Stage 2 - Environmental Investigations
Shoalhaven Region
HMAS Creswell

Part A - Stage 2 Environmental Assessment

Australian Government Department of Defence

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MAUNSELL | AECOM

HMAS Creswell

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Prepared by

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Executive Summary

Background

This report presents the results of a *Stage 2 Environmental Investigation (Stage 2 EI*) into ground contamination at HMAS CRESWELL located at College Road, Jervis Bay, NSW, within the Shoalhaven Region. The investigation was undertaken by Maunsell Australia Pty Ltd (Maunsell).

The overall objective of the Stage 2 EI program was to provide an understanding of the risk posed by the identified Areas of Concern (AoC) at the site and provide a remediation and/or management strategy for each of the AoCs.

A *Site Management Plan* (SMP) has been developed that will allow Defence to maintain its current and future capabilities, protect human health of site users and minimise the impact on the environment within the site and its surrounding catchment areas.

The purpose of the investigation was to:

- Identify potential land contamination at each nominated AoC;
- Delineate the vertical and horizontal extent of contamination at each AoC and develop a plan for management of environmental risks that is consistent with relevant jurisdictional requirements;
- Conduct a risk assessment using the Defence *Environmental Risk Management Framework*; and
- Provide management strategy that addresses the risks.

This report has been prepared in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999* and other relevant Defence documents. This included collaboration with the Defence appointed Technical Advisor (TA) Andrew Kohlrusch (ERM Australia).

Investigation Staging and Sampling Methodology

The detailed investigation staging and sampling methodology for the HMAS CRESWELL Stage 2 EI is detailed in the December 2005 *HMAS ALBATROSS, HMAS CRESWELL and Jervis Bay Range Facility –Sampling and Analysis Plan – Stage 2 Environmental Investigation* (the SAP).

Details of the investigation staging and sampling methodology, assessment criteria and data validation and quality assessment are presented in **Section 5, 6 and 7**, respectively.

Investigation Results and Discussion

The following **Table 1.1** summarises the findings of the investigation.

A *Site Management Plan* (SMP) incorporating the management requirements summarised in the tables below and detailed **Section 12** and **Table 10,** has been developed. The SMP includes monitoring requirements and remediation recommendations considered necessary to address the risks across the site. Areas of "*high*" risks (i.e. USTs and in-ground infrastructure) will require some form of remediation and a separate RAP. Areas of "*medium risk"* will be managed by both water monitoring and infrastructure integrity monitoring, while areas of "*low risk"* will be managed by the Site EMP and activity/contractor specific EMPs/ECCs (provided landuses remain unchanged and no incidents occur that could change the risk rating).

Overall, the contamination issues, either current or potential future, at the HMAS CRESWELL site is comprised of the summation of all the AoCs identified during the *Stage 2 EI.* Due to the size of the site

and the localised complexities within each AoC in regards to the sources, pathways and receptors one site wide management strategy would not achieve the desired reduction and/or management of the assessed risks. However, the adopted strategy of *Site Management Plan* development and implementation, designed with each specific AoC in mind, will be more effective in targeting immediate *very high* and *high* contamination risk AoCs while providing short and long term monitoring and/or management strategies to ensure *Medium* and *Low* risk contamination AoCs do not escalate in the future. Additionally, the *Site Management Plan* also provides for short and long term boundary monitoring and sampling which will endeavour to provide a snap shot of the health of the site and as such the effectiveness of the specific AoC management.

Table 1.1: Summary of Areas of Concern at HMAS CRESWELL

Issues	Recommendations	Estimated Cost	Risk After Implementation
HIGH			
Fire Station (SW0040)			
On-site use of hydrocarbons and AFFF chemicals. Use of AFFF in training on golf course.	REMEDIATION: Relocation of testing AFFF capability to designated facilities MONITORING: annual sampling with a review after 2 years at Groundwater monitoring well MW01. See the *Water Quality Management Plan* (Maunsell, July 2006) for details. MANAGEMENT: Develop and/or implement Site-specific EMP and any Activity-specific EMP (fire station practices), which might apply. Audit and review the implementation of EMP biennially.	(1) Remediation = $1,500 to $8,000 (relocation); (2) Monitoring = $1,200 to $1,500 per round; and (3) EMP/ Management = $500 to $3,500 (biennially).	**Low if AFFF capability testing relocated to designated facilities**
Former Golf Club House (SW0146)			
Former location of the Golf Club House that had Asbestos Containing Materials. ACM Impacts detected	REMEDIATION: For the area impacted by ACM an immediate response should be to isolate the area with fencing and signage and then undertake densely spaced sampling grid across the AoC area to delineate extent of impact. Based on this assessment, determine appropriate remedial measures - could include: Manage as is, Cap impacted area with human health barrier (preferred), or lastly, excavate and dispose of impacted soils. MONITORING: None MANAGEMENT: Develop and/or implement Site EMP and any activity specific EMP for ACM in surface soils. Audit site/activity specific EMP applying to this AoC every 4 years. If/when impacted soils are removed, revise/discontinue EMPs accordingly.	(1) Remediation = $1,500 to $8,000; (2) Monitoring = na; and (3) EMP/ Management = $500 to $1,500 (biennially).	**Low if ACM were removed via remediation**
MEDIUM			
Sewerage Treatment Plant (remote0147)			
Sewerage Treatment prior to storage for irrigation.	Remediation: None. Monitoring: In-ground structure (sumps) biennial integrity testing (with a review after 6 years). Remove/replace *compromised* structures and validate. Six-monthly Surface water inlet and groundwater monitoring MW12. Refer: Water Quality Monitoring Plan - 2006 for details. Management: Develop and/or implement Site-specific EMP and any Activity-specific EMP (STP practices). Audit after 2 years.	(1) Remediation = na; (2) Monitoring = $1,200 to $1,500 per round and integrity testing $2000 to $6000; and (3) EMP/ Management = $500 to $1,800 (biennially).	**Medium**

