct a groundwater monitoring program around the encapsulation. The program should at least include monitoring at the following wells – WG50S, WG93S/I/D, WG94S, WG95S, WG96S/I/D, WG200S/I/D, WG202S/I/D, WG203I/D, WG218S/I/D, WG219S/I/D and WG220S/I/D for the chemicals listed below.

b) The licensee must submit a six monthly progress report which includes the results of the above monitoring and an interpretive comment on the monitoring results to Manager, Sydney Industry, EPA, PO Box 668 Parramatta 2124.

c) At least two months prior to the commencement of the Construction and Site Establishment Works, the licensee must provide the EPA with a proposal for ongoing groundwater monitoring around the encapsulation. The proposal must include groundwater monitoring at a minimum of once every three months for the first year after Construction and Site Establishment Works commence and every six months for not less than four years thereafter, unless otherwise agreed in writing by the EPA. The proposal is to be implemented at the commencement of the Construction and Site Establishment Works.

Chemicals to be analysed in the Car Park groundwater monitoring program

VOLATILE CHLORINATED HYDROCARBONS
Chlorinated Methanes
Pentachloroethane
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,2-Dichloroethane
1,1-Dichloroethane
Chloroethane
Tetrachloroethene
Trichloroethene
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
1,1-Dichloroethene
Vinyl chloride

SEMIVOLATILE CHLORINATED HYDROCARBONS
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4- Dichlorobenzene
1,2,4-Trichlorobenzene
1,3,5-Trichlorobenzene
1,2,4,5-Tetrachlorobenzene
Pentachlorobenzene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Hexachloropropylene

E4 Completion reporting

E4.1 Within three months of Reinstatement of the CPWE Site (Stage 6 in EPA's recommended Approval conditions) Orica must provide a report to the EPA, the Community Participation and Review Committee (CPRC) and the NSW Office of Water demonstrating complete achievement of the remediation objectives for the Car Park Waste.

E5 GTP SPECIAL CONDITIONS

AUDITS AND REVIEWS

The objective of this condition is:

To conduct a series of ongoing independent audits to validate the predictions contained in the Environmental Impact Statement (EIS) submitted to the EPA on 15 November 2004 and compliance with this licence, and to the extent required by any other approval, compliance with those approval conditions relating to the project;

To conduct environmental reviews with the aim of optimising performance;

To conduct engineering audits to ensure the performance of the plant will not deteriorate in the longer term; and

To identify remedial measures that can be implemented in the event an audit shows a discrepancy between actual and predicted performance.

This condition comprises two parts:

Part A - Environmental Review and Independent Audit

Part B - Engineering Audit

PART A - ENVIRONMENTAL REVIEW AND INDEPENDENT AUDIT REQUIREMENTS

General Requirement

The licensee must undertake comprehensive environmental reviews and independent audits of the works undertaken in accordance with the EIS.

Each Environmental Review and Independent Audit must include the components specified in Conditions E5.1 and E5.2.

E5.1 ENVIRONMENTAL REVIEW

The licensee must conduct an Environmental Review for submission with each Annual Return.

The Environmental Review must include the following programs:

- Dioxin Monitoring Technical Review
- Groundwater Treatment Plant Water Reuse Strategy
- Groundwater Monitoring Program

E5.1.1 Dioxin Monitoring Technical Review

The licensee must conduct a program that includes, but is not limited to the following:

A review of technical options and scientific developments relating to discrete and continuous dioxin monitoring technologies.

E5.1.2 Groundwater Treatment Plant (GTP) Water Reuse Strategy

The licensee must conduct a program that includes, but is not limited to the following:

An investigation into opportunities to maximize the reuse of treated water from the groundwater treatment plant and reduce the amount of treated water discharged to waters provided the reuse or reduction can be achieved in a safe and practical manner and it will provide the best environmental outcome, in the circumstances.

