Approaches to Antarctic solid waste management logistics: past, present, potential

Sandra Potter, Bachelor of Fine Arts
Submitted in partial fulfilment for Master of Environmental Management

Centre for Environmental Studies
University of Tasmania
Hobart, Tasmania, Australia
May 2003

Statement of Authenticity

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university and to the best of the author's knowledge and belief the thesis contains no copy or paraphrase of material previously published or written by other persons except where due reference is made in the text of the thesis.

Sandra Potter

Abstract

Past and present solid waste management practices in Antarctica, and the local impacts of waste, are described. The provisions of Annex III of the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) are reviewed, in particular the requirement to remove waste from Antarctica and clean up past waste disposal sites and abandoned infrastructure. It is noted that the language used in the Protocol, and the absence of clearly defined environmental standards for the region, make examination of the compliance of signatories problematic.

Australian, French, Russian, Chinese and Japanese program policy and operations in East Antarctica are discussed. Issues related to the on-site processing, containment and shipment of waste are considered in an Integrated Solid Waste Management System framework. Particular reference is made to the differing demands presented by the erection and demolition of facilities, the handling of annually generated and principally non-hazardous domestic waste, and the clean up of abandoned, and often contaminated, sites.

A lack of sufficiently-detailed, reliable and consistently-described data on the composition and production of waste, the volumes accumulated, and the effects and efficiency of Antarctic operations, currently hinders strategic planning. Nevertheless it is suggested that a collaborative approach to the removal of waste from coastal sites between 30°E (Syowa station) and 140°E (Dumont d'Urville) is logistically feasible and attractive on environmental, practical and economic grounds. Australia is appropriately positioned, geographically and in the Antarctic Treaty System (ATS), to take a lead role in promoting and implementing a coordinated, regional approach.

Concomitantly it is argued that ATCPs need to give greater attention to philosophical and theoretical issues related to operating in Antarctica, the debate involving enquiry beyond that associated with scientific objectivity and analysis. Similarly, establishing the means by which the participation of stakeholders outside the ATS can be enhanced, requires urgent consideration.

Dedication

To Charlie, without whom

Contents

Figures

Tables

Appendixes

Abbreviations and acronyms

AAD	Australian Antarctic Division [of Environment Australia]
AAP	Australian Antarctic Program
AAT	Australian Antarctic Territory
ACS	Australian Customs Service
AEON	Antarctic Environment Officers Network
AHC	Australian Heritage Commission
AMSA	Australian Maritime Safety Authority
ANARE	Australian National Antarctic Research Expeditions
Annex III	Annex III to the Protocol on Environmental Protection to the Antarctic Treaty: Waste disposal and waste management
AQIS	Australian Quarantine and Inspection Service
ASMA	Antarctic Specially Managed Area (under Annex V of the Madrid Protocol)
ASPA	Antarctic Specially Protected Area (under Annex V of the Madrid Protocol)
AT	Antarctic Treaty
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Party
AT(EP) Act	[Australian] *Antarctic Treaty (Environment Protection) Act* 1980
ATS	Antarctic Treaty System
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CEP	[Antarctic Treaty] Committee for Environmental Protection
CHINARE	Chinese Antarctic Research Expeditions
COMNAP	Council of Managers of National Antarctic Programs
DDU	Dumont d'Urville
DPIWE	[Tasmanian Government] Department of Primary Industries, Water and the Environment
EA	Environment Australia
EIA	environmental impact assessment
ESD	ecologically sustainable development
HDPE	high-density polyethylene