Issues	Recommendations	Estimated Cost	Risk After Implementation
Boat Shed and Gardener Stores (remote0149)			
Storage of gardeners' equipment, tools and chemicals Jervis Bay is located less than 50 metres from the potential sources	Remediation: None Monitoring: None Management: Review and audit EMP every 4 years and development of Potential Acid Sulphate Soils Site Management Plan (ASSMP) for excavations that may occur below the water table at this location.	1) Remediation = na; (2) Monitoring = na; and (3) EMP/ Management = $2000 to $5000 (biennially).	**Low**
Treated Effluent Storage and Irrigation Areas (SW0035)			
The storage and irrigation of treated effluent from the site sewerage treatment plant has the potential to impact humans and surrounding environment if not managed appropriately	Remediation: None. Monitoring: Six-monthly at surface water low tide CRES2B and Dam CRESSTP3 and groundwater well MW16. Refer: Water Quality Monitoring Plan - 2006 for details. Management: Manage in accord with Environment ACT effluent irrigation guidelines (Environment ACT Wastewater Reuse for Irrigation Environment Protection Policy, July 1999), as well as Site-specific EMP and any Activity-specific EMP (lawn-mowing and irrigation), which might apply. Development of Potential Acid Sulphate Soils Site Management Plan (ASSMP) for excavations that may occur below the water table on the low lying areas of the golf course/Site	(1) Remediation = None; (2) Monitoring = $4,500 to $8,000 per round; and (3) EMP/ Management = includes ASSMP $2000 to $11,000 (biennially).	**Low**
Slipway (SW0039)			
On-site use and/or occurrence of hydrocarbons, antifouling paints, metals and solvents chemicals.	Eco-toxicology study proposed for Jervis Bay Marine Park (proposed for 2006/2007 year) may propose remedial or management requirements.	(1) Remediation = $1,500 to $28,000 (eco-tox study of wharf area); (2) Monitoring =na; and (3) EMP/ Management = $500 to $1,500 (biennially).	**Medium**

Issues	Recommendations	Estimated Cost	Risk After Implementation
Pistol Range (Stop Butt) SW0041			
Former Pistol Range/Stop Butt. Concentrations of heavy metals (lead) were detected in the groundwater during the Stage 2 EI above the adopted site criteria.	Remediation: Assess feasibility/cost and desirability of implementing recommended on-site containment cell approach (SMEC, 2005) as a means of minimising human health and ecological risks associated with the continued presence of the 'naked' stopbutt soils at this location. If it is considered feas ble/desirable, implement RAP (SMEC 2005) or suitable revision based on (SMEC, 2005) and validate. Monitoring: Annual Groundwater monitoring. At MW14 and MW15. *Refer:* Water Quality Monitoring Plan - 2006 for details. Review Monitoring (WQMP) after 2 years and again after removal/containment of Pb impacted Stopbutt soils is implemented. Management: Develop and/or implement Site EMP and any activity specific EMP for Pb fragments in surface soils for site activities which disturb the stopbutt soils (gardening or personnel movements across the area). Audit site/activity specific EMP applying to this AoC every 4 years. If/when impacted soils are removed, revise/discontinue EMPs accordingly.	(1) Remediation = $4,500 to $850K (remove stopbutt); (2) Monitoring = $2,200 to $3,500 per round; and (3) EMP/ Management = $500 to $3,500 (biennially).	**Low if source (Lead impacted soils) removed**
Transport Yard - UPSSs 1-3 (SW0116 and SW0117)			
Contractors workshop for various uses, including vehicle storage/maintenance. Pre-existing UPSS tanks were present (no longer, but residual impact may be present in the subsurface).	Remediation: None Monitoring: Annual Groundwater monitoring of MW02. Refer: Water Quality Monitoring Plan - 2006 for details. Management: Develop and/or implement Site-specific EMP and any Activity-specific EMP (mechanical workshop practices), which might apply. Audit and review the implementation of EMP biennially.	(1) Remediation = na; (2) Monitoring = $1,200 to $1,500 per round; and (3) EMP/ Management = $500 to $1,000 (biennially).	**Low**
Canteen - UPSS 5 and 6 (SW0120 and SW0121)			
Site/Staff vehicle refueling Jervis Bay is located less than 100 metres from the potential sources.	REMEDIATION: the UPSS is >25 years *considered risk reducing* to replace. MONITORING: annual sampling with a review after 2 years at MW05 and MW06. See the *Water Quality Management Plan* (Maunsell, July 2006) for details. Biennial Integrity testing of UPSSs, drains and sumps - if they are to remain in use. Develop RAP, remove/re-line/replace compromised structures and validate if integrity testing and/or monitoring indicates the UPSSs, drains and/or sumps have become comprised. MANAGEMENT Management of the UPSSs, under the protocols laid down in Defences Underground Petroleum Storage Systems (UPSS) Management Guidelines for Regional Environmental Officers (June 2004). Follow Site EMP and any Activity Specific EMP mandated for the AoC. Audit the implementation of EMP/s every 4 years.	(1) Remediation = $3,500 to $25,000 (UPSS removal); (2) Monitoring = $2,200 to $2,800 per round and integrity testing $2000 to $6000; and (3) EMP/ Management = $500 to $3,500 (biennially).	**Low (after UPSS removal)**

Issues	Recommendations	Estimated Cost	Risk After Implementation
Wharf - UPSS7 and UPSS8 (SW0122 and SW0123)			
Engine/vehicle refuelling, marine maintenance activities etc. Jervis Bay is located less than 20 metres from the potential sources. UPSS 7 removed and UPSS 8 remains *in situ*	REMEDIATION: the UPSS is >25 years *considered risk reducing* to remove/replace. MONITORING: annual sampling with a review after 2 years at MW09 and MW10. See the *Water Quality Management Plan* (Maunsell, July 2006) for details. Biennial Integrity testing of UPSSs, drains and sumps - if they are to remain in use. Develop RAP, remove/re-line/replace compromised structures and validate if integrity testing and/or monitoring indicates the UPSSs, drains and/or sumps have become comprised. MANAGEMENT Management of the UPSSs, under the protocols laid down in Defences Underground Petroleum Storage Systems (UPSS) Management Guidelines for Regional Environmental Officers (June 2004). Follow Site EMP and any Activity Specific EMP mandated for the AoC. Audit the implementation of EMP/s every 4 years.	(1) Remediation = $3,500 to $25,000 (UPSS removal); (2) Monitoring = $2,200 to $2,800 per round and integrity testing $2000 to $6000; and (3) EMP/ Management = $500 to $3,500 (biennially).	**Low (after UPSS removal)**
Site In-ground structures - UPSSs, sumps, pits etc.			
During the Stage 2 EI several areas were investigated that had in-ground sumps/UPSSs used for oily water, waste water storage prior to disposal and fuel storage.	Remediation: Conduct inventory of all in-ground sumps, pit and holding systems. Monitoring: None. Integrity testing of sumps while they remain in use - biennially. Management: Management of any sumps located, under the protocols laid down in Defences Underground Petroleum Storage Systems (UPSS) Management Guidelines for Regional Environmental Officers (June 2004): Remove/re-line/replace compromised structures and validate. Improve environmental management practices, create/review existing activity specific EMP and audit every 4 years	(1) Remediation = $3,500 to unknown (removal); (2) Monitoring = integrity testing $2000 to $6000; and (3) EMP/ Management = $500 to $2,500 (biennially).	**Low**