E5.1.3 Groundwater Monitoring Program

The licensee must conduct a Groundwater Monitoring Program which must include but not be limited to the following:

(a) Monitoring of groundwater to assess whether the extraction of groundwater will result in any actual or potential impacts to surface waters or habitats in the locality;

(b) Review the conclusions of the groundwater assessments and modelling that was undertaken as part of the EIS, including using all monitoring data collected under this license or other approvals for this project;

(c) include a mechanism to regularly review the effectiveness of the monitoring program to ensure it is effective in detecting the presence of actual or potential impacts not already identified; and

(d) Make recommendations about changes to existing monitoring and frequency of monitoring.

The program must be prepared and implemented in consultation with DECC.

E5.2 INDEPENDENT AUDIT

The licensee must engage (and bear the full cost of), an independent and suitably qualified auditor to undertake comprehensive Independent Audits of the project.

The auditor must:

- be a certified environmental auditor who has gained certification from a certification body (such as Registrar Accreditation Board and Quality Society of Australasia international (RABQSA) formerly known as (QSA) who have been accredited by the Joint Accreditation Services Australia & New Zealand (JAS/ANZ);
- have Lead Environmental Auditor certification; and
- have held lead environmental certification for at least 2 years.

The licensee must consult with the Independent Monitoring Committee in the selection of the auditor.

The Independent Audit must:

(a) be carried out in accordance with ISO 19011:2003 - Guidelines for Quality and/ or Environmental Management Systems Auditing;

(b) take into account representative operating conditions including worst case scenarios which relate to the groundwater treatment plant;

(c) assess compliance with the requirements of this licence, and to the extent required by any other approval, compliance with those approval conditions relating to the project;

(d) assess the project against the predictions made and conclusions drawn in the EIS and supporting documents prepared by the licensee;

(e) include a review of the documentation relevant to the requirements of conditions E5.1; and

(f) include a statement on the effectiveness of the overall environmental management and performance of the project.

Independent Audits must be prepared for the first three reporting periods during which the groundwater treatment plant has commenced operation.

The following Independent Audit reports have been submitted in accordance with this requirement:

- Independent Audit Report Botany Groundwater Remediation Program (KMH Environmental, September 2006);
- Validation Audit and Environmental Review Botany Groundwater Remediation Program (KMH Environmental, September 2007); and

- Validation Audit and Environmental Review Botany Groundwater Remediation Program (KMH Environmental, October 2008).

The EPA has considered the need for further Independent Validation Audits in light of the environmental performance of the GTP and on that basis no Audit is required for 2009 or 2010.

E5.3 PART B - ENGINEERING AUDIT

E5.3 General requirement

The licensee must make arrangements for, and bear the full cost of, an independent auditor to undertake engineering audits of the groundwater treatment plant and associated plant and equipment (including all control systems) to ensure it is maintained in a proper and efficient condition and operated in a proper and efficient manner with respect to its environmental and safety capability and performance.

Matters to be addressed in the audits must include but not be limited to;

(a) Review of the frequency of inspections and maintenance programs to ensure they are effective in detecting actual or potential changes in the environmental and safety performance;

(b) Review of procedures for detecting changes to the equipment which could impact on performance, including corrosion and wear; and

(c) Review of results of internal inspections of all equipment, using video techniques where appropriate.

The licensee must consult with the Independent Monitoring Committee in the selection of the auditor.

The engineering audits must generate a report for submission to the DECC, DEW, Sydney Water Corporation, City of Botany Council, Orica Groundwater Community Liaison Committee and be available for public inspection on request.

The report must be submitted with each Annual Return

- At the end of every 5th reporting period, for the first 15 years of operation of the groundwater treatment plant (ie September 2012, September 2017 and September 2022); and then

- Every 2nd reporting period in which the plant remains in operation (ie September 2024 and then every two years thereafter).

The EPA may require the licensee to undertake works to address the findings or recommendations presented in the Report as a requirement of this licence. Any such works shall be completed within such time as the EPA may agree.

E6 INDEPENDENT MONITORING COMMITTEE

E6.1 The licensee must service an Independent Monitoring Committee with technical and community representatives relating to the Groundwater Treatment Plant and its operation. The licensee must provide monitoring information and reports and consult with this Committee as required by the relevant conditions of this licence.