HM	Historic Monument (under Annex V of the Madrid Protocol)
IAATO	International Association of Antarctica Tour Operators
ICSU	International Council for Science
IFRTP	Institut Français pour la Recherche et la Technologie Polaires
IGY	International Geophysical Year
IEE	Initial Environmental Evaluation
IP	[ATCM] Information Paper
IPEV	Institut Polaire Français Paul Emile Victor
ISWM	Integrated Solid Waste Management
IUCN	World Conservation Union (formerly International Union for the Conservation of Nature and Natural Resources)
JARE	Japanese Antarctic Research Expeditions
Madrid Protocol	Protocol on Environmental Protection to the Antarctic Treaty
MARPOL	International Convention for the Prevention of Pollution from Ships
MRF	materials recovery facility
MSW	municipal solid waste
NEPM	[Australian] National Environment Protection Measures
NGO	non-government organisation
NSF	[American] National Science Foundation
PET	polyethylene terephthalate
PCB	polychlorinated biphenyl
PVC	polyvinyl chloride
RAE	Russian Antarctic Expeditions
RTA'd	returned to Australia
SCAR	Scientific Committee on Antarctic Research (a subcommittee of the ICSU)
SPA	Specially Protected Area (under Annex V of the Madrid Protocol)
SSSI	Site of Special Scientific Interest (under Annex V of the Madrid Protocol)
TEU	twenty-four equivalent unit (shipping container)
USA	United States of America
USAP	United States Antarctic Program
WP	[ATCM] Working Paper

Chapter One – Introduction

1.1 Background

> At present the Antarctic Treaty forbids the dumping of atomic wastes in Antarctica ... this decision for the Antarctic Treaty was made without adequate scientific advice ... of all the places in the world the Antarctic is probably the safest place to bury such wastes. I hope that at some stage the Treaty will be altered to permit controlled disposal of radioactive wastes in Antarctica ...
>
> Phillip G. Law, Australian Antarctic Division,
> Department of External Affairs (Law 1963)

Law's vision of Antarctica as a depository for hazardous waste from other continents has not been realised. Rather, in 1991 parties to the Antarctic Treaty (AT) of 1961 adopted an environmental protection regime, the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol), that includes a waste management annex calling for the removal of waste *from* the region, and the clean-up of past land-based waste disposal sites and abandoned structures insofar as their removal does not cause greater adverse environmental impact than leaving the material *in situ*.

The legacy of science and its supporting activities in Antarctica is estimated to amount to between 1 and 10 million m^2 of abandoned, unconfined materials (Snape et al. 2001a). Even so, very little is known about the real environmental impacts of waste disposal sites on the Antarctic continent (Riddle et al. 2000). The impacts of waste tend to be discussed in the context of their potential degradation of human-determined values ascribed to the area, in particular Antarctica's value as a global laboratory for science and as a wilderness of varying culturally-determined and changing amenity related values.

Waste materials and waste disposal sites within Antarctica may, and in some instances have, resulted in the leaching of heavy metals, hydrocarbons and other hazardous materials into the local environment (Hansom and Gordon 1988); the poisoning of wildlife (Hemmings 1990); wildlife injury or entrapment (Harris 1991); and landscape alteration and habitat destruction (SCAR/COMNAP 1996, ICSU

1989); with changes to local conditions leading to potentially permanent alterations to species assemblages (Cameron 1972, Dayton and Robilliard 1971). Indeed, Dayton and Robilliard describes rubbish as having literally smothered to death an area's benthic flora. Dumped waste is also reported to have buried nesting sites (Frederickson 1971), displaced nesting birds (Waterhouse 2001), and contributed to the retreat of vegetation (Parker 1971). Wayward cement dust has caused physical damage to lichens (Adamson et al. 1994).

Antarctic tip sites provide a source of material that wildlife may mistake for food (SCAR 1985). Poorly-managed organic waste materials are a source of food for wildlife (McIvor undated, Pfenningwerth 2001), provide habit for or are a source of introduced organisms (Schofield 1972, Cameron 1972) and a vector of diseases potentially transmittable to wildlife (Kerry 1993, Schofield 1971, Anderson 1998, Hughes 2003). Waste handling methods and the presence of waste are also considered to have caused changes to wildlife behaviour – leading skuas to scavenge for food at stations rather than at sea (Kerry 1993) and to nest in the vicinity of stations (Waterhouse 2001). Elsewhere, the reduced nesting of species has been linked to disturbance contributed to by the process of transferring waste to dumps (Frederickson 1971).

