Lead Expert Working Group Report on Managing Residual Lead Contamination in North Lake Macquarie

Report prepared for the
NSW Environment Protection Authority

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21 December 2016

Mr Barry Buffier
Chair and CEO
EPA

Dear Barry,

Final Report – Lead Exposure Management for Suburbs Surrounding the Former Pasminco Lead Smelter

In December 2014, you established the Lead Expert Working Group (LEWG) to evaluate the effectiveness of the Lead Abatement Strategy and other remediation activities relating to lead contamination as a result of former smelting activities in North Lake Macquarie.

This report presents the Working Group's findings and recommendations and proposes a path forward to address the uncertainties regarding lead contamination in this region. The recommendations in this report draw on consultations with the community, government agencies, and researchers, and are informed by four expert workshops convened to address the complex issues. In addition, a literature review commissioned by the EPA about best practice for managing lead contamination from smelting operations is released with this report.

In addition to the LEWG members, I would like to acknowledge the assistance of many people – in particular the community members to who took the time to explain their concerns; those who reviewed the report chapters; representatives from other government agencies in NSW who provided technical advice; colleagues in research organisations; and the EPA team which worked hard to synthesise and represent a range of opinions.

Yours sincerely

21 December 2016

ADAM GILLIGAN
Regional Director North
Chair – Lead Expert Working Group
Environment Protection Authority

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Acknowledgments

Adam Gilligan, Chair of the Lead Expert Working Group (LEWG), extends his appreciation and gratitude to Matthew James, Dr Craig Dalton, Dean Chapman, Professor Mark Taylor, Associate Professor Stephen Cattle and Graeme Nyland for their integrity, commitment, patience and professionalism in undertaking their obligations under the LEWG Terms of Reference.

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We also acknowledge the expert advice from Professor Brian Gulson and Dr Tony Morrison from Macquarie University, who provided detailed and constructive comments on the draft.

The Working Group also acknowledges the Lake Macquarie Lead Community Reference Group (LCRG), whose contributions greatly assisted in our understanding of the issues facing the local community. We also appreciate and thank each member of the LCRG for their insightful feedback and suggestions for improving individual recommendations. We thank Greg Piper (LCRG Chair), Deputy Mayor Wendy Harrison, Councillor Robert Denton, Councillor Luke Cubis, Tony Cade, Nicole Gerrard, Emma Hale, Anne Sullivan, Lloyd Hill and Karen McCraw.

Most importantly, the Working Group extends its immense gratitude to Rachael Martin of the NSW Environment Protection Authority (EPA). Rachael has been Secretary for the Working Group since 2015 and lead author of this report. Rachael’s commitment and dedication to the project is greatly appreciated.

How this report is structured

This final report provides the overall findings and recommendations of the Lead Expert Working Group in an executive summary. The detail, evidence and rationale to support the various findings and recommendations are provided in the proceeding chapters, and the findings are embedded within these chapters. While some chapters have been included as background information only, they provide important historical information and set the stage for discussion. The full list of recommendations is provided in the final chapter.

Abbreviations

Air NEPM	*National Environment Protection (Ambient Air Quality) Measure 1998*
ANZECC	Australian and New Zealand Environment and Conservation Council
AS	Australian Standard
BLL	blood lead level
CSIRO	Commonwealth Scientific and Industrial Research Organisation
LCRG	Lead Community Reference Group
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change and Water
DoP	Department of Planning
EMP	Environmental Management Plan
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
GIS	geographic information system
HIL	Health Investigation Level
HNE Health	Hunter New England Health
ICP	institutional controls program
IEUBK	Integrated Exposure Uptake Biokinetic Model
IFL	Incitec Fertilisers Limited
ISF	Imperial Smelting Furnace
ISP	Imperial Smelting Process
LAS	Lead Abatement Strategy
LEP	Local Environmental Plan
LEWG	Lead Expert Working Group
LMCC	Lake Macquarie City Council
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NLM	North Lake Macquarie
NPI	National Pollutant Inventory
Pb	chemical symbol for lead

PCA	Principal Certifying Authority
PCCS	Pasminco Cockle Creek Smelter
mg/kg	parts per million (equivalent to mg/kg)
µg/dL	micrograms per decilitre
SAR	site audit report
SAS	site audit statement
SEPP	State Environmental Planning Policy
SPCC	State Pollution Control Commission
ToR	Terms of Reference
TSP	total suspended particulates
TV	trigger value
XRF	X-ray fluorescence

Executive summary

Background

The Lead Expert Working Group (LEWG) was established by the NSW Environment Protection Authority (EPA) Chair and Chief Executive Officer Barry Buffier in December 2014. The group was established to evaluate the effectiveness of the Lead Abatement Strategy (LAS) and other remediation activities relating to lead contamination arising from the former Pasminco Cockle Creek Smelter (the smelter) located in the North Lake Macquarie suburb of Boolaroo, New South Wales.

The purpose of the LEWG was to establish what has been done in the past and to determine what actions are required in the future to further address legacy lead contamination in the North Lake Macquarie area, particularly where exposure pathways have been identified. The specific functions of the LEWG were to:

1 consider actions taken to date to limit exposure of children to lead in the Boolaroo area and surrounding suburbs if appropriate including the actions and outcomes of the Lead Abatement Strategy

2 respond to the outcomes of the 2015 blood lead monitoring program, being planned by the Department of Health, on options for further lead management should the need be identified

3 provide advice to the EPA on cost-effective, long-term disposal options for the management of black slag and lead-contaminated soil

4 provide advice to the EPA on measures to protect the local community from ongoing and future risks[1] associated with legacy contamination arising from the former Pasminco lead smelter.

The LEWG comprises representatives from the EPA, Hunter New England (HNE) Health, Lake Macquarie City Council (LMCC), the Contaminated Site Auditor Scheme and academia. Working in partnership with the LEWG, the Lake Macquarie Lead Community Reference Group (LCRG) was established in 2015 to enable the community to engage directly with government and experts on issues related to potential lead and lead slag contamination in Lake Macquarie. The LCRG consists of nine members, including two Lake Macquarie City councillors. Members were selected to represent a broad range of community interests, and the group is chaired by the State Member of Parliament for Lake Macquarie.

Between December 2014 and November 2015, the LEWG held a total of seven meetings to plan future activities and address pressing issues raised by the LCRG. These meetings were followed by a series of four workshops, held in February, May, July and September 2016 to:

[1]In addition to the risk to human health, the term ‘risk’ is used in this report to incorporate multiple vulnerabilities including social, financial, environmental and legal vulnerabilities.

1 evaluate the Lead Abatement Strategy and other remedial activities in detail

2 identify any ongoing future issues regarding human health, social inequities and additional burdens associated with legacy lead contamination from smelting operations in North Lake Macquarie

3 develop a comprehensive list of recommendations to address these issues.

Central to the health risk component of the LEWG report were the outcomes of a blood lead screening program, conducted by HNE Health in June and July 2015. The results of this screening program, aimed at vulnerable populations including children under five years of age and pregnant women, concluded that since the smelter closed in 2003, the risk of children accumulating excess lead has remained low, with no children tested in 2015 having blood lead levels above the national threshold of 5 micrograms per decilitre (µg/dL). Consistent with the significant decline in children's blood lead levels since the smelter closed in September 2003, HNE Health suggested that active smelter emissions, rather than the lead content in soils, were a significant contributor to blood lead in children in the immediate vicinity of the smelter.

Despite the blood lead screening results indicating that none of the participants had levels above 5µg/dL, the LEWG was challenged with establishing whether legacy lead contamination in residential soils and on public land posed an ongoing risk to the community. During its deliberations, the LEWG took into consideration two key sources of environmental lead contamination as a result of Pasminco smelting operations:

1 lead-contaminated dust

2 black slag, a by-product of the smelting operations widely used for construction purposes in North Lake Macquarie.

The LEWG concluded that a 'no further action' approach would not be scientifically defensible since the degree, geographical extent and nature of environmental lead contamination in Lake Macquarie are not well-understood. The EPA commissioned a literature review (Attachment D) to report on practices to manage (i) lead-contaminated smelter dust and lead slag in soil and, (ii) the associated human exposure, by addressing the following key areas:

- remediation and management programs that have been undertaken for comparable lead contamination sites and areas, ensuring that specific details regarding the form and species of lead are identified
- the success of the programs and consideration of 'best practice'
- how the success or otherwise of the programs was evaluated or measured
- the cost of the programs and indicative costs associated with management practices and strategies identified
- where exposure control was used, the methods used and their effectiveness
- where relevant, definitions and references for the meanings of 'bioaccessibility', 'bioavailability' and 'bioaccumulation' for consistency in reporting.

The literature review further informed the LEWG's key findings and recommendations.

Review process

The 22 recommendations detailed in this report describe actions to address a series of issues associated with environmental lead contamination as a result of Pasminco Cockle Creek Smelter (PCCS) operations in North Lake Macquarie, New South Wales. These solutions-based recommendations range from the development of a streamlined approach for addressing the immediate and long-term burdens associated with contaminated land, to the establishment of a statewide strategic program to manage legacy lead contamination in New South Wales. At the core of these recommendations is the requirement for a continuous and long-term commitment from LMCC, the EPA and HNE Health, coupled with the need for an ongoing open, transparent and collaborative relationship between these stakeholder groups and the community.

The LEWG developed its recommendations using a consensus-based decision-making process. This approach required each member to fully understand the complexities of each issue, and to communicate their respective positions in an informed manner.

Given the interrelated nature of the recommendations, it is intended that the complete list of recommendations be implemented in full. The LEWG considers that omission of any one of the recommendations would not constitute a comprehensive response. This will require a commitment of resources and funding from the NSW Government, as well as ongoing collaboration between the EPA, other state and local agencies such as the council, HNE Health, the Department of Planning and Environment, and the local community.

Key findings and recommendations

This section provides an overview of the key findings from the work of the LEWG and the proposed recommendations. The findings are linked to the following LEWG Terms of Reference (ToR) (Attachment A):

ToR 1 – Consider actions taken to date to limit exposure of children to lead in the Boolaroo area and surrounding suburbs if appropriate including the actions and outcomes of the Lead Abatement Strategy.

ToR 2 – Respond to the outcomes of the 2015 blood lead monitoring program, being planned by the Department of Health, on options for further lead management, should the need be identified.

ToR 3 – Provide advice to the EPA on cost-effective, long-term disposal options for management of black slag and lead contaminated soil.

ToR 4 – Provide advice to the EPA on measures to protect the local community from ongoing and future risks associated with legacy contamination arising from the former Pasminco lead smelter.

Finding 1 ToR 1

The Lead Abatement Strategy (LAS), aimed at reducing human exposure to lead dust in residential soils within the LAS area, was partially successful. Of the total number of eligible properties, around 37% did not participate in the program. The contamination status of approximately 736 properties with the LAS area therefore remains unknown. Furthermore, the abatement methods applied under the LAS did not achieve full remediation at the

majority of the participating properties. While the LAS did not aim for full remediation, it is important that current and future residents be aware of the location and degree of lead contamination on their properties. This is particularly relevant because the abated soils were not validated or tested against the clean-up criteria.

Recommendation 1: Lake Macquarie City Council, funded by the NSW Government, establishes a role for ongoing community involvement to monitor ongoing issues and to identify future issues regarding legacy lead contamination in Lake Macquarie through a risk communication framework.

Recommendation 2: Lake Macquarie City Council provides a point of contact and means of disseminating educational materials among the community, agencies and external stakeholders, and updated materials are distributed as they become available. Communication activities may include, but are not limited to:

1 a voluntary code of practice within the real estate industry to ensure that tenants and landowners are appropriately informed of any lead-contaminated soils at residential properties

2 a dedicated point of contact within Lake Macquarie City Council for agencies to provide and discuss new educational materials

3 information about managing capped contaminated material

4 information on living with lead in the environment

5 information on the process for assessing development applications on contaminated land

6 information via Dial Before You Dig on working with lead-contaminated soils.

Finding 2 ToR 2

While the major source of lead exposure to the community no longer exists following the smelter closure in 2003, future exposure could occur via ingestion or inhalation of lead and other contaminants that persist in the soil and dust within North Lake Macquarie. This would be likely to impact only the members of the community who are more susceptible to exposure e.g. children under five years of age who display pica[2].

Recommendation 3: Hunter New England Health notifies Lake Macquarie City Council of the results of any investigation in response to notifications that indicate the need for a coordinated community response, and provides regular updates on public health aspects of lead control and blood lead findings in the area.

Finding 3 ToR 1

The sampling methods used to establish the LAS area and assess the degree of soil lead contamination were not consistent with best practice and therefore cast a degree of uncertainty over the relevance of this area for ongoing management.

Recommendation 4: The EPA reviews all available data associated with the development of the LAS lead contamination survey grid to determine whether the grid boundary corresponds to the geographic zone of soil lead dust contamination as a result of the former Pasminco smelter operations. The EPA provides advice to Lake Macquarie City Council on whether the

[2] Pica is the persistent eating of substances, such as dirt or paint, which have no nutritional value.

lead contamination survey grid accurately reflects the extent of potential contamination of properties around the smelter.

Finding 4 ToR 1

Active airborne emissions arising from the former Pasminco smelter directly contributed to childhood lead exposure in North Lake Macquarie, as demonstrated by blood lead screening results, while the smelter was in operation. Since the closure of the smelter the community is no longer at risk from active airborne emissions from the smelter.

There are no recommendations associated with this finding.

Finding 5 ToR 2

Results from the Hunter New England Health blood lead screening program conducted in 2015 established that lead uptake by vulnerable populations within North Lake Macquarie (i.e. children aged less than five years and pregnant women) does not require further investigation as all blood lead levels were less than the recently revised National Health and Medical Research Council (NHMRC) blood notification criteria of 5µg/dL. Although these results indicate that exposure to lead is not a current health concern in North Lake Macquarie, there is a requirement for ongoing surveillance to enable early detection and rapid characterisation of any blood lead notifications if they occur.

Recommendation 5: NSW Health continues ongoing enhanced surveillance for lead notifications in children in the Boolaroo, Speers Point and Argenton suburbs, conducted by the Public Health Unit, noting the reduced level of blood lead resulting in notification. This enhanced surveillance involves annual reminder letters to local General Medical Practitioners (GPs) to identify children at higher risk of lead exposure to offer blood lead testing. Any notifications are followed up by the Public Health Unit using the protocol endorsed by the Chief Health Officer's expert group on lead: Lead in blood control guideline.

Finding 6 ToR 4

Although there exists a requirement for Lake Macquarie City Council to maintain accurate records of contaminated land, there is no formal requirement for utilities and other agencies to notify LMCC of contamination issues as they arise, nor is there a requirement for utilities and other agencies to manage lead contamination issues in accordance with LMCC policies. There is a need to align contaminated land management practices in the council area so that a consistent approach is adopted by all land managers, agencies and utilities.

Recommendation 6: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, works with utilities and public authorities to apply measures comparable with LMCC's *Environmental Management Plan for Contaminated Land in Council's Care and Control*. Comparable measures include:

1 sourcing contamination status information from LMCC's contaminated land database

2 notifying LMCC of any contamination issues so they may be recorded in LMCC's database

3 appropriately managing contamination using measures comparable to LMCC policies and plans

4 providing information, for example via Dial Before You Dig enquiries.

Recommendation 7: Lake Macquarie City Council continues to maintain a central database of contaminated land in Lake Macquarie City, including records of initial contamination status, abatement and remediation, current contamination status and land use, and changes in land use.

Finding 7 ToR 4

At present, groundwater below the Pasminco smelter site is known to be contaminated with smelter by-products. In addition, black slag is widely distributed around the foreshores of Lake Macquarie. The environmental impact of this contamination on water quality in Lake Macquarie is not well-understood.

Recommendation 8: The EPA, Lake Macquarie City Council and licensed operations continue to monitor water quality in surface water and groundwater around North Lake Macquarie. The EPA analyses this information and identifies any material pollution from stormwater or groundwater or other discharge issues.

Recommendation 9: The EPA reviews a requirement for ongoing water quality monitoring upon conclusion of remediation activities at the Pasminco smelter site.

Recommendation 10: The EPA investigates the impacts of Pasminco smelter slag on water quality in the Lake Macquarie region, especially where slag is either permanently inundated by, or in intermittent contact with, surface water or groundwater. The EPA then provides recommendations to the NSW Office of Water in relation to the suitability of groundwater extraction in affected areas.

Finding 8 ToR 4

There is a need to review whether responsible-party legislation or its equivalent (polluter pays) in New South Wales or under Australian Government legislation is adequate to mitigate the impacts and liabilities for remediation of contamination being externalised onto the community and environment in the future.

Recommendation 11: The EPA continues to develop an environmental liabilities management framework to provide a predictable, transparent and consistent approach for the management of risks associated with environmental liabilities. In support of the development of this framework, the EPA reviews existing legislation to streamline its operation by identifying gaps, inconsistencies and areas that could benefit from new approaches, such as appropriate regulatory instruments for managing the financial risks associated with on- and off-site contamination.

Finding 9 ToR 4

At present, Lake Macquarie City Council's property notations do not differentiate between land that is actually and potentially contaminated above the residential Australian Health Investigation Level (300 milligrams per kilogram [mg/kg] – parts per million). In order to facilitate a streamlined development assessment process, it is necessary to readily differentiate those properties that are known to be contaminated and those that are not.

Recommendation 12: Lake Macquarie City Council revises its Contaminated Land Policy so that section 149 planning certificate[3] notations differentiate between remediated land with soil levels above and below the residential Health Investigation Level for lead.

Finding 10 ToR 4

Development that does not meet the provisions of *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* requires compliance with *State Environmental Planning Policy No 55 – Remediation of Land* (SEPP 55). Compliance with SEPP 55 results in a development assessment process which often leads to additional costs and significant delays for developers of contaminated land. Exempt and Complying Development may have similar risks in relation to contamination, but it does not currently require the same level of risk management. The risk associated with the development or demolition of existing dwellings and structures as Complying Development in the North Lake Macquarie area is such that lead dust in soils or dwellings may be remobilised and create a local, additional pathway of exposure to lead.

Recommendation 13: Lake Macquarie City Council amends its Development Control Plan (DCP) for development of land known to be contaminated with atmospheric lead or black slag from the smelter. The revised DCP describes a streamlined approach for the assessment of residential soil contamination by assuming a level of contamination based on existing information, in order to reduce the cost of the development assessment process. The revised DCP describes standard remedial action plans, which are to the EPA's satisfaction, for routine development activities where risks are able to be adequately identified and managed.

Recommendation 14: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, takes steps to ensure that Exempt and Complying Development that is likely to result in the disturbance of contaminated soil within Lake Macquarie City is appropriately managed to minimise harm to human health and the environment.

Recommendation 15: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, considers the relevant management measures proposed in this report as part of its State Environmental Planning Policy review program.

Finding 11 ToR 3

Removal of black slag and lead-contaminated soil from residential properties, for residential development or remediation purposes, imposes an additional financial burden on members of the community. The lack of a suitable local repository for lead-contaminated soils represents an ongoing source of frustration for the community due to the costs and inconvenience associated with soil removal, transportation and disposal.

Recommendation 16: The EPA considers all appropriate options for the disposal of contaminated materials associated with legacy lead contamination as a result of smelting activities in Lake Macquarie City, taking into consideration:

[3] Section 149 planning certificates are issued in accordance with the *Environmental Planning and Assessment Act 1979*. A person may request a s.149 certificate from council to obtain information about their own property. Generally, s.149 certificates are requested when a property is redeveloped or sold.

1 affordability

2 public accessibility

3 suitability of the facility to contain the materials received.

Recommendation 17: Lake Macquarie City Council continues to apply conditions of development consent that require tracking and appropriate disposal of contaminated soil.

Finding 12 ToR 4

Currently, there is a desire within the community for a government authority to provide additional support to help residents manage legacy lead contamination issues. Lake Macquarie City Council is the most appropriate authority to provide this support, however, it currently does not have responsibility for this nor the resources to undertake these additional support functions.

Recommendation 18: The NSW Government establishes an ongoing funding stream for Lake Macquarie City Council to develop and maintain a small interdepartmental team to manage additional legacy lead issues beyond the usual remit of local government (subject to council approval and availability of a sufficient funding source). The team is responsible for:

1 expanding record keeping and mapping of known contamination and remediation

2 providing funding support and advice to public and private landholders wishing to undertake voluntary soil assessment and property remediation

3 following up on any Hunter New England (HNE) Health investigations regarding high blood lead levels to identify site remediation options

4 managing access to a local repository within the Lower Hunter for lead-contaminated soils

5 identifying a point of contact for community enquiries about living with lead and voluntary management measures

6 regularly engaging with HNE Health regarding blood lead levels tested by General Practitioners and outcomes of follow-up investigations

7 expanding engagement collateral to include advice on maintaining contamination barriers and hygiene, and improving links to and from HNE Health information.

Implementation of this recommendation will facilitate a streamlined approach across the local government area consistent with LMCC's Development Control Plan, LMCC's *Environmental Management Plan for Contaminated Land in Council's Care and Control*, and the *National Environment Protection (Assessment of Site Contamination) Measure 1999*.

Recommendation 19: Lake Macquarie City Council, the EPA and NSW Health develop a risk-based decision management tool, in consultation with the community, to identify and prioritise access to services supported by the proposed funding stream described in Recommendation 18.

Recommendation 20: Lake Macquarie City Council develops a streamlined approach for the assessment of residential lead contamination within the local government area and ensures the degree of risk is appropriately matched to the level of action.

Recommendation 21: Lake Macquarie City Council continues to maintain an up-to-date environmental management plan (EMP) for dealing with legacy lead contamination on land within council's care and control. The EMP is reviewed every five years, or following new recommendations on lead exposure from health or environmental agencies (e.g. National Health and Medical Research Council, National Environment Protection Measures, etc.).

Finding 13 ToR 4

Legacy environmental lead contamination from smelting and mining operations (and other sources) is a statewide issue that requires a consistent and streamlined response from the EPA. There is also a need for a single point of contact within the EPA to coordinate the review of research proposals related to lead contamination in New South Wales and to address community concerns when findings from such research are made available.

Recommendation 22: The NSW Government provides the EPA with support for the establishment and operation of a statewide Lead Strategy Group to act as a conduit between the EPA and local councils or other appropriate local bodies across New South Wales. The EPA strategy group is responsible for promoting effective communications and resolving enquiries relating to statewide lead contamination issues.

The EPA strategy group acts as:

- a first point of contact for future lead-related research in New South Wales
- a platform upon which research findings are communicated
- a conduit through which relevant authorities may be notified of changes to relevant policies, guidelines and technical documents.

Chronology of key events described in this report

Year	Key event	Chapter
1897	Zinc production commences at Cockle Creek	2
1961	Imperial Smelting Furnace commissioned	1
1973	High proportion of children tested have blood lead levels ≥10µg/dL (acceptable level was 40µg/dL)	7
1979	Ambient air quality goal for lead is set at 1.5µg/m^3	7
1982–83	State Pollution Control Commission declares significant environmental lead pollution at Boolaroo	2
1985	Smelter in full production; lead emissions are approximately 92 tonnes per annum	3
1991	Local parliamentary task force recommends blood lead testing of children	7
	Health risk assessment reveals elevated lead levels in residential soils	7
1992	CSIRO report to Pasminco finds most heavy metals in Pasminco slag are bioavailable; report not publicised	4
1994	Lake Macquarie City Council calls for an assessment on the suitability of Pasminco black slag in council's operations	4
1995	Lead contamination survey grid is set out in the conditions for development consent for the smelter upgrade	6
1998	NHMRC reduces blood lead goal from ≤25 to ≤10µg/dL	7
	Guideline for lead in ambient air is reduced from 1.5 to 0.5µg/m^3	3, 7
2001	Pasminco notifies the EPA that the smelter site presents a significant risk of harm, as defined in the NSW *Contaminated Land Management Act 1997*	2
2002	The EPA declares the smelter site a remediation site due to significant lead, cadmium and zinc contamination	2
2003	Smelter shuts down in September	
	Administrator appointed to manage remediation and redevelopment of the smelter site in November	2
2005	Report shows an association between the decline in children's blood lead levels and the reduction in ambient air lead – post-smelter closure	7

Year	Key event	Chapter
2006	Groundwater monitoring of the smelter site and site boundary commences; reveals significantly elevated levels of zinc	5
2007	Approval for the remediation project is granted in February	5
	Lead Abatement Strategy documentation is prepared in October	6
	Smelter remediation commences	5
2013	Lead Abatement Strategy is completed in February	5
2014	*Newcastle Herald* begins a campaign in November: 'Toxic Truth: The Pasminco Story'	8
	Formation of Lead Expert Working Group and Lake Macquarie Community Lead Reference Group in December	1
2015	Remediation of smelter site is completed	5
	NHMRC releases its statement and information paper: *Evidence on the Effects of Lead on Human Health*	9
	Hunter New England Health conducts a blood lead screening program in North Lake Macquarie in June and July	9
	Blood lead screening report is published online in September; all blood lead levels were less than 5µg/dL	9
2016	Blood lead notification level is formally amended from 10 to 5µg/dL under section 51(2) of the *Public Health Act 2010* (in February)	9

Chapter 1: Role of the Lead Expert Working Group and Lake Macquarie Lead Community Reference Group

The Lead Expert Working Group

The Lead Expert Working Group (LEWG) was established by the NSW Environment Protection Authority (EPA) on the recommendation of the EPA Chair and Chief Executive Officer, and in response to community concerns regarding:

- lead levels in Boolaroo
- the effectiveness of the Lead Abatement Strategy (LAS) program, which was completed in February 2013.

Since its establishment in December 2014, the LEWG has met on a regular basis to discuss strategies for addressing the Terms of Reference (ToR). The ToR (Attachment A), meeting minutes and associated documents, as well as relevant information on each of the LEWG members are publicly accessible via the LEWG webpage: Lead safety.

Purpose, functions and role

The LEWG was tasked with four key functions, as described in the ToR:

1 consider actions taken to date to limit exposure of children to lead in the Boolaroo area and surrounding suburbs if appropriate including the actions and outcomes of the Lead Abatement Strategy

2 respond to the outcomes of the 2015 blood lead monitoring program, being planned by the Department of Health, on options for further lead management, should the need be identified

3 provide advice to the EPA on cost-effective, long-term disposal options for management of black slag and lead contaminated soil

4 provide advice to the EPA on measures to protect the local community from ongoing and future risks associated with legacy contamination arising from the former Pasminco lead smelter.

Responsibilities of the LEWG include:

- providing advice and guidance to the EPA and government broadly
- addressing any issues that may arise as a result of new information becoming available related to the issue
- reconciling differences in opinion and approach, and resolving disputes arising from them.

The roles of individual members of the LEWG include:

- appreciating the significance of the issue for any stakeholders and representing their interests
- being an advocate for positive environmental and community outcomes.

LEWG membership

The LEWG is a multidisciplinary group comprised of members from regulatory, public health, and academic backgrounds with experience in distinct but complimentary fields of environmental lead contamination, contamination regulation, environmental health and urban planning (Table 1).

Table 1: LEWG membership summary

Organisation Title	**Nominated member**	**Role within the LEWG**
NSW EPA		
Regional Manager, Hunter	Adam Gilligan	Chair
Technical Officer	Rachael Martin	Secretary and report author
Operations Officer	Lauren Spring	Secretary (until Oct 2015)
Regulatory Officer	Matthew James	EPA representative
Hunter New England Health		
Public Health Physician	Craig Dalton	NSW Health representative
Lake Macquarie City Council		
Environmental Security Coordinator	Dean Chapman	Lake Macquarie City Council representative
Macquarie University		
Professor of Environmental Sciences	Mark Taylor	Academic representative
University of Sydney		
Associate Professor in Soil Science	Stephen Cattle	Academic representative
Ramboll Environ		
EPA-approved contaminated site auditor	Graeme Nyland	Contaminated Site Auditor Scheme representative

Lake Macquarie Lead Community Reference Group

The Lake Macquarie Lead Community Reference Group (LCRG) was established by the EPA to enable the community to engage directly with government and experts on issues related to lead and lead slag contamination in Lake Macquarie City. The ToR of the LCRG (Attachment B) are available on the EPA website: Lake Macquarie Lead Community Reference Group.

Purpose and functions

The primary purpose of the LCRG is to provide a forum to enable local communities in the suburbs of Boolaroo, Argenton and Speers Point in the Lake Macquarie area to engage with the EPA, NSW Health, Lake Macquarie City Council (LMCC), independent scientific experts, and industry on issues including potential human health risks related to contamination of soil with lead, and lead slag from the former Pasminco site.

The LCRG also considers the issues of lead in the wider Lake Macquarie local government area, where disposal of lead slag from the Pasminco Cockle Creek Smelter (PCCS) site was widespread. The LCRG acknowledges that oversight of compliance with relevant government approvals by the company responsible for the former Pasminco smelter site remains with the relevant government agencies.