Note: The Independent Monitoring Committee will be serviced by the licensee in conjunction with the existing Orica Groundwater Community Liaison Committee which is also serviced by the licensee.

E7 Financial Assurance

The objective of this condition is to secure or guarantee funding for or towards the ongoing operating costs of the Groundwater Treatment Plant and associated groundwater collection infrastructure.

E7.1 Unconditional and irrevocable bank guarantee

E7.1.1 A financial assurance, in favour of the EPA, in the form of an unconditional and irrevocable bank guarantee dated 7 February 2007 for the amount of fourteen million four hundred thousand dollars ($14,400,000) must be maintained for or towards the ongoing operating costs of the Groundwater Treatment Plant (GTP) and associated groundwater collection infrastructure and thereafter until such time as the EPA is satisfied the premises are environmentally secure.

Note: $14.4 million is 20% of the net present value of the outstanding provision ($72 million) of the long term operating costs identified in the licensee’s submission on the appropriate form or amount of the financial assurance, dated 30 September 2006.

E7.2 Requirement to increase the amount of the financial assurance

E7.2.1 The licensee must increase the amount of financial assurance in accordance with the following schedule based on the financial position of Orica Limited as determined by its Standard & Poors credit rating:

- i) While a Standard & Poors credit rating remains at BBB+ or above, the bank guarantee required will be $14.4 million; and
- ii) If the Standard & Poors credit rating falls to BBB the bank guarantee required will be $35 million; and
- iii) If the Standard & Poors credit rating below BBB the bank guarantee required will be $72 million.

E7.3 Requirement to report credit rating in each annual return

E7.3.1 The licensee must include in each licence annual return evidence of Orica Limited’s credit rating for the whole period of the licence year.

E7.4 Requirement to report any changes in credit rating

E7.4.1 The licensee must advise the EPA as soon as practical and in any event within five days of receiving advice from Standard & Poors of any change to the credit rating of Orica Limited.

Note: Orica Australia Pty Ltd is the licensee and Orica Limited is the parent company. The credit rating relates to Orica Limited.

E7.5 Varying the magnitude of the financial assurance

E7.5.1 The EPA reserves the right to vary the magnitude of the financial assurance at any time depending upon any reassessment of possible cost(s) of rehabilitation of the premises or any other reason which the EPA deems to be appropriate and reasonable to ensure environmental security.

Note: The EPA will review the above arrangement every three years including consideration of Consumer Price Index (CPI) adjustments, or more frequently if considered necessary by the EPA or if requested by the licensee, in light of the remaining works required to complete the remediation.

E7.5.2 The EPA will only draw on the Financial Assurance to fund or recover the reasonable costs in carrying out, or directing or supervising the carrying out by another person, of any work or program, including the likely costs and expenses in directing and supervising the carrying out of the work or program, to meet the requirements of the licence relating to the Groundwater Treatment Plant and associated infrastructure where in the opinion of the EPA the licensee has failed to meet these requirements.

E7.6 Requirement to submit a review every three years

E7.6.1 The licensee must provide the EPA with a review of the outstanding capital and operating costs for the Groundwater Treatment Plant and associated groundwater collection infrastructure **every three years commencing 5 February 2010.**

E7.7 Requirement to advise of changes to deed of cross guarantee

E7.7.1 The Licensee must advise the EPA in advance if it proposes to change and as soon as possible if it does change its deed of cross guarantee lodged with the Australian Securities and Investment Commission, whereby financial liabilities are shared across the Orica group of companies.

E7.8 Requirement to advise of any changes which may affect ability to fund

E7.8.1 The licensee must notify the EPA of any proposed corporate restructure, scheme of arrangement or appointment of an external administrator that will or may directly or indirectly affect the licensee’s short or long term ability to fund the operation of the Groundwater Treatment Plant and associated groundwater collection infrastructure.

E8 Hexachlorobenzene (HCB) Waste Repackaging Plant Special Conditions

E8.1 Fugitive Emissions

E8.1.1 The licensee must design, construct, operate and maintain ventilation systems for the buildings in which the operation of the HCB waste repackaging lines is to occur so that the pressure within the building lies below atmospheric pressure at all times.