'Significant' (ICSU 1989) and 'obvious' (Riddle 2000) degradation of aesthetic, wilderness and/or landscape values have occurred in some areas as a result of the presence of waste. Harris (1991) found evidence of man's presence in the form of scattered debris appearing within every 10 m on Maxwell Bay and Fildes Peninsula beaches on the Antarctic Peninsula, and rubbish has been retrieved 20 km from its source (Anon. 1989). A recent study seeking to determine the quantity and types of debris lost from a station, found windblown materials in the rock crevice nests and potential nest sites of petrels (Olivier and Woehler 2002). The open burning of waste has resulted in the release of particulates, gases, plastics, heavy metals and hydrocarbons into the atmosphere (NSF 1979, Hansom and Gordon 1988). Poor incineration practices continue to have similar effect.

Furthermore, waste and inappropriate on-site material handling practices raise occupational health and safety concerns related to; potential or actual exposure to asbestos during the demolition of old facilities (CEP 2002d); odour from faeces

(ICSU 1989); burns and fires from incinerator use (ICSU 1989); exposure to pathogens in decomposing foodstuffs (Snape and Riddle 1998); hygiene and disease risks (AAD 2001a); injuries resulting from being struck by wind blown debris; exposure to medical and laboratory wastes; and manual handling.

The thought of waste in Antarctica is also a cause of community concern (Shurley 1972, Knowles 1989, Handmer et al. 1993), even to those with no personal experience of the area. Peter Scott, summarises the possible symbolic importance of Antarctica for many: 'Even though most people will never have the opportunity of seeing [Antarctica] for themselves … it is still a great consolation to know that somewhere on Earth there exists a white continent that is an almost pristine wilderness (May 1998, p.5). It is for this reason perhaps, that higher environmental standards than those that apply elsewhere may be appropriate for Antarctica.

Waste and the impacts of waste are often attributed to being the exclusive product of the support of science rather than the conduct of scientific research itself. Field programs may though, for example, involve the placement of survey and sampling stakes and pegs, and small constructions over a vast area. These items are commonplace in Fildes Peninsula, King George Island (Harris 1991), and in the Vestfold Hills in East Antarctica. Though many are likely abandoned, this status can be difficult to establish. Reports exist too of penguins entangled in meteorological balloon debris. Balloons are routinely launched from numerous stations throughout Antarctica. Ironically though, the greatest waste management related concern to parties to the AT appears to be the potential for pollutants to impact on the value of the continent as a resource for science, both on a local scale, and with respect to monitoring global changes.

While many of the most disturbing waste management practices have been modified or discontinued, and some ambitious and resource-intensive clean-up programs have been embarked upon, some highly questionable activities continue – deliberately, incidentally or inadvertently.

Assessments of the significance of wastes' impacts and appropriate environmental management have been muddied by questions of scale; the scales at which impacts occur, and the scale at which environmental protection should be addressed – at a station or within a defined, specially protected area; limited to the territory that an ATCP claims; or on an Antarctic-wide or bioregion-based approach? On average, Antarctic stations are estimated to impact on 2–3 km^2 of the environment in terms of physical damage, and 80 km^2 in terms of the fallout of pollutants (Hansom and Gordon 1998). For likely that reason, in 1989 the Scientific Committee on Antarctic Research (ICSU 1989) deemed the impacts of waste on the environment of Antarctica to be negligible. Other authors cited in Hansom and Gordon (1988) similarly describe the impacts as unimportant in view of the size of the continent. While the reasoning behind these conclusions is understood, it is not always noted that many stations are located, sometimes side-by-side, in ice free areas which account for as little as 0.4% of the continent. These ice free areas have immense importance as habitats and breeding grounds for Antarctica's flora (mosses, lichens, grass and cushion plants) and fauna (seals and seabirds); as such they are often referred to as 'oases'. The terrestrial ecosystem is also considered to be fragile. Plants and animals live in Antarctica at the limits of their range or are adapted to cope with the strictures of extreme physical conditions; factors that render them susceptible to changes in the environment (Hansom and Gordon 1998). It is unlikely therefore, that the environmental impacts of inappropriately managed waste will be minor or transitory.