The LCRG performs several functions, as listed in the agreed ToR:

- provide a conduit to inform and advise the community of actions being taken to investigate and manage legacy issues associated with the former Pasminco smelter site
- promote dialogue and good working relationships between the company responsible for the former Pasminco smelter site, the community, government agencies and other stakeholders in relation to management of legacy issues associated with the former Pasminco smelter site
- identify and review any community concerns or complaints relating to the management of legacy issues associated with the former Pasminco smelter site and surrounds
- provide a forum for discussion and comment on the progress of recommendations of the LEWG in relation to management of legacy issues associated with the smelter site
- discuss community concerns and review the resolution of these concerns
- discuss how best to communicate relevant information on the progress of management of legacy issues associated with the smelter site to the broader community
- work cooperatively towards outcomes of benefit to the stakeholders represented on the reference group and the wider community.

The LCRG may perform the following functions, as listed in the agreed ToR:

- provide feedback to the company and relevant state agencies regarding management of legacy issues and community relations outcomes associated with the former smelter site
- undertake regular visits to the former smelter site and surrounds, as necessary
- review the company and relevant state agencies' processes for handling matters of community concern regarding legacy issues associated with the former smelter site
- provide advice to the company and relevant state agencies on how to address community relationships.

LCRG membership

The LCRG comprises nine members (Table 2). Expressions of interest for membership were sought from the community and industry, and members were selected to represent a broad range of community interests. Biographical information on each of the LCRG members is provided in Chapter 13: Consultation.

Table 2: Lake Macquarie LCRG members and their roles

Organisation Title	**Nominated member**	**Role within the CRG**
NSW Legislative Assembly		
Independent State Member	Greg Piper	Chair
Lake Macquarie City Council		
Deputy Mayor	Wendy Harrison	LMCC representative
Councillor	Robert Denton	LMCC representative
Councillor	Luke Cubis	LMCC representative (since October 2015)
Equipment Resource Group & Housing Concepts		
General Manager	Lloyd Hill	Business representative
Boolaroo Public School		
	Nicole Gerrard	School representative
	Tony Cade	Community representative
	Karen McCraw	Community representative
	Emma Hale	Community representative
	Anne Sullivan	Community representative

The LCRG works in partnership with the LEWG, and is supported by the following individuals:

- a representative of the company responsible for the former Pasminco smelter site
- an officer or employee of Lake Macquarie City Council
- an officer or employee of NSW Health
- an officer or employee of the EPA.

Process of the review

During the first phase of the LAS review, the LEWG scoped the components to be included in the review, guided by the LEWG ToR. The LEWG also identified the key elements for a literature review report which assisted the group in the refinement of the final recommendations. These discussions were held during a series of seven meetings. The minutes of these meetings are published on the EPA website: Lead Expert Working Group – Lead exposure management for the suburbs surrounding the former Pasminco lead smelter.

Following these meetings a series of four workshops were held in February, May, July and September during 2016 to:

- systematically evaluate the remedial activities in more detail
- identify any ongoing future issues regarding human health, social inequities and additional burdens associated with legacy lead contamination from smelting operations in North Lake Macquarie
- develop a comprehensive list of recommendations to address these issues.

The findings and recommendations in this report reflect the outcomes of the LEWG workshops.

Chapter 2: History of Pasminco Cockle Creek Smelter

The Pasminco Cockle Creek Smelter ('the smelter') was the second largest producer of zinc in Australia and a significant producer of lead bullion, copper sulfate, cadmium, sulfuric acid and selenium. With respective annual capacities for zinc and lead of 97,300 tonnes per annum and 40,700 tonnes per annum, the smelting operations were highly competitive on an international scale (Siegmund 2000). Annual export earnings generated for Australia exceeded $115 million with $60 million injected each year into the local economy. This chapter begins with a brief description of the smelter location, followed by the evolution, history and environmental impacts of the smelting operations.

Location

The smelter site is located 2 kilometres north of the northern end of Lake Macquarie, and directly adjacent to the township of Boolaroo in the Lower Hunter region of New South Wales, approximately 13 kilometres south-west from the city of Newcastle.

Situated on 191 hectares of land, the smelter complex is surrounded by three residential suburbs which extend predominantly north and south from the smelter within Lake Macquarie City (Figure 1), with the closest residential properties located on the boundary of the smelter property. These three residential suburbs are home to approximately 5500 residents (2011 census):

- Boolaroo (4.1 square kilometres, population 933)
- Argenton (1.6 square kilometres, population 1370)
- Speers Point (2.7 square kilometres, population 3230).

Settlement and development of Boolaroo and Argenton are closely linked with the development of the smelting works.

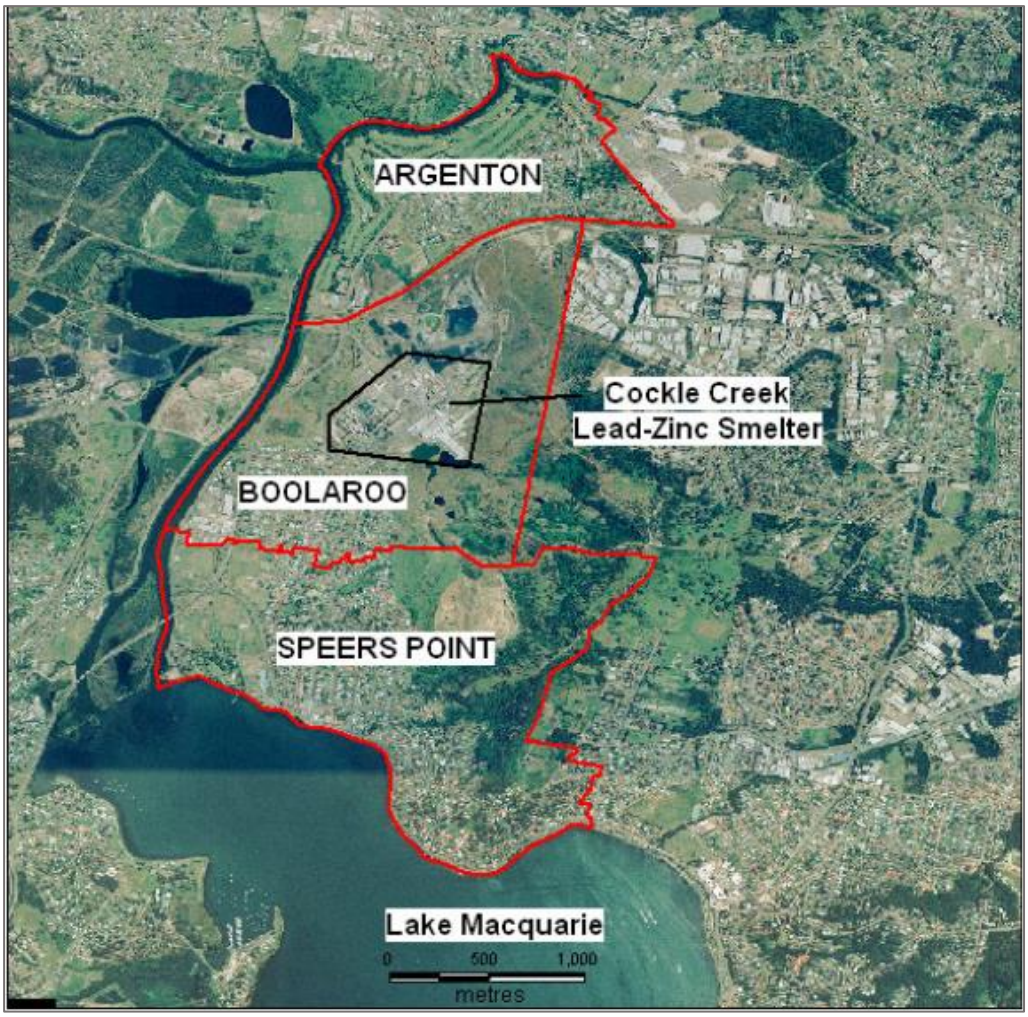

Figure 1: Location of the Pasminco Cockle Creek Smelter site in relation to neighbouring suburbs Boolaroo, Argenton and Speers Point in North Lake Macquarie, New South Wales

Image: Willmore et al. 2006.

Smelting operations and processes

In 1895, Sulphide Corporation selected the Cockle Creek site for an electrolytic zinc plant for the treatment of ore transported primarily from the Central Mine at Broken Hill. The Cockle Creek site was ideal for ore processing due to the nearby abundant supplies of coal and coke, and because it was centrally located for land and sea transportation of treated ore. Figure 2 shows the extent of the early ore processing operations during the early 1900s.

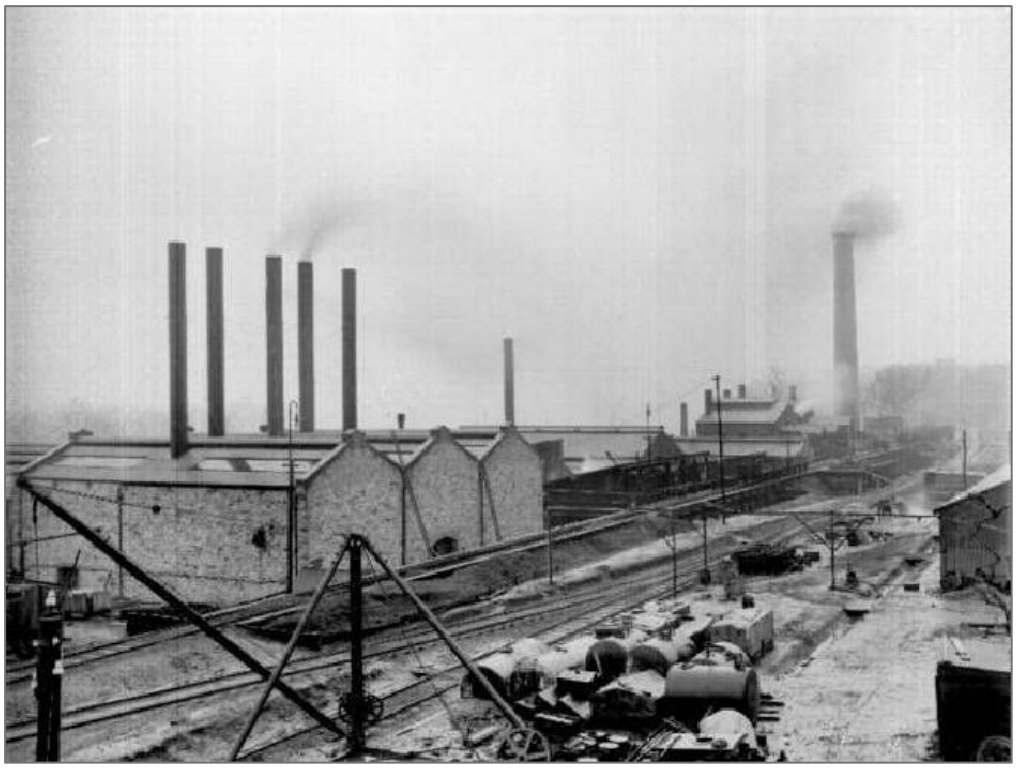

Figure 2: Cockle Creek Sulphide Works circa 1900

Image used with permission of Newcastle Region Library.

Zinc production commenced at Cockle Creek in 1897, however, the zinc recovery process proved uneconomical and the plant was converted to an orthodox (conventional) lead smelting plant for the treatment of gold, silver and lead ores. Although the main source of crude ore and concentrates was the Broken Hill mine orebody, large tonnages were purchased from other regions in Australia and New Zealand.

A silver–lead refinery, horizontal zinc retort plant and copper sulfate plant were added later, and up to three blast furnaces operated simultaneously until 1922, producing an estimated 30,000 tonnes per annum of lead during the First World War. Following the decline in purchased ore supplies after the war, smelting and refining operations at the Cockle Creek site closed down while roasting operations continued. Between 1923 and 1952, Broken Hill concentrates were roasted to produce calcine, which was shipped elsewhere for further treatment (Bureau of Mineral Resources, Geology and Geophysics 1952).

In 1961, the Imperial Smelting Furnace (ISF), also known as the zinc blast furnace, was commissioned to enable the simultaneous smelting of zinc and lead concentrates. The Imperial Smelting Process (ISP), a variant of the conventional blast furnace technology, involved sintering the zinc and lead concentrates at high temperatures in order to remove sulfur and other impurities, and to convert the fine ore concentrates into workable agglomerates for further smelting.

As illustrated in Figure 3, during the sinter roast, the sinter gasses pass through an acid plant for the recovery of sulfuric acid, while the sintered product is mixed with hot coke and smelted to produce zinc vapour, molten lead and slag. As the zinc vapour and other hot gasses pass out of the blast furnace and into a condenser, the stream is cooled with a spray of cooled molten lead. The lead absorbs the zinc vapour, and upon cooling, the zinc forms a layer on the molten lead which is then recovered as an impure molten zinc metal (98.3%).

The purity of the zinc is refined by distillation in columns to produce zinc ingots or bars with a purity of up to 99.95%.

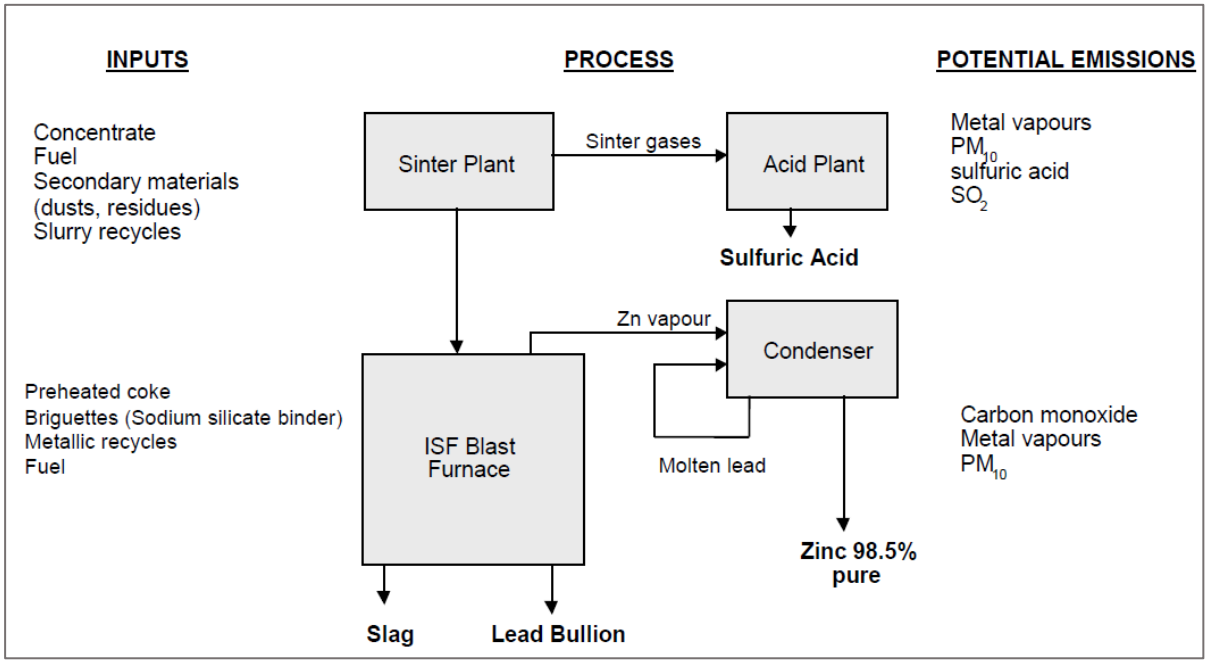

Figure 3: Schematic diagram showing the Imperial Smelting Furnace (ISF) process and the associated by-products

Image: NPI 1999.

Ancillary industries

Various ancillary industries were undertaken at the Cockle Creek site including the manufacture of sulfuric acid, hydrochloric acid, fertilisers and cement. The sulfuric acid and fertilisers were manufactured using the secondary products of the smelting process. When low metal prices forced smelting operations to shut down in 1922, these ancillary industries became important sources of revenue and were subsequently expanded to accommodate increasing demands for agricultural and building products.

Of particular note, Incitec Fertilisers Limited (IFL) operated as a fertiliser manufacturing and distribution plant adjacent to the smelter site, and remained connected to the smelter until its closure in 2003. The two plants had a close relationship given that one of the by-products of the smelter was sulfuric acid. This acid was pumped through connecting pipes from the smelter site to the IFL site and mixed with phosphate in order to manufacture fertiliser.

Smelter emissions and environmental impacts

Atmospheric emissions of dust (i.e. particles less than 100 micrometres [µm] in size, including PM_{10}) and aerosols (i.e. particles generally less than 1µm in size, including metal vapours, sulfuric acid, sulfur dioxide [SO_2] and carbon monoxide) are generated in varying degrees during nearly every step of the lead smelting process (see 'Potential emissions' in Figure 3).

Depending on topography, climate and other meteorological factors, atmospheric deposition of dust and aerosols generated by smelting operations is typically greatest within 1–2

kilometres of the source, but may be detected up to 20 kilometres away (Csavina et al. 2012). Lead is typically present in emissions from lead smelters, and was the key metal of concern in vapours and dust generated by the operations at the Cockle Creek site.

Due to their smaller particle size, lead-bearing fumes and aerosols associated with stack emissions can travel greater distances than dust generated by other smelting processes and activities. The most significant sources of lead contamination due to smelting include fugitive emissions from the smelter stack and sinter building. The potential sources of environmental lead contamination as a result of smelting activities are shown in Table 3.

Table 3: Common sources of lead emissions, categorised by emission type, arising from the Pasminco Cockle Creek Smelter

Emission type	Source
Fume/aerosol	Blast furnace stack
	Fugitive emissions from the sinter building
	Molten lead
Dust	Stockpiles of waste product
	Periodic clean-outs of the blast furnace
	Fugitive emissions from unloading and storage of concentrates
	Slag leaving the blast furnace area
	Wind erosion
	Mechanical erosion

Since the early 1900s, smelting operations at the Pasminco Cockle Creek Smelter (PCCS) site have resulted in significant on-site and off-site heavy metal contamination, especially lead. On- and off-site contamination in North Lake Macquarie is typical of contamination associated with similar smelting activities in Australia (e.g. Mount Isa, Queensland and Port Pirie, South Australia) and overseas (e.g. Bunker Hill, northern Idaho, USA).

During smelting operations, the primary sources of environmental lead contamination included the smelter stack emissions, and fugitive emissions resulting from various aspects of the smelting process (see Figure 3).

Another important source of lead contamination in North Lake Macquarie is granulated black slag which was used as landfill in numerous private and public sites throughout the Lake Macquarie City and surrounds. A detailed description of the lead dust emissions and granulated slag is provided in Chapter 3: Air emissions and Chapter 4: Use of slag in the community, respectively.

Regulatory intervention

During the smelter's 128 years of operation, emissions from ore processing and materials stored or deposited on the premises were the primary sources of contamination in the surrounding environment and local community. Residential soils and house dust in the suburbs of Boolaroo, Argenton and Speers Point (within 2 kilometres from PCCS) were identified as potential sources of lead exposure, particularly for young children.

Early efforts to reduce the impacts of the smelter on the community were largely ineffective in their role to protect the health of the residents, particularly those living in close proximity to

the smelter, due to the presence of continued and rapid recontamination by the smelter (Dalton & Bates 2005).

On 12 November 2001 Pasminco Limited (Administrator Appointed) notified the EPA that the site presented a significant risk of harm based on an assessment against the criteria detailed in the NSW *Contaminated Land Management Act 1997*.

In 2002, the EPA verified the notification and declared the site a remediation site under s.21 of the Contaminated Land Management Act on the basis that it was contaminated, in particular with lead, cadmium and zinc, in such a way as to present a significant risk of harm. Remediation of the site was subject to approvals under s.75J of the NSW *Environmental Planning and Assessment Act 1979*.

The PCCS site is now subject to the following regulatory instruments:

- Environment Protection Licence 5042 (EPL) issued by the EPA under the NSW *Protection of the Environment Operations Act 1997*
- Declaration of Significantly Contaminated Land 21027 (formerly Declaration of Remediation Site) made under the Contaminated Land Management Act
- Management Order 23008 (formerly Remediation Order) issued under the Contaminated Land Management Act
- Project Approval 06-0184/9036299 issued by the Department of Planning under s.75J of the Environmental Planning and Assessment Act.

Chapter 3: Air emissions

Smelter stack and fugitive dust emissions generated by the Pasminco Cockle Creek Smelting operations resulted in widespread lead and other trace metal contamination of the surrounding environment. Air emissions from the smelter included total suspended particulates (TSP) and deposited dust, and included components such as sulfur dioxide, lead, cadmium and zinc (NPI 1999).

This chapter begins with an overview of how the regulatory environment for air emissions standards shifted over time and discusses the impacts the smelter emissions had on local air quality, with an emphasis on lead as the contaminant of concern.

Legislative framework

Contemporary air quality emissions standards

In Australia, air quality emission standards are set by the individual states and territories. In New South Wales, Part 5.4 (s.124–135) of the Protection of the Environment Operations Act deals specifically with air pollution and prescribes the standards of concentrations for scheduled premises.

Metallurgical activities, including production of non-ferrous metals from copper, lead and zinc concentrations, are listed as scheduled activities and therefore subject to requirements under the Protection of the Environment Operations Act. S.124 of the Act states:

> *The occupier of any premises who operates any plant in or on those premises in such a manner as to cause air pollution from those premises is guilty of an offence if the air pollution so caused, or any part of the air pollution so caused, is caused by the occupier's failure: (a) to maintain the plant in an efficient condition, or (b) to operate the plan in a proper and efficient manner.* (s.124, Protection of the Environment Operations Act).

Any scheduled premises must therefore ensure that impurities in emissions from point sources, such as chimneys and stacks, remain below the prescribed standards of concentration set out in the regulations.

In NSW, the Protection of the Environment Operations (Clean Air) Regulation 2010 (Clean Air Regulation) prescribes standards of concentration for emitted substances in accordance with the date the premises commenced operations and the type of substance emitted. For lead emissions, if an activity or premises commenced operations prior to July 1986, the standard of concentration for lead was 20 milligrams per cubic metre (mg/m^3).

As pollution-reduction technologies have improved over time the limits for industrial lead emissions in New South Wales have become increasingly strict (Table 4). The standard of concentration for lead emitted from premises or activities that commenced after September 2005 was lowered to $1mg/m^3$.

Table 4: Standards of lead concentration (mg/m^3) for general activities and plant in Australia
Protection of the Environment Operations (Clean Air) Regulation – Schedule 4

Time period	Standard of lead concentration (mg/m^3)
pre July 1986	20
post July 1986 – pre-August 1997	10
post August 1997– pre-September 2005	5
post September 2005	1

Licensing

Industry in Australia is regulated by a licensing system which specifies that certain industrial activities must be carried out with a pollution licence issued by the relevant environmental authority. Australian industrial emission limits aim to ensure that:

- appropriate technology is used in the processes that result in the emission of pollutants
- the various components of plant are operated in an efficient manner
- pollution control equipment is correctly maintained and operated.

Ambient air quality

Air emissions measured and regulated at the source of creation (e.g. chimney or stack) do not take into account the fate and transport of the emission, nor do they capture uncontrolled emissions. Off-site air monitoring is therefore undertaken to measure the impacts of industry on air quality in surrounding areas.

In 1998, the National Environment Protection Council (NEPC) incorporated Australia's first national ambient air quality standards into the *National Environment Protection Measure for Ambient Air Quality* (Air NEPM). In New South Wales the Air NEPM is applied under the Protection of the Environment Operations Act and the Clean Air Regulation.

The Air NEPM requires monitoring stations to be installed in areas with populations greater than 25,000, and sets standards for carbon monoxide, nitrogen dioxide, photochemical oxidants (such as ozone), sulfur dioxide, lead and coarse particulates. Off-site air quality monitoring programs are often undertaken to detect uncontrolled particulate emissions from industrial activities that may impact air quality and human health.

The standards set out in the Air NEPM in 1998 are legally binding on all levels of government, and were to be met by 2008. The current maximum allowable exceedance for ambient lead is 0.5 micrograms per cubic metre (µg/m^3) (1-year averaging period). Prior to 2008, the EPA's goal for lead in ambient air was set at 1.5µg/m^3 (90-day average).

Lead emissions from Pasminco Cockle Creek Smelter

Prior to the enactment of the Protection of the Environment Operations Act, there were minimal pollution control measures in place at the smelter. Significant quantities of lead and other air impurities were consequently released from the smelter causing widespread environmental degradation, as well as high lead concentrations in the soil and housing of the North Lake Macquarie suburbs of Boolaroo, Argenton and Speers Point.

In 1982–83 the State Pollution Control Commission (SPCC) declared that lead pollution levels observed at Boolaroo (in air, groundwater and surface water) were the highest in New South Wales (see Prior & Partridge 2010).

Figure 4 shows that lead emissions from the smelter declined significantly following the lead-in-air reduction strategy that was implemented concurrently with the smelter upgrade program. The conditions of consent for the smelter upgrade program in 1995 directed that smelting operations were not to cause off-site exceedances of ambient levels of lead in air.

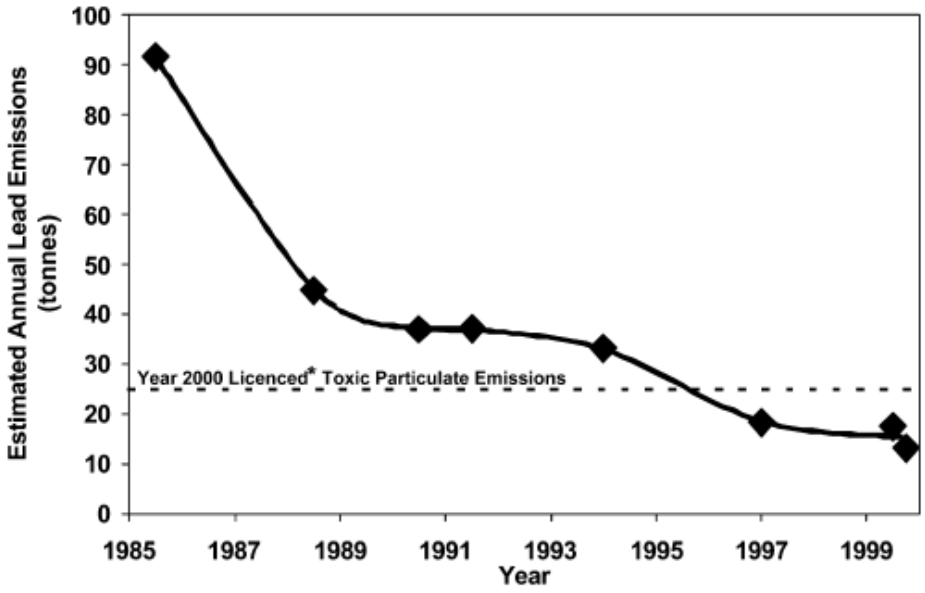

Figure 4: Estimates of smelter lead mass emissions from 1985–1986 to 2000

Image: Morrison 2003.

Prior to shutdown in 2003, the smelter was emitting an estimated 11,000 kilograms (11 tonnes) of lead per year – a significant reduction compared with annual lead emissions in the 1980s as described in Table 5.

Table 5: Lead emissions generated by the Pasminco Cockle Creek Smelter over time

Source: EPA.

Year	Lead emissions per year / emission reduction activity
1985	92,000 kg or 92 tonnes (full smelting operations)
1995	Lead-in-air reduction strategy
1999	Amendment to development approval for increased production and stronger environmental controls
2000	14,000 kg or 14 tonnes
2001	20,000 kg or 20 tonnes
2002	11,000 kg or 11 tonnes
2003	11,000 kg
2003–4	2,300 kg or 2.3 tonnes (plant shut down in 2003)

Long-term trends in ambient lead levels

Ambient lead concentrations were monitored at a number of locations to the north and south of the plant (Figure 5; west monitor and school monitor are not shown). Off-site ambient air was monitored as early as 1972, however, early air monitoring was limited to one or two monitoring locations only.