Abbreviations

AC	Asbestos Cement
ACM	Asbestos Containing Material/s
AFFF	Aqueous Film Forming Foam
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
AoC	Area of Concern
B(a)P	Benzo (a) pyrene
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene
CDTF	Counter Disaster Training Facility
CoC	Contaminants of Concern
COC	Chain of Custody
CoPC	Contaminants of potential concern
CSM	Conceptual Site Model
CSR	Contaminated Sites Register
DEC	NSW Department of Environment & Conservation
DEMS	Defence Estate Management System
DIPNR	NSW Department of Infrastructure Planning and Natural Resources (now the Department of Planning and Department of Natural Resources
DLWC	NSW Department of Land and Water Conservation, now incorporated into the Department of Natural Resources DNR
DPWS	NSW Department of Public Works and Services
DQI	Data Quality Indicator
DQOs	Data Quality Objectives
EMP	Environmental Management Plan
EQL	Estimated Quantitation Limit
HIL	Health Based Soil Investigation Level
JBRF	Jervis Bay Range Facility
LOR	Limit of Reporting
Mg/kg	Milligrams per kilogram
MW	Monitoring Well
NAPL	Non-aqueous phase liquid
NATA	National Analytical Testing Authority
NEPC	National Environment Protection Council
NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
NHMRC	National Health and Medical Research Council
NSW EPA	NSW Environment Protection Authority, now incorporated into the Department of Environment and Conservation (DEC)
OCP	Organochlorine Pesticide
OPP	Organophosphorous Pesticide
PAH	Polycyclic Aromatic Hydrocarbon
PBIL	(Provisional) Phytotoxicity-Based Investigation Levels
PCB	Polychlorinated Biphenyl
PCSM	Preliminary Conceptual Site Model

PID	Photoionisation Detector
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
RAN	Royal Australian Navy
RPD	Relative Percentage Difference
SAP	Sampling Analysis Plan
RANSSSS	School of Ship Survivability and Safety
SMP	*Site Management Plan*
SNSW	Southern New South Wales
STP	Sewage Treatment Plant
SVOC	Semi-volatile Organic Compounds
SWL	Standing water level
TA	Technical Advisor
TPH	Total Petroleum Hydrocarbons
UCLavg	Upper Confidence Limit of the arithmetic average contaminant concentration
µg/L	Micrograms per litre
UPSS	Underground Petroleum Storage System
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
WBCL	Wreck Bay Community Land

1.0 Introduction

1.1 Statement of Intent

CH2M HILL Australia Pty Ltd (CH2M HILL) in partnership with Maunsell Australia Pty Ltd (Maunsell) was commissioned by the Department of Defence (Defence) on 5 October 2005 to undertake a *Stage 2 Environmental Investigation* (Stage 2 EI) at HMAS CRESWELL (the Site) located at College Road, Jervis Bay, NSW, within the Shoalhaven Region (**Figure 1.0 and 1.1**).

Defence have determined, as their overall objective for the Stage 2 EI program, that the outcome should provide a definitive understanding of the individual and collective 'true risk' posed by selected previously identified "Areas of Concern" (AoC) at HMAS CRESWELL. Then, on the basis of this true risk determination, provide a remediation and/or management strategy for each of the identified AoCs at the Site.

The management strategy is to permit Defence to maintain its *capability* at HMAS CRESWELL and is to be presented in the form of a *Site Management Plan* (SMP). The SMP is to directly address the environmental and human health risks posed by each of the AoC (individually and cumulatively) by considering the type and level of contamination at each ***source*** (AoC) in relationship to potential exposure to distant ***receptors*** (environmental and human health), taking into account any potential attenuation effect likely to be encountered along the ***pathway*** between source and receptor. The level of management effort required (SMP) is therefore to be determined by the combined effect of each of the factors described above (*source, pathway and receptors)*, that is, what constitutes the 'true risk' posed by the AoC before and after management.

The prime deliverables for the environmental investigation program are to be the results of the investigation program (which permit assessment of the risk) *and* the SMP to allow Defence to manage the identified risks in order to maintain capability. The SMP has been prepared separately to this Stage 2 EI Report.

1.2 Context

The Stage 2 EI at HMAS CRESWELL is one of three such Stage 2 EIs, undertaken concurrently, as part of the contract DES 155/05 "*Conduct of Stage 2 Environmental Investigations at HMAS Albatross, HMAS CRESWELL and Jervis Bay Range Facility*" (9 August 2005).

The outcome of each Stage 2 EI has been documented separately in three reports, titled:

- HMAS Albatross - Stage 2 Environmental Investigations.
- HMAS CRESWELL - Stage 2 Environmental Investigations.
- Jervis Bay Range Facility - Stage 2 Environmental Investigation.

This report presents the outcome of the HMAS *CRESWELL - Stage 2 Environmental Investigations* component of the contracted works.

All three of the Defence sites, the subject of these *Stage 2 Environmental Investigation* works, are located on Commonwealth land within the Shoalhaven Region, south of Nowra. These sites can be briefly described as comprising:

- **HMAS Albatross** consists of administration, operations and accommodation buildings on the eastern side of the site. An airfield, comprising two runways, is located north and west of the main operational facility, with field training areas beyond.
- **HMAS CRESWELL** comprises a naval training facility, and includes residential accommodation for Defence personnel, contractors and their families, an enclosed wharf area and surrounding breakwater, and support facilities.
- **Jervis Bay Range Facility (JBRF)** (also referred to as the *Jervis Bay Air Field*) comprises an airfield, operational buildings associated with the range facility and the School of Ship Survivability and Safety ('RANSSSS'). This base is not permanently manned.

The land surrounding these three Defence bases generally comprises agricultural areas, Crown Reserves, State Forests, an Industrial Park (Albatross), Marine Park, National Parks and/or an abandoned quarry (JBRF).