E8.2 Concentration Limits

E8.2.1 The licensee shall establish, in consultation with the EPA, a maximum break-through limit for volatile organic compounds for monitoring / discharge points 29, 30, 31 and 32. For the purposes of monitoring volatile organic compounds, a suitable organic compound equivalent for volatile organic compounds must also be determined. Reference conditions for the break-through limit must be dry, 273 K and 101.3 kPa.

Note: The licensee provided information regarding breakthrough limits for Points 29, 30 and 31 in correspondence dated 4 July 2008.

E8.3 Shutdown Requirements

E8.3.1 If the break-through limit described in condition E8.2.1 at monitoring/discharge points 29 or 30 is exceeded after completion of commissioning, the HCB repackaging facility must shutdown as soon as practical after the exceedance is reported (twice daily checks are undertaken during operation). The licensee must only restart the HCB repackaging facility after the carbon bed is replaced with a new or regenerated activated carbon bed. Replacement carbon is not required in the event that the exceedance is found to be a technical error and is unjustified.

E8.3.2 If the break-through limit described in condition E8.2.1 at monitoring/discharge points 31 and / or 32 is exceeded after completion of commissioning, material transfer processes must shutdown as soon as practical after the exceedance is reported (twice daily checks are undertaken during operation). The licensee must only restart the material transfer processes after the carbon bed is replaced with a new or regenerated activated carbon bed. Replacement carbon is not required in the event that the exceedance is found to be a technical error and is unjustified.

E8.3.3 If any concentration limit described in condition L3.3 at monitoring/discharge point 26, 27 or 28 is exceeded after completion of commissioning, the HCB repackaging facility must shutdown on receipt of the relevant monitoring data. The licensee can only restart the HCB repackaging facility after receiving written approval from the EPA.

E8.4 Repackaging Process Trials Plan

E8.4.1 Prior to the commencement of the operation of the HCB Repackaging Plant, the licensee must undertake Repackaging Trials to demonstrate that repackaging activities will be undertaken within acceptable environmental limits.

E8.4.2 Prior to the commencement of Repackaging Trials, the licensee must prepare and submit for the approval of the EPA a **Repackaging Process Trials Plan** (‘Plan’). The Plan must be prepared in consultation with the EPA and must provide a program to quantitatively confirm that the HCB Repackaging Plant will meet the environmental performance described in the Environmental Assessment. In particular, the Plan must include, but not be limited to the following:

a) a description of the smoke tests to be undertaken at Store J, Store E and Store H to ensure that the installed vapour / dust extraction systems are effective in preventing the escape of unfiltered air from these enclosures;

b) details in relation to trials to confirm extraction system performance and absorption rates;

c) a description of trials to be undertaken with substance(s) having low risk of environmental harm to confirm the environmental performance of the HCB Repackaging Plant. This must include a description of each step undertaken to test the ability of the Plant to meet the requirements of the Environment Protection Licence;

d) the quantity and type of substance(s) to be used in the trial and an outline of why the substance(s) would reasonably represent the actual materials to be processed; and

e) details of monitoring that will be undertaken to measure and confirm compliance with the emission limits within the Environment Protection Licence. This must include stack emission tests and mass balance calculations that account for material captured in the activated carbon vent controls, present in the fugitive emissions within the Repackaging Plant working area(s) and material otherwise not accounted for in the mass balance such as fugitive emissions to the environment.

Note: In relation to this condition the licensee has submitted the following Repackaging Process Trials Plans to the EPA:

Repackaging Process Trials Plan for Store J dated November 2006

Repackaging Process Trials Plan for Stores E, G & H dated February 2007

E8.4.3 The licensee can only commence repackaging trials after the EPA has approved the Repackaging Process Trials Plan described in conditions E8.4.2.

Note: In relation to this condition the EPA has approved the Repackaging Process Trials Plans listed in Condition E8.4.2.