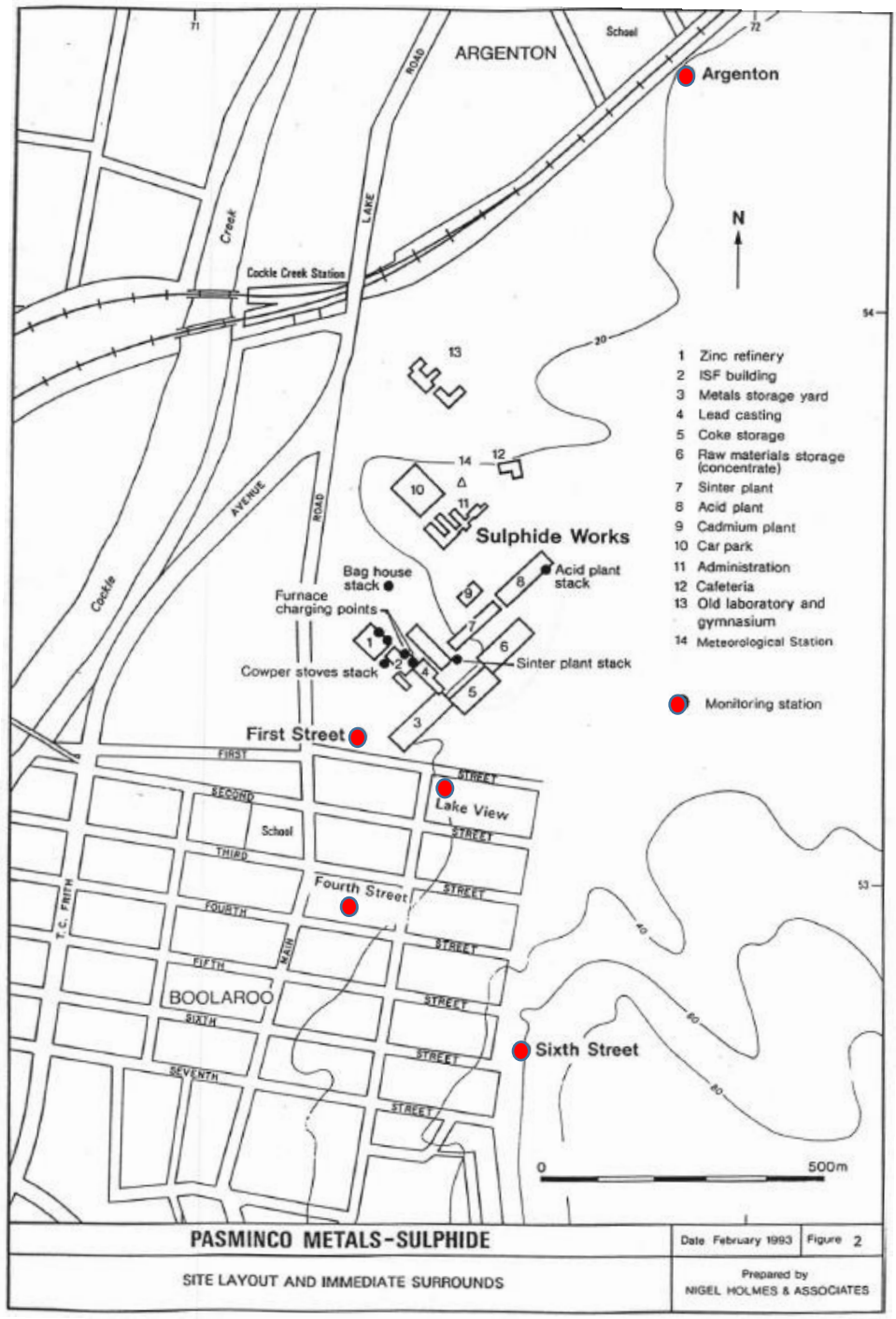

Figure 5: Locations of the off-site air monitoring stations surrounding the smelter

Image: Nigel Holmes & Associates.
West monitor and Boolaroo Public School monitor not shown.

Figure 6 shows the long-term variability in annual average airborne lead concentrations[4] as recorded at various monitoring sites on PCCS land (i.e. north and south boundaries), Boolaroo and Argenton, from 1973 to 2014. Variability in the graph reflects three key periods in the history of the smelter:

1 full production with minimal controls on emissions pre-1985

2 introduction of the lead-in-air reduction strategy in 1995

3 plant shutdown and smelter closure in 2003.

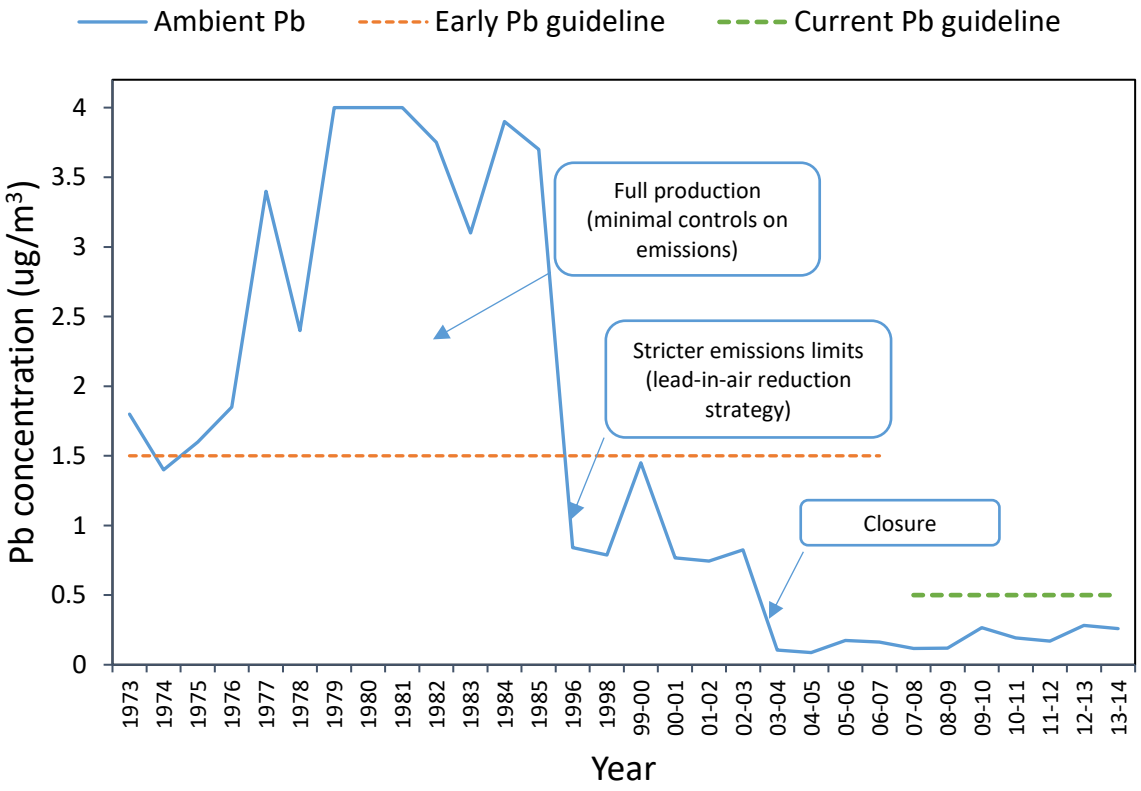

Figure 6: Annual average lead-in-air concentration between 1973 and 2000 (µg/m^3) averaged for all sampling locations mentioned in Figure 5

Note: some annual values are based on data from one air monitor only.

The data presented in Figure 6 show that prior to 1996, annual average lead air concentrations exceeded the (then) NHMRC (1996) goal of 1.5µg/m^3 (90-day average). After this time, annual average lead concentrations decreased and remained below threshold, most likely due to improved environmental controls associated with the smelter upgrade.

In 1995, consent conditions for the 1995 proposed smelter upgrade directed that the smelter:

> *… achieve an ambient level of lead in air of 1.5µg/m^3 or less for 95% of the time (i.e. 95% of annual 90-day running averages) at the boundary of the buffer zone … and the [World Health Organization] WHO goal for ambient lead*

[4] Air emissions data sourced from EPA files. Data derived from a range of sources, including Pasminco annual returns, environmental quarterly reports (1996 and 1998), environmental audit of the Pasminco smelter site (1999–2000), and a summary of the community ambient air monitoring program.

> *in air of 1.0ug/m^3 or less at the boundary of the buffer[5] zone for 95% of the time from 31 December 1997.* (DUAP 1995, pp. 3–4)

The strategies, to decrease both stack and fugitive emissions decreased the average lead levels from around 3.5 to <1ug/m^3. The significant reductions in off-site air lead concentration reflects the decreased mass emission of lead from approximately 92 tonnes per annum in 1988 (CIEP 1995) to the 2003 level of approximately 11 tonnes (Table 5).

Licence conditions at Pasminco Cockle Creek Smelter

The Cockle Creek pollution licence did not impose any specific limits in regard to air pollution, although off-site air quality monitoring was required. The pollution licence for PCCS required ambient air quality to be monitored and reported in an annual return.

[5] In 1991, residents in the streets surrounding the smelter were asked to consider selling their homes to the company in an effort to reduce the impact of lead fallout in the area. It was proposed that homes in First, Second and Third streets could be bought to create a buffer zone between the plant and the surrounding community (Legislative Assembly Hansard, 3 December 1991).

Chapter 4: Use of slag in the community

Generation, storage and distribution of slag

One of the by-products generated by the smelting operations at the PCCS site was a finely granulated vitreous slag characterised by elevated concentrations of residual heavy metals including copper, lead and zinc, and to a lesser extent, arsenic and cadmium (Douglas Partners 2010). Prior to 1922 an estimated 800,000 tonnes of 'old blast furnace' slag was generated by the lead blast furnace process and stockpiled on the smelter site (Dames & Moore 1994). This material was stored in an extensive stockpile at the PCCS site (Figure 7), until the site was remediated in 2015. Slag generated by the blast furnace had a relatively high lead content of around 2.5%.

Figure 7: Stockpiles of lead slag at the Pasminco Cockle Creek Smelter site in 1996

Photo by Ron Bell; image: *Newcastle Herald* 2014.

Slag generated by the more modern ISF process, which commenced in the 1960s, was managed in accordance with its lead content (Dames & Moore 1994):

- slag with lead content greater than 2% was separated and recycled
- slag with lead content between 1 and 2% was used for pipe bedding, road subsurface, drainage and on-site landscaping
- slag with lead content below 1% was sold for abrasive blasting, pipe bedding, landfill and drainage.

ISF slag was considered to be chemically inert based on a widely accepted incorrect assumption, since discredited (Batley 1992; Morrison, Swierczek & Gulson 2016), that the lead and other trace metals were tightly bound within a glassy matrix. Due to its favourable physical properties, load-bearing capacity, abundant and free supply, and the belief that it

was environmentally benign, the slag was widely used by the public and municipal authorities including LMCC.

Slag was used for a variety of purposes such as bulk fill, as a surface levelling material, to backfill walls and drains, and as a drainage medium. The scale of use ranged from a single trailer load for a small residential project (e.g. road base for a residential driveway) to large projects to fill low-lying land and stabilise areas along the Lake Macquarie foreshore.

Production figures for the smelter indicate that approximately 2.1 million tonnes of slag were distributed into the surrounding environment (Morrison, Swierczek & Gulson 2016). Until 1994, annual estimates of granulated slag used within the community were (Dames & Moore 1994):

- grit blasting material 24,000 tonnes per annum
- road base and pipe bedding 30,000 tonnes per annum
- on-site landscaping 20,000 tonnes per annum
- off-site landfill 3000 tonnes per annum
- on-site pipe bedding 3000 tonnes per annum.

The use of granulated slag in the community decreased over time and was formally discontinued by LMCC in 1994. The practice of distributing slag within the community ceased due to concerns associated with heavy metal leaching from the slag deposits (LMCC 1994). Further restrictions on the use of slag were enforced in 1999, when PCCS operators were prevented from stockpiling slag on the smelter site. Slag produced after this time was transported to another Pasminco-operated facility in western New South Wales where it was used as backfill for mine shafts (Australasian Slag Association 2000).

Limited information exists regarding the locations of the slag, the quantities that were distributed, and to whom the slag was supplied. Locations where slag was used within the community were not typically recorded, and most of the material that was used has remained in place. LMCC maintains a record of all known slag-affected sites and this information is available on request to landowners and purchasers. LMCC acknowledges that it may not be aware of all instances of slag-impacted sites in the area and recommends that the public reports the presence of slag on public or private land for assessment. Where confirmed, LMCC will record the presence of slag. LMCC makes the following general statement in a fact sheet on managing black slag-affected soils: ‘Black slag may be found in foreshore reserves, parks, sports fields, drains, retaining walls, roadways, and on private property’ (LMCC 2015).

Early investigations into the environmental impacts of slag

In the early 1990s, increased public awareness of environmental contamination issues led to concerns regarding the widespread use of slag, especially in public areas. In 1992, Pasminco commissioned an independent (Commonwealth Scientific and Industrial Research Organisation [CSIRO]) investigation into the short-term leachability of heavy metals in slag (Batley 1992). Results from the leaching experiments demonstrated that rainwater was unlikely to release concentrations of heavy metals above the Australian and New Zealand guidelines for environmental fresh waters, while sea water could mobilise significant concentrations of zinc and cadmium at levels exceeding the criteria for marine waters (Batley 1992).

The Batley (1992) report also described the bioavailability of heavy metals in the slag using biologically relevant fluids, including a simulated stomach fluid. The results from this component of the investigation lead to the following conclusion:

> *Most of the heavy metals present in the slag are in readily bioavailable forms. It is likely that ingested slag reaching the gut would readily release lead, zinc, cadmium and copper, and this could have toxic consequences.* (Batley 1992, p.5)

The Batley (1992) report also demonstrated an inverse trend between particle size and the leachable metal fraction, indicating that slag dust particles represent a significant source of bioavailable lead, zinc and other trace metals. This finding was particularly important because it demonstrated that dust emissions from slag stockpiles, and other secondary sources, were potentially hazardous for the surrounding community as well the environment more broadly.

The findings from the 1992 report on lead solubility did not enter the public domain and the Pasminco slag continued to be distributed and utilised in the community. As mentioned above, the use of granulated slag in the community decreased over time and was formally discontinued by LMCC in 1994.

Phasing out slag use

In 1994, Pasminco commissioned an environmental impact statement (EIS) for the modernisation of the smelter – a venture that was expected to increase slag production from 80,000 to 100,000 tonnes per annum (Dames & Moore 1994). Among other matters, the report identified and addressed the issues associated with slag generation, storage, distribution and disposal.

The EIS, which refers to the findings of the 1992 report, prompted LMCC to call for an assessment on the suitability of using granulated slag in council's operations in 1994. A list of preliminary guidelines for the ongoing use of slag were proposed in the assessment (LMCC 1994):

1 Slag should be covered with 500 millimetres of clean fill.

2 Slag should not be placed in contact with soil or groundwater which has a pH below 5.0.

3 Slag should not be used in or adjacent to acid sulfate soils.

4 Slag should not be used in or adjacent to council's garbage tips, as acid may be produced by the decomposition of organic matter.

5 Slag should not be placed in direct contact with sea water.

6 Slag should not be stored or stockpiled where it can be accessed by the public or where dust may blow on to adjoining areas.

7 Staff who work with slag should maintain a high level of personal hygiene (e.g. washing hands before eating, etc.).

LMCC's Works and Technical Services Committee also recommended that LMCC discontinue the use of granulated slag from Pasminco in council's operations (LMCC 1994). It was also recommended that LMCC seek guidance from Pasminco as to whether any controls had been applied with respect to the sale or distribution of slag, and if not, if such guidelines could be issued (LMCC 1994). The response from Pasminco management was

that the company had '… instituted a policy that zinc slag should not be used as a residential fill because of concerns that children may have access to zinc slag' (Pasminco 1994). LMCC's Works and Technical Services Committee also recommended that the matter be referred to the EPA (LMCC 1994).

Batley's (1992) recommendations on the usage of slag in the environment were largely unheeded, and were overlooked until they were 'rediscovered' during an independent study by Tony Morrison of Macquarie University in 2010.

Management of slag and slag-impacted soils

Slag used for construction, drainage and fill purposes represents a potential source of environmental trace metal contamination in Lake Macquarie City and the Lower Hunter region. Although lead is commonly considered the main contaminant of concern in slag-impacted soils, slag also contains varying concentrations of arsenic, cadmium, chromium, copper and zinc. The legacy of slag usage, both in public and residential areas, is an ongoing and significant issue of concern within the community.

Slag and slag-impacted soils in public spaces under LMCC's care and control are managed predominantly by LMCC as detailed in *Environmental Management Plan for Contaminated Land in Council's Care and Control* (LMCC 2013). However, it should be noted that the scope of this chapter does not extend to non-land-based contamination.

A series of fact sheets advising the community on the health risks associated with slag, strategies to minimise their exposure, as well as restrictions on development, are available on the LMCC website: Environmental Fact Sheets:

- Fact sheet 12 – Contaminated Land in the Lake Macquarie City – Including the Pasminco Lead Abatement Strategy area
- Fact sheet 12A – Managing Black Slag Affected Soils
- Fact sheet 12B – Building Projects on Contaminated or Potentially Contaminated Land.

Based on expert advice from Hunter New England Health, LMCC advises the community that the health risks associated with exposure to slag are low, providing the slag is covered with an adequate barrier (LMCC 2015). In instances where the surface cover is inadequate or disturbed, the relative risk of adverse health impacts associated with exposure to slag particles increases for vulnerable sectors of the community. There are, however, a number of sites where patches of slag have become exposed and consequently represent a potential source of exposure in the community or increase the risk of heavy metal mobilisation if not managed.

For example, the recent exposure of slag along the foreshore of Lake Macquarie at Marmong Point following storms in April 2015 highlighted this issue with the EPA (Figure 8).

Figure 8: Exposed black slag on the Lake Macquarie foreshore

Image: *Newcastle Herald* 2015

In April 2015, heavy storms lead to the collapse of a retaining wall along the Lake Macquarie foreshore at Marmong Point, exposing a 100-metre stretch of Pasminco black slag. A portion of the unconsolidated material washed into the lake prompting concerns from local residents about the ongoing management of slag in the environment. Stabilisation works were undertaken at the site to minimise the risk of future exposure.

Potential disposal options for slag on residential properties and public open space are discussed in Chapter 12: Local waste disposal.

Chapter 5: Smelter remediation

The Pasminco Cockle Creek Smelter site covers over 200 hectares, including the main smelter site, the west side of Munibung Hill, the triangular paddock between Main Road and TC Frith Ave, and Cardiff West Estate. The former Incitec Pivot site which was surrounded by the smelter was formerly part of the site, and was remediated in conjunction with the smelter site. The smelter was used for the smelting of zinc and lead products and associated by-products from 1896. This resulted in lead emissions and production of slag by-products which were extensively used as fill both on and off site. While off-site remediation and testing commenced in the 1990s, on-site remediation planning did not advance until the smelter shut down in 2003.

Initial activities conducted included soil and groundwater assessment, enhancement of site water management and assessment, and removal and disposal of all saleable materials. A preliminary remedial action plan (RAP) was prepared in 2004.

The preferred remediation strategy was for all contaminated soil and slag to be placed in an on-site containment cell to be constructed over stockpiles of old slag. Cell design, an interim groundwater management plan and an overarching RAP were prepared and were subject to audit by an EPA-accredited contaminated sites auditor. Remediation commenced by 2008 after most buildings and infrastructure were demolished in 2006 (except for the site office which was demolished later and the old laboratory building which has been refurbished and remains). The site was divided into parcels for the purpose of staged remediation. More detailed RAPs were prepared for each parcel, and were also subject to audit.

The contaminants of concern were identified by sampling for a wide range of potential contaminants as indicated by the general site history. Primary contaminants were found to be lead, cadmium and zinc, and other metals such as arsenic, manganese and mercury to a lesser extent. The metals were generally expected to occur together, with lead the main indicator of contamination. Polycyclic aromatic hydrocarbons and petroleum hydrocarbons were included in remediation criteria for parts of the site. However, the main contaminants which dictated the level of remediation were lead in soil over most of the site, cadmium in parts such as near the former cadmium plant, and zinc in groundwater.

The site had been extensively covered in uncontrolled fill which originated from the smelting operations. Below the fill material the natural sequence included sandy clays or clays, sandstone, siltstone, shales, conglomerates, coal and tuff. All fill material was potentially contaminated with heavy metals. While highly variable, total lead concentrations in fill were up to the order of 400,000mg/kg. High concentrations in natural soil are mainly directly beneath fill, and up to the order of 15,000mg/kg lead. Areas that were not filled, such as Munibung Hill, had high lead concentrations from atmospheric deposition but total concentrations were generally much less than the concentrations in slag fill. It was decided that the steep upper slopes of Munibung Hill, which are to remain undeveloped, would not be remediated as this could cause more environmental damage.

Remediation was conducted by excavating all fill and shallow natural soil or rock and placing it into the containment cell. The cell ultimately covered 23 hectares and contained approximately 2 million cubic metres of contaminated soil. Since the cell was placed onto existing slag stockpiles, it does not have a base liner, so leachate from the cell could

continue to contaminate underlying groundwater. This is managed by cut-off trenches constructed both upslope and downslope of the cell, which collect groundwater for treatment at a water treatment plant constructed near the cell. The upslope drain is designed to reduce groundwater entering the cell by intercepting and diverting groundwater. The downslope drain is to capture any groundwater that migrates through the cell despite the capping and upslope drain, and also to reduce groundwater levels beneath the cell footprint as the cell has no base liner. The cell is capped with a drainage system and low permeability material, which aims to minimise future infiltration into the cell.

Site investigation criteria adopted for soil were the criteria applicable at the time of remediation planning, which included Health Investigation Levels (HILs) for heavy metals from the *National Environment Protection (Assessment of Site Contamination) Measure 1999*. In a conservative approach, the HILs were adopted as remediation criteria. The NEPM was amended in 2013, but this did not affect the HILs for the main contaminants of concern on the smelter site. Applicable HILs adopted were those for standard residential use (300mg/kg for lead) for parts of the site that could possibly be used for residential development, including Munibung Hill, or those for commercial or industrial uses (1500mg/kg for lead) for parts of the site designated for possible commercial use.

Groundwater essentially occurs in two aquifer systems – a shallow, unconfined, probably perched aquifer within unconsolidated soils and fill, and a deeper aquifer in fractured bedrock. Most of the groundwater contamination, which is principally zinc, occurs in the shallow aquifer, in which the primary pathways for movement of contaminants off site was through the catchments draining to the South West Dam and Hawkes Dam. The interim strategy was to extract groundwater from three pumping wells installed in each catchment in 2006 to inhibit off-site migration within two flow paths off the site, which were through the South West Dam and Hawkes Dam discharges. Extracted water was pumped to the existing PCCS effluent treatment plant (since demolished and replaced by a new treatment plant near the cell) for treatment and discharge under an environment protection licence. The deep aquifer, found within fractured bedrock, contained lower concentrations of dissolved metals, and groundwater within the deep aquifer is likely to flow beneath the nearby Cockle Creek. All surface water runoff from the site was also collected and pumped to the effluent treatment plant.

Groundwater monitoring has been conducted since 2006 in a series of programs covering wells across the site and on the site boundary. Historically groundwater results were compared to trigger values derived from Australian and New Zealand Environment and Conservation Council (ANZECC 2000) 95% trigger values for marine aquatic ecosystems, reflecting the receiving waters of Cockle Creek. Trigger values are concentrations that, if exceeded, indicate a potential environmental problem and act as a trigger for further assessment. They are not necessarily remediation criteria. Background concentrations of zinc typically exceeded the ANZECC 2000 trigger value of 15 micrograms per litre (µg/L). Zinc concentrations of up to 2 million µg/L were recorded in the shallow aquifer and results exceeding 20,000 µg/L were common.

Remediation of the site by excavation and placement into the cell has now been completed. Remediation was conducted progressively in over 30 parcels and subparcels, in accordance with specific RAPs. In areas where there was no fill, such as the developable parts of Munibung Hill, the process involved removal of vegetation and scraping of the top 0.05–0.3 metres of the natural soil. The scraped soil was placed in the containment cell. The depth of scraping was estimated from initial sampling using an X-ray fluorescence (XRF) field screening instrument. Additional scraping was conducted if screening with XRF indicated that

contamination remained above the site criteria. In areas of fill, all fill was removed to depths indicated by initial assessments. This was up to 7 metres deep.

Where screening with the XRF found lead concentrations exceeding 300mg/kg in possible residential areas, these areas were re-excavated prior to validation sampling. The XRF was not used for final validation, which was conducted by laboratory analysis in accordance with validation plans which were reviewed by the site auditor. The main elements of the validation plan included base samples collected on a 15-metre triangular grid with all samples analysed for lead and 25% of the samples analysed for the other metal contaminants of concern. Walls of excavations, drainage lines and depressions were sampled at a greater frequency and all samples analysed for the contaminants of concern. Where samples failed the validation criteria (the HILs), additional excavation was undertaken. At a number of locations, such as near the former cadmium plant where contamination was found to have extended deep into natural weathered rock, the process was repeated on multiple occasions. Ultimately, thousands of samples have been analysed, with a very small number exceeding the HILs. Because of the nature of the remediation, average lead concentrations over the majority of the site are below 300mg/kg.

Progressive site audit reports (SARs) and site audit statements (SASs) have been prepared by the site auditor as lots or parcels have been completed. Completed audit reports are provided to the EPA and LMCC. Due to potential changes in lot boundaries as development plans are finalised, and because further earthworks may be conducted to prepare a site for development, some of the SARs and SASs are in draft form. The intention is to finalise the audits at the completion of the earthworks to incorporate changes on the site to that time, and to reflect the final lot boundaries.

Remediation of the site by excavation of contaminated soil resulted in removal of the shallow aquifer across the majority of the site. Monitoring wells were progressively installed and destroyed during the remediation process. A post-remediation groundwater monitoring program is now being conducted in accordance with a groundwater management and monitoring plan which includes monitoring of leachate from the cell and groundwater conditions downslope of the cell, and site-wide monitoring of the shallowest water-bearing body remaining. Post-remediation monitoring wells were installed in locations where high concentrations had been recorded pre-remediation and to obtain site coverage, and existing wells were also used where possible.

While post-remediation dissolved metals concentrations over most of the site are at levels that would not present a risk to human health if groundwater was extracted for use, high concentrations are still recorded in some wells. Therefore, a moratorium on groundwater extraction for beneficial use or a warning to potential users over the whole site is likely.

The major components of the remediation project for the smelter site were completed in 2015. The cell and unremediated parts of Munibung Hill are subject to a long-term environmental management plan.

Chapter 6: The Lead Abatement Strategy

This chapter provides an overview of the Lead Abatement Strategy (LAS), including the establishment of the lead contamination survey grid and perceived inequities between those inside and outside the grid. It sets out the key objectives of the program and the limitations of the lead abatement approach. The *Lead Abatement Strategy Implementation Documentation* is included at Attachment C.

Purpose of the LAS

Emissions generated by the smelter resulted in lead contamination of soils in parts of Boolaroo, Speers Point, Argenton, Teralba and other neighbouring land. Emissions included those released from the smelter stack, as well as fugitive emissions from other sources of lead (e.g. windborne particles from stockpiles of slag).

The LAS was developed by Pasminco, in conjunction with a lead specialist, for the Deed Administrators of the smelter, and approved by the Minister for Planning in 2007. The key objective of the LAS was to 'achieve a reduction in human exposure to lead dust contamination in surface soils' (Zines 2007). The LAS implementation documentation acknowledged that dust was the main causative factor of the elevated lead in blood levels in children residing in the surrounding area, and was therefore the emphasis of the abatement program.

In order to understand the main objectives of the remediation and abatement strategies implemented under the LAS, it is important to review the definitions for each strategy.

Remediation aims to correct the contamination issue through means of a systematic approach to identify a permanent remedy, such as removal or containment of the contaminant source. According to the Contaminated Land Management Act, remediation of contaminated land includes the following actions:

1 preparing a long-term management plan (if any) for the land

2 removing, dispersing, destroying, reducing, mitigating or containing the contamination of the land

3 eliminating or reducing any hazard arising from the contamination of the land (including by preventing the entry of persons or animals on the land).

Abatement of contaminated materials, on the other hand, refers to the in situ encapsulation of such materials in a manner that renders it acceptable and safe as determined by applicable governing authorities. It should be noted that, while not intended as a permanent solution, abatement strategies aim to reduce or eliminate the degree of exposure intensity to the contaminants of concern.

Development of the lead contamination survey grid

The lead contamination survey grid was set out in the 1995 Conditions of Development Consent, approved by the (then) Minister for Urban Affairs and Planning, for the upgrade of the smelter to delineate the area considered to be potentially contaminated with lead dust resulting from operations at PCCS (Zines 2007). This grid was developed by integrating:

- data from a pilot soil survey conducted in 1992
- data on blood lead levels of child residents
- contour mapping.

Soil and blood lead data were derived from an earlier environmental health risk assessment conducted in 1991 (Galvin et al. 1993). The environmental health risk assessment involved a pilot soil survey to assist in defining a zone where children might be at risk, followed by a general soil survey to assess the area within this zone. The pilot soil survey involved sampling two transects: (i) along the east rim of Argenton, and (ii) along a line east of the residential margin of Boolaroo and Speers Point (Galvin et al. 1993).

The pilot study was conducted prior to the LAS program that was established in 2007. For the general soil survey, a total of 202 samples were collected to a depth of 50 millimetres[6] across a grid superimposed on an area 2 kilometres north, south and east of the lead smelter, and extending west of the smelter site to Cockle Creek (Figure 9a). Average soil lead concentrations were calculated and superimposed over the gridded image (Figure 9b). The final LAS area was refined by taking into consideration landscape contours and blood lead levels (Figure 9c).

[6] The Lead in Soil and Dust Working Group report (1994) recommended that the upper 20-millimetre soil profile be sampled for health risk assessment purposes as it is considered the most toxicologically relevant medium, and collection of the top 50 millimetres be collected for site assessment purposes only. The Australian Standard (AS 4874—2000) recommends that the 0–20 millimetre soil layer be collected for the investigation of potentially contaminated soil and deposited dust as a source of lead available to humans.

Figure 9a: Lead contamination survey grid

Source: Lead Abatement Strategy Implementation Documentation 2007 (Attachment C).