Activities in Antarctica involve a significant logistical commitment. Areas south of the Antarctic Circle experience an extended period of total darkness. Temperatures are low – varying with latitude, elevation and distance from the coast. Inland the typical range is between –40 and –70°C during the coldest months, and –15 to –30°C in the warmest months. (In 1983, an extreme of –89.6°C was recorded at the Russian station Vostok.) While temperatures in coastal areas are typically less severe (between –15 and –32°C in winter, and +5 and –5°C in summer), these regions are prone to katabatic winds of velocities as high as 320 km/h. When blowing over areas of powder-like snow, drift and blizzards are produced and can reduce visibility to within metres. 'White-out' conditions, where the reflection of sunlight between the ice and cloud layers result in the disappearance of the horizon, and visual perception of one's surroundings is lost, have been described by Antarctic aviators as a condition much like flying in a glass of milk.

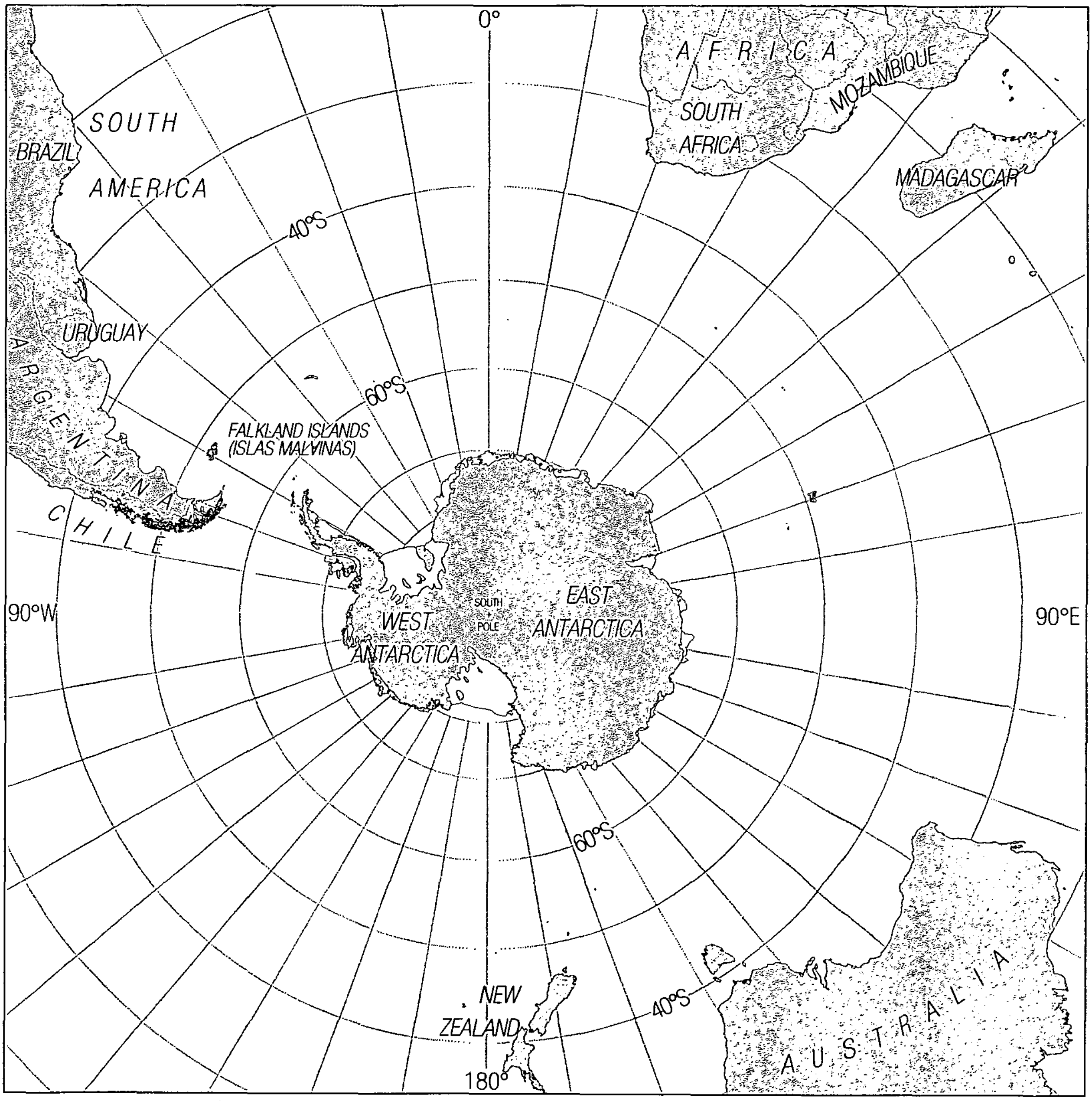

Figure 1. Antarctica relative to surrounding land masses.

As well as being the world's coldest, windiest, highest and driest continent, Antarctica is also remote from other land masses (Figure 1). The closest neighbouring continent, South America, is approximately 1200 km distant. Most of Antarctica's 42 year-round, and 40 summer research stations (Skare 2000), rely heavily on the summer delivery and removal of materials by sea. Depending on the Antarctic destination and timing of visits, ships may need to negotiate floating pack ice which can extend some 2200 km from the coast (Hansom and Gordon 1998). The 'pack' ranges in area between 4 000 000 km^2 in summer and 22 000 000 km^2 in winter (SCAR 2002). Even on a local scale, winds and currents may change readily navigatable areas into unpassable, dense conglomerates of ice in the space of hours and trap ships in the height of summer. Submerged pieces of ice ('bergy bits') act as navigation hazards that are difficult to detect by radar, especially in gale conditions.