E8.4.4 The licensee must undertake repackaging process trials strictly in accordance with the approved Repackaging Process Trials Plan. In the event that the licensee intends to vary the trials from that described in the Repackaging Process Trials Plan, the licensee must seek further approval for the proposed changes from the EPA. Implementation of variations to an approved Repackaging Process Trials Plan will only occur following EPA's approval of the variations.

E8.4.5 Within 28 days of the completion of the Repackaging Trials (the Trials), the licensee must prepare and submit a **Repackaging Process Trial Report** to the EPA. The report must include, but not be limited to the following:

a) details of the Trials, describing steps undertaken during each Trial. This must include an indication of when each step was undertaken;

b) the quantity of substance(s) processed, including a detailed mass balance accounting for all substance(s) processed;

c) an assessment of whether the process will perform with minimal risk of environmental harm and within the requirements of the Environment Protection Licence, on the basis that the Trials are representative of the actual operation; and

d) any recommended improvements to the Repackaging process in response to the results of the Trials.

Note 1: In relation to this condition the licensee has submitted the following Repackaging Process Trial Reports to the EPA:

Repackaging Process Trials Report for Store J dated 1 June 2007

Repackaging Process Trials Report for Stores G & H dated 18 July 2007

Note 2: A report for Store E is to be submitted following trials at that Store.

E8.4.6 The licensee must only commence operation of the Repackaging Process after completion of the Repackaging Trials as described in condition E8.4.1 and with the approval of the EPA after it has considered the Repackaging Process Trials Report as described in condition E8.4.5.

Note: In relation to this condition the EPA has approved operations as follows:

Store J – correspondence dated 8/6/07

Stores G & H – correspondence dated 10/9/07

E8.5 Notification Requirements

E8.5.1 If on receipt of a certificate of laboratory analysis, the laboratory analysis results demonstrate that the concentration of any discharge parameter has exceeded a limit specified in conditions L3.3 for any of the monitoring / discharge Points 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 or 36, then the licensee must notify the EPA within 24 hours of receipt of the certificate.

E8.6 Waste Generation and Management

E8.6.1 This Environment Protection Licence does not permit the removal of hexachlorobenzene waste from the premises unless and until the necessary separate approvals are obtained by the licensee for an ultimate destruction / disposal location for these wastes.

E8.7 Groundwater Injection and Recovery

The object of this condition is to permit the installation and operation of plant and equipment to conduct a trial of Groundwater Injection and Recovery (GIR). The trial GIR will establish the potential for GIR to perform a backup function to maintain hydraulic containment on the Secondary Containment Area in the event of GTP inoperability for periods exceeding four weeks.

E8.7.1 The licensee must conduct a GIR trial in accordance with the methodology set out in the letter from URS Australia Pty Ltd to the licensee dated 16 March 2009 titled WCIE 4431 Groundwater Injection and Recovery (GIR) – Trial Description. Within six weeks of completion of the trial the licensee must submit to the EPA a report detailing the findings of part 2.4 Reporting requirements of the above document.

E8.8 Bioaugmentation Trial

Objective

The objective of this trial is to assess the impacts of biostimulation and bioaugmentation treatment on 1,2-dichloroethane concentrations in the Botany Sands Aquifer.

The Trial

The trial must be conducted in accordance with the document titled: ”*Proposal for the in situ bioremediation of 1,2-dichloroethane through bioaugmentation of Area A groundwater (Southlands, Botany)* prepared on the licensee’s behalf by The Centre for Marine Bio-innovation - University of New South Wales, as presented in the licensee’s email correspondence of 14 December 2009 and with the conditions of this licence.

Reporting

Within 12 weeks of the trial being completed, the licensee must submit a report to the Manager Sydney Industry, PO Box 668 Parramatta 2124 containing an evaluation of the trial including but not limited to:

- The impact of a biostimulation treatment on 1,2-dichloroethane concentrations in the Botany Sands Aquifer;
- The impact of a combined biostimulation and bioaugmentation treatment on 1,2-dichloroethane concentrations in the Botany Sands Aquifer; and
- The impact of the treatment on the indigenous microbial communities.