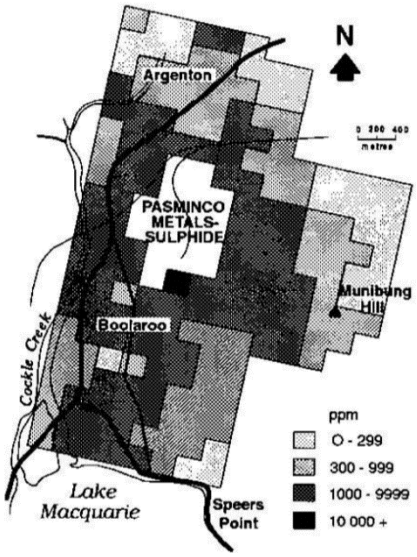

Figure 9b: Average soil lead concentrations (mg/kg) in Argenton, Boolaroo and Speers Point

Source: Galvin et al. 1993.

Figure 9c: Pasminco Lead Abatement Strategy Area (defined by the red line)

Source: Pasminco Lead Abatement Strategy website: Lead Abatement Strategy.

Identification of eligible properties

Residential properties within the lead contamination survey grid area were deemed eligible to participate in the LAS program, and were collectively referred to as the 'Nominated Properties' (Zines 2007). The LAS was limited to residential properties, and not public open spaces. The LAS Implementation Documentation cited the following statement from the *Port Pirie Lead Implementation Program – Future Focus and Directions* (DoH SA 2005) as the primary reason why the LAS focused on residential properties[7]:

> *Infants and toddlers are at greater risk due to increased exposure (mouthing behaviour), increased ability to absorb lead and the susceptibility of their rapidly developing nervous systems. Older children, adolescents and non-occupationally exposed adults exhibit near normal blood levels unless significantly exposed during early life.* (DoH SA 2005, p.1)

[7] Residential properties were the focus of the Lead Abatement Strategy presumably due to the fact that the most vulnerable populations (i.e. infants and toddlers) are likely to be exposed in the home environment. This assumption is based on introductory statements on lead exposure in the Lead Abatement Strategy Implementation Documentation: (i) 'Direct ingestion may arise… very young children playing in the backyard and putting soiled hands in their mouth' (Zines 2007, p8); (ii) 'Another pathway is from dirt in the backyard being tracked into the household…' (Zines 2007, p8).

LAS implementation

Reviews of the LAS program

The LAS was approved and endorsed by the Directors-General of the NSW Department of Environment, Climate Change & Water (DECCW) and the Department of Planning (DoP) in 2007. The site auditor review of the LAS Implementation Documentation concluded that the LAS sampling and abatement procedures provided:

- a reliable means of determining lead concentration in surface soil
- an effective approach to establishing exposure pathway barriers to lead in surface soil.

In October 2007, LMCC wrote to the EPA (then part of DECCW) to raise its concerns following a protracted period of negotiations between DECCW and PCCS regarding the formulation of the LAS. The following list summarises LMCC's concerns regarding the LAS, as detailed in the letter to the EPA:

- Council-owned land within the LAS grid boundary, such as open space, playing fields and road reserves, as well as the Department of Education and Training properties, were not nominated for inclusion in the LAS, despite the fact these properties host activities by children.
- Garden beds were excluded from the LAS sampling and implementation phases; therefore the risks of direct and indirect exposures to soil lead from these locations were not addressed.
- Properties containing slag were excluded from the LAS program; there was limited information in the LAS Implementation Documentation to justify this exclusion.
- The LAS did not address future scenarios that may render the abatement techniques ineffective; no attempt to evaluate the suitability of the cap-and-cover approach was provided.
- While the LAS aimed to minimise the risks to human health, environmental degradation such as the risk of lead leaching into groundwater was not considered in the strategy.
- The timeframes assigned for community consultation (two to three months) and to carry out the LAS scope of works (two years) were inadequate.
- Conditional approval for the remediation of the PCCS site specified that the lead abatement program should describe an alternative method for fulfilling the role of the Environmental Health Centre (EHC) should the EHC cease to exist[8].
- The LAS Implementation Documentation stated that participation in the LAS would facilitate the removal of notations on s.149 certificates; LMCC had not adopted a formal position on this issue and were seeking legal advice at the time of writing their correspondence to the EPA.

[8] The North Lake Macquarie Environmental Health Centre in Boolaroo was established in 1996. The Centre closed at the end of 2006 due to observed improvements in children's blood lead levels since the smelter shutdown in 2003.

Stages of the LAS

The LAS was undertaken in three stages: consultation, sampling and implementation (Figure 10). The following subsections describe these stages in more detail.

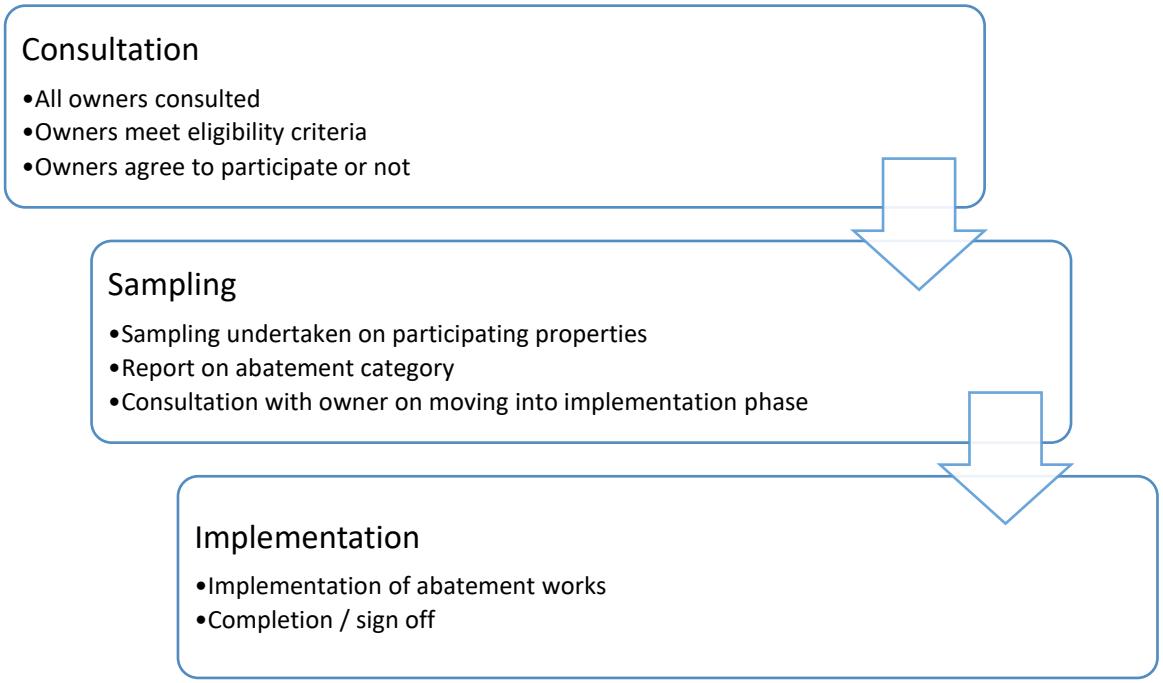

Figure 10: The three stages of the LAS

Adapted from Pasminco Pty Ltd., n.d.

Consultation

The aim of the initial consultation period was to provide sufficient information to the owners of all nominated properties within the LAS area to enable them to make an informed decision regarding their participation in the LAS program. Plain language letters and pamphlets describing the aims of the LAS and the proposed methodologies were distributed to each of the nominated property owners, and a dedicated page on the PCCS website was established which provided updates on the LAS program.

Following the initial consultation period, nominated property owners were offered an opportunity to participate in the LAS on a voluntary basis and were provided with the following options:

1 to elect to participate in the LAS

2 to elect to participate in the LAS and also undertake additional work at their own expense

3 to elect not to participate in the LAS.

The second phase of the consultation period, undertaken during implementation of the LAS, was focused on providing the LAS participants with information regarding the progress of the LAS program. According to the LAS Implementation Documentation, this consultation period was also aimed at providing the community with strategies to minimise exposure to lead through other pathways such as consumption of homegrown produce and inhalation of household dust (Zines 2007).

Reasons for non-participation

One of the reasons why residents elected not to participate in the LAS was due to the requirement to sign the Lead Abatement Program Participation Agreement (the Agreement) releasing Pasminco from future claims unless they were grossly negligent in their lead abatement actions or in removing lead from properties. By signing the Agreement, property owners released Pasminco from future responsibility, not only within their own property, but from all future liability. The Agreement was sent with the initial participation letter, and, among others, included the following liability clauses:

> *LIABILITY*
>
> *11.1. The Participant undertakes to advise the next owner that the LAS has been carried out, will not be repeated and that future owners will therefore not be eligible for participation or have any right to make a claim under the LAS.*
>
> *11.2. The Participant:*
>
> *(a) acknowledges that PCCS is subject to the Deed of Company Arrangement executed on or about 4 October 2002 pursuant to Part 5.3A of the Corporations Act 2001 (Cth); and*
>
> *(b) agrees that it will not terminate this agreement, make any Claim or exercise any right under this Agreement as a result of or in relation to:*
>
> *(i) PCCS being subject to the Deed of Company Arrangement or the other deeds of company arrangement; or*
>
> *(ii) any event, act, matter or circumstance that occurs or may occur after the date of this Agreement relating to any winding up of PCCS.*
>
> *(c) The Participant acknowledges that:*
>
> *(i) this Agreement is entered into with the authority of the Deed Administrators on behalf of PCCS solely in their capacity as agents of PCCS; and*
>
> *(ii) the Deed Administrators will bear no liability whatsoever, personal or otherwise, in respect of this Agreement.* (PCCS 2011, p.7)

The LEWG recently sought advice from the Lake Macquarie Lead Community Reference Group on potential reasons why a large proportion of the community elected not to participate in the LAS. One of the reasons relates to confusion as to what exactly constituted the LAS, and what were potentially different works under a different program. Some community members who received abatement works (possibly by NSW Health) under a different name were of the belief that they had participated in the LAS. Other community members conducted their own small-scale abatement works, and therefore did not see the need to participate. There was also an indication that some residents believed the LAS was not needed.

Measurement of soil lead concentrations

Soils collected from participating Nominated Properties were analysed for lead in accordance with the methods described in the LAS Implementation Documentation (Zines 2007). The aim of the sampling program was to measure the degree of lead contamination in residential soils to determine the appropriate level of abatement action. This sampling program was independent of the general soil survey used to establish the LAS area.

The soil sampling program was restricted to the measurement of total lead concentrations in surface soil of the Nominated Property's lawns (including bare soil areas). Composite soil samples were collected from the top 50 millimetres at accessible locations of individual properties and sent to a National Association of Testing Authorities, Australia (NATA) accredited laboratory for lead analysis. Details of the sampling locations and other significant features at individual Nominated Properties were recorded in a site diagram.

Portions of residential areas were excluded from the sampling program and therefore did not receive any form of assessment or abatement:

1 garden beds, due to the likelihood the soil would have been turned over and therefore would not provide an accurate reflection of soil contamination due to atmospheric fallout

2 areas less than 2 metres from a building or fence, due to the potential of soil lead contamination from lead paint or other building materials containing lead

3 areas used for car maintenance or car activity, due to the potential for increased soil lead levels from fuel spills or exhaust emissions

4 areas where slag is evident were noted on the site plan but not included in the sampling program as they did not reflect soil contamination as a result of surficial dust deposition

5 council-owned land at the front of the property.

In addition to point 4 above, slag-impacted areas were not included in the LAS because '… slag was used on a voluntary basis whereas dust deposition was not a voluntary action' (Zines 2007, p.8). It should be noted, however, that it was PCCS that made the slag freely available, and provided advice that it was safe for use within the community (see Chapter 4: Use of slag in the community).

Implementation of abatement works

The primary objective of the lead abatement action under the LAS was to provide a barrier over lead-impacted soil to reduce the pathways for human exposure to lead-contaminated dust. Although the level of abatement undertaken at participating Nominated Properties was primarily determined by the average soil lead concentration, the ground surface conditions were also an important factor for determining the specific abatement action to be applied (Table 6). Properties with a soil lead concentration of less than 300mg/kg did not receive abatement because this value represents the Australian Health Investigation Level (HIL) for

lead in residential soils. The LAS categories and specific actions were based on the criteria developed by the NSW Government Lead Taskforce (1994)[9].

Table 6: Soil lead abatement categories developed for the LAS

LAS Implementation Document, 2007.

Category	Measured lead concentration	Proposed abatement action
1	<300mg/kg	No lead abatement action.
2	>300mg/kg but <1000mg/kg	**Option a** – if grass covered then barrier exists and no further action necessary. **Option b** – if not covered by grass but can be, then till and apply turf, maintaining practical ground levels for particular site. **Option c** – when in shady spot with low grass cover, add 25mm of topsoil and mulch cover.
3	>1000mg/kg but <1500mg/kg	**Option a** – for already grassed areas, add additional 25mm of topsoil. **Option b** – if not covered by grass but can be, add 25mm of topsoil and apply turf, maintaining practical ground levels for particular site. **Option c** – when in shady spot with low grass cover add 40mm of topsoil and mulch cover.
4	>1500mg/kg but <2500mg/kg	**Option a** – for already grassed areas, add additional 50mm of topsoil as barrier. **Option b** – if not covered by grass but can be, then add 50mm of topsoil and apply turf. **Option c** – when in shady spot with low grass cover, add 50mm of topsoil and mulch cover.
5	>2500mg/kg but <5000mg/kg	**Option a** – for already grassed areas, excavate 50mm of topsoil and replace with 50mm of new topsoil as barrier – replace grass cover (if suitable lead content) or otherwise apply new turf. **Option b** – if not covered by grass but can be, then excavate 50mm of topsoil and then replace with 50mm of new topsoil and apply new turf. **Option c** – when in shady spot with low grass cover, excavate 50mm of topsoil, and then replace with 50mm of new topsoil and mulch cover.

[9] The NSW Government Lead Taskforce report specified '**In the absence of better data and on the strict understanding that further validation work must be done** the following remediation strategy could be used as a guideline for site specific/child specific residential property implementation provided there is reference to sampling and analytical techniques and evaluation of analytical data to justify the action'.

Soil lead (mg/kg)	**Action**
<300	No action
300–1500	Grass cover or other appropriate barrier
1500–5000	Top dress with 50 mm clean soil and grass or other appropriate barrier
>5000	Soil replacement (top 200 mm)

Category	Measured lead concentration	Proposed abatement action
6	>5000mg/kg	Investigate soil profile vertically to determine level of excavation required (expect 100mm maximum) and then excavate, reinstate with new topsoil and apply new turf, maintaining practical levels for particular site or mulch as above.

Numbers of LAS participants[10]

According to the Ferrier Hodgson[11] LAS database, there are 2665 properties within the lead contamination survey grid area, including land used for residential, commercial and public open space, as well as vacant land. The LAS program was restricted to land used for residential purposes only, and therefore applied only to a subsection of the total properties.

A total of 1969 properties were considered by Ferrier Hodgson to be eligible to participate in the LAS program. It can only be assumed that 696 properties were deemed ineligible, due to those properties being classed as non-residential land. Of the 1969 eligible properties, 1238 (63%) properties elected to participate in the LAS program following the initial invitation from PCCS, leaving 731 (37%) properties that did not volunteer to participate.

Of the 1238 properties that volunteered to participate in the LAS program, 1226 (99%) properties had their soils tested for lead. The remaining 12 (1%) properties were not tested due to the following reasons:

1 Upon physical inspection, the property was deemed ineligible due to the land being classed as non-residential or vacant (7 properties).

2 The owner elected to cease participation before the sampling was conducted (1 property).

3 The owner ceased participation due to failing to respond to correspondence (4 properties).

Taking into consideration points 2 and 3 above, it is reasonable to state that of the 1969 properties that were deemed eligible to participate, 736 (37%) properties were not assessed for lead contamination under the LAS program.

[10] The figures cited in this section are consistent with information provided to the EPA in an email from the Deed Administrator, Ferrier Hodgson, 6 February 2015.

[11] In September 2001, Ferrier Hodgson was appointed the Deed Administrator after Pasminco declared bankruptcy and went into voluntary administration.

Finding 1

The Lead Abatement Strategy (LAS), aimed at reducing human exposure to lead dust in residential soils within the LAS area, was partially successful. Of the total number of eligible properties, around 37% did not participate in the program. The contamination status of approximately 736 properties with the LAS area therefore remains unknown. Furthermore, the abatement methods applied under the LAS did not achieve full remediation at the majority of the participating properties. While the LAS did not aim for full remediation, it is important that current and future residents be aware of the location and degree of lead contamination on their properties. This is particularly relevant because the abated soils were not validated or tested against the clean-up criteria.

The testing program revealed that 783 (64%) of the 1226 tested properties fell into categories 1 or 2 (option a), or were a mix of these two categories. While no lead abatement action was required the residents at these properties were provided with educational materials. According to the LAS Implementation Documentation, the educational materials were specific to the abatement categories (Zines 2007).

Having classified 783 properties as ‘no lead abatement action required’, an additional 6 properties were deemed either (i) ineligible (4 properties) or (ii) the owner elected to complete their own abatement works (2 properties). Therefore, abatement works were recommended for a total of 437 properties.

Between the time the properties were tested and completion of the lead abatement works, a number of properties withdrew from the LAS program, or were deemed to have ceased participation due to failing to respond to correspondence.

Based on the numbers provided by Ferrier Hodgson, of the 437 recommended properties, 359 (82%) received abatement works. Therefore, 78 (18%) properties that required abatement did not receive abatement under the LAS program (i.e. 437 properties recommended for abatement minus 359 properties that received abatement).

The number of properties that received abatement action under the LAS program, listed by LAS category, are shown in Table 7. It is not clear why 23 properties in category 1 received abatement.

Table 7: Tested properties categorised by soil lead content and LAS category

Category	Lead content (mg/kg)	PCCS follow-up report
1	<300	23
2	>300 but <1000	147.5[12]
3	>1000 but <1500	102
4	>1500 but < 2500	67.5
5	>2500 but <5000	16.5
6	>5000 mg/kg	2.5
	Total abatement works	**359**

Approximately 38% (748 properties) of the eligible properties did not volunteer therefore did not undergo a soil lead assessment. Around 40% of the eligible properties that volunteered to participate in the LAS program were found to have soil lead concentrations below the pre-determined threshold of 300mg/kg, and therefore received educational materials only. The LAS program was completed in February 2013.

Criticisms of the LAS

The methods used to (i) assess residential soil lead contamination, and (ii) abate contaminated soils, have been subject to widespread and ongoing criticism from a number of different groups, including research scientists, the media and individuals within the local community.

One of the more obvious issues associated with the implementation of the LAS was that properties were assessed and abated on a voluntary basis. As detailed above, of the total number of properties eligible to participate, around 40% did not volunteer and therefore did not receive abatement.

Furthermore, the LAS did not assess or abate areas where slag was evident because the program was restricted to the assessment and abatement of lead-contaminated dust from airborne deposition. As a consequence of these two restrictions, there remain up to 1427 properties within the LAS grid boundary that have not been assessed for contamination with lead dust or slag. Therefore, while the major cause of lead exposure to the community no longer exists (smelting and the associated operations), future exposure may occur through ingestion or inhalation of lead and other contaminants that remain in soil and dust in the community.

[12] Properties that had only their front or backyard abated/remediated were included as a 0.5 in the LAS statistics (i.e. half of the property was abated/remediated).

Finding 2

While the major source of lead exposure to the community no longer exists following the smelter closure in 2003, future exposure could occur via ingestion or inhalation of lead and other contaminants that persist in the soil and dust within North Lake Macquarie. This would be likely to impact only the members of the community who are more susceptible to exposure e.g. children under five years of age who display pica.

Another key issue identified with the LAS was the lack of validation work following completion of the abatement works. Validation is used widely to demonstrate that remedial action has rendered the land fit for its intended use. Although the NSW Government Lead Taskforce report (Lead in Soil and Dust Working Group1994) emphasised the importance of validation work following abatement actions similar to those undertaken as part of the LAS, to date there has been no systematic follow-up assessment of lead contamination at properties abated under the LAS. Although property owners received a Certificate of Completion following participation in the LAS, this was only valid for a particular time and place and only certified that the works were undertaken in accordance with the LAS Implementation Documentation. Final lead-in-soil testing was not conducted following the LAS.

In an effort to identify whether the lack of an independent assessment of the LAS (e.g. validation) requires further consideration, a study was undertaken by Macquarie University to evaluate the effectiveness of the LAS in a small number of residential properties (Harvey et al. 2015). The study observed no statistically significant difference between pre-abatement and post-abatement soil lead levels, indicating that the abatement methods used in the LAS (i.e. shallow soil capping, mulching or grass covering) inadequately mitigated the long-term potential risk of lead exposure from soil and dusts at the investigated properties. It is important to note the study was based on limited data and may therefore not be indicative of wider trends. It is also important to note the Harvey et al. (2015) study was undertaken prior to the start of the LEWG and was a separate and independent study.

Another one of the key issues underpinning the criticism of the LAS relates to the sampling method used to assess the degree of residential soil contamination from surficial deposition. For the purposes of defining the LAS area and assessing the degree of soil lead contamination, soil samples were collected from a default sampling depth of 50 millimetres. This sampling depth is not consistent with the recommendations of the *Report of the Lead in Soil and Dust Working Group* (1994). This report advised that the upper 20 millimetres would probably be the most toxicologically relevant sampling medium for health risk assessment purposes, and that the upper 50 millimetres should be collected for site assessment purposes only.

Australian Standard (AS) 4874–2000 *Guide to the investigation of potentially contaminated soil and deposited dust as a source of lead available to humans* (Standards Australia 2000), recommends that for firm soil and sandy soil, the upper 0–20 millimetres and 0–50 millimetres be sampled, respectively. It could be contended that, given the purpose of the LAS sampling program was to assess the degree of contamination from surficial deposition, the top 20 millimetres would have been a more appropriate and conservative sampling medium.

Sampling from the less conservative soil depth of 50 millimetres casts a level of doubt on the appropriateness of the LAS area and the levels of lead in residential soils. The effect of

diluting highly contaminated soil (from the surficial deposition of lead-contaminated dust) with uncontaminated or less contaminated soil layers would inevitably lead to the reporting of lower lead levels in soil.

Finding 3

The sampling methods used to establish the LAS area and assess the degree of soil lead contamination were not consistent with best practice and therefore cast a degree of uncertainty over the relevance of this area for ongoing management.

Perceived inequities between those living inside and outside the LAS area

While it is acknowledged the LAS area was based on information available at the time, and served a useful purpose, it has created perceived inequities between residents who live just inside and just outside the LAS grid boundary. In terms of development assessment, properties within the grid are assumed to be potentially contaminated, and the development assessment process proceeds in accordance with *State Environmental Planning Policy No 55 – Remediation of Land* (SEPP 55). Properties outside the LAS grid boundary will follow the same process if there is reason to believe the site may be contaminated. The assumption that properties within the LAS grid boundary are potentially contaminated has led to a general perception by some of those residents that they are subject to unfair and costly soil testing, assessments and remediation.

Chapter 7: Previous studies and testing (1991–2006)

Prior to the implementation of the LAS, a number of investigations were undertaken to assess (i) lead contamination in the North Lake Macquarie area, and (ii) lead exposure in North Lake Macquarie children. Environmental monitoring of lead has been conducted through a range of methods including systematic soil lead testing, dust deposition monitoring, lead in high volume air sampling, and ad hoc testing within residences, to identify exposures of individual children (e.g. Ouw & Bisby 1976; Galvin et al. 1993; Kachenko & Singh 2006).

Due to the commonly observed associations between the degree of lead contamination in the environment and children's blood lead levels, these variables were often investigated concurrently. This chapter discusses the soil, dust and blood lead results separately, and then describes the relationships between selected parameters. It should be noted that some lead abatement works were undertaken during this time through the local Environmental Health Centre (EHC), but these works do not constitute the abatement program under review in this report.

Regulatory environment and background information

Prior to reporting the findings from previous studies aimed at investigating the impacts of smelting operations on the environment, a brief discussion on the regulatory environment in which the smelter operated is warranted.

Lead in residential soil: Guidance on levels of contaminants in soil which may require investigation were formalised in 1992, with the publication of *Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC & NHMRC 1992). The Environmental Soil Quality Guideline, as prescribed by the ANZECC guidelines, was 300mg/kg, and this value is the current national Health Investigation Level[13] (HIL) for low-density residential soils with accessible soil, children's daycare centres, preschools and primary schools (National Environment Protection [Assessment of Site Contamination] Measure, amended in 2013).

Lead in ambient air: In 1979 the NHMRC recommended an ambient air quality goal for lead of 1.5µg/m^3 based on a three-month average, and this standard was adopted Australia-wide. Almost two decades later, the National Environmental Health Forum noted a critical need for revision of the goal in light of a substantial increase in knowledge concerning the health effects of lead at very low concentrations. In 1998, the guideline for lead in ambient air was lowered to 0.5µg/m^3 (NEPC 1998).

[13] Health Investigation Levels (HILs) are defined as 'the concentrations of a contaminant above which further appropriate investigation and evaluation will be required' (National Environment Protection [Assessment of Site Contamination] Measure, Schedule B4, p.2). HILs are not intended to be clean-up levels and an exceedance of a HIL does not automatically imply that a significant health risk is likely to be present. Site-specific assessments are required to determine whether a clean-up is required.

Blood lead levels: While the health impact of lead is likely related to the total body burden of lead, under steady state exposure conditions, population blood lead surveys can identify if excess lead is being accumulated. As a biomarker, blood lead levels integrate multiple mediators of the final body lead burden including the chemical profile of lead compounds, bioaccessibility, absorption factors, diet, compounds that inhibit lead absorption in soil or diet, and genetic factors.

Guideline values for blood lead levels, developed and periodically reviewed by the NHMRC, have declined over time. In 1993, the 1987 blood lead goal of less than 25µg/dL was abandoned and a new goal of less than 10µg/dL for all Australians was recommended. An interim goal of less than 15µg/dL by the end of 1998 was adopted as a target, particularly for children aged between one and four years. It was recommended that 90% of all children in this age group should have a blood lead level of below 10µg/dL by 1998.

The new NSW blood lead notification level of 5µg/dL as evidence of excess exposure to lead came into effect in February 2016, under s.51(2) of the *Public Health Act 2010*.

Residential soil lead

A pilot soil survey of the area surrounding the smelter was undertaken in 1991 to determine the geographical extent of soil contamination as a result of smelter emissions (Galvin et al. 1993). This study observed widespread lead contamination in the area surrounding the smelter, with 70% of soil samples (0–50 millimetre depth) exceeding the level for further investigation: 300mg/kg. The mean soil lead concentration reported was 1430mg/kg (range:20–21,460mg/kg). Of the 202 soil samples tested, 33% had a lead concentration greater than 1000mg/kg. Most of the samples with a lead concentration greater than 2000mg/kg were within 400 metres of the smelter boundary – an area which includes residential properties.

A study in 2006 reported that lead, and other heavy metals associated with smelter emissions, decreased significantly with depth, suggesting surficial contamination (Kachenko & Singh 2006). The average topsoil (0–30 centimetre depth) and subsoil (60–90 centimetre depth) lead concentrations, within a 2-kilometre radius of the smelter, were 363 and 64mg/kg, respectively[14]. An interpolated map of lead concentrations within the 1991 survey area that shows the locations of the highly impacted areas (in red: >4000mg/kg lead) supports the inverse relationship between soil lead content and distance from the smelter (Figure 11; Willmore 2006). Significantly greater levels of lead in residential soils were observed south of the smelter (mean: 1823mg/kg), compared with the north (941mg/kg).

[14] The relatively low lead concentrations reported here are not consistent with the higher values reported elsewhere in this report, presumably because the Kachenko and Singh (2006) study regarded *topsoil* as the 0–30 centimetre depth increment.