1.3 This Report

As stated above, this report presents the outcome of the "HMAS CRESWELL - *Stage 2 Environmental Investigations",* and includes recommendations for a standalone *Site Management Plan* (SMP) which details recommended management measures to permit ongoing capability for the Site, whilst providing acceptable human health and environmental conditions for site users and the surrounding environment.

The reporting comprises two separate parts:

Part A	Stage 2 Environmental Investigations	Details the Stage 2 EI undertaken at the Site between November 2005 and February 2006 by Maunsell/CH2M HILL, together with the results and assessed areas of concern (AoC), and then describes the outcomes in terms of their 'true risk', and how these risks might be sustainably managed (the detailed SMP).
Part B	*Site Management Plan*	Provides 'user friendly' guidance sheets, each of which provide 'one page' summary of the SMP as they relate to each of the high and Medium Risk areas of concern, as

Part A of (this report) has been prepared in accordance to the *National Environment Protection (Assessment of Site Contamination) Measure 1999 and* with reference to the following documents:

- Australian Department of Defence – HMAS CRESWELL – Stage One Contamination Assessment Report – GHD June 2005;
- Proposal (Final Version): Stage 2 Environmental Investigation – HMAS Albatross, HMAS CRESWELL and Jervis Bay Range Facility, August 2005; and
- Australian Government – Department of Defence Corporate Services and Infrastructure Group Contamination Risk Assessment Guidance 2005.

1.4 Background

Defence commissioned a *Stage 1 Contamination Site Assessment* (GHD 2005) for HMAS CRESWELL. This assessment identified a number of potentially impacted areas on the Site which were preliminarily classified (risk ranked).

On the basis of the preliminary risk ranking, designated areas, referred to as 'areas of concern' (AoC), were deemed appropriate for further investigation to define their 'true risk', and then individually and collectively assessed as to how they are best managed to allow ongoing capability for the Site, whilst

providing acceptable human health and environmental conditions for site users and the surrounding environment. In this way, the outcomes of the Stage 1 Assessments have, in part, triggered the Stage 2 EI.

Defence has indicated that it intends to continue ownership of the Site under its current use/s as well as retain areas for conservation purposes. Current land use of the Site best fits under the generic (NEPC 1999) *National Environment Protection Measure* (NEPM) 1999 *Health Investigation Level (HIL) - F Industrial/Commercial* land use. Specific areas of the Site do, however, better fit within other NEPM land use classification, namely, residential land use (where site occupants reside temporarily or permanently on-site in accommodation designed for this purpose) and recreational land use (including areas where sporting and other recreational activities take place). The data obtained from the Stage 2 EI investigation has, therefore, been considered in the light of these alternative land use designations in those areas where they apply (i.e. field data with comparison against criteria which apply to these more sensitive land use categories).

1.5 Objectives

Defence, in their SOR documentation for the proposed Stage 2 Environmental Investigations (Stage 2 EI), that:

> *"The objective of the Stage 2 investigation is to provide Defence with an outcome with regard to verifying the nature and extent of anticipated areas of contamination and the management options for each of the contaminated sites identified…"*

On this basis, the outcome of the Stage 2 EI was to enable the development of a *Site Management Plan* (SMP) for the Site that would:

- Allow Defence to maintain its current and future capabilities;
- Protect human health of site users; and
- Minimise the impact on the environment within the site and its surrounding catchment areas.

The other key outcomes of the Stage 2 EI have been to identify any significant environmental and human health risks ('true risks') associated with each AoC and to provide the appropriate management strategies for these AoCs (namely the SMP), and the Site as an entity, such that Defence are able to maintain their capability at the Site with only manageable, acceptable impacts remaining on site.

The purpose of the investigation, therefore, was to:

- Identify potential land contamination at nominated AoC, associated with Site activities and potentially including those related to heavy metals, hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), asbestos, pesticides, volatile organic compounds (VOCs), semi-volatiles organic compounds (SVOCs), AFFF, explosives and the presence of unexploded ordnance (UXOs);
- Delineate the vertical and horizontal extent of contamination at each AoC and develop a plan for management of environmental risks that is consistent with relevant jurisdictional requirements. This plan is to be endorsed by the Technical Advisor;
- Review the risk management requirements with reference to the Defence *Environmental Risk Management Framework*; and
- Define the environmental risk to Defence associated with each specific AoC and to provide a management strategy that addresses the risks.

Stage 2 - Environmental Investigations - Shoalhaven Region
Jervis Bay Range Facilities

Part A - Stage 2 Environmental Investigation Report

Australian Government Department of Defence

August 2006

MAUNSELL | AECOM

Jervis Bay Range Facilities

Prepared for

Australian Government Department of Defence

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Executive Summary

Background

This report presents the results of a *Stage 2 Environmental Investigation (Stage 2 EI*) into ground contamination at the Jervis Bay Range Facility (JBRF) located along Jervis Bay Road, Jervis Bay, ACT, 2540 within the Shoalhaven Region. The investigation was undertaken by Maunsell Australia Pty Ltd (Maunsell).

The overall objective of the Stage 2 EI program was to provide an understanding of the risk posed by the identified Areas of Concern (AoC) at the site and provide a remediation and/or management strategy for each of the AoCs.

A *Site Management Plan* (SMP) has been developed that will allow Defence to maintain its current and future capabilities, protect human health of site users and minimise the impact on the environment within the site and its surrounding catchment areas.

The purpose of the investigation was to:

- Identify potential land contamination at each nominated AoC;
- Delineate the vertical and horizontal extent of contamination at each AoC and develop a plan for management of environmental risks that is consistent with relevant jurisdictional requirements;
- Conduct a risk assessment using the Defence *Environmental Risk Management Framework*; and
- Provide management strategy that addresses the risks.

This report has been prepared in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999* and other relevant Defence documents. This included collaboration with the Defence appointed Technical Advisor (TA) Andrew Kohlrusch (ERM Australia).

Investigation Staging and Sampling Methodology

The detailed investigation staging and sampling methodology for the JBRF Stage 2 EI is detailed in the December 2005 *HMAS ALBATROSS, HMAS CRESWELL and Jervis Bay Range Facility – Sampling and Analysis Plan – Stage 2 Environmental Investigation* (the SAP).

Details of the investigation staging and sampling methodology, assessment criteria and data validation and quality assessment are presented in **Section 5, 6 and 7**, respectively.

Investigation Results and Discussion

The following **Table 1.1** summarises the findings of the investigation.