Summary of Special Conditions - Completed and Ongoing

Special Condition	Description	Completed Date
1	Delineation and remediation of the source of HCBD and associated compounds in the vicinity of HCB encapsulation cell	23/04/2004
2	Remediation of Car Park Waste and Impacted Materials	28/02/2006
3	Timetable for Remediation of Car Park Waste and Impacted Materials (Condition E1)	**Ongoing**
4	Progress reporting on remediation works to remove the source of HCBD and associated compounds (Condition E2)	**Ongoing**
5	Ongoing monitoring to confirm the integrity of the Car Park Waste Encapsulation (Condition E3)	**Ongoing**
6	Completion reporting (Condition E4)	**Ongoing**
7	Proposals for future works	01/12/2004
8	Supply of air quality modeling report of air emissions	24/12/2004
9	Emission Limits Based upon minimum plant performance	30/09/2004
10	Emission monitoring plan	30/09/2004
11	Emergency release emission management plan	30/09/2004

Special Condition	Description	Completed Date
12	Independent Auditor to conduct annual Audits and Reviews (Condition E5)	**Ongoing**
13	Independent Monitoring Committee (Condition E6)	**Ongoing**
14	Financial Assurance for ongoing costs of the Groundwater Treatment Plant established 31January 2007 (Condition E7).	**Ongoing**
15	In-Situ Bioremediation Pilot Scale Field Trial in Car Park Waste Encapsulation soil 2005/2006	20/06/2006
16	Modifications to the Thermal Oxidiser and Heat Exchanger Serving the Groundwater Treatment Plant	30/07/2006
17	Groundwater Treatment Plant Commissioning Plan	28/02/2007
18	Groundwater Treatment Plant Thermal Oxidiser Unit – Low Temperature Trials	24/10/2007
19	Hexachlorobenzene (HCB) Waste Repackaging Plant (Condition E8)	**Ongoing.**

Appendices

Dictionary

General Dictionary

In this licence, unless the contrary is indicated, the terms below have the following meanings:

3DGM [in relation to a concentration limit]	Means the three day geometric mean, which is calculated by multiplying the results of the analysis of three samples collected on consecutive days and then taking the cubed root of that amount. Where one or more of the samples is zero or below the detection limit for the analysis, then 1 or the detection limit respectively should be used in place of those samples
Act	Means the Protection of the Environment Operations Act 1997
activity	Means a scheduled or non-scheduled activity within the meaning of the Protection of the Environment Operations Act 1997
actual load	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 1998
AM	Together with a number, means an ambient air monitoring method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.
AMG	Australian Map Grid
anniversary date	The anniversary date is the anniversary each year of the date of issue of the licence. In the case of a licence continued in force by the Protection of the Environment Operations Act 1997, the date of issue of the licence is the first anniversary of the date of issue or last renewal of the licence following the commencement of the Act.
annual return	Is defined in R1.1
Approved Methods Publication	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 1998

Publication	
assessable pollutants	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 1998
BOD	Means biochemical oxygen demand
CEM	Together with a number, means a continuous emission monitoring method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.
COD	Means chemical oxygen demand
composite sample	Unless otherwise specifically approved in writing by the EPA, a sample consisting of 24 individual samples collected at hourly intervals and each having an equivalent volume.
cond.	Means conductivity
environment	Has the same meaning as in the Protection of the Environment Operations Act 1997
environment protection legislation	Has the same meaning as in the Protection of the Environment Administration Act 1991
EPA	Means Environment Protection Authority of New South Wales.
fee-based activity classification	Means the numbered short descriptions in Schedule 1 of the Protection of the Environment Operations (General) Regulation 1998.
flow weighted composite sample	Means a sample whose composites are sized in proportion to the flow at each composites time of collection.
general solid waste (non-putrescible)	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
general solid waste (putrescible)	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
grab sample	Means a single sample taken at a point at a single time
hazardous waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
licensee	Means the licence holder described at the front of this licence
load calculation protocol	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 1998
local authority	Has the same meaning as in the Protection of the Environment Operations Act 1997
material harm	Has the same meaning as in section 147 Protection of the Environment Operations Act 1997
MBAS	Means methylene blue active substances
Minister	Means the Minister administering the Protection of the Environment Operations Act 1997
mobile plant	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
motor vehicle	Has the same meaning as in the Protection of the Environment Operations Act 1997
O&G	Means oil and grease
percentile [in relation to a concentration limit	Means that percentage [eg.50%] of the number of samples taken that must meet the concentration limit specified in the licence for that pollutant over a specified period of time. In this licence, the specified period of time is the Reporting Period unless otherwise stated in this licence.