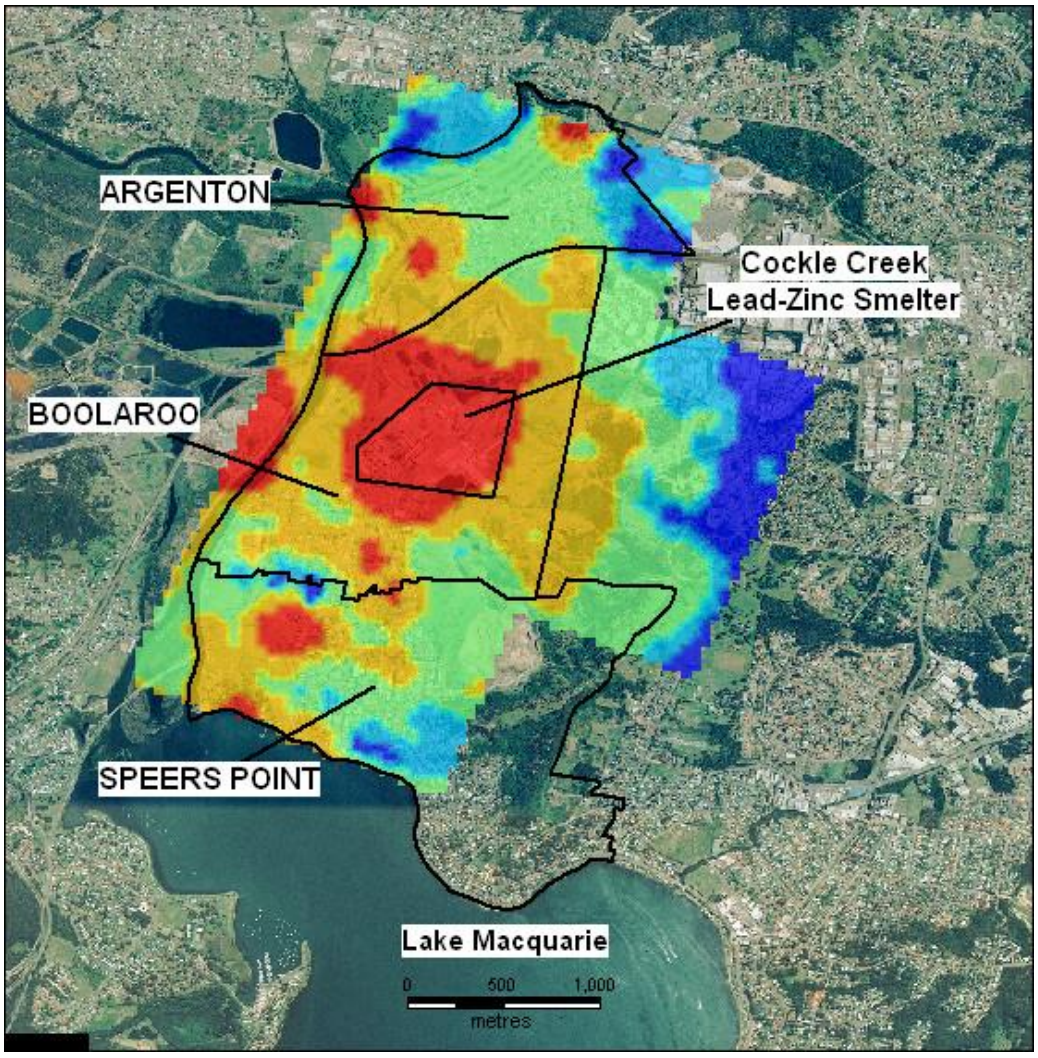

Figure 11: Interpolated 1992 soil lead concentration in the suburbs surrounding the Cockle Creek lead–zinc smelter, North Lake Macquarie, NSW, Australia

Navy: soil lead <150mg/kg, turquoise: 150mg/kg – <300mg/kg, green: 300mg/kg – <1000mg/kg, orange: 1000mg/kg – <4000mg/kg, red: ≥4000mg/kg.
Image: Willmore et al. 2006.

Household dust monitoring

Two measurements of lead may be reported when dust is considered a source of exposure:

- lead loading (micrograms of lead per square metre: µg/m^2)
- lead concentration (micrograms of lead per gram of dust: µg/g).

Dust lead loadings (i.e. the amount of lead on a surface with which a child may come into contact) are a direct measurement of lead available for a child to ingest and are therefore a better predictor of lead uptake than the dust lead concentrations.

During the health risk assessment conducted by the Hunter Area Public Health Unit in 1991 (Galvin et al. 1993), samples of dust were collected from ceilings, rooms and vacuum cleaners from homes immediately south of the smelter where children had elevated blood lead levels. The analyses showed extremely elevated levels of lead in most of the homes

tested, particularly in the finer dust particles. The range of lead in household dust ranged between 23 and 35,870mg/kg.

In 1997, the EHC commenced abatement activities in Boolaroo and Argenton homes, and public areas. Carpet dust lead concentrations ranged from 631mg/kg to 2328mg/kg with an average of 1669mg/kg in 13 houses situated from 225 metres to 1.1 kilometres from the smelter that were prioritised for the Individual Household Abatement program.

Airborne lead

The impacts of PCCS operations on airborne lead levels in the area surrounding the smelter are discussed in Chapter 3: Air emissions, and will not be discussed in depth here. Briefly, prior to 1985, minimal controls on the smelter to restrict emissions resulted in elevated, off-site airborne lead levels, which persisted for several years. Annual lead-in-air levels gradually decreased over time, most likely in response to improved emissions control technologies. Within 15 days of the closure of the smelter in 2003, the average daily airborne lead concentration dropped below the current national standard of 0.5µg/m^3.

Blood lead screening

The earliest known study into children's blood lead levels was undertaken in 1973 in the suburbs of Boolaroo and Argenton (Ouw & Bisby 1976). The study found that 86% of 204 children aged between 10 months and 14 years had a blood lead concentration equal to or in excess of 10µg/dL (Ouw & Bisby 1976). The percentage of children with blood lead levels greater than 20µg/dL and 35µg/dL were 17% and 2% respectively, and no blood lead exceeded 40µg/dL. At this time of the investigation, the acceptable blood lead level in the United States was 40µg/dL.

In 1991, the Hunter Public Health Unit initiated an investigation into child resident blood lead levels in the North Lake Macquarie area in response to a local parliamentary task force recommendation. This study was the first to recognise the concerning community-wide elevation of blood lead levels in the study area. At the time of publishing the study findings (Galvin et al. 1993), the NHMRC had set a national blood lead goal of less than 10µg/dL (NHMRC 1993).

Recruitment for the 1991 study included a door-knock survey of 1000 homes in the suburbs of Boolaroo and Argenton, as well as an invitation to parents of children attending, or eligible to attend, a local primary school. The study focused on two populations, categorised by age:

- children one to four years living within 2 kilometres of the smelter
- a primary school-aged group attending two of the local schools in Boolaroo and Argenton.

Of the 124 children aged one to four years, 84% had a blood lead level equal to or greater than 10µg/dL and 6% equal to or greater than 25µg/dL. Among the children of primary school age, 68% had blood lead levels equal to or greater than 10µg/dL and 4% equal to or greater than 25µg/dL. A blood lead level of 25µg/dL had been considered a 'level of concern' since 1987 (NHMRC 1993).

From 1991 to 2006, blood lead testing was offered annually to all child residents under the age of 13 years, and more frequently to individuals with blood lead level above the former NHMRC goal of 10µg/dL. In 2000, a monthly clinic was established at the EHC in Boolaroo to

provide free blood lead testing to volunteer residents. From 2001, the EHC shifted its focus from community-wide screening of all children to targeting children under five years of age; children in this age group engage in more frequent hand-to-mouth activity, and are more susceptible to the adverse developmental effects of lead. Pregnant women were also encouraged to have a blood test, due to the risk of lead crossing the placenta during pregnancy or being absorbed after birth.

The blood lead concentration data recorded between June 1991 and June 2006 shows an overall decreasing trend in the percentage of children in both age categories with blood lead levels greater than or equal to the then current NHMRC guideline of 10µg/dL (Figures 12 and 13). Of particular note in Figure 12 is the steep decreasing trend in blood lead levels after the smelter permanently closed in 2003. Annual blood lead monitoring continued for two years following closure of the smelter during 2004–05 and 2005–06. Details regarding the methods for recruitment, blood collection, blood lead determination, and statistical analysis of the 2004–05 program have been described in the report by Dalton and Bates (2005). Venous blood was collected and tested in the laboratory using the protocols established in the reference document AS 2636–1988 – *Sampling of venous and capillary blood for the determination of lead or cadmium concentration* (Standards Australia 1988).

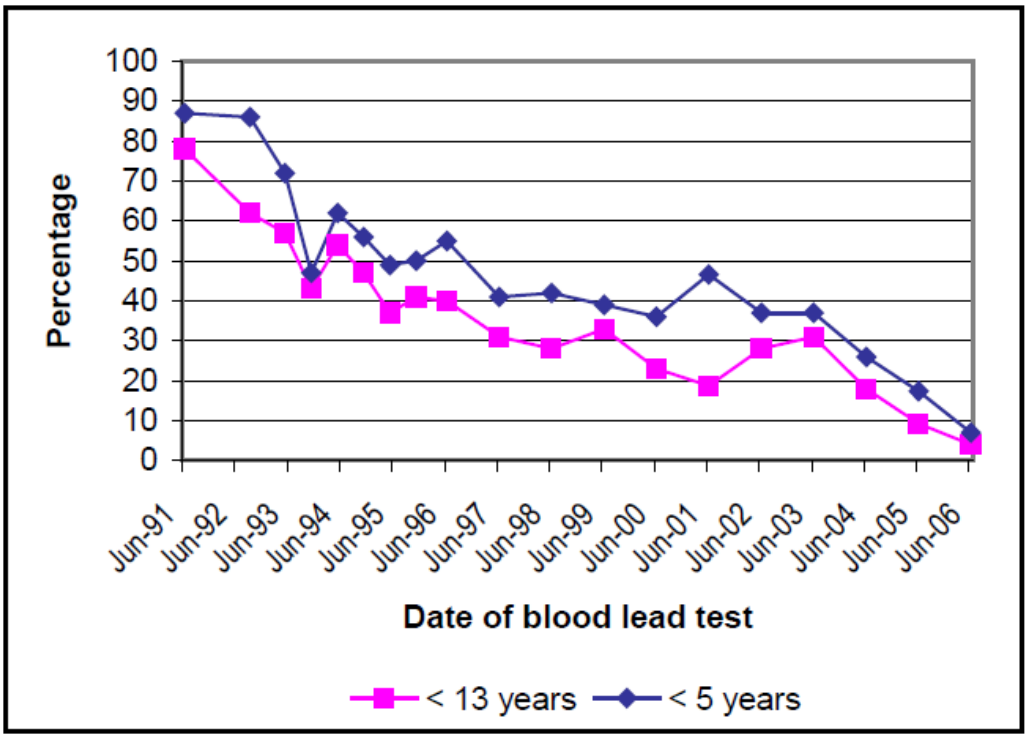

Figure 12: Percentage of blood lead levels greater than or equal to 10µg/dL of children <5 years and <13 years resident in North Lake Macquarie, NSW Australia, June 1991–June 2006

Image: Dalton 2016.

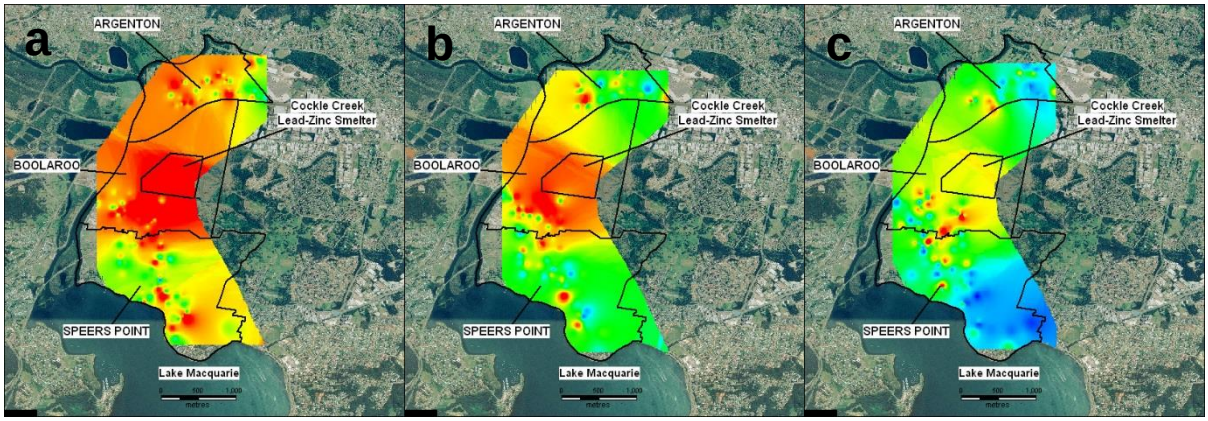

Figure 13: Interpolated blood lead levels of child residents in the suburbs surrounding the Cockle Creek lead–zinc smelter in (a) 1992, (b) 1996 and (c) 2002

Navy: blood lead level <5.5µg/dL, turquoise: 5.5 – <7.5µg/dL, green: 7.5 – <10µg/dL, yellow: 10 (the then current NHMRC national level of concern) – <15µg/dL, red: ≥15µg/dL. Images: Willmore et al. 2006.

The main limitation of the blood lead screening program conducted between 1991 and 2005 relates to the representativeness of children's blood lead levels in the study area. The voluntary nature of the blood lead testing program, and repeat testing of those children with elevated blood leads, were identified as factors influencing how reflective the children tested were of the broader target population (Dalton & Bates 2005).

Impact of smelter activities on children's blood lead levels

It is difficult to predict the impact of closure of a lead smelter on children's blood lead levels, as the relationship between these parameters is complex and there are few such events upon which to draw information. There exist, however, some convincing associations between PCCS emissions and children's blood lead levels.

It has been suggested that the overall decreasing trend in blood lead levels observed between 1991 and 2003 (i.e. pre-smelter closure) was due to a combination of factors, such as the introduction of the lead-in-air reduction strategy in 1995 and an increase in public awareness about lead safety, resulting in exposure-reducing behavioural change (Willmore et al. 2006). As discussed in Chapter 3: Air emissions, the gradual reduction in lead emissions arising from the smelter resulted in an overall decline in ambient air lead levels, and as shown in Figure 14, there is a close association between the levels of lead in ambient air and children's blood. There is also a close association between the peaks and troughs of these two parameters, indicating that smelting emissions were a significant source of lead exposure by local children.

Based on the weight of evidence described above, it was proposed that while the smelter was in operation, the principal source of lead for young children was fresh or recent smelter emissions (Dalton & Bates 2005). Following smelter closure, average blood lead levels in children under five years of age declined from 9.6µg/dL in 2003–04 to 4.5µg/dL in 2005–06. The proportion of children in this age category with a blood lead level greater than 10µg/dL also declined from 40% in 1997 to 26% in 2004, to 7% in 2006.

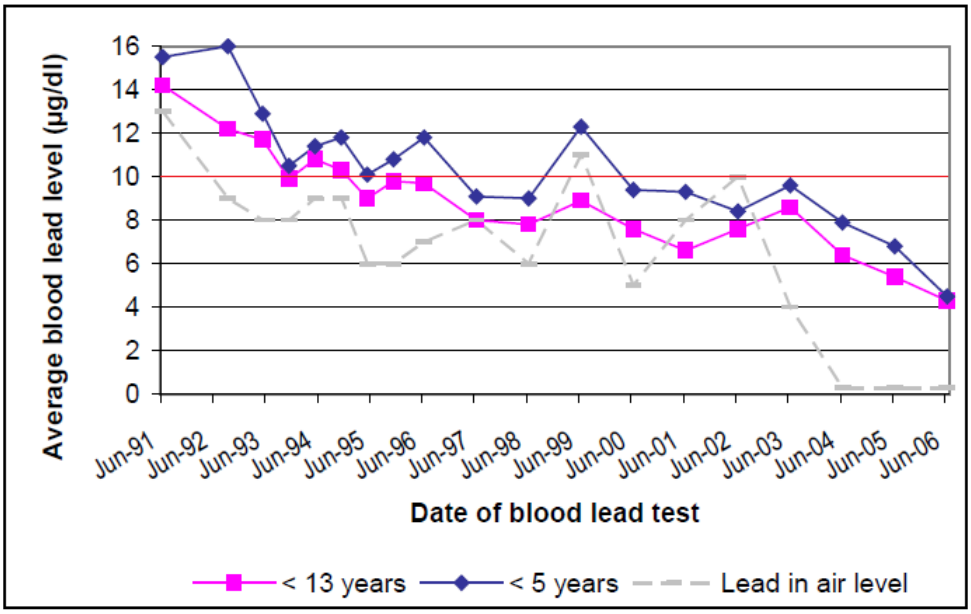

Figure 14: Lead-in-air levels and mean blood lead levels of children <5 years and <13 years resident in North Lake Macquarie, New South Wales Australia, June 1991–June 2006

Red line signifies the former NHMRC goal of 10µg/dL.
Image: Dalton 2016.

The most important finding of the 2005–06 blood lead analysis was a suppression of the typical peak in blood lead levels usually seen at two years of age (Figure 15). Although this peak was observed in 2002–03 and 2003–04 (and in prior analyses of data back to the early 1990s), it was not observed during 2004–05 or 2005–06. The smelter was still operating in the first three months of the 2003–04 blood monitoring year, but with the closure of the smelter on 12 September 2003, the 2004–05 period was the first full year of blood lead monitoring since active smelter emissions stopped. This finding highlights the importance of active smelter emissions in determining blood lead levels, particularly in children less than three years of age. Children's blood lead levels typically peak at around two years of age as their hand-to-mouth behaviour and susceptibility to lead absorption reaches a peak. This is also the key age during which accumulation of lead within the body may have a lifelong impact.

Finding 4

Active airborne emissions arising from the former Pasminco smelter directly contributed to childhood lead exposure in North Lake Macquarie, as demonstrated by blood lead screening results, while the smelter was in operation. Since the closure of the smelter the community is no longer at risk from active airborne emissions from the smelter.

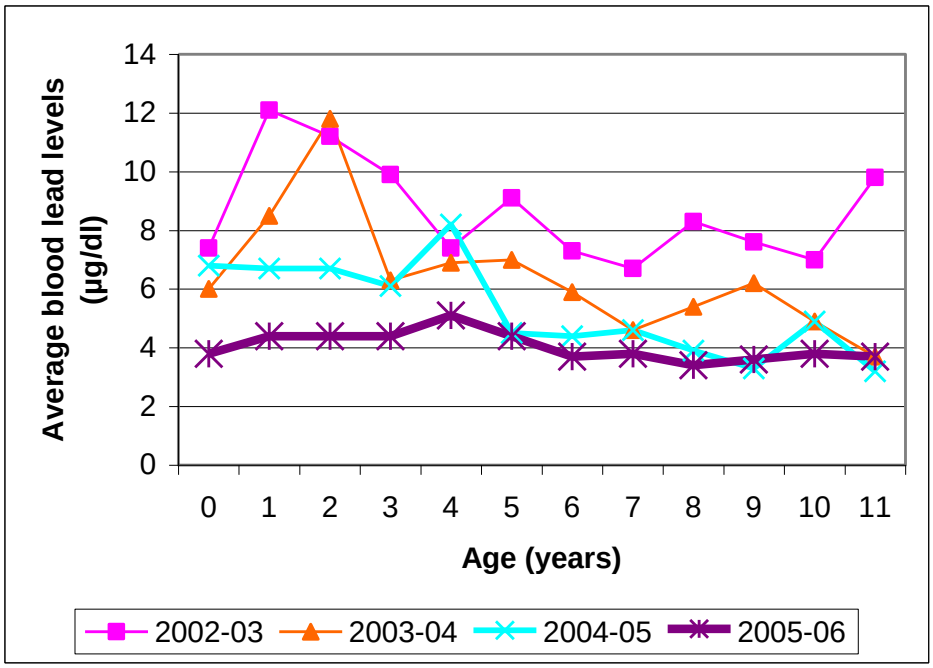

Figure 15: Average blood lead levels by age group of children <12 years from 2002–03 to 2005–06, resident in North Lake Macquarie, New South Wales, Australia, June 1991–June 2005

Image: Dalton 2016.

A discrete but complementary study undertaken to identify and distinguish between the different sources of lead in children resident in North Lake Macquarie (Gulson et al. 2004) supported the blood lead monitoring data. Lead isotopic analyses of household dust samples and children's deciduous teeth (data collected during 1998) were used to assign proportions to the potentially contributing lead sources (i.e. smelter emissions, gasoline and lead paint). The findings indicated that between 55 and 100% of lead in children's teeth could be attributed to smelter emissions.

Chapter 8: Recent events and publicity

The purpose of this chapter is to highlight the volume and nature of media attention that was generated in relation to lead contamination in North Lake Macquarie, particularly since November 2014 when a special investigation, 'Toxic Truth', was launched by the *Newcastle Herald.* The media articles released during this campaign were an important driver of increased public interest and concern within the local community. This chapter describes the sequence of media events leading up to the formation of the Lead Expert Working Group. **The Lead Expert Working Group does not endorse the content of the media items listed in this chapter, nor propose that the content is relevant to the Working Group findings and recommendations.**

The Pasminco smelting site has been the subject of some media attention since it ceased operations in 2003, but the site and its contamination legacy was brought into the foreground of the local and then wider news cycle in November 2014, when the *Newcastle Herald* launched its special investigation: 'Toxic Truth'.

Since then, the Toxic Truth stories have formed the spine of reporting on the Pasminco lead legacy with local news outlets also publishing related stories, and with contextually relevant news – like the change to acceptable lead level regulation and studies linking lead exposure to violent behaviour – prompting more metropolitan and national media attention.

The first instalment of Toxic Truth was a 17-page Saturday newspaper special. It was based on several key elements:

- A CSIRO report from June 1992 reported that black slag was leaching into the local environment and could be absorbed by humans. According to the *Newcastle Herald* article, the report was not made public at the time, and Pasminco continued to give away slag
- Journalists involved in the Toxic Truth investigation suggested there were limitations in the existing lead abatement strategy following the closure of the Pasminco smelter, particularly in regard to the prevalence of black slag.
- The *Newcastle Herald* sent a freedom of information request to Lake Macquarie City Council. The 2012 document cited the council as referring the black slag problem to the EPA in 1994, but the issue remaining in LMCC's hands.
- Tests were conducted by Professor Mark Taylor and his team at Macquarie University. Funded by the *Newcastle Herald*, this team collected 130 soil and vacuum cleaner dust samples from three suburbs that are home to more than 5500 people. The joint study – and the ensuing 39-page report – found that slag was present in a bioavailable form in the area and pointed to insufficiencies in the Boolaroo Lead Abatement Strategy.

The Toxic Truth feature launched with an associated website which included video interviews with affected residents, historic photo galleries and an interactive map which detailed findings about the 130 soil and vacuum cleaner dust samples taken across three suburbs.

An ABC *Lateline* episode also aired on 21 November 2014, coinciding with the launch of the Toxic Truth series.

Articles under the Toxic Truth banner continued into mid 2015, looking at the effects of lead on health and behaviour, updates on the establishment and work of the Lead Expert Working Group, news of LMCC's remediation works, and interviews with local community groups including the Boolaroo Action Group.

Local Hunter region radio, NBN and Prime television news, and then national ABC radio and television (including a *Lateline* feature on 11 November 2014) followed up on the story, focusing on the health effects of lead and, more specifically, slag. While the *Newcastle Herald* progressed the Toxic Truth banner to the emerging and local Williamtown contamination story, national media continued to report on contextually relevant news, namely the existence of other lead-affected areas in Australia – like Broken Hill – and wider lead-related issues including the lowering of the acceptable lead level to 5µg/dL and reports linking lead exposure in children to higher levels of aggression in adult life. ABC's *Catalyst* focused on this link intensely in its 1 December 2015 program, 'Lead Astray'.

Blood lead levels

Local blood tests

Date	Article title	Publication/series
19 May 2015	Faster lead-blood level tests soon available	*Newcastle Herald* Toxic Truth
28 June 2015	Free blood-lead tests for children offered with $20 gift voucher	*Newcastle Herald* Toxic Truth
21 July 2015	Blood-lead test results please Boolaroo Action Group	*Newcastle Herald* Toxic Truth

High lead levels linked to violence

Date	Article title	Publication/series
26 November 2014	High correlation between children exposed to lead and violent crimes	*Newcastle Herald* Toxic Truth
1 December 2015	Lead Astray	ABC *Catalyst* program
17 February 2016	Higher lead levels linked to violent crime	*The Australian* (via AAP)
17 February 2016	Study links childhood lead exposure to violent crime	*NBN News*
17 February 2016	Australian study finds higher lead levels are linked to violent crime	*news.com.au*

Date	Article title	Publication/series
18 February 2016	Boolaroo residents concerned by lead behaviour study showing exposed children more likely to commit violent crimes	*ABC News* online

New lead threshold

Date	Article title	Publication/series
19 May 2015	Health regulator halves lead exposure threshold	*Newcastle Herald* Toxic Truth
19 May 2015	The verdict's in: we must better protect kids from toxic lead exposure	*The Conversation*
20 May 2015	Call for child lead exposure levels to be halved amid concerns about behaviour, IQ	*The Sydney Morning Herald*

In May 2015, the NHMRC announced new guidelines under which action must be taken if a person records a blood lead level greater than 5µg/dL, aligning Australian levels with those of the United States, Canada and Germany. This news was picked up by the *Newcastle Herald*, *The Australian*, *The Sydney Morning Herald* and *The Conversation* (an online academic/journalistic website).

Articles pointing to studies linking lead exposure to violent behaviour were published as part of the Toxic Truth campaign and formed the foundation of the *Catalyst* program 'Lead Astray'. In early 2016, the release of the Macquarie University paper 'The relationship between atmospheric lead emissions and aggressive crime: an ecological study' (Taylor et al. 2016), prompted further articles across local and metropolitan news on the subject of lead exposure. In the study, researchers analysed air lead concentration in six NSW suburbs including Boolaroo at Lake Macquarie and Port Kembla, as well as Lane Cove, Rozelle, Earlwood and Rydalmere in Sydney. The study, published in the journal *Environmental Health*, found environmental lead exposure during childhood was the strongest predictor of assault rates later in life.

'When comparing results between suburbs in New South Wales we found that for every additional microgram of lead in the air, assault rates 21 years later rose by 163 assaults per 100,000 persons,' said one of the authors, Professor Mark Taylor. The authors noted however, that the study was one of association, not causation.

Lead testing and methodology

Date	Article title	Publication/series
21 November 2014	High volume heavy metal	*Newcastle Herald* Toxic Truth
22 November 2014	Testing methodology and quality assurance report	*Newcastle Herald* Toxic Truth
20 March 2015	Pollution test results will be made public	*Newcastle Herald* Toxic Truth

In conjunction with the launch of its Toxic Truth series, the *Newcastle Herald* published a series of articles describing the methodology and quality assurances of the joint study it had commissioned with Macquarie University.

Community response and working groups

Date	Article title	Publication/series
27 February 2014	Public meeting about Boolaroo roundabout	*Newcastle Herald*
23 November 2014	Residents treated like 'second class citizens' after Pasminco closure	*Newcastle Herald* Toxic Truth
12 December 2014	Opinion: Boolaroo – the Town I call home	*Newcastle Herald*
17 December 2014	Boolaroo expert group holds first lead review meeting	*Newcastle Herald* Toxic Truth
18 December 2014	Boolaroo Action Group seeks community rep on panel	*Newcastle Herald* Toxic Truth
10 February 2015	Lead pollution the focus of public meeting	*Lakes Mail*
26 February 2015	Public meeting hears failed lead clean-up didn't meet world's best practice	*ABC News* online
1 May 2015	Lead pollution group to work with community	*Newcastle Herald* Toxic Truth
2 February 2016	Lake Macquarie community 'left in the dark' over lead contamination meetings	*ABC News* online
11 April 2016	Lake Macquarie locals on Pasminco lead smelter contamination claim discrimination	*ABC News* online

Articles gauging community response covered various sentiments, including residents' health concerns, calls for transparency and participation on working groups.

Criticism of the lead contamination grid was also reported, with claims that hundreds more properties across Warners Bay, Macquarie Hills, Booragul, Teralba, Edgeworth, Cardiff and Glendale should have been included in the LAS – claims supported by the Macquarie University test results.

Despite the criticism of the grid and concern for ongoing health consequences, an alternative perspective regarding the 'discrimination' and 'stigma' suffered by Boolaroo residents was also present. Articles in the *Newcastle Herald* and *ABC News* online pointed out that some Boolaroo residents wanted to 'end the stigma hanging over their area' to be able to continue their lives without the spotlight being turned to their suburb and linking their homes to lead contamination. This perspective connected to residents' desire for property prices to be allowed to flourish without the impinging factor of lead news, and the new subdivision and associated setting-up of businesses be allowed to progress smoothly.