A *Site Management Plan* (SMP) incorporating the management requirements summarised in the tables below and detailed **Section 12** and **Table 10,** has been developed. The SMP includes monitoring requirements and remediation recommendations considered necessary to address the risks across the site. Areas of "*high*" risks (i.e. USTs and in-ground infrastructure) will require some form of remediation and a separate RAP. Areas of "*medium risk"* will be managed by both water monitoring and infrastructure integrity monitoring, while areas of "*low risk"* will be managed by the Site EMP and activity/contractor specific EMPs/ECCs (provided landuses remain unchanged and no incidents occur that could change the risk rating).

Overall, the contamination issues, either current or potential future, at the JBRF site is comprised of the summation of all the AoCs identified during the *Stage 2 EI.* Due to the size of the site and the

localised complexities within each AoC in regards to the sources, pathways and receptors one site wide management strategy would not achieve the desired reduction and/or management of the assessed risks. However, the adopted strategy of *Site Management Plan* development and implementation, designed with each specific AoC in mind, will be more effective in targeting immediate *very high* and *high* contamination risk AoCs while providing short and long term monitoring and/or management strategies to ensure *Medium* and *Low* risk contamination AoCs do not escalate in the future. Additionally, the *Site Management Plan* also provides for short and long term boundary monitoring and sampling which will endeavour to provide a snap shot of the health of the site and as such the effectiveness of the specific AoC management.

Table 1.1: Summary of Areas of Concern at the Jervis Bay Range Facility

Issues	Recommendations	Estimated Cost	Risk After Implementation
VERY HIGH			
Former Building 115 (Demolished Building) (SW0145)			
The former building 115 was constructed of asbestos cement. This material now surrounds the building footprint.	Remediation: Immediate: Fencing off the area with signage. Undertake densely spaced sampling grid across the AoC area to fully delineate extent of impact. Develop Remedial Action Plan (RAP) and Asbestos Management Plan (AMP) for remediation of the ACM impacted area - by excavating surface soils approximately 0.1-0.2m deep within impact area as defined in the Jervis Bay Facility Stage 2 Environmental Investigation (Maunsell Australia, 2006). Dispose of impacted soils to approved landfill by licensed contractor/transport. Replace excavated soils (fill excavation) with clean virgin excavated material and/or bitumen/concrete seal. Monitoring: None Management: Improve environmental management practices, create/review existing activity specific EMP, e.g. Gardeners EMP, including the preparation of an Asbestos Management Plan Audit Gardeners EMP and other activity specific EMPs.	(1) Remediation = $250K to $450K; (2) Monitoring = na; and (3) Management/ EMP = $500 to $1,500 (biennially).	**Low if ACM removed**
HIGH			
Counter Disaster Training Facility (CDTF), or Fire fighting training facilities (FFTF) or the RANSSSS (SW0025)			
Current facility uses gas. However the former facility utilised waste fuels/oils as fuel for training exercises - on unsealed surfaces. Impacts were identified within Mary Creek soils, surface waters, sediments and groundwater by Coffey Partners, PPK and PB. Currently this area is being managed under the PB (March 2004) JBRF Mary Creek Headwaters Remediation Project – Remedial Action Plan (RAP) and therefore this Stage 2 EI does not incorporate further investigations into this AoC.	Remediation: as per *Jervis Bay Range Facility – Mary Creek Headwaters Remediation Project – Remedial Action Plan* (PB, 2005). Monitoring: Water and Soil Quality Monitoring as per *Sampling and Analysis Plan: Mary Creek and Headwaters Remediation Project – Validation Sampling and Aftercare Monitoring, Jervis Bay Range Facility* (PB, 2005) Six-monthly at Sediment locations S1-7, Groundwater wells PBMW1, PBMW2, PBMW3, PBMW4 and Surface water SW 1-8 with a review after 2 years. Refer: Water Quality Monitoring Plan - 2006 for details Management: Develop new or review existing site-specific and/or activity specific EMP/s for RANSSSS Operations. *Audit* the implementation of EMP after 2 years.	(1) Remediation = underway (PB, 2006); (2) Monitoring = $5,800 to $8,500 per round; and (3) Management/ EMP = $500 to $2,500 (biennially).	**Medium**
Mary Creek (SW0026)			
Subject of Investigations and Remediation by others - not in the scope of this Stage 2 EI (SKM/PB, 2004-2006)	Subject to remediation by other (RAP by SKM/PB, 2005) *Refer*: Sampling and Analysis Plan: Mary Creek and Headwaters Remediation Project – Validation Sampling and Aftercare Monitoring, Jervis Bay Range Facility (PB, 2005) Monitoring: six-monthly at Groundwater Wells PBMW1, PBMW2 and MW15, and surface water PBSW1 and PBSW5 with review after 2 years. NOTE: PBSW5, PBMW1 and PBMW2 (above) are equivalent to PB (2005) SW1, SW5, MW1 and MW2, respectively.	(1) Remediation underway (PB, 2006); (2) Monitoring = $5,800 to $7,500 per round; and (3) Management/ EMP = $500 to $2,500 (biennially).	**Low** **if PB RAP Implemented and successful**

Issues	Recommendations	Estimated Cost	Risk After Implementation
MEDIUM			
Boundary (remote0146)			
Site boundary and or buffer boundary found Heavy metals and TPH impacts during the Stage 2 EI	Remediation: None. Monitoring: six-monthly at groundwater wells MW12, MW13, MW14, MW15, MW16, MW17 and MW18 and Surface water JBRF1, JBRF2 and JBRF3 with review after 2 years *Refer*: Water Quality Monitoring Plan (WQMP) - 2006 for details Management: Follow Site EMP and any Activity Specific EMP mandated for the AoC. Audit the implementation of EMP/s on biennial basis.	(1) Remediation = na; (2) Monitoring = $9,800 to $11,500 per round; and (3) Management/ EMP = $500 to $2,500 (biennially).	**Medium**
Drum Disposal Area (SW0027)			
Area was used to dump drums containing tarry material. Concentrations of heavy metals and PAH were detected in the groundwater during the Stage 2 EI above the adopted site criteria	Remediation: as per *Jervis Bay Range Facility - Mary Creek Headwaters Remediation Project - Remial Action Plan* (PB, 2005) [currently underway January 2006 - June 2006] Monitoring: six-monthly at groundwater well MW09 with a review after 2 years (f results show stable/decreasing trends monitoring can be altered to annual or bi-annual monitoring). Management: None	(1) Remediation = NA; (2) Monitoring = $1500 to $2,00K; and (3) Management/ EMP = NA.	**Low**
Airfield Refuelling Compound (UPSS 1-3) (SW0125-127)			
Temporary Jet Fuel spillage-capture and storage for refuelling operations (disused) – Leak capture tanks. Stage 2 Ei detected impacts in groundwater for TPH, ethylbenzene	Remediation: remove/replace the tanks Monitoring: annual at groundwater well MB09 and MW07 with review after 2 years. *Refer*: Water Quality Monitoring Plan (WQMP) - 2006 for details. Integrity testing of UPSSs and sumps if they are to remain in use under their intended operational usage - biennially. Management: Management of the UPSSs, under the protocols laid down in Defences Underground Petroleum Storage Systems (UPSS) Management Guidelines for Regional Environmental Officers (June 2004). Develop new or review existing site-specific and/or activity specific EMP/s and *Audit* the implementation of EMP after 2 years	(1) Remediation = $75K to $155K; (2) Monitoring = $2,500 to $2,500 per round; and (3) Management/ EMP = $500 to $1,500 (biennially).	**Low if tanks removed and replaced with above ground infrastructure**