Ninety-five per cent of Antarctica's nearly 18 000 km of coastline is subject to permanent glacier ice. The few deep water anchorages and beaches suitable for landings are rare and tend to be surrounded or intruded by ridges of ice that develop from the action of the pack being driven onshore by winds and currents. On arrival in Antarctica, vessels usually moor alongside ice edges; wedge into fast ice and load and unload directly onto sledges; or anchor offshore and, using their crane, discharge cargo onto barges, boats or amphibious vehicles. Operations are remote from ports, refuelling facilities, ship repair yards, emergency services and other marine infrastructure; few routine shipping support services are available. In summary, waste management under these conditions can be a physically difficult, resource intensive and complex task.

1.2 Definition of key terms

Brown and Black's (2002) definition of waste, namely, materials that at a particular point in time or place are unwanted and thus useless, has been adopted in this thesis. The study scope has however, been narrowed to solid waste, and then as the term is commonly used rather than as it may be technically defined. Accordingly, the handling of sewage, for example, has not been addressed beyond the discussion of the impacts of waste practices generally.

Solid waste management is defined by Tchobanoglous et al. (1993, p. 7) as:

> the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid waste in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes.

Their definition includes 'all administrative, financial, legal, planning and engineering functions involved in solutions to all problems of solid wastes' (Tchobanoglous et al. 1993, p. 7). Integrated solid waste management (ISWM) is defined as 'the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals' (Tchobanoglous et al. 1993, p. 15). It therefore necessitates that all the functional elements of the system are evaluated, and that the interfaces and connections are considered.

1.3 Aims and objectives

The aim of this study is to examine the applicability of ISWM system-founded theory and principles to Antarctic operations.

The objectives of this study are to:

- describe the nature of Antarctic waste and to examine contemporary solid waste handling practices (Chapter 2);
- review the provisions of the waste management annex of the Madrid Protocol, and the responses of national Antarctic program operators (Chapter 3);
- using an ISWM system framework, analyse logistical issues peculiar to the on-site handling, removal and processing of solid waste from Antarctica (Chapter 4); and
- examine East Antarctic activities as a regional case study for the development of cooperative, waste management operations (Chapter 5).