Lead abatement strategy and ongoing remediation

LAS

Date	Article title	Publication/series
6 October 2014	Australian community at risk of lead poisoning	*Reportage online*
21 November 2014	Opinion: Boolaroo clean-up a failure	*Newcastle Herald*
21 November 2014	University study finds high levels of lead, heavy metals in NSW towns	ABC *Lateline*
23 November 2014	Pasminco clean-up complete	*Newcastle Herald*
24 November 2014	MP calls for review into 'failed' smelter clean-up	*Newcastle Herald* Toxic Truth
24 November 2014	Grid's net not cast widely enough: study	*Newcastle Herald* Toxic Truth
25 November 2014	Conroy calls for EPA assurance Boolaroo safe	*Newcastle Herald* Toxic Truth
30 November 2014	Waiver deal could face legal challenge	*Newcastle Herald* Toxic Truth
2 December 2014	'Cap and cover' failed to protect	*Newcastle Herald* Toxic Truth

Remediation works

Date	Article title	Publication/series
28 November 2014	Evidence of leaching 'confirms' suspicions	*Newcastle Herald* Toxic Truth
30 November 2014	Goodwill sought in land clean-up	*Newcastle Herald* Toxic Truth
2 March 2015	Time frame to clean up lead left by Pasminco outrages residents in Boolaroo, Speers Point, Argenton	*Newcastle and Lake Macquarie Star*
21 June 2015	Exposed – Black slag on lake shore uncovered by storm	*Newcastle Herald* Toxic Truth
6 August 2015	Containment cell proposed	*Newcastle Herald* Toxic Truth
21 November 2014	Taxpayers to pay for clean-up	*Newcastle Herald* Toxic Truth
24 December 2015	Pasminco fined over Cockle Creek zinc breaches	*ABC News* online

Bunker Hill comparison

Date	Article title	Publication/series
25 November 2014	Pollution remains despite 'remediation site' label	*Newcastle Herald* Toxic Truth
11 December 2014	Pasminco remediation criticised: US best practice example	*Newcastle Herald* Toxic Truth

Limitations of the lead abatement strategy were pointed out by the *Newcastle Herald's* Toxic Truth series, with major concerns surrounding black slag exposures and the risk of leaching, the sufficiency of contaminated soil removal programs, and the issue of garden beds and household dust. A poll, run by the *Newcastle Herald*, found 86% of respondents in favour of the NSW Government reviewing the lead abatement strategy at Boolaroo and surrounds.

The clean-up program in Esperance, Western Australia, was held up as a 'world's best practice' example to which Boolaroo was not comparable.

The clean-up of the Bunker Hill community, a former smelter site in Idaho, United States, was also compared to that for the Boolaroo smelter site. Professor Mark Taylor described the funding, clean-up, and mining-company-pays model of Bunker Hill as a 'world's best-practice approach' to cleaning up pollution.

Looking forward

Boolaroo redevelopment

Date	Article title	Publication/series
13 September 2013	10 years since Pasminco smelter closure	*ABC News* online
11 September 2015	Boolaroo a real estate darling	*Newcastle Herald*

Future fund

Date	Article title	Publication/series
21 November 2014	Residents want profits for clean-up	*Newcastle Herald* Toxic Truth
6 August 2015	Fund needed to handle lead contamination – Greg Piper MP	*Newcastle Herald* Toxic Truth
31 January 2016	Greg Piper wants a future fund for Pasminco pollution – poll	*Newcastle Herald*

The theme redevelopment of the Boolaroo site – including the construction of the roundabout and the subdivision and sale of land – emerged alongside articles, opinion pieces and a poll pointing to the need to future-proof the former Pasminco site with long-term remediation programs – including maintaining the cap and cover in perpetuity – and a possible 'legacy fund'.

Independent Lake Macquarie Member of Parliament Greg Piper said work had to be done to future-proof the area and ensure costs did not fall on to community members.

'People should not be burdened with any costs associated with the contamination,' Mr Piper said.

'We need systems in place if a home is demolished or if someone comes along and puts in a pool or does other damage to the cap and cover barrier.'

'I believe there will need to be a trust fund set up and we need to decide who is going to administer it.'

A January 2016 poll run by the *Newcastle Herald* recorded 72% of respondents in favour of the establishment of a future fund for Boolaroo residents. In this article, EPA Hunter Region manager Adam Gilligan confirmed that call for a future fund would be considered in the LEWG report to government.

Chapter 9: Recent blood lead results

This chapter is a modified version of the Hunter New England Local Health District Blood Lead Screening in North Lake Macquarie, 2015 final report (available online; HNE Health 2015). It includes an additional section, which provides an examination of the study limitations, entitled 'Blood lead screening study considerations'. This addition was written in consultation with the Lead Expert Working Group members.

Summary

Following concerns being raised about residual lead contamination in the areas surrounding the Pasminco Cockle Creek Smelter, a blood lead screening clinic was conducted over three weeks in June and July 2015 for children under five years of age and pregnant women using the Lead Care II 'point of care' testing device. The previous screening program, conducted in 2005–06, found that 7% and 32% of children under five years of age had respective blood lead levels of ≥10 µg/dL and ≥ 5µg/dL, which confirmed a rapid decline in blood lead levels following the closure of the smelter in 2003. Seventy two children participated in the screening program in June and July 2015 and all blood lead levels were ≤5µg/dL with 88% below the Lead Care II's lowest level of detection of 3.3µg/dL. Eight pregnant women were tested and all had blood lead levels ≤5µg/dL.

The screening survey confirms the downward trend observed in 2005–06 and that the risk of children accumulating excess lead in the area has remained low since the closure of the smelter. Children's blood lead levels in the past were likely driven by fresh smelter emissions with high mobility and bioavailability.

Background

As discussed in Chapter 7*:* Previous studies and testing, the overall decline in children's blood lead levels observed between 1991 and 2006 was closely associated with decreases in ambient air lead concentrations. After the closure of the smelter in September 2003, the average blood lead levels in children less than five years of age steadily declined from 9.6µg/dL in 2003–04 to 6.8µg/dL in 2004–05 and to 4.5µg/dL in 2005–06. The proportion of children in this age category with lead levels ≥10µg/dL has also declined from 40% in 1997 to 26% in 2004, 17% in 2005 and 7% in 2006.

In November 2014, environmental science researchers from Macquarie University collected and had tested at the National Measurement Institute, North Ryde, Sydney, soil samples from both private and public land as well as dust samples from residential homes in the Boolaroo area. The data showed that the majority of soil samples analysed had lead concentrations greater than the NEPM Health Investigation Level (Harvey et al. 2015). There was intense media coverage of the issue and concern in the community. Despite the fact that previous reductions in blood lead levels suggested that soil levels were not driving blood lead levels in North Lake Macquarie (contrary to Willmore et al. 2006), it was prudent to respond to community concerns about the potential risk of residual lead in soils in the area by offering blood lead testing.

Promotion of the blood lead screening clinic

Between 29 June and 17 July 2015, Hunter New England Health invited residents of Boolaroo, Argenton and Speers Point to participate in a survey to assess blood lead levels in children aged six months to less than five years, and pregnant women. To promote the clinic and maximise access a range of strategies were used:

- multiple media releases and alerts resulting in local television stories
- extensive radio coverage across local commercial, community and public stations
- newspaper reports including in a free weekly newspaper delivered to all households in the area.

One week prior to commencement of the clinic, a letterbox drop (1700 letters) was made to all households and businesses in the main street of the target suburbs. Flyers were distributed to the local preschool, library, pharmacies, doctors' offices, local supermarket point of sale counters, and other businesses with high customer traffic. Medical practices were asked to hand the flyer to parents of children from the area and, in particular, identify any children with behavioural problems or pica that may predispose them to lead exposure.

A door-knocking campaign was conducted two weeks after the letterbox drop which focused on the streets that were closest to the smelter where children historically had the highest blood lead levels. Parents that were home were advised of the clinic and flyers were left where residents were not in attendance. The clinic was also promoted on a community administered *Lead Lowdown* Facebook page, Lake Macquarie City Council's website and in online posts by Lead Community Reference Group Chair and Independent Member of Parliament representing Lake Macquarie, Greg Piper.

The clinic was open on Mondays from 1pm until 7pm and each Tuesday to Friday from 9am until 1pm. Gift vouchers valued at $20 were provided by the Lead Community Reference Group, and funded by the EPA, as a token of appreciation for participation in blood lead screening.

Blood lead screening method

The machine used to test lead levels was the Lead Care II 'point-of-care' testing device. This device uses the capillary method which is less invasive than venous testing and can provide a result within three minutes. The Lead Care II can detect blood lead levels as low as 3.3µg/dL. Levels below 3.3µg/dL display as 'low'. The device was calibrated on a daily basis and with the opening of each new test kit as required under the manufacturer's instructions.

After receiving their test results, families and pregnant women were seen by an Environmental Health Officer who provided a standard fact sheet on lead and relevant advice on prevention of lead exposure.

Blood lead levels were entered into the patient record using CHIME (Community Health Information Management Enterprise) and analysed using Microsoft Excel.

Results

There were 72 children tested who were between six months and less than five years of age and resident in one of three above-mentioned suburbs. Seventeen were from Argenton, 18

were from Boolaroo and 37 were from Speers Point. Sixty-nine of the 72 children lived in the target area for at least the prior six months. None of the 72 children had a blood lead level above 5µg/dL (Table 8).

Table 8: Blood lead levels of children aged six months to less than five years in North Lake Macquarie, 29 June – 17 July 2015

Age	<3.3µg/dL	3.3 to ≤5µg/dL	>5µg/dL	Total
6 months – 11 months	9	2	0	11
1 year – 23 months	18	1	0	19
2 years – 35 months	10	1	0	11
3 years – 47 months	17	2	0	19
4 years – 59 months	9	3	0	12
Total	63 (88%)	9 (12%)	0	72 (100%)

In addition to the children reported in Table 8, 13 children aged six months to less than five years who resided outside the target suburbs were tested for a range of reasons including parental concern for children living in adjacent suburbs or a physical connection with one of the suburbs such as attending preschool or their parent's workplace. This group of children had a higher proportion of lead levels in the 3.3 to ≤5µg/dL (30.8%) compared with those residing in target suburbs (12.5%) (Table 9).

Table 9: Blood lead levels of children aged six months to less than five years comparing children from North Lake Macquarie to non-resident children attending the clinic, 29 June – 17 July 2015

Area	Blood lead level					
	<3.3µg/dL		3.3 to ≤5µg/dL		Total	
	n	%	n	%	n	%
North Lake Macquarie	63	87.5	9	12.5	72	100.0
Non-North Lake Macquarie	9	69.2	4	30.8	13	100.0
Total	72	84.7	13	15.3	85	100.0

A further breakdown of blood lead levels, age group and suburb can be found in Appendix A to this chapter. While the numbers are small, there is no suggestion of the typical peak in blood lead levels around two to three years of age seen in other settings and in North Lake Macquarie prior to the smelter closure (Figure 16).

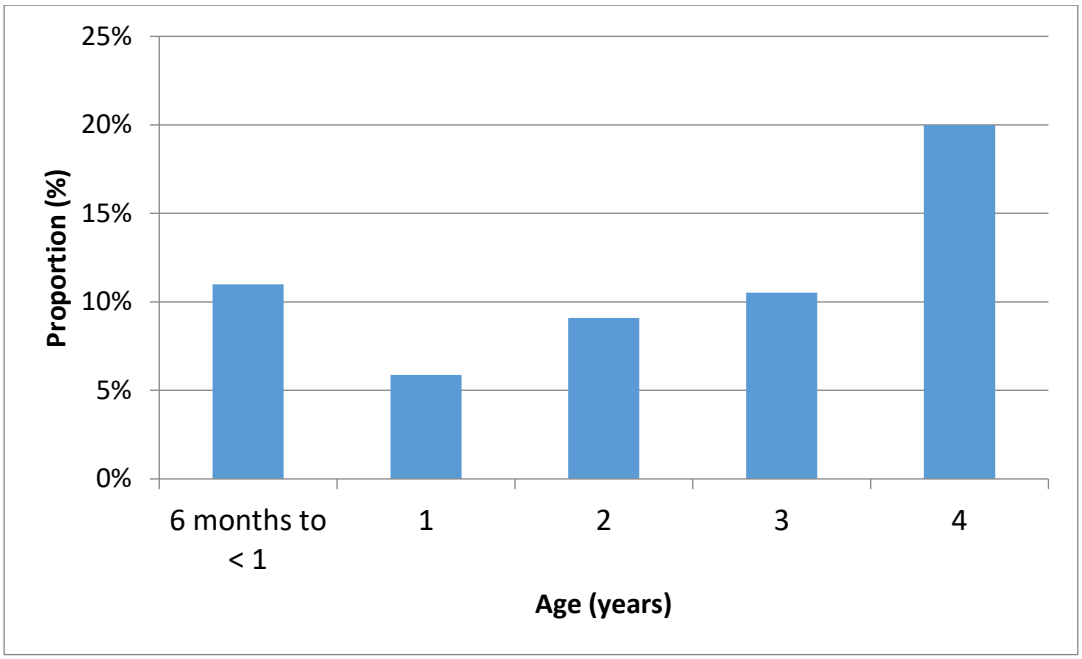

Figure 16: Proportion of children with blood lead levels between 3.3 and 5µg/dL by age group, North Lake Macquarie, 29 June – 17 July 2015

Image: Hunter New England Population Health.

A total of eight pregnant women attended the clinic. All were from the North Lake Macquarie area and all had a blood level ≤5µg/dL.

The estimated participation rate for children six months to less than five years of age in the June and July clinic was 22%. For the suburb of Boolaroo, which was historically most affected by lead smelter emissions, the estimated participation rate was 35% (Table 10).

Table 10: Proportion of all North Lake Macquarie children aged six months to less than five years of age tested, by suburb, June and July 2015

	Children tested aged six months to less than five years*	
Suburb	**n**	**%**
Argenton	17	23%
Boolaroo	18	35%
Speers Point	37	19%
Total	*72*	22%

*removing ½ of 0–1 year-olds from 2011 Census

Previous surveys targeted the same group of children aged under five years old and living in one of the three North Lake Macquarie suburbs. The recent sample size is comparable to past screening programs with 24% (69 of 289) of under five year-olds participating in screening over the entire 12-month period of the 2004–05 program and 45% (130 of 289) participating in the entire 12 months of screening including the July clinic in 2005–06. A mapping exercise (not published here for privacy reasons) showed that children who attended the blood lead screening service currently reside in what are known to be the areas

affected by lead-in-soil contamination historically and where, in 2002, children had experienced elevated blood lead levels (see Chapter 7: Previous studies and testing).

Discussion

It has been nine years since the last lead screening program in North Lake Macquarie. Previous blood lead screening reports were based on monthly clinics with a heavily promoted annual clinic in July each year.

This is the first cohort of children to be screened who have grown up in the area since the closure of the smelter in 2003. The results of this survey are reassuring, with no blood lead levels recorded above 5µg/dL. In May 2015, the NHMRC released its review on the effects of lead on human health. This review concluded that adverse health effects of lead in children can occur in blood lead levels greater than 10µg/dL, but the evidence is insufficient and unclear to determine whether health effects occur at levels greater than 5µg/dL but less than 10µg/dL.

The results of the survey confirm the previous downward trend of blood lead levels in young children. As the Lead Care II cannot detect levels below 3.3µg/dL and instead gives a reading of 'low', we were not able to calculate mean lead levels to compare to previous survey results. While the Lead Care II is not as accurate as clinical laboratory testing, it does have a high correlation with laboratory testing at a population level. The Lead Care II may be subject to falsely elevated readings if the specimen is contaminated with lead either through inadequate handwashing or by contact with lead at some point in the testing process. Two children who had initial results above 5µg/dL with the Lead Care II, returned levels between 3.3 and ≤5µg/dL on a repeat test after further handwashing. Two staff members that had initial blood lead levels between 3.3 and ≤5µg/dL returned levels below 3.3µg/dL on repeat testing (confirmed with laboratory testing of venous samples). If there is a systematic bias due to the use of the Lead Care II, it is likely that it overestimates blood lead levels due to sporadic contamination.

HNE Population Health has reminded local General Practitioners servicing the North Lake Macquarie area annually to continue to check blood lead levels of children less than five years of age with risk factors for lead exposure such as behavioural disorders, developmental delay, exposure to renovation, or pica. From 2009 to 2014, of 18 children tested by General Practitioners in the area only three returned a blood lead level between 5 and 9µg/dL, the remainder were ≤5µg/dL.

While these findings are reassuring, enhanced surveillance will continue. Paediatricians have been asked to maintain a low threshold for recommending testing and the antenatal service at John Hunter Hospital will offer blood lead testing to pregnant women from the North Lake Macquarie postcode of 2284. Point-of-care testing using the Lead Care II continued to be available at monthly clinics in Warners Bay until February 2016 for those who missed out on recent screening.

While factors other than fresh smelter emissions may have contributed to a decrease in lead exposure, the closure of the smelter resulted in a more than 80% reduction in the lead in air levels between 2002 and 2004 (North Lake Macquarie Environmental Health Centre 2004, unpublished data, see Figure 17). Reductions in lead exposure due to the phasing out of lead in paint from the 1970s and phasing out of lead in petrol from 1985 to 2002 are unlikely to have contributed significantly to the subsequent rapid decline in blood lead levels (or lead-in-air levels) following the closure of the smelter in September 2003 (see Figure 17). A

similar reduction in blood lead levels occurred among children aged 6 to 60 months living in Trail, Canada, when the lead smelter was replaced with a lower emission smelter technology decreasing the average lead in air from 1.1µg/m^3 in 1996 compared with 0.28µg/m^3 in 1997 (Hilts 2003). Blood leads in Trail halved over three years without any change or enhancement to remediation programs.

Reductions of approximately 50% were observed in lead loadings and concentrations in outdoor dustfall, street dust and indoor dustfall after smelter emissions were reduced in Trail, Canada (Hilts 2003). Slight reductions were observed in carpet dust and soil lead concentrations. The authors noted these finding challenged prevailing theories about the contribution of soil lead levels and concluded that increased attention should be paid to the importance of active sources of highly bioavailable and mobile lead-bearing dusts. This finding parallels the reduction in average blood lead levels in the United States associated with the reduction in lead-in-air levels from phasing out of leaded gasoline without any significant remediation of historically contaminated soils (Pirkle et al. 1994).

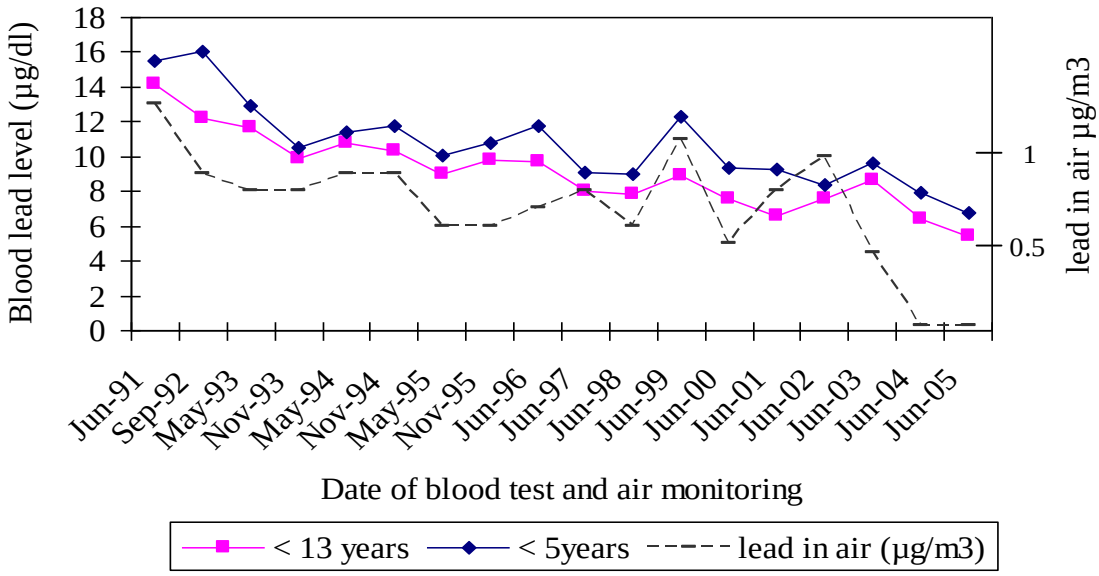

Figure 17: Blood lead levels of children less than five years and less than 13 years and lead-in-air levels, North Lake Macquarie, 1991–2006

Image: Hunter New England Population Health.

Lead remediation in the North Lake Macquarie area has been limited since the closure of the smelter. Residential soil assessment for the LAS that followed the closure of the smelter was offered to 1969 eligible properties in the area. Of those, 1238 accepted the offer of testing and after exclusions (vacant land, non-residential property, previously owned by Pasminco, owners retracting the offer) 1226 properties were sampled. Of those, abatement work was recommended for 437 properties and work was completed on 359 of those (after some owners withdrew from the strategy).

While there have been interventions such as the *Final Whistle* (a document containing personal narratives of local people living with lead) and the *Lead Safe Blitz* (a video on lead safety) to remind the community of lead control interventions, informal discussions with parents at the clinic did not indicate that parents were applying the often extensive lead control activities practised while the smelter was in operation. Therefore, it is unlikely the decrease in blood lead levels can be explained by behavioural modification.

The recent results are reassuring and confirm the downward trend of blood lead levels in young children. However, it is important that parents and pregnant women are aware of other potential sources of lead including pre-1970 paint, which may pose a risk, particularly during home renovations.

Blood lead screening study considerations

The LEWG accepts the findings of the *Blood Lead Screening in North Lake Macquarie, 2015* report. When viewed in combination with previous blood lead studies prior to the smelter closure and cessation of lead emissions from the smelter, the results of the current blood lead screening study provide a good indication that the risk of children accumulating excess lead in North Lake Macquarie has remained low.

However, there are potential limitations worthy of consideration:

- Participation rate – there was a participation rate of only 22% among children less than five years old. Consequently, it is not possible to determine if those sampled are truly representative of the overall population.
- Self selection – the study group was self-selected and this may have resulted in bias. This bias could have arisen because parents who participated in the program were more concerned and more vigilant about lead exposure.
- Survey conducted in winter – because blood lead levels can have a seasonal peak in summer in some settings, there is a concern that conducting the survey in June and July may have underestimated the average blood lead level of the children. The seasonality effect on blood lead levels has been identified in a recent systematic review on the colder-to-warmer changes in children's blood lead concentrations (Ngueta, Gonthier & Levallois 2015). The increase in children's blood lead concentrations during warmer months was found to be most important for children with blood lead levels <10µg/dL during the colder months, and has been attributed to the combined effect of two factors: (i) the increased exposure due to soil and dust mobilisation, and (ii) changes in gastrointestinal lead absorption rates due to increased sunlight-induced vitamin D synthesis. Ngueta, Gonthier and Levallois (2015) estimated a 1.25-fold increase in summer blood lead levels in the range found in North Lake Macquarie. This is consistent with other studies, suggesting any underestimation due to seasonal effects would be less than or equal to 1µg/dL in this cohort.
- Use of finger-prick test – while the Lead Care II 'point-of-care' testing device is excellent for screening, it has a lower detection limit of 3.3µg/dL. Although the use of a finger-prick test is considered more acceptable to parents and children it can be impacted by residual lead on children's fingers. Attempts were made to thoroughly wash children's hands before the test, however, this may have been incomplete.

In light of the above limitations and considerations, there may have been a small underestimation of blood lead levels due to summer-related effects, however, equally there could have been an overestimation of the blood lead levels. Nevertheless, on balance it is unlikely that the general population of children in North Lake Macquarie have excessive lead exposure as defined by the 2015 NHMRC statement on lead. Again, we are missing the ability to estimate the average population blood lead level by virtue of the finger-prick test – this needs noting as does the objective of the blood lead level study: to determine whether

children were subject to excessive lead exposure (i.e. >5µg/dL), not to calculate an average blood lead value.

The LEWG recommends there is a forward strategy to quantify and address any residual risk in the community from the legacy contamination associated with the former smelter operations. Additionally, while the survey provides an indication of average exposures across the community, it will be important to identify and protect against rare, high-risk exposures (such as mobilising ceiling dust in a house with children) that could place children at heightened risk. Additionally, children with developmental risk factors should be screened to ensure they are not accumulating excess lead. Such an approach aligns with the precautionary principle and the need to ensure there is intergenerational equity in environmental and human health outcomes as detailed in the following Acts the EPA administers: s.9 of the NSW Contaminated Land Management Act and s.6(2) of the NSW *Protection of the Environment Administration Act 1991*. A future research program should aim to assess residual risk, and understand the environmental lead exposure of those children shown not to be accumulating excess lead in North Lake Macquarie.

Finding 5

Results from the Hunter New England Health blood lead screening program conducted in 2015 established that lead uptake by vulnerable populations within North Lake Macquarie (i.e. children aged less than five years and pregnant women) does not require further investigation as all blood lead levels were less than the recently revised NHMRC blood notification criteria of 5µg/dL. Although these results indicate that exposure to lead is not a current health concern in North Lake Macquarie, there is a requirement for ongoing surveillance to enable early detection and rapid characterisation of any blood lead notifications if they occur.

Chapter 9 Appendix A

Table 11: Blood lead levels of children aged six months to less than five years, by age, blood lead level and suburb in North Lake Macquarie, 29 June – 17 July 2015

	Blood lead levels			
Age (years)	<3.3µg/dL	3.3 to ≤5µg/dL	>5µg/dL	Total
Suburb				
Argenton				
6 months to <1	2	0	0	2
1	5	1	0	6
2	0	1	0	1
3	5	0	0	5
4	2	1	0	3
Total	14	3	0	17
Boolaroo				
6 months to <1	1	0	0	1
1	4	0	0	4
2	3	0	0	3
3	5	2	0	7
4	3	0	0	3
Total	16	2	0	18
Speers Point				
6 months to <1	6	2	0	8
1	9	0	0	9
2	7	0	0	7
3	7	0	0	7
4	4	2	0	6
Total	33	4	0	37
Total	**63**	**9**	**0**	**72**

Chapter 10: Literature review: fit-for-purpose comparison

In April 2016, the EPA sought the services of a consultant to undertake a literature review and prepare a report on practices to manage lead and lead slag in soil and associated human exposure. The literature review was prepared for the EPA to inform the deliberations of the LEWG, and is provided at Attachment D. Specifically, the objective of the consultancy was to review literature relevant to programs aimed at reducing human exposure to lead and to report on the following key areas:

- the success of the programs and consideration of 'best practice'
- how the success or otherwise of the programs was evaluated or measured
- the cost of the programs and indicative costs associated with management practices and strategies identified
- where exposure control was used, the methods used and their effectiveness
- where relevant, definitions and references for the meanings of 'bioaccessibility', 'bioavailability' and 'bioaccumulation' for consistency in reporting.

Review of UniQuest report recommendations

The literature review proposed a total of 17 recommendations to address a wide range of issues associated with lead contamination. In September 2016, the LEWG participated in a workshop aimed at responding to each recommendation by addressing the following questions:

- Is the recommendation of a high, medium or low priority?
- Has the recommendation been actioned already?
- Does the recommendation align with the LEWG recommendations?
- Is the recommendation relevant to the North Lake Macquarie context?

LEWG response to the literature review recommendations

This section lists each of the literature review recommendations as they appear in the literature review report (Attachment D). The references cited in the literature review recommendations can be found in Attachment D.

Literature review recommendation 1

To ensure the lead abatement measures are maintained, it is strongly recommended that LMCC be involved with the recording of the requirement for ongoing management of Nominated Properties where lead abatement measures have been implemented.

LEWG response: The LEWG considered this to be a high priority recommendation that is currently addressed by LMCC. Council maintains a property database that records the

current contamination status of land parcels throughout the city, where known. *Council Policy – Managing Contaminated or Potentially Contaminated Land in Lake Macquarie* (LMCC 2016) requires the application of notations as a component of s.149 planning certificates. These notations notify restrictions on development of land use and advise readers to contact council for further information about the contamination status of land.

Literature review recommendation 2

If not already occurring, LMCC should consider the requirement for a permanent physical barrier to indicate the separation of clean and contaminated materials as part of an institutional controls program (ICP[15]).

LEWG response: The LEWG considered this recommendation to be of high priority and acknowledged that the installment of a permanent physical barrier to separate clean and residual contaminated materials was not an objective of the LAS. The LEWG agreed that permanent physical barriers were relevant in North Lake Macquarie and their application would be considered on a case-by-case basis.

Literature review recommendation 3

The remediation of all properties surrounding the smelter site is not yet complete. The responsibility to monitor and manage this appears to have been devolved to property owners under LMCC development and planning controls. Completion of remediation within the LAS area was not validated for soil contamination. Further examination is needed to understand if the works undertaken and institutional controls provide sufficient protection.

LEWG response: The LEWG considered this recommendation to be of low to medium priority, primarily due to the encouraging results of the recent blood lead screening program which indicated that the risk of excessive lead accumulation in young children remains low since the closure of the smelter. However, the LEWG acknowledged that in order that the current protection measures are maintained in the long term due to the fact that the hazard remains in the environment, a range of institutional controls would be appropriate. This recommendation closely aligns with LEWG Recommendation 18 and may be implemented through additional funding.