Abbreviations

AC	Asbestos Cement
ACM	Asbestos Containing Material/s
AFFF	Aqueous Film Forming Foam
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
AoC	Area of Concern
B(a)P	Benzo (a) pyrene
BTEX	Benzene, Toluene, Ethyl-benzene and Xylene
CDTF	Counter Disaster Training Facility
CoC	Contaminants of Concern
COC	Chain of Custody
CoPC	Contaminants of potential concern
CSM	Conceptual Site Model
CSR	Contaminated Sites Register
DEC	NSW Department of Environment & Conservation
DEMS	Defence Estate Management System
DIPNR	NSW Department of Infrastructure Planning and Natural Resources (now the Department of Planning and Department of Natural Resources
DLWC	NSW Department of Land and Water Conservation, now incorporated into the Department of Natural Resources DNR
DPWS	NSW Department of Public Works and Services
DQI	Data Quality Indicator
DQOs	Data Quality Objectives
EMP	Environmental Management Plan
EQL	Estimated Quantitation Limit
HIL	Health Based Soil Investigation Level
JBRF	Jervis Bay Range Facility
LOR	Limit of Reporting
Mg/kg	Milligrams per kilogram
MW	Monitoring Well
NAPL	Non-aqueous phase liquid
NATA	National Analytical Testing Authority
NEPC	National Environment Protection Council
NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
NHMRC	National Health and Medical Research Council
NSW EPA	NSW Environment Protection Authority, now incorporated into the Department of Environment and Conservation (DEC)
OCP	Organochlorine Pesticide
OPP	Organophosphorous Pesticide
PAH	Polycyclic Aromatic Hydrocarbon
PBIL	(Provisional) Phytotoxicity-Based Investigation Levels
PCB	Polychlorinated Biphenyl
PCSM	Preliminary Conceptual Site Model

PID	Photoionisation Detector
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
RANSSSS	Royal Australian Navy School of Ship Survivability and Safety
RAN	Royal Australian Navy
RPD	Relative Percentage Difference
SAP	Sampling Analysis Plan
SMP	*Site Management Plan*
SNSW	Southern New South Wales
STP	Sewage Treatment Plant
SVOC	Semi-volatile Organic Compounds
SWL	Standing water level
TA	Technical Advisor
TPH	Total Petroleum Hydrocarbons
UCLavg	Upper Confidence Limit of the arithmetic average contaminant concentration
µg/L	Micrograms per litre
UPSS	Underground Petroleum Storage System
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds
WBCL	Wreck Bay Community Land

1.0 Introduction

1.1 Statement of Intent

CH2M HILL Australia Pty Ltd (CH2M HILL) in partnership with Maunsell Australia Pty Ltd (Maunsell), was commissioned by the Department of Defence (Defence) on 5 October 2005 to undertake a *Stage 2 Environmental Investigation* (Stage 2 EI) at the Jervis Bay Range Facility (JBRF) (the Site) located along Jervis Bay Road, Jervis Bay, ACT, 2540 within the Shoalhaven Region (**Figure 1.0 and 1.1**). JBRF is sometimes referred to as the Jervis Bay Air Field.

Defence have determined, as their overall objective for the Stage 2 EI program, that the outcome should provide a definitive understanding of the individual and collective 'true risk' posed by selected previously identified "Areas of Concern" (AoC) at the JBRF. Then, on the basis of this true risk determination, provide a remediation and/or management strategy for each of the identified AoCs at the Site.

The management strategy is to permit Defence to maintain its *capability* at the JBRF and is to be presented in the form of a *Site Management Plan* (SMP). The SMP is to directly address the environmental and human health risks posed by each of the AoC (individually and cumulatively) by considering the type and level of contamination at each ***source*** (AoC) in relationship to potential exposure to distant ***receptors*** (environmental and human health), taking into account any potential attenuation effect likely to be encountered along the ***pathway*** between source and receptor. The level of management effort required (SMP) is therefore to be determined by the combined effect of each of the factors described above (*source, pathway and receptors)*, that is, what constitutes the 'true risk' posed be the AoC before and after management.

The prime deliverables for the environmental investigation program are to be the results of the investigation program (which permit assessment of the risk) *and* the SMP to allow Defence to knowledgeably manage the identified risks in order to maintain capability. The SMP has been prepared separately to this Stage 2 EI report.

1.2 Context

The Stage 2 EI at the JBRF is one of three such Stage 2 EI's, undertaken concurrently, as part of the contract DES 155/05 "*Conduct of Stage 2 Environmental Investigations at HMAS Albatross, HMAS Creswell and Jervis Bay Range Facility*" (9 August 2005).

The outcome of each Stage 2 EI has been documented separately in three reports, titled:

- HMAS Albatross - Stage 2 Environmental Investigation.
- HMAS Creswell - Stage 2 Environmental Investigation.
- Jervis Bay Range Facility - Stage 2 Environmental Investigation.

This report presents the outcome of the *JBRF - Stage 2 Environmental Investigation* component of the contracted works.

All three of the Defence sites, the subject of these *Stage 2 Environmental Investigation* works, are located on Commonwealth land within the Shoalhaven Region, south of Nowra. These sites can be briefly described as comprising:

- **HMAS Albatross** consists of administration, operations and accommodation buildings on the eastern side of the site. An airfield, comprising two runways, is located north and west of the main operational facility, with field training areas beyond.
- **HMAS Creswell** comprises of a naval training facility, and includes residential accommodation for Defence personnel, contractors and their families, an enclosed wharf area and surrounding breakwater, and support facilities.
- **Jervis Bay Range Facility (JBRF)** (also referred to as the *Jervis Bay Air Field*) comprises an airfield, operational buildings associated with the range facility and the School of Ship Survivability and Safety ('RANSSSS'). This base is not permanently manned.