of a sample]	of time is the Reporting Period unless otherwise stated in this licence.
plant	Includes all plant within the meaning of the Protection of the Environment Operations Act 1997 as well as motor vehicles.
pollution of waters [or water pollution]	Has the same meaning as in the Protection of the Environment Operations Act 1997
premises	Means the premises described in condition A2.1
public authority	Has the same meaning as in the Protection of the Environment Operations Act 1997
regional office	Means the relevant EPA office referred to in the Contacting the EPA document accompanying this licence
reporting period	For the purposes of this licence, the reporting period means the period of 12 months after the issue of the licence, and each subsequent period of 12 months. In the case of a licence continued in force by the Protection of the Environment Operations Act 1997, the date of issue of the licence is the first anniversary of the date of issue or last renewal of the licence following the commencement of the Act.
restricted solid waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
scheduled activity	Means an activity listed in Schedule 1 of the Protection of the Environment Operations Act 1997
special waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
TM	Together with a number, means a test method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.
TSP	Means total suspended particles
TSS	Means total suspended solids
Type 1 substance	Means the elements antimony, arsenic, cadmium, lead or mercury or any compound containing one or more of those elements
Type 2 substance	Means the elements beryllium, chromium, cobalt, manganese, nickel, selenium, tin or vanadium or any compound containing one or more of those elements
utilisation area	Means any area shown as a utilisation area on a map submitted with the application for this licence
waste	Has the same meaning as in the Protection of the Environment Operations Act 1997
waste type	Means liquid, restricted solid waste, general solid waste (putrescible), general solid waste (non-putrescible), special waste or hazardous waste

Special Dictionary

ug/L	Means micrograms per litre.
approved	Means approved in writing by the EPA. The EPA’s approval may be given unconditionally, or subject to conditions.
CPWE	Means Car Park Waste Encapsulation
FTIR	Means Fourier Transform Infra Red Spectrometer
GTP	Means Groundwater Treatment Plant.
HCB	Means hexachlorobenzene.

HCBD	Means hexachlorobutadiene.
HCE	Means hexachloroethane.
kL	Means kilolitre.
L/s	Means litres per second.
mL	Means millilitres.
ML	Means megalitres.
SSU	Means Steam Stripping Unit.
TRC	Means total residual chlorine.
VEC	Means Vapour Emission Capture system.
VOC	Means Volatile Organic Compound, a substance which contains carbon and has a vapour pressure greater than 2 mm of mercury at 25 deg.C and 101.3 kPa.

Mr Mark Gifford

Environment Protection Authority

(By Delegation)

Date of this edition - 29-Jan-2010

End Notes

1	Licence varied by notice 1000723, issued on 01-Aug-2000, which came into effect on 22-Aug-2000.
2	Licence varied by 010937 (ALaN) s.58 notice, issued on 01-Sep-2000, which came into effect on 26-Sep-2000.
3	Licence varied by notice 1008660, issued on 27-Jul-2001, which came into effect on 21-Aug-2001.
4	Licence varied by notice 1014464, issued on 15-Jan-2003, which came into effect on 09-Feb-2003.