Literature review recommendation 4

Institutional controls appear to be currently separated into different policy documents of LMCC. It would be valuable if the ICP existed in its own right as a point of orientation or ‘road map’ to all relevant controls. In so doing, a review should be undertaken which identifies any controls which are currently absent but may be needed, based on learnings from leading practice lead clean-up programs elsewhere. The ICP by LMCC, with the endorsement of the EPA and NSW Health, will need to ensure those aspects within and excluded from the LAS are addressed, as well as:

a. unsealed roads and road shoulders and railway easements

b. flood impacts which could mobilise or expose contaminated materials

[15] An institutional controls program (ICP) describes non-engineered measures such as administrative and legal controls to help minimise the potential for human exposure to known environmental contaminants and/or protect the integrity of a remedial measure.

c. controls over soil and rock removal from the base of hill slopes which could initiate instability. Also the requirement for construction of walls at the base of slopes as part of remediation to avoid sloughing into residential yards, re-exposing contaminated soils

d. site selection and development of a containment structure for future slag recovered through remediation (and other lead-contaminated materials) that can demonstrate, based on leaching property studies, retention of seepage from slag that might enter ground and surface waters

e. management of lead-contaminated groundwater from interactions with surface water and soils in the vicinity of the former PCCS and interaction with Cockle Creek and Cockle Bay to minimise any effects on the aquatic ecosystem of Lake Macquarie. It should be determined if some aspects of this may be the responsibility of Ferrier Hodgson as part of post-remediation monitoring and maintenance.

f. Contaminated sediments in Cockle Creek and North Lake Macquarie require further assessment.

g. Specific ICP for long term management of the PCCS site, including monitoring that is updated, needs to take account of the current practices set out by enHealth (2012) and the NEPC (2013) for contaminated soil.

h. Should monitoring reveal there is any worsening of the levels of human exposure to lead in specific locations in the future, which cannot be easily remediated, consider some areas currently zoned residential, to be rezoned for a lower risk land use, based on the accepted health risk assessment approach as described above.

i. All recommendations from earlier studies, if not captured already, should be summarised in an overarching document (or web-page). The purpose of this step is intended to bring together all NLM lead contamination knowledge and study recommendations as well as how those recommendations have been implemented. If not implemented, then it should be stated why not. This would enable a proactive and risk-based approach to long term management of lead in NLM. High risk areas and issues could be identified through this process. Lead contamination is a long term issue so systems and personnel need to be focussed on management in the long term. This report identifies some of these risks, but perhaps not all. (During the review it was not easy to find the direct association between recommendations made in specific reports and LMCC policy updates. This does not imply they actions haven't occurred. For example, Douglas Partners' (2010) recommendations on black slag cannot be directly traced to an action plan). With any long life program, recommendations from earlier studies can be lost unless there is a strategic and continuous focus on knowledge management;

j. Good quality spatial data management to enable the superimposition of a range of datasets on the NLMA to inform lead risk management (e.g. Flood levels, acid sulfate soils, and soil lead concentrations).

k. Funding of the ongoing ICP as overseas studies noted that local rates and state taxes may not be enough. The ICP needs to be fully costed in order to evaluate resourcing requirements in the long term. Most programs identified there was no clear end point. A team of people with an appropriate skills set, whose responsibilities are solely focussed on the ICP is likely to be required. A legacy fund in some form is required to sustain the ICP.

LEWG response: The LEWG considered that consolidating contaminated land management documentation is a low priority. However, the issues raised in the list are currently captured

under a number of different procedures, controls and guidelines administered by LMCC, and are therefore considered to be adequately addressed via these documents. However, the LEWG acknowledged there is a need to develop a cross-reference matrix that shows which guiding documents refer to lead contamination. This document would constitute the point of orientation or 'road map' to all relevant controls. While this has not yet been undertaken, the requirement for a single point of contact for lead contamination issues has been addressed in varying degrees in LEWG recommendations 2, 13, 18 and 21. Development of the cross-reference matrix is appropriate for the North Lake Macquarie context and will be implemented in conjunction with other processes aimed at streamlining lead contamination management.

Literature review recommendation 5

High rainfall and flooding related remobilisation risks need to be evaluated to ensure control measures are put in place in high risk areas of the lower Cockle Creek Catchment, Cockle Bay and North Lake Macquarie aquatic ecosystems.

LEWG response: While the LEWG considered this to be of low priority, the issue of water quality has been addressed in LEWG recommendations 8, 9 and 10. In addition, LEWG recommendation 18(1) proposes that LMCC expands mapping of known contamination and remediation subject to funding from the NSW Government. LMCC should also identify flood remobilisation of contaminated soil as a potentially re-contaminating activity within its development assessment and contaminated land management processes.

Literature review recommendation 6

Further studies are required to investigate the pathways through the food chain to humans (via fish and shellfish), that may be current health risks, and also to study if bioaccumulation is a potential health risk to local people gathering local aquatic species as food sources.

LEWG response: The LEWG considered this to be of low priority. This determination was primarily in response to results of a report conducted in the 1990s indicating that lead concentrations observed in aquatic biota did not pose an unacceptable health risk to consumers of local seafood (Hunter Public Health Unit 1997). However, the LEWG accepted that over time there may have been some remobilisation and transport of lead in the sediments of Cockle Creek and the northern end of Lake Macquarie. Therefore, the EPA should reinvestigate the impacts of lead contamination on aquatic biota, particularly edible fish and crustaceans and, if applicable, incorporate the findings into either the EPA's or LMCC's risk management framework.

Literature review recommendation 7

The *Winding Creek and Lower Cockle Creek Floodplain Risk Management and Plan* (WMA Water 2016; final draft, April 2016) should inform an environmental health study to evaluate the risk of lead recontamination. This should address remobilisation locations on the floodplain, banks and bed as well as Cockle Bay sediments and foreshore areas with the aim of quantifying risks for recontamination and applying control measures.

LEWG response: The LEWG considered this to be of medium priority and agreed that it could be addressed through multi-layer mapping that allows for the visualisation of contaminated sites and high-risk flood-prone areas.

Literature review recommendation 8

Collating all existing data and knowledge on the lead contaminated zone of Cockle Creek Catchment, Cockle Bay and North Lake Macquarie is an imperative. An Environmental Management Plan is required for Cockle Creek and Cockle Bay to integrate all knowledge on the status of contamination and risks of recontamination. From this process, knowledge gaps can be more clearly identified. A systematic program of investigation is then required to address knowledge gaps as part of the risk assessment process. This would need to consider all possible lead pathways and human interactions with the river, lake, bed and banks which could remobilise contaminated sediments in order to evaluate human health risks. Then, a management strategy for these contaminated materials can be developed which will highlight areas that need to follow on. It is not clear if these areas are included in the LMCC Environmental Management Plan (EMP). Engagement with relevant stakeholders needs to occur as a matter of course and control measures applied.

LEWG response: The lead-contaminated zone of Cockle Creek and Cockle Bay sediments are subject to a remediation order under the Contaminated Land Management Act. The LEWG recognises a requirement for the EPA to review this order to determine whether there has been any disturbance to the sediments or remobilisation of lead and other heavy metals from the sediments.

Literature review recommendation 9

Ensuring the maintenance of a centralised Blood Lead Level database by the NSW Health Department is considered necessary so that if future BLL screening requires the relevant historic data, the data can be available and made reference to, when new data are gathered. Planning for future BLL screening to ensure recontamination is not impacting human health is recommended, including in summer instead of winter. The application of BLL measurement was adopted for the Pasminco Boolaroo site before the availability of the accepted enHealth (2012) Australian health risk assessment methodology was in place. Currently BLL is assessed as the exposure step of the enHealth (2012) health risk assessment framework only. However, the hazard identification step considering contamination levels and dose of the health risk assessment framework for the remediated Pasminco smelter site that brings exposure assessment (BLL measurement) together is incomplete. Thus the risk assessment for the remediated Pasminco smelter site, according to current land management practice is not complete.

LEWG response: The LEWG recognises the centralised database of blood lead notifications is important for monitoring blood lead levels, however, the other recommendations are not endorsed. The LEWG understands that confirmed cases of elevated blood lead levels (i.e. a person with a venous blood lead level of ≥5µg/dL) are entered into the NSW Notifiable Conditions Information Management System, in accordance with the NSW Health Lead in Blood Control Guideline. The LEWG considers that maintenance of this database satisfies the need to be able to call upon future and historic blood lead data. In response to the recommendation for future blood lead screening to ensure that recontamination events are not impacting human health, the LEWG accepts the advice from NSW Health which has advised against future testing due to the low risks associated with lead contamination in this locality. However, targeted testing of high-risk children will continue to be promoted. With regards to testing in summer instead of winter, there is conflicting opinion regarding this matter within the LEWG but it is unlikely to have a significant impact on this population. The comment about the role of blood lead testing in risk assessment does not align with NSW Health's interpretation of the enHealth guidelines (2012) or the NEPM.

Literature review recommendation 10

Site-specific assessment of bioaccessibility for lead as incorporated in the NEPM for contaminated soil by NEPC (2013) should be carried out using in-vitro tests that simulate the gastro-intestinal system such as the physiologically-based extraction test (PBET) in-vitro assay (Ruby et al. 1996) or Unified BARGE Method (UBM) (Denys et al. 2012) by following the accepted practice of the NEPC (2013, Schedule B4). Methods based on gastric-only phase do not simulate intestinal absorption of lead, the key absorption step in humans, and overestimate the prediction of lead bioavailability for human health risk assessment.

LEWG response: The LEWG considered this to be a low priority for the short term, but a medium priority for the long term. The LEWG accepted that the 2015 blood lead screening program provided a reliable indication of the current risk posed by lead contaminated soils in the North Lake Macquarie area, and agreed that the overall decline in children's blood lead levels over time demonstrates an encouraging trend. However, in the absence of any future blood lead surveillance programs in North Lake Macquarie, and in order for the long-term risks to be better understood, the EPA has proposed that an investigation into the bioaccessibility of lead in soil would be a sensible approach. The EPA is aware of the appropriate methods for the measurement of bioaccessible lead in soil and will ensure that any testing is conducted in accordance with the approved methods. Data gathered from the proposed bioaccessibility testing program will be shared with the relevant agencies.

Literature review recommendation 11

Procedures within the LMCC EMP [Environmental Management Plan] should include a review of the GIS database for the location of lead contamination prior to works being undertaken.

LEWG response: The LEWG considers this recommendation as high priority. This recommendation directly aligns with LEWG recommendation 6. This requires the Department of Planning and Environment to develop controls to require utilities and other agencies to apply appropriate measures when dealing with contaminated land. The LEWG recommendation also states these measures should be in accordance with LMCC's Environmental Management Plan for Contaminated Land whereby there is a requirement for agencies and utilities to notify LMCC of any contamination issues so they may be recorded in council's database.

Literature review recommendation 12

The IEUBK (Integrated Exposure Uptake Biokinetic Model) is useful for validating soil total and bioaccessible-adjusted lead measurements but should not be the sole criterion for estimating health-protective soil concentrations as the input data may not all be correct (as happened at Trail, Canada) and needs to be validated by actual BLL measurement. Geographically complex sites may need improved methods involving GIS techniques that allow spatial relationships between populations and hazards to be examined and a decision making structure that follow the accepted Australian health risk assessment procedures of enHealth (2012). Generally, the surface terrain of the former smelter site is sloping towards Cockle Creek but is not considered to be a complex one. The use of GIS for plotting and comparing BLL with soil lead for NLM also demonstrated that the former smelter site is not a complex terrain (Willmore et al. 2006).

LEWG response: The LEWG considered this recommendation to be of low priority and not entirely relevant since the contaminated soil has been contained on the former smelter site. The current health-protective soil concentrations applied in North Lake Macquarie are consistent with the generic Health Investigation Levels (HILs) as prescribed in the NEPM. The HILs are intentionally conservative as they assume a worst-case exposure scenario, and they may be applied to all soil types to a depth of up to 3 metres. This particular recommendation should be revisited should a site-specific health-protective soil concentration for lead be applied to North Lake Macquarie in future.

Literature review recommendation 13

Site specific clean up levels can be derived from IEUBK model and be supported by site-specific measures of bioaccessible lead noting that lead uptake occurs via the intestinal phase and not from the gastric/stomach phase where solubilisation occurs.

LEWG response: The LEWG did not reach agreement on whether a site-specific clean-up level would be of benefit to the community. LMCC argued that the current guideline levels for lead in soil are aligned with the NEPM and the Guidelines for the NSW Site Auditor Scheme. LMCC also argued that the application of a standard remedial action plan (RAP), as described in LEWG recommendation 13, assumes a level of contamination and therefore a site-specific level would be superfluous, and of no consequence, to remedial activities. NSW Health has informed the LEWG that consideration of a site-specific clean-up level could be undertaken in conjunction with a sampling program to measure lead in soils in locations where participants from the 2015 blood lead screening program reside. The approach promoted by NSW Health is based upon the assumption that assessment of the soil lead levels in the environment of the 72 children who were not accumulating excess lead would provide guidance on targets for remediation levels in the area. The EPA has recommended that a site-specific target level should be further explored to avoid the unnecessarily conservative application of the HILs for lead in North Lake Macquarie – an approach which is consistent with the tiered approach for contaminated site assessment as described in Schedule B4 of the NEPM: Guideline on Site Specific Health Risk Assessments. The derivation of a contaminant-specific clean-up level for Lake Macquarie City will remain an ongoing matter for investigation and discussion.

Literature review recommendation 14

In the NLMA [North Lake Macquarie Area] there is no single publicly available map outlining areas where clean-up works have been undertaken or where contamination is still known to exist. There should be a collective goal of LMCC and NSW EPA to improve transparency and accessibility of mapped data. Leading practice programs overseas are characterised by such transparency.

LEWG response: Although the LEWG considered this recommendation to be of high priority, there was some concern over the context in which the data would be shared and consequently interpreted. The LEWG generally agreed that mapping of contamination to improve accessibility for the relevant agencies and utilities would be of benefit. This recommendation closely aligns with LEWG recommendation 18(1).

Finding 6

Although there exists a requirement for LMCC to maintain accurate records of contaminated land there is no formal requirement for utilities and other agencies to notify LMCC of contamination issues as they arise, nor is there a requirement for utilities and other agencies to manage lead contamination issues in accordance with LMCC policies. There is a need to align contaminated land management practices in the council area so that a consistent approach is adopted by all land managers, agencies and utilities.

Literature review recommendation 15

Accumulation of lead and other metal levels accumulated in home grown vegetables at Boolaroo and surrounding suburbs has received limited study. This subject needs to be assessed as part of any further health risk assessment of exposure of individuals from soil in gardens of residential houses at Boolaroo.

LEWG response: The LEWG considers the issue of lead exposure via consumption of homegrown vegetables of high importance. Although the specific actions to address this matter, as proposed under literature review recommendation 15 are generally not supported by the LEWG, it was agreed that greater awareness of potential sources of lead exposure should be emphasised through educational materials. This is already addressed through LMCC fact sheets which recommend that homegrown produce be grown in clean soils in containers or raised beds. This recommendation also aligns with LEWG recommendation 18(7) which proposes to expand engagement collateral to include advice on maintaining contamination barriers and hygiene, and improving links to and from HNE Health information.

Literature review recommendation 16

The groundwater quality objectives for the PCCS site remediation (being undertaken by Ferrier Hodgson) are not within the scope of this review; however, groundwater data, monitoring sites and water quality status before, during and after the remediation should be reviewed. In the absence of this knowledge, groundwater and potential surface water interactions could pose potential risks for recontamination.

LEWG response: The LEWG considered this was a medium priority recommendation and agreed it has been addressed under LEWG recommendation 9 whereby the EPA is to review a requirement for ongoing water quality monitoring upon conclusion of remediation activities at the Pasminco smelter site.

Finding 7

At present, groundwater below the Pasminco smelter site is known to be contaminated with smelter by-products. In addition, black slag is widely distributed around the foreshores of Lake Macquarie. The environmental impact of this contamination on water quality in Lake Macquarie is not well-understood.

Literature review recommendation 17

The State government should review whether Responsible Party legislation or its equivalent (polluter pays) in NSW or under Australian government legislation is adequate to mitigate the impacts and liabilities for remediation of contamination being externalised onto the community and environment in the future.

LEWG response: The LEWG deemed this to be a high priority recommendation and agreed it was not captured in the original list of LEWG recommendations. The original list of LEWG recommendations was therefore updated with an additional recommendation which closely aligns with literature review recommendation 17.

The EPA's environmental liabilities project aims to ensure that environmental liabilities created or acquired by a business are a cost of that business – not a cost borne by the community. The principal output of the project will be an 'environmental liabilities management framework', which will provide a predictable, transparent and consistent approach for the management of risks associated with environmental liabilities. The framework will include guidelines, practice notes (e.g. internal procedures for operations officers) and calculators. Instruments that will be used include bank guarantees and other forms of financial assurance, insurance, public positive covenants and other instruments under active consideration. The development and implementation of this framework will be progressive across sectors and major facilities based on the level of priority.

For certain high-risk major facilities, a tailored approach will be taken. While the EPA already has powers to require financial assurances and insurance, the project also includes a review of the existing legislation to streamline its operation by identifying gaps, inconsistencies and areas that could benefit from new approaches. This includes looking at appropriate instruments for managing financial risk associated with both on-site and off-site contamination.

Finding 8

There is a need to review whether responsible party legislation or its equivalent (polluter pays) in New South Wales or under Australian Government legislation is adequate to mitigate the impacts and liabilities for remediation of contamination being externalised onto the community and environment in the future.

Chapter 11: Planning and development on contaminated land

This chapter describes the planning and development approval process for land that is actually or potentially contaminated. This process applies to all types of land contamination, although the discussion here focuses on lead contamination in soil. The requirements for managing contaminated land vary depending on the type of development proposed and the level of contamination present on a site.

The legislative framework

In New South Wales, the management of contaminated land is a shared responsibility between the EPA, NSW Department of Planning and Environment, and local councils. Under the Contaminated Land Management Act, the EPA regulates significantly contaminated sites (see Part 3 Division 2 of the Contaminated Land Management Act). The EPA:

- regulates the appropriate investigation and clean-up of significantly contaminated land
- administers the NSW Site Auditor Scheme under Part 4 of the Contaminated Land Management Act
- makes or approves guidelines for use in the assessment and remediation of contaminated sites
- administers the public record of regulated sites under the Contaminated Land Management Act.

Development on contaminated or potentially contaminated sites that are not regulated by the EPA are managed by local councils through land-use planning processes, underpinned by:

- the Environmental Planning and Assessment Act
- State Environmental Planning Policy No 55 – Remediation of Land (SEPP 55)
- SEPP 55 Managing Land Contamination Guidelines
- Lake Macquarie Local Environmental Plan 2014 (LEP)
- Lake Macquarie Development Control Plan 2014 (DCP)
- other relevant legislation, standards and guidelines.

LMCC has developed a framework to regulate development on sites which are contaminated or potentially contaminated, and that do not pose an unacceptable risk to human health or the environment under its current or approved use (sites that do pose an unacceptable risk to human health are regulated by the EPA). The planning and development approval process will determine what remediation or abatement is required to ensure that land subject to a development application is suitable for its intended use.

Managing contaminated land during development

When carrying out development assessment functions under the Environmental Planning and Assessment Act, the local council must consider the possibility that a previous land use, or a current nearby land use, has caused contamination of the site, as well as the potential risk to health or the environment from that contamination. The general principle of the guidelines for regulating land contamination is that a precautionary approach be adopted when exercising a development assessment function, and the identification of land contamination issues occurs at an early stage in the planning and development assessment process in order to prevent harm and reduce delays and costs.

Lake Macquarie City Council procedures comply with relevant legislation and guidelines, and ensure that the development of contaminated land, or suspected contaminated land, occurs so as to minimise risk to the community and the environment. If contaminants are present, LMCC will require land developers to remediate the land as part of the development consent.

Contaminated land thresholds

The national standard for contaminated land is the National Environment Protection (Assessment of Site Contamination) Measure (NEPC 2013), which is established under the Commonwealth *National Environment Protection Council Act 1994.* This standard prescribes investigation levels, that when exceeded, trigger further assessment and management response where necessary, to minimise impacts to human health and the environment.

Contaminated land thresholds, the level at which detailed site investigation is required, are consistent with the Health Investigation Levels prescribed in the NEPM. The specific lead-in-soil Health Investigation Levels for various types of land use are currently:

- 300 parts per million[16] for low-density residential land uses
- 600 parts per million for recreational land uses
- 1200 parts per million for high-density residential land uses
- 1500 parts per million for commercial and industrial land uses.

If a site has lead-in-soil contamination at more than 300 parts per million, the property planning certificate identifies the site as being subject to a council policy related to contamination (see below). Properties throughout Lake Macquarie City, including those within the Pasminco LAS area, with final lead-in-soil levels above 300 parts per million, have contamination-related development restrictions, regardless of any remediation works undertaken on site. This may include properties with a LAS Certificate of Completion.

If remediation is required during the development process, the landowner (or the polluter, if known) is responsible for managing the required remediation. This includes all remediation costs and any legal implications.

Contamination notations on s.149 planning certificates

The s.149 planning certificate (s.149 certificate) provides information about a particular parcel of land. If the parcel is significantly contaminated, and therefore regulated by the EPA under the NSW Contaminated Land Management Act, it will have a notation under Clause 19 of the s.149 certificate.

[16] Parts per million or ppm is the equivalent to milligrams per kilogram (mg/kg).

For other contaminated land, development is regulated by the local council. Information about whether development restrictions apply to the land because of its contamination status is provided in Clause 7e of the s.149 certificate. There are four possible notations for land in LMCC:

1 **contaminated/potentially contaminated sites** – where there is a history of contamination, or a contaminating industry occurred on, or impacted, the land. A list of industries that may cause land contamination is provided in SEPP 55. This includes:

   a properties that have been assessed as being contaminated, and where remediation or abatement has not occurred

   b properties where no assessment has been undertaken and are considered potentially contaminated due to previous land use, or proximity to a pollution source

2 **sites with some form of remediation** – where land has a previous site contamination history or is in the vicinity of a contamination source, and the land has undergone some form of remediation

3 **sites that are not contaminated** – where land has undergone some form of testing (e.g. participation in the Pasminco LAS), and found to be under the contaminated land threshold

4 **no clear site history** – where council records do not contain a clear site history for the land or there is inadequate knowledge of uses that may have led to contamination or potential contamination.

Finding 9

At present, LMCC's property notations do not differentiate between land that is actually and potentially contaminated above the residential Health Investigation Level (300mg/kg). In order to facilitate a streamlined development assessment process, it is necessary to readily differentiate those properties that are known to be contaminated with smelter emissions and those that are not.

Building projects on contaminated or potentially contaminated land

Development types

Contaminated land management requirements vary depending on whether the project is classified as Exempt or Complying Development, or if a development application is required.

Minor works with minimal impacts (Exempt Development)

'Exempt Development' works are those that meet the requirements of Part 2 of *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008*. These projects are generally minor residential works, and include compliant demolition and construction projects such as balconies and decks (subject to size restrictions), garden sheds, driveways, chicken coops, vegetable gardens and emergency works.

Exempt Development does not require council consent or approval providing the proposal complies with the development standards set out in Part 2 of the State Environmental Planning Policy (Exempt and Complying Development Codes). There is no ability for council to impose requirements regarding contaminated land as part of these developments.

Works with low impacts (Complying Development)

'Complying Development' works are those that meet the requirements of Part 3 of State Environmental Planning Policy (Exempt and Complying Development Codes). These projects are generally moderate residential works, and include, but are not limited to compliant building of single and two-story dwellings, dwelling extensions, and in-ground swimming pools. A Complying Development Certificate (CDC) application is required to be submitted to the Principal Certifying Authority (PCA), which can be either council or a private certifier. The consent of the PCA is necessary prior to any work commencing.

For Exempt and Complying Development, it is the responsibility of the property owner and their contractors to ensure that contaminated or potentially contaminated soils are managed in a manner that will not impact residents, visitors and neighbours. There is no requirement for a private certifier or the proponent to advise council of the contamination status or remediation activity on the land.

Excavation and demolition works

Works involving the demolition of structures may require contamination management and reporting as specified in AS 2601–2001 *The demolition of structures*. The proponent will be required to provide an environmental management plan to the PCA outlining the methods for controlling fugitive emissions from the site during the demolition process. This is to include the storage and transport of contaminated dust and soil.

Works requiring excavation of contaminated or potentially contaminated soils should also conform with AS 1726 *Geotechnical site investigations*, and AS 4482.1 *Guide to the investigation and sampling of sites with potentially contaminated soil – Non-volatile and semi-volatile compounds*.

The PCA (council or private certifier) will ensure compliance with any relevant consent requirements regarding demolition works. Again, there is no requirement for private certifiers or the applicant to advise council of contamination and remediation on the land.

Works that require a development application

Development that is not defined as Exempt or Complying Development will require a development application. Works that require a development application require consent from council (or another consent authority in some instances).

All work that requires a development application must be managed in accordance with the Lake Macquarie Development Control Plan 2014 (and as referenced therein: *Council Policy – Managing Contaminated or Potentially Contaminated Land in Lake Macquarie*, SEPP 55 and the associated SEPP 55 planning guidelines). The DCP describes specific requirements for management of contamination during development, including a:

1 preliminary site investigation report

2 detailed site investigation report

3 remedial action plan.

These requirements are discussed in further detail below.

1 **Preliminary site investigation report** – This is undertaken to identify any historical or current activities that may lead to contamination of the site, and provide a preliminary assessment of any site contamination. A preliminary site investigation report is not required for properties within the LAS lead contamination survey grid, as most of the properties are deemed to be contaminated or potentially contaminated.

2 **Detailed investigation report** – This may be required where the preliminary investigation indicates the land is contaminated or that it has been used for an activity that may have caused contamination. Council may accept Pasminco LAS sampling reports (prepared after 2010) for this purpose. Council officers may request further information if the detailed investigation report is deemed insufficient for the assessment purpose.

3 **Remedial action plan** – If the detailed investigation report reveals that contamination is above the relevant contamination threshold for the proposed land use, council officers may request a remedial action plan be prepared by a suitably qualified consultant, outlying options for remediation of contaminated soils and management during works. These options generally include off-site removal or on-site storage/management, or both.

If council deems the remedial action plan is sufficient for the purposes being proposed, and assuming there are no other pending issues with the application, council may grant consent to carry out development (subject to relevant remediation conditions of consent).

After the completion of development work, council will request evidence that contamination was managed in accordance with the remedial action plan and approved conditions of consent.

If off-site removal was used to manage contamination, council may request as a condition of consent, a validation report (follow-up testing) to confirm that contamination levels are below the contamination threshold.

If on-site storage was used to manage contamination, council may request as a condition of consent, a long-term environmental management plan (and a validation report) from a suitably qualified consultant, to ensure the location of contamination is documented, and the material is managed effectively. Council may also require a restrictive covenant on the title of the land parcel under s.88B of the *Conveyancing Act 1919*.

Once council officers are satisfied with the evidence of any remedial action according to the conditions of any consent, the remediation process is finalised and council's records for the site are updated to note the current status of the land and the development activity (including remediation) that has been undertaken.

Safe and productive development of contaminated land

Lake Macquarie City Council is committed to ensuring that the use of contaminated or potentially contaminated land occurs so as to minimise risk to the community and the environment by ensuring compliance with the requirements of the Contaminated Land Management Act, SEPP 55 and the associated *Managing Land Contamination – Planning Guidelines – SEPP 55 – Remediation of Land* (DUAP & EPA 1998).

Council is required to consider the potential impacts of contamination through the development assessment processes, and recognises that the legislative arrangements are complex and place an additional administrative and economic burden on development within Lake Macquarie City.

Council has been progressively introducing changes to its development assessment process to assist residents and proponents of current and proposed development to respond positively and proactively to contaminated-land-based hazards and risks, both past and present.

Further changes to facilitate a more streamlined development assessment process are under consideration, including:

- improving soil contamination data within the City
- amending council's Contaminated Land Policy, and associated s.149 planning certificate notations, to differentiate sites that have been remediated below the investigation trigger levels and to separately identify actually and potentially contaminated sites
- improving systems to record and make available contaminated land data to inform the development assessment process
- amending the Lake Macquarie Development Control Plan to describe a streamlined approach for the assessment of residential soil contamination in areas of known contamination
- establishing an interdepartmental team within council to ensure the development assessment process is applied consistently, and in proportion to the degree of risk.

Finding 10

Development that does not meet the provisions of State Environmental Planning Policy (Exempt and Complying Development Codes) requires compliance with SEPP 55. Compliance with SEPP 55 results in a development assessment process which often leads to additional costs and significant delays for developers of contaminated land. Exempt and Complying Development may have similar risks in relation to contamination, but it does not currently require the same level of risk management. The risk associated with the development or demolition of existing dwellings and structures as Complying Development in the North Lake Macquarie area is such that lead dust in soils or dwellings may be remobilised and create a local, additional pathway of exposure to lead.

Chapter 12: Local waste disposal

Current arrangements for waste disposal

Lake Macquarie City Council imposes conditions of consent for development applications involving the remediation or abatement of contaminated land. At a minimum, LMCC will request a contamination assessment report, and remedial action plan (RAP) prior to the issue of a construction certificate. The RAP must be deemed suitable for the works on site, and be prepared to the satisfaction of council in accordance with appropriate policies and guidelines[17]. Such RAPs include methodology on the disposal of contaminated soils.

In the case of contamination being stored on site, and where disturbance or removal of the material may occur in the future, council will apply a condition of consent requiring a contaminated site environmental management plan (EMP). The EMP document must be prepared to the satisfaction of council, and, as for the RAP, must include any downstream removal, storage and disposal of contaminated soil or materials. EMP's must be certified by suitably qualified and experienced persons[18], and must be lodged with council prior to works commencing on site.