The land surrounding these three Defence bases generally comprises agricultural areas, Crown Reserves, State Forests, an Industrial Park (Albatross), Marine Park, National Parks and/or an abandoned quarry (JBRF).

1.3 This Report

This report presents the outcome of the "*Jervis Bay Range Facility - Stage 2 Environmental Investigations"* and includes recommendations for a standalone *Site Management Plan* (SMP) which details recommended management measures to permit ongoing capability for the Site, whilst providing acceptable human health and environmental conditions for site users and the surrounding environment.

The reporting comprises two separate parts:

Part A	*Stage 2 Environmental Investigation.*	Details the Stage 2 EI undertaken at the Site between November 2005 and February 2006 by Maunsell/CH2M HILL, together with the results and assessed *areas of concern* (AoC), and then describes the outcomes in terms of their 'true risk', and how these risks might be sustainably managed (the detailed SMP).
Part B	*Site Management Plan*	Provides 'user friendly' *guidance sheets*, each of which provide 'one page' summaries of the SMP as they relate to each of the Very High, High, Medium and Low Risk areas of concern.

This report has been prepared in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999 and* with reference to the following documents:

- Australian Department of Defence – Jervis Bay Range Facility – Stage One Contamination Assessment Report – GHD June 2005;
- Proposal (Final Version): Stage 2 Environmental Investigation – HMAS Albatross, HMAS Creswell and Jervis Bay Range Facility, August 2005;
- Australian Government – Department of Defence Corporate Services and Infrastructure Group Contamination Risk Assessment Guidance 2005; and
- Maunsell/CH2M HILL - December 2005 - HMAS Albatross, HMAS Creswell and Jervis Bay Range Facility –Sampling and Analysis Plan (SAP) – Stage 2 Environmental Investigation

1.4 Background

A *Stage 1 Contamination Site Assessment* (Stage 1) (GHD 2005) was undertaken for the JBRF in 2005. The Stage 1 identified and classified (risk ranked) a number of potentially impacted areas on the Site.

On the basis of the risk ranking, designated areas, referred to as 'areas of concern' (AoC), were deemed appropriate for further investigation to define their 'true risk', and then individually and collectively assessed as to how they are best managed to allow ongoing capability for the Site, whilst providing acceptable human health and environmental conditions for site users and the surrounding environment. In this way, the outcomes of the Stage 1 assessment have, in part, triggered the Stage 2 EI.

Defence has indicated that it intends to continue ownership of the Site under its current use/s as well as retain areas for conservation purposes. Current land use of the Site best fits under the generic *National Environment Protection Measure* (NEPM) 1999 *Health Investigation Level (HIL) - F Industrial/Commercial* land use.

1.5 Objectives

Defence, in their SOR documentation for the proposed Stage 2 Environmental Investigations (Stage 2 EI), that:

> *"The objective of the Stage 2 investigation is to provide Defence with an outcome with regard to verifying the nature and extent of anticipated areas of contamination and the management options for each of the contaminated sites identified…"*

On this basis, the outcome of the Stage 2 EI was to enable the development of a *Site Management Plan* (SMP) for the Site that would:

- Allow Defence to maintain its current and future capabilities;
- Protect human health of site users; and
- Minimise the impact on the environment within the site and its surrounding catchment areas.

Other key outcomes of the Stage 2 EI have been to identify any significant environmental and human health risks ('true risks') associated with each AoC and to provide the appropriate management strategies for these AoCs (namely the SMP), and the Site as an entity, such that Defence are able to maintain their capability at the Site with only manageable, acceptable impacts remaining on site.

The purpose of the investigation, therefore, was to:

- Identify potential land contamination at each nominated AoC associated with Site activities and potentially including those related to heavy metals, hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), asbestos, pesticides, volatile organic compounds (VOCs), semi-volatiles organic compounds (SVOCs), Aqueous Film Forming Foam (AFFF) and explosives;
- Delineate the vertical and horizontal extent of contamination at each AoC and develop a plan for management of environmental risks that is consistent with relevant jurisdictional requirements;
- Review the risk management requirements with reference to the Defence *Environmental Risk Management Framework*; and
- Define the environmental risk to Defence associated with each specific AoC and to provide a management strategy that addresses the risks.

In summary, the Stage 2 EI facilitates examination of the selected AoC's potential to pose a *true risk* to the health of site users and the surrounding environment, and secondly, allows for the refinement of the Conceptual Site Model (CSM) as the primary input into the design of sustainable management practices for the respective AoCs and the Site as a whole.

2.0 Design of the Investigation Scope of Work

2.1 Introduction

The approach to designing the *scope of work* for the investigation at the Site, such that it specifically targets the inferred contamination at each AoC, and permits the assessment of '*true risk*' posed individually and collectively by each AoC, was undertaken on the basis of two processes, namely:

- A detailed review of available data, including:
  - Stage 1 Contamination Site Assessment (GHD, 2005)
  - Observations made during a site visit in November 2005
  - Statement of Requirement for *Stage 2 Environmental Investigations at HMAS Albatross, HMAS Creswell and Jervis Bay Range Facility* (Defence, 9/8/2005)
- The construction of a *Preliminary Conceptual Site Model* (PCSM) which included an assessment of each AoC as it might constitute a contaminant *source,* the *pathway/s which mobile* contaminants may exploit as they migrate to reach a sensitive *receptor*, be that human health or an environmental receptors.

To provide Defence with a Stage 2 EI outcome unencumbered with requirements for further investigation, industry standard investigations techniques (refer to **Section 6.0**) (following an investigative approach based on the NEPM), were employed in conjunction with the key elements of the USEPA (2001) 'Triad[1] Approach'. The latter permitted the work plan (scope of work) to change dynamically to accommodate real-time decisions (based on incoming field screening and laboratory results).