End Notes

5	Licence varied by notice 1025431, issued on 24-Dec-2003, which came into effect on 18-Jan-2004.
6	Licence varied by notice 1035261, issued on 30-Apr-2004, which came into effect on 30-Apr-2004.
7	Licence varied by notice 1040183, issued on 07-Sep-2004, which came into effect on 07-Sep-2004.
8	Licence varied by notice 1041498, issued on 26-Oct-2004, which came into effect on 27-Oct-2004.
9	Licence varied by notice 1041954, issued on 03-Nov-2004, which came into effect on 03-Nov-2004.
10	Licence varied by notice 1043560, issued on 14-Feb-2005, which came into effect on 22-Feb-2005.
11	Licence varied by notice 1048337, issued on 23-Aug-2005, which came into effect on 17-Sep-2005.
12	Licence varied by notice 1052073, issued on 14-Nov-2005, which came into effect on 25-Nov-2005.
13	Licence varied by notice 1060389, issued on 12-May-2006, which came into effect on 12-May-2006.
14	Licence varied by notice 1060540, issued on 22-May-2006, which came into effect on 22-May-2006.
15	Licence varied by notice 1061917, issued on 10-Jul-2006, which came into effect on 10-Jul-2006.
16	Licence varied by updating references to the Clean Air Reg, issued on 25-Jul-2006, which came into effect on 25-Jul-2006.
17	Licence varied by notice 1063885, issued on 11-Aug-2006, which came into effect on 11-Aug-2006.
18	Licence varied by notice 1067354, issued on 30-Nov-2006, which came into effect on 30-Nov-2006.
19	Licence varied by notice 1068717, issued on 24-Jan-2007, which came into effect on 24-Jan-2007.
20	Licence varied by notice 1069198, issued on 30-Jan-2007, which came into effect on 30-Jan-2007.
21	Licence varied by notice 1072335, issued on 13-Jun-2007, which came into effect on 13-Jun-2007.
22	Licence varied by notice 1074666, issued on 02-Jul-2007, which came into effect on 02-Jul-2007.
23	Licence varied by notice 1075713, issued on 10-Jul-2007, which came into effect on 10-Jul-2007.
24	Licence varied by repair to Annual Return Archive, issued on 17-Jul-2007, which came into effect on 17-Jul-2007.
25	Licence varied by notice 1076456, issued on 01-Aug-2007, which came into effect on 01-Aug-2007.
26	Licence varied by notice 1077124, issued on 17-Aug-2007, which came into effect on 17-Aug-2007.
27	Licence varied by notice 1079428, issued on 15-Nov-2007, which came into effect on 15-Nov-2007.
28	Licence varied by notice 1080326, issued on 28-Nov-2007, which came into effect on 28-Nov-2007.

End Notes

29	Licence varied by notice 1082555, issued on 05-Feb-2008, which came into effect on 05-Feb-2008.
30	Licence varied by notice 1084923, issued on 29-Apr-2008, which came into effect on 29-Apr-2008.
31	Licence varied by notice 1085288, issued on 19-Jun-2008, which came into effect on 19-Jun-2008.
32	Licence varied by notice 1089856, issued on 01-Jul-2008, which came into effect on 01-Jul-2008.
33	Licence varied by notice 1090610, issued on 20-Aug-2008, which came into effect on 20-Aug-2008.
34	Licence varied by notice 1091819, issued on 12-Sep-2008, which came into effect on 12-Sep-2008.
35	Condition A1.3 Not applicable varied by notice issued on <issue date> which came into effect on <effective date>
36	Licence varied by notice 1093630, issued on 12-Dec-2008, which came into effect on 12-Dec-2008.
37	Licence varied by notice 1095981, issued on 06-Jan-2009, which came into effect on 06-Jan-2009.
38	Licence varied by notice 1098432, issued on 22-Apr-2009, which came into effect on 22-Apr-2009.
39	Licence varied by notice 1100329, issued on 10-Jun-2009, which came into effect on 10-Jun-2009.
40	Licence varied by notice 1103282, issued on 10-Jul-2009, which came into effect on 10-Jul-2009.
41	Licence varied by notice 1106600, issued on 10-Dec-2009, which came into effect on 10-Dec-2009.
42	Licence varied by notice 1110616, issued on 29-Jan-2010, which came into effect on 29-Jan-2010.