Further to the review and approval of the site RAP, and EMP (as appropriate), council has a standard condition of consent for the disposal of contaminated soil that states:

> *The surface layers of soil on this property may be affected by abnormal levels of lead. If excavation or removal of any soil is anticipated, it will be necessary to provide council with details on the excavation, collection, management, and disposal of the soil.* (LMCC standard condition of development consent)

It is important to note that this standard condition of consent is for consideration only, and council officers may choose to modify the condition of consent as appropriate for the site.

Currently, if a person carrying out works on their property generates excavated material that contains lead-impacted soil or slag, there are a number of possible scenarios:

- The waste is not identified as contaminated (generally because it has not been sampled and analysed), and is disposed of at a licensed waste facility or another facility approved to receive that waste. This could include a site that has development consent for filling of land.
- The waste is sampled, analysed and classified according to the EPA *Waste Classification Guidelines*. It can cost up to $1000 to have soil samples taken and analysed by a suitably qualified person.
- Waste from within the LAS area typically contains lead levels that result in the waste being classified as hazardous. As a result, the waste must be transported to the

[17] Guidelines and policies that are important for council in considering the appropriateness of remediation strategies and RAPs include the Lake Macquarie Local Environmental Plan, the Lake Macquarie Development Control Plan, the National Environment Protection (Assessment of Site Contamination) Measure, SEPP 55 and the associated SEPP 55 planning guidelines.

[18] Suitably qualified and experienced persons for the assessment (and preparation) of EMPs are as set out in the EPA website: Contaminated land.

hazardous waste facility at Kemps Creek in Sydney in the absence of a closer, licensed facility. The costs for transport to Kemps Creek are in the order of $50/tonne. The cost to dispose of hazardous waste at Kemps Creek is $440+GST/tonne. This includes $133.10/tonne for the Waste Levy imposed by the NSW Government. It should be noted that this process could be followed proactively, or in response to a condition of development consent.

Finding 11

Removal of black slag and lead-contaminated soil from residential properties, for residential development or remediation purposes, imposes an additional financial burden on members of the community. The lack of a suitable local repository for lead-contaminated soils represents an ongoing source of frustration for the community due to the costs and inconvenience associated with soil removal, transportation and disposal.

Proposed solutions

To address the costs of sampling and analysis, the EPA has developed an approval process for a landfill to accept lead slag-contaminated materials without further analytical testing. This operates by assuming a level of lead within the material based on representative sampling and analysis conducted by the EPA. As a result, residents in the area are not obliged to undertake their own testing to assess the level of lead in the material, a significant cost saving.

The EPA is continuing to explore options to build a containment cell at an existing local waste facility to take affected soils from the North Lake Macquarie area. This will reduce the costs to landowners wishing to dispose of contaminated materials to landfill for the following reasons:

- transport costs will be significantly lower compared to transport to Kemps Creek
- waste disposal costs will be based on a practical, low-cost disposal option, not the high costs of hazardous waste disposal.

The EPA has agreed to waive the Waste Levy on the disposal of lead-affected soil and slag from the LAS area.

The process is complex and will take some time to resolve.

Chapter 13: Consultation

Lake Macquarie Lead Community Reference Group

The Lake Macquarie Lead Community Reference Group (LCRG) was established by the EPA to enable the community to engage directly with government and experts on issues related to potential lead and lead slag contamination in the suburbs of Boolaroo, Argenton and Speers Point.

The LCRG is working in partnership with the LEWG. The group's functions include:

- providing a conduit to inform the community on all matters relating to this issue
- providing a voice for the community to raise concerns and issues
- facilitating ongoing communication between industries and the local community.

LCRG membership

As discussed in Chapter 1, the LCRG comprises nine members. Expressions of interest for membership were sought from the community and industry, and members were selected to represent a broad range of community interests:

Chair – Greg Piper

Greg Piper is the Independent State Member of Parliament for Lake Macquarie and served as Mayor of the city from 2004 to 2012. He was elected to the council in 1991 and has had a long involvement with lead contamination issues in North Lake Macquarie, representing residents of the affected areas at both local and state government level.

Community representative –Tony Cade

In 2013, Tony became the Chief Executive Officer of HunterNet Co-operative Limited, a Hunter-based network of engineering and manufacturing companies. Tony previously held the position of Group General Manager, Veolia Environment and senior executive positions within Waste Service NSW (WSN), the Hunter Waste Planning and Management Board, Newcastle City Council and BHP Steel.

Tony possesses strong leadership skills, a track record in developing and implementing business and strategic plans, has extensive experience in building business relationships, and is well-connected with all three tiers of government. Tony has an extensive network of alliances and relationships with many charitable and community organisations.

Tony has tertiary qualifications in metallurgy and economics and has completed executive education programs at Harvard Business School (Boston), Wharton Business School (Pennsylvania), and IMD (Switzerland).

School representative – Nicole Gerrard

Nicole Gerrard has worked as an environmental planner for over four years and previous to this as an ecologist for over ten years. She has prepared hundreds of reports such as flora and fauna reports, bushfire threat assessments, statements of environmental effects, environmental impact statements and '7-part tests' (significance assessments for threatened species). Nicole's experience includes working for ERM, a large multi-national environmental consulting company, and managing her own business for almost eight years.

Community representative – Emma Hale

Emma lives in Speers Point with her husband and daughter. She has worked for a number of public sector agencies in analytical and research roles after initially training to be a dietitian. Emma is currently working in a compliance-based position and is a volunteer with a local out-of-school-hours care service.

Community representative – Anne Sullivan

Anne is a retired teacher who has always lived in North Lake Macquarie and has taught in the Newcastle and Lake Macquarie regions. Currently she is employed as a casual academic with the Education Faculty at Newcastle University. Anne has always maintained a keen interest in environmental issues all over the Hunter region and also has many and varied connections with the Lake Macquarie community.

Business representative – Lloyd Hill

Lloyd has worked in the mining sector for over 34 years. He has performed senior management and technical roles for a number of blue-chip mining companies at operations throughout Australia and around the world. Lloyd's experience spans the full cycle of assets from resource exploration and evaluation to conceptual design, pre-feasibility, construction, operation, and management. Lloyd's reputation has enabled him to develop key relationships with major manufacturing partners in China, including China Shipping and China Coal Technology & Energy Group, partnering with them across Australasia and Canada, through his role as General Manager for Equipment Resource Group and Housing Concepts.

Community representative – Karen McCraw

Karen moved to Boolaroo with her husband and children just over three years ago. She loves the beauty and history of the area and wants to help the environment repair what past industry has impacted. Her passions are training and development, community engagement and gardening and she loves a fresh coffee. Her professional background includes all levels of hospitality, including senior management, and her current role is in administration.

Lake Macquarie City Council representative – Deputy Mayor Wendy Harrison

Wendy is the Deputy Mayor of Lake Macquarie City Council and has been a councillor since 2004.Before retiring from full-time work, she was a manager for Hunter TAFE. Wendy has lived at Speers Point for more than 45 years where she has been actively involved with the community.

Lake Macquarie City Council representatives

Councillor Robert Denton
(member until November 2016)

Councillor Luke Cubis – (member from October 2016)

Luke lives at Speers Point and is actively involved in the community. He is a former primary school teacher who is now the CEO of a local charity.

The LCRG is supported by:

- Richard Bastow – Ferrier Hodgson – the company responsible for the former Pasminco lead smelter site
- Christine Harle – Lake Macquarie City Council
- Dr Craig Dalton – NSW Health (HNE Health Public Health Unit)
- Adam Gilligan – EPA (LEWG Chair).

Achievements

The LCRG has achieved the following:

- held 15 LCRG meetings
- assisted NSW Health with the design and development of the blood lead level testing program
- promoted blood lead level testing clinics to the community through distribution of information to preschools, schools, industry and businesses
- presented community concerns to the LEWG and government agencies. These included community concerns about constraints on development in the area, issues with cost-effective waste disposal and blood lead levels
- presented information to the LEWG on planning and development constraints from a community perspective
- reviewed data on changes in property values in the area relative to other parts of the region, and produced a fact sheet on the issue for the community
- provided a conduit between the community and government agencies
- participated in the Living Smart Festivals at Speers Point by hosting a ‘Living with Lead’ stall.
- provided feedback to government agencies regarding the Marmong Point slag issue
- briefed the NSW Minister for the Environment on the work of the LCRG
- convened a public meeting in association with the LEWG on 2 February 2016, which was attended by over 60 people

- provided feedback to the LEWG on the LEWG findings and recommendations.

Issues of concern raised by the LCRG and residents

The LCRG members raised a variety of issues of concern with regard to legacy lead contamination in the North Lake Macquarie area. These were communicated to the LEWG through the following channels:

- Nicole Gerrard's presentation to the LEWG entitled 'Living in the Grid of Nominated Properties' on 31 August 2015
- Nicole Gerrard's letter to the LEWG and LCRG (Gerrard 2015)
- community feedback forms received following the Lake Macquarie LCRG public information evening held on 2 February 2016
- an email from LCRG member Emma Hale, listing the key issues of concern raised by LCRG members (19 March 2016)
- a list of concerns identified in broader consultation with the community.

Upon review of the combined LCRG contributions (listed above), it was clear that residents in the North Lake Macquarie area share many similar concerns regarding the impacts of legacy lead contamination on their communities, ranging from human health to the financial and social burdens associated with living with legacy contamination. The LCRG and community members also voiced concerns regarding LMCC's management of residential development within the LAS area. Having taken into consideration all of the issues it was clear there were several key themes under which individual issues could be categorised:

Health

- The LCRG members have expressed concerns regarding the likelihood of children having elevated blood lead levels now and in the future.

Social burden

- The LCRG members and residents are concerned over the stigma attached to Boolaroo as having a population which is more affected by lead pollution than all other areas.

Financial burden

- The LCRG members and residents who live within the LAS area claim they are required to undertake costly assessments, remediation, environmental plans and audit reports, etc. as part of the development application process.
- The residents feel the additional burdens associated with council's development application requirements are unfair.
- The LCRG members and residents have expressed concerns over the lack of an affordable location to dispose of lead-contaminated soil. Residents who wish to develop their properties claim they are faced with high costs for soil removal.
- Residents are confused as to why additional planning and development constraints are imposed by council when the recent blood lead screening indicates there are no health problems associated with legacy lead contamination in the North Lake Macquarie area.

Access to resources and information

- The LCRG members and residents claim there is a lack of adequate and accurate information being available to the community.
- The LCRG members and residents would like to see a one-stop shop or central point of contact or coordination for lead legacy issues within council.
- Residents have expressed concerns over uncertainty around sources of funding for residents who may incur costs associated with lead remediation.
- The LCRG members and residents have expressed concerns over the lack of access to a convenient location for the safe disposal of lead-contaminated soil.
- Residents feel that it is council's responsibility to provide a free or subsidised service to the community for the disposal of lead-contaminated soils.
- Residents have expressed a need for a publicly available list of affordable and suitable environmental contamination assessors.

Environmental concerns

- Residents claim that atmospheric fallout from the former Pasminco smelter was not restricted to the frequently mentioned suburbs of Boolaroo, Argenton and Speers Point, but also impacted other suburbs within North Lake Macquarie.
- Residents report that during heavy rainfall their homes are inundated by runoff which is claimed to be from the former Pasminco smelter site.
- Residents report they have observed heavy water flowing down Main Road during heavy rainfall, as well as flooded footpaths.
- The LCRG members feel there is uncertainty about the future use of the remediated area surrounding the containment cell on the former Pasminco smelter site.

Finding 12

Currently, there is a desire within the community for a government authority to provide additional support to help residents manage legacy lead contamination issues. Lake Macquarie City Council is the most appropriate authority to provide this support, however, it currently does not have responsibility for this nor the resources to undertake these additional support functions.

Finding 13

Legacy environmental lead contamination from smelting and mining operations (and other sources) is a statewide issue that requires a consistent and streamlined response from the EPA. There is also a need for a single point of contact within the EPA to coordinate the review of research proposals related to lead contamination in New South Wales and to address community concerns when findings from such research are made available.

LCRG feedback regarding LEWG recommendations

The LCRG were invited to comment on the LEWG findings and recommendations. Comments were provided to the LEWG from six individuals through the LCRG. The LCRG comments were evaluated to identify where there was a clear majority position on individual findings and recommendations. Following this evaluation, the comments were summarised by the EPA and forwarded to the LEWG for consideration. Since most of the LCRG comments on the LEWG findings and recommendations were intended for LMCC and the EPA, the responses to the LCRG were from these two organisations.

In light of the LCRG comments, the EPA and LMCC determined that some minor amendments to specific recommendations were warranted. The amendments were intended to provide greater clarity to the community regarding the specific details surrounding individual recommendations.

Chapter 14: List of LEWG recommendations

Recommendation 1: Lake Macquarie City Council, funded by the NSW Government, establishes a role for ongoing community involvement to monitor ongoing issues and to identify future issues regarding legacy lead contamination in Lake Macquarie through a risk communication framework.

Recommendation 2: Lake Macquarie City Council provides a point of contact and means of disseminating educational materials among the community, agencies and external stakeholders, and updated materials are distributed as they become available. Communication activities may include, but are not limited to:

1 a voluntary code of practice within the real estate industry to ensure that tenants and landowners are appropriately informed of any lead-contaminated soils at residential properties

2 a dedicated point of contact within Lake Macquarie City Council for agencies to provide and discuss new educational materials

3 information about managing capped contaminated material

4 information on living with lead in the environment

5 information on the process for assessing development applications on contaminated land

6 information via Dial Before You Dig on working with lead-contaminated soils.

Recommendation 3: Hunter New England Health notifies Lake Macquarie City Council of the results of any investigation in response to notifications that indicate the need for a coordinated community response, and provides regular updates on public health aspects of lead control and blood lead findings in the area.

Recommendation 4: The EPA reviews all available data associated with the development of the LAS lead contamination survey grid to determine whether the grid boundary corresponds to the geographic zone of soil lead dust contamination as a result of the former Pasminco smelter operations. The EPA provides advice to Lake Macquarie City Council on whether the lead contamination survey grid accurately reflects the extent of potential contamination of properties around the smelter.

Recommendation 5: NSW Health continues ongoing enhanced surveillance for lead notifications in children in the Boolaroo, Speers Point and Argenton suburbs, conducted by the Public Health Unit, noting the reduced level of blood lead resulting in notification. This enhanced surveillance involves annual reminder letters to local General Medical Practitioners (GPs) to identify children at higher risk of lead exposure to offer blood lead testing. Any notifications are followed up by the Public Health Unit using the protocol endorsed by the Chief Health Officer's expert group on lead: Lead in blood control guideline.

Recommendation 6: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, works with utilities and public authorities to apply measures comparable with LMCC's *Environmental Management Plan for Contaminated Land in Council's Care and Control*. Comparable measures include:

1 sourcing contamination status information from LMCC's contaminated land database

2 notifying LMCC of any contamination issues so they may be recorded in LMCC's database

3 appropriately managing contamination using measures comparable to LMCC policies and plans

4 providing information, for example via Dial Before You Dig enquiries.

Recommendation 7: Lake Macquarie City Council continues to maintain a central database of contaminated land in Lake Macquarie City, including records of initial contamination status, abatement and remediation, current contamination status and land use, and changes in land use.

Recommendation 8: The EPA, Lake Macquarie City Council and licensed operations continue to monitor water quality in surface water and groundwater around North Lake Macquarie. The EPA analyses this information and identifies any material pollution from stormwater or groundwater, or other discharge issues.

Recommendation 9: The EPA reviews a requirement for ongoing water quality monitoring upon conclusion of remediation activities at the Pasminco smelter site.

Recommendation 10: The EPA investigates the impacts of Pasminco smelter slag on water quality in the Lake Macquarie region, especially where slag is either permanently inundated by, or in intermittent contact with, surface water or groundwater. The EPA then provides recommendations to the NSW Office of Water in relation to the suitability of groundwater extraction in affected areas.

Recommendation11: The EPA continues to develop an environmental liabilities management framework to provide a predictable, transparent and consistent approach for the management of risks associated with environmental liabilities. In support of the development of this framework, the EPA reviews existing legislation to streamline its operation by identifying gaps, inconsistencies and areas that could benefit from new approaches, such as appropriate regulatory instruments for managing the financial risks associated with on- and off-site contamination.

Recommendation 12: Lake Macquarie City Council revises its Contaminated Land Policy so that section 149 planning certificate notations differentiate between remediated land with soil levels above and below the residential Health Investigation Level for lead.

Recommendation 13: Lake Macquarie City Council amends its Development Control Plan (DCP) for development of land known to be contaminated with atmospheric lead or black slag from the smelter. The revised DCP describes a streamlined approach for the assessment of residential soil contamination, by assuming a level of contamination based on

existing information, in order to reduce the cost of the development assessment process. The revised DCP describes standard remedial action plans, which are to the EPA's satisfaction, for routine development activities where risks are able to be adequately identified and managed.

Recommendation 14: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, takes steps to ensure that Exempt and Complying Development that is likely to result in the disturbance of contaminated soil within Lake Macquarie City is appropriately managed to minimise harm to human health and the environment.

Recommendation 15: The Department of Planning and Environment, in consultation with the EPA and Lake Macquarie City Council, considers the relevant management measures proposed in this report as part of its State Environmental Planning Policy review program.

Recommendation 16: The EPA considers all appropriate options for the disposal of contaminated materials associated with legacy lead contamination as a result of smelting activities in Lake Macquarie City, taking into consideration:

1 affordability

2 public accessibility

3 suitability of the facility to contain the materials received.

Recommendation 17: Lake Macquarie City Council continues to apply conditions of development consent that require tracking and appropriate disposal of contaminated soil.

Recommendation 18: The NSW Government establishes an ongoing funding stream for Lake Macquarie City Council to develop and maintain a small interdepartmental team to manage additional legacy lead issues beyond the usual remit of local government (subject to council approval and availability of a sufficient funding source). The team is responsible for:

1 expanding record keeping and mapping of known contamination and remediation

2 providing funding support and advice to public and private landholders wishing to undertake voluntary soil assessment and property remediation

3 following up on any Hunter New England (HNE) Health investigations regarding high blood lead levels to identify site remediation options

4 managing access to a local repository within the Lower Hunter for lead-contaminated soils

5 identifying a point of contact for community enquiries about living with lead and voluntary management measures

6 regularly engaging with HNE Health regarding blood lead levels tested by GPs and outcomes of follow-up investigations

7 expanding engagement collateral to include advice on maintaining contamination barriers and hygiene, and improving links to and from HNE Health information.

Implementation of this recommendation will facilitate a streamlined approach across the local government area consistent with LMCC's Development Control Plan, LMCC's *Environmental Management Plan for Contaminated Land in Council's Care and Control*, and the *National Environment Protection (Assessment of Site Contamination) Measure 1999*.

Recommendation 19: Lake Macquarie City Council, the EPA and NSW Health develop a risk-based decision management tool, in consultation with the community, to identify and prioritise access to services supported by the proposed funding stream described in Recommendation 18.

Recommendation 20: Lake Macquarie City Council develops a streamlined approach for the assessment of residential lead contamination within the local government area and ensures the degree of risk is appropriately matched to the level of action.

Recommendation 21: Lake Macquarie City Council continues to maintain an up-to-date environmental management plan (EMP) for dealing with legacy lead contamination on land within council's care and control. The EMP is reviewed every five years, or following new recommendations on lead exposure from health or environmental agencies (e.g. National Health and Medical Research Council, National Environment Protection Measures, etc.).

Recommendation 22: The NSW Government provides the EPA with support for the establishment and operation of a statewide Lead Strategy Group to act as a conduit between the EPA and local councils or other appropriate local bodies across New South Wales. The EPA strategy group is responsible for promoting effective communications and resolving enquiries relating to statewide lead contamination issues.

The EPA strategy group acts as:

- a first point of contact for future lead-related research in New South Wales
- a platform upon which research findings are communicated
- a conduit through which relevant authorities may be notified of changes to relevant policies, guidelines and technical documents.

References

ANZECC 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC and NHMRC 1992, *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites,* Australian and New Zealand Environment and Conservation Council and National Health and Medical Research Council, Canberra.

Australasian Slag Association 2000, Copper slag aggregates solve local supply problem*, The Australasian Slag Association Quarterly Newsletter*, vol. 1, issue 4, p. 2.

Batley GE 1992, Leachability of lead and other trace metals from lead-zinc smelter slag, Investigation Report CET/LHIR077, report prepared by CSIRO for Pasminco Metals-Sulphide Pty Ltd.

Bureau of Mineral Resources, Geology and Geophysics 1952, *Australian resources of Sulphur-bearing minerals,* report prepared by PB Nye and GF Mead for the Commonwealth Government, Ministry of National Development.

Csavina J, Field J, Taylor MP, Gao S, Landázuri A, Betterton EA and Sáez AE 2012, A review on the importance of metals and metalloids in atmospheric dust and aerosol from mining operations, *Science of the Total Environment*, vol. 433, pp. 58–73.

Dalton CB and Bates LI 2005, Impact of closure of a large lead-zinc smelter on elevated blood lead levels of children in adjacent suburbs, Boolaroo, Australia, *Environmental Exposure and Health*, vol. 85, pp. 377–387.

Dames and Moore 1994, *Environmental Impact Statement, Pasminco Metals Sulphide, Boolaroo Smelter Asset Modernisation Program – Part 2*, report prepared for Pasminco Metals – Sulphide Pty Limited, ISBN 0 646 19923 4.

DoH SA 2005, *The Port Pirie lead implementation program – future focus and directions,* report prepared by EJ Maynard, LJ Franks & MS Malcolm, Department of Health (South Australia), Adelaide.

Douglas Partners 2010, *Report on the management of slag affected sites in Lake Macquarie Council area*, report prepared for Lake Macquarie City Council, Douglas Partners, West Ryde.

DUAP 1995, *Conditions of Development Consent*, Department of Urban Affairs and Planning, Sydney, NSW.

DUAP & EPA 1998, *Managing Land Contamination: Planning Guidelines: SEPP 55 – Remediation of Land*, Department of Urban Affairs and Planning and NSW Environment Protection Authority, Sydney.

eNHealth 2012, *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards,* Department of Health and Aged Care and eNHealth Council, Canberra.

Galvin J, Stephenson J, Wlodarczyk J, Loughran R and Waller G 1993, Living near a lead smelter: an environmental health risk assessment in Boolaroo and Argenton, New South Wales, *Australian Journal of Public Health*, vol. 17, no. 4, pp. 373–78.

Gerrard N 2015, Nicole Gerrard to Adam Gilligan (Expert Group Chairperson), Greg Piper (Community Group Chairperson) and Group Members, letter 10 August 2015.

Gulson GL, Mizon KJ, Davis JD, Palmer JM and Vimpani G 2004, Identification of sources of lead in children in a primary zinc-lead smelter environment, *Environmental Health Perspectives*, vol. 112, no. 1, pp. 52–60.

Hale E 2016, Emma Hale to Adam Gilligan (Expert Group Chairperson), email, 19 March 2016.

Harvey PJ, Taylor MP, Kristensen LJ, Grant-Vest S, Rouillon M, Wu L and Handley HK 2015, Evaluation and assessment of the efficacy of an abatement strategy in a former lead smelter community, Boolaroo, Australia, *Environmental Geochemistry and Health*, vol. 38, no. 4, pp. 941–54.

Hilts SR 2003, Effect of smelter emission reductions on children's blood lead levels, *Science of the Total Environment*, vol. 303, no. 1–2, pp. 51–8.

HNE Health 2015, *Blood lead screening in North Lake Macquarie, 2015*, Hunter New England Health Local Health District, http://www.hnehealth.nsw.gov.au/hneph /EnvironmentalHealth /Documents/blood-lead-screening-2015.pdf.

Hunter Public Health Unit 1997, *Heavy metals in Lake Macquarie: a cross-sectional survey*, report prepared by J Wlodarczykyk, K Beath and The University of Newcastle Research Association, in association with John Wlodarcyzyk Consulting Services, NSW.

Kachenko AG and Singh B 2006, Heavy metals contamination in vegetables grown in urban and metal smelter contaminated sites in Australia, *Water, Air and Soil Pollution*, vol. 169, issue 1, pp. 101–123.

Lead in Soil and Dust Working Group 1994, *Report of the Lead in Soil and Dust Working Group*, prepared for the NSW Government Lead Taskforce, https://www.lead.org.au/soil&dust/Recommendations_&_Proposed_Strategy.pdf.

LMCC 1994, *Use of granulated slag from Pasminco Metals Sulphide*, report prepared by Director Engineering & Technical Services, Lake Macquarie City Council, NSW.

LMCC 2007, *Symon Walpole to John Coffey,* letter, 23 October 2007, Lake Macquarie City Council, NSW.

LMCC 2013, *Environmental Management Plan for Contaminated Land in Council's Care and Control*, Lake Macquarie City Council, NSW.

LMCC 2015, *Fact sheet 12A – Managing Black Slag Affected Soils*, Lake Macquarie City Council, NSW.

LMCC 2016, *Council Policy: Managing Contaminated or Potentially Contaminated Land in Lake Macquarie*, Lake Macquarie City Council, NSW.

Morrison AL 2003, An assessment of the effectiveness of lead pollution reduction strategies in North Lake Macquarie, NSW, Australia, *The Science of the Total Environment*, vol. 303, pp. 125–138.

Morrison AL, Swierczek Z and Gulson BL 2016, Visualisation and quantification of heavy metal accessibility in smelter slags: The influence of morphology on availability, *Environmental Pollution*, vol. 210, pp. 271–81.

NEPC 1998, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council.

Ngueta G, Gonthier C and Levallois P 2015, Colder-to-warmer changes in children's blood lead concentrations are related to previous blood lead status: Results from a systematic review of prospective studies, *Journal of Trace Elements in Medicine and Biology*, vol 31, no. 29, pp. 39–46.

NHMRC 1993, *Lead in Australians: summary statement of the 115th session of the National Health and Medical Research Council, 2 June 1993, regarding revision of the 1987 (103rd session): guidelines for lead in Australia*, National Health and Medical Research Council, Canberra.

NHMRC 1996, *Ambient air quality goals recommended by the National Health and Medical Research Council*, (publication rescinded by NHMRC on 19 March 2002), National Health and Medical Research Council, https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments /eh23.pdf.

NPI 1999, *Emission estimation technique manual for zinc concentrating, smelting and refining*, National Pollutant Inventory, Environment Australia, Canberra.

Ouw KH and Bisby JA 1976, Lead absorption in children residing near a New South Wales lead smelting complex (Australia), *Bulletin of Environmental Contamination and Toxicology*, vol. 15, no. 1, pp. 49–54.

Pasminco n.d., Lead Abatement Strategy, http://www.pasminco.com.au/index.php/lead-abatement-strategy.

PCCS 2011, *Lead Abatement Program Participation Agreement ('Agreement')*, Pasminco Cockle Creek Smelter Pty Ltd (Subject to Deed of Company Arrangement), Melbourne Victoria.

Pirkle JL, Brody DJ, Gunter EW, Kramer RA, Paschal DC, Flegal KM and Matte TD 1994, The decline in blood lead levels in the United States: the National Health and Nutrition Examination Surveys (NHANES), *Jama*, vol. 272, no. 4, 284–91.

Prior J and Partridge E 2010, *The Australian experience: A comparative analysis of the effects of contamination and its remediation on individuals and communities at two Australian sites,* CRC Care Technical Report no. 17, CRC for Contamination Assessment and Remediation of the Environment, Adelaide, Australia.

Siegmund AHJ 2000, Primary lead production – a survey of existing smelters, in JE Dutrizac, JA Gonzalez, DM Henke, SE James and SHJ Siegmund (eds), *Lead-Zinc 2000*, John Wiley & Sons, Inc, pp. 53–116, DOI: 10.1002/9781118805558.

Standards Australia 1988, *Sampling of venous and capillary blood for the determination of lead or cadmium concentration*, AS 2326-1988, Standards Australia, NSW.

Standards Australia 2000, *Guide to the potentially contaminated soil and deposited dust as a source of lead available to humans*, AS 4874-2000, Standards Australia, NSW.

Taylor MP, Forbes MK, Opeskin B, Parr N and Lanphear 2016, The relationship between atmospheric lead emissions and aggressive crime: an ecological study, *Environmental Health*, vol 15, no. 23**, DOI: 10.1186/s12940-016-0122-3.**

Willmore A, Sladden T, Bates L and Dalton CB 2006, Use of a geographic information system to track smelter-related lead exposures in children: North Lake Macquarie, Australia, 1991–2002, *International Journal of Health Geographics*, vol. 5, no. 30, DOI: 10.1186/1476-072X-5-30.

Zines D 2007, *Pasminco Cockle Creek Smelter Lead Abatement Strategy Implementation Documentation*, report prepared for Ferrier Hodgson for the Pasminco Cockle Creek Smelter Site Redevelopment Project, http://www.pasminco.com.au/files/20110414133639936.pdf.

Attachments

Attachment A – Lead Expert Working Group Terms of Reference

Attachment B – Lake Macquarie Lead Community Reference Group Terms of Reference

Attachment C – Lead Abatement Strategy Implementation Documentation

Attachment D – UniQuest Literature Review: Report on Practices to Manage Lead (Pb) and Lead Slag in Soil and Associated Human Exposure