Consultation with Defence and their appointed Technical Advisor (TA), Mr Andrew Kohlrusch (ERM Australia), has occurred throughout the project duration to achieve agreement on the project direction and to ensure the optimum outcome. This consultation has included regular reviews of results as they were received from the field and the various service providers, and which allowed changes to the scope of the Stage 2 EI program. The consultation also permitted the CSM (refer to **Sections 2.3 and 9**) to evolve, to ensure a definitive outcome and to permit all of the Stakeholders' interests to be adequately addressed, including, Defence personnel, adjacent property owners, downstream users, the Department of Environment and Heritage, National Park Authorities and surrounding communities.

The additional benefit of employing the Triad Approach, in conjunction with the ongoing TA consultation, is that other impacted areas not previously identified may be uncovered and investigated promptly (as part of these Stage 2 EIs) in order to complete the risk assessment.

Two primary inputs to deciding the most appropriate scope of work, namely the risk assessment and the CSM, are discussed in the following sections prior to detailing the selected scope of work.

[1] The USEPA (2001) 'Triad' approach relies first on thorough, systematic planning to articulate clear project goals and encourage negotiations to determine the desired decision confidence. Only then can a multidisciplinary technical team determine what information is needed to meet those goals. A key feature of his planning is identifying what uncertainties could compromise decision confidence and allowing team members with appropriate sampling and analytical expertise to explore cost-effective strategies to minimise those uncertainties. Often, the most cost-effective work strategy involves the second leg of the Triad, which is using a dynamic work plan to make real-time decisions in the field. The third leg of the Triad is using field analytical methods to generate real-time on-site measurements that support the dynamic work plan. There are significant advantages to using this Triad approach. Projects managed using these concepts have demonstrated cost savings up to 50% over traditional management approaches that rely on repeated trips to the field to fill data gaps that become apparent only as laboratory results are interpreted weeks or months later after sampling.

2.2 Stage 1 Risk Assessment Outcomes

The Stage 1 for the Site was completed by GHD in June 2005. The scope of works for the Stage 1 included:

- A literature review;
- Discussions with knowledgeable site personnel; and
- Identification of risks associated with the contamination on Site.

The outcome of the Stage 1 provided a preliminary risk ranking (High, Medium and Low) for each of the AoCs as summarised in **Table 1** (attached). As part of the Stage 2 program of work, data contained within the Stage 1 report has been reviewed, and the *current* Defence Estates Management System (DEMS) Contaminated Sites Register (CSR) Risk Assessment tool (version June 2005) utilised to review and re-assign the Stage 1 Risk Rankings for each identified AoCs within the Site. The reassigned Risk Rankings tables provided by DEMS are provided in **Appendix A**.

In general, the Risk Rankings have remained similar to those as reported by GHD (June 2005), that is as follows:

Table 2.1: Risk Rankings

Asset - Site	Risk Ranking GHD (June 2005)
SW0125 – UPSS 1	Medium
SW0126 – UPSS 2	Medium
SW0127– UPSS 3	Medium
SW0128 – UPSS 4	Medium
SW0027 – Drum Disposal	High
SW0031 – Kalkarra Launch	Medium
SW0129 – UPSS 5	Medium
SW0029 – Fuelling Area	Medium
SW0030 – Spray Booth	Medium
SW0142 – Transformer	Low
SW0143 – Toxic Store	Medium
SW0144 – Wash Down Bay	Medium
SW0145 – Demolished building	Low

It is worth noting that the DEMS CSR tool uses a complex matrix approach to evaluate perceived risk. The tool compares “Consequence”, associated with a perceived risk, and the “Likelihood” of that risk occurring. Risks are then assigned a “Level” and a “Score”, and a “Risk Band” is calculated. The Risk Bands have been used to compare results with those "Risk Rankings" reported in the Stage 1. Moreover, the DEMS CSR also assigns a “Priority” number to further prioritise any management action.

With this in mind, and as some of the Stage 1 data is minimal, using the DEMS CSM tool may lead to a somewhat conservative result. Some of the Site assets could not be re-evaluated using the DEMS CSR tool if we considered there was insufficient or ambiguous data in the Stage 1 report to assign a practical ranking. In some cases an asset was assigned a Risk Ranking during the Stage 1, but no data was available for review to make a DEMS CSR comparison. In these cases, the Risk Ranking remains “Not Assessed”.

Table 1 (attached) summarises the preliminary risk rankings. The DEMS Estate Risk Assessment summary tables for each AoC/assets re-assessed are included in **Appendix A**.

2.3 Preliminary Conceptual Site Model

A Preliminary Conceptual Site Model (Preliminary CSM) was developed (Figure 2.1) to assist in defining the most appropriate scopes of work for each of the Stage 2 EIs undertaken at the three Shoalhaven Sites.

This Preliminary CSM integrated all the information about AoCs that was available at the initiation of the program of investigation works. In essence, the Preliminary SCM provided a framework to guide the decision-making with regard to the scope of the Stage 2 EI at the initiation of the investigation, and through its duration, when changes to the scope were being considered to close data gaps.

The information gathered during the Stage 2 EI at the JBRF was then used to re-assessed and refine the Preliminary CSM, and develop the more representative CSM discussed in **Section 9**. Preliminary CSM and develop the refined Conceptual Site Model (CSM) discussed in **Section 9**. This, in turn, was used as an input to the assessment of risk, and hence assists with the selection of the most applicable site management strategies and ongoing monitoring programs.

The components of the model are described in the following sections.

2.3.1 Fate and Transport

The PCSM allowed for the assessment of the fate and transport of Contaminants of Potential Concern (CoPC) potentially arising from the Site's historical activities (i.e. AoCs), within the *on-site* environment and focuses on the progressive identification of potential **sources, migration pathways** and **receptors**.

Sources

Contamination sources that have the potential to impact the subsurface environment, namely, soil and groundwater, were pinpointed and classified as either primary or secondary depending on the way the contaminants may be exposed to or stored in these environments.

Potential source areas and types for the JBRF are identified in **Table 1** and schematically illustrated in **Figure 2.1**.

Migration Pathways and Transport Mechanisms

Transport of the CoPC away from the inferred sources (AoC) and, potentially, off-site may occur via a variety of migration mechanisms and pathways. These also allow processes such as particulate flow (suspended solids), leaching, dissolution, separate phase migration, adsorption, dispersion and volatilisation to be active. Migration mechanisms and pathways were inferred to include primarily the following:

- Above ground flow (run-off and vapour emission);
- Unsaturated Flow (involving gravity driven, leaching and dissolution processes);
- Man-made Conduits;
- Shallow aquifer flow (in perched groundwater systems); and
- Deep Bedrock Aquifer Groundwater Flow in the Regional Bedrock Aquifer.