A motivation for undertaking this research has been the desire to contribute to knowledge bridging two related but in practice, separately managed, Australian Antarctic Program (AAP) activities – affecting environmental protection through organisational and administrative processes, and planning and conducting Antarctic operations in the support of science. The author has acquired first hand experience in both areas – as a long-serving logistics planner and voyage leader, and as an environmental (policy) officer with the Australian Antarctic Division (AAD). *The views expressed in this dissertation are, however, the author's and do not represent the official view or policy of the AAD.*

Quilty's (2002) observation that Antarctic policy development (specifically Australian) occurs hidden from public view, warrants mention in relation to the concerns of this thesis. The widely-expressed desire of the AT community is to make environmental management decisions informed by science. It is little acknowledged though, that environmental policy choices unavoidably involve making highly significant value judgements. Unless the values underlying deliberations are made explicit, public understanding of administrative decisions is likely to be poor. So, while the intention has been to present a critique framed in an unbiased, rational and non-flammatory manner, this thesis also aims to promote discussion and further knowledge on contemporary Antarctic environmental policy development.

1.4 Methodology

Information sourced in the conduct of this research included scientific papers, conference proceedings, monographs and other academic critiques; and government and corporate policy statements and procedures. Program-specific details including waste generation data were obtained from AT Consultative Meeting (ATCM) working papers (WPs) and information papers (IPs); AT Committee for Environmental Protection (CEP) documents; Council of Managers of National Antarctic Programs (COMNAP) documents; and information exchanges made by AT Consultative Parties (ATCPs) in accordance with Articles II and VII of the AT. Sources not examined were the 'members only' pages of the websites of COMNAP, the CEP, ATCMs and the Antarctic Environment Officers Network (AEON). These may well have provided the study with greater dimension.

Comment was also obtained via personal communications with staff or representatives of a range of organisations and companies including the AAD, the French Polar Institute Paul Emile Victor (IPEV), Japan's National Institute of Polar Research, Antarctic Logistics Centre International in South Africa, Polar Latitudes

Pty Ltd in Australia, the Australian Quarantine and Inspection Service (AQIS), Antarctic New Zealand, the Australian Bureau of Statistics and various Australian port authorities. Unpublished information was also obtained from the libraries resource centres and/or photographic collections of the AAD, the University of Tasmania, the University's Institute of Antarctic and Southern Ocean Studies, and the Antarctic Cooperative Research Centre (Antarctic CRC), also in Hobart, Tasmania. While this research may attract criticism because of its seemingly unstructured and random approach to the literature review, it is believed that the key sources of publicly available information have been accessed.

Early in the scoping phase the decision was made not to attempt to survey national Antarctic programs operators, in particular with the aim of acquiring waste generation data. The reasons were threefold; concern about the achievability in the time available; concern about the probable existence of 'survey fatigue'; and the likelihood of the compilation of data of comparable quality and coverage not being advanced since the Antarctic Treaty System (ATS) supported survey undertaken by SCAR (ICSU 1989) which concluded that attempting to estimate the total waste produced in Antarctica, by extrapolating from the data cited by operators with complete replies to those giving incomplete or non-existent replies, was of little value. With respect to the notion of survey fatigue, an unacceptable risk of conducting intensive data collection programs without a mandate accepted by the participants is the potential for the activity to diminish their interest in contributing to similar research embarked upon by a recognised body such as COMNAP.

1.5 Limitations of the research

Whereas Antarctica is defined in the AT as the area south of 60°S latitude, the shear scope of Antarctic waste management issues led to the limitation of this research to the continent (its ice sheet, ice shelves and ice free areas) and its near-shore environment – and then, with a focus on the eastern sector. This is of course, an artificial boundary adopted for practical reasons; paradoxically it is argued here that a holistic approach to the management of waste issues is required.

A detailed analysis of the policies and activities of each program operating on the continent was not possible due to time constraints, and difficulties in accessing and translating documents, especially those of a potentially sensitive nature. Rather, the broad responses of program operators to ATS environment protection developments are discussed. Similarly, while the author has been able to draw upon observations made during visits to various stations, a detailed inspection of the sites discussed was not possible in the period between research task development and finalisation. The expense, remoteness of sites, and the lead-time and range of activities involved in organising inter and intra-continental transport would make anything other than relatively limited exposure difficult to achieve in less than several summer periods.

Waste generation and waste management within the Antarctic tourism industry is not discussed although a significantly greater number of tourists than personnel attached to national programs visit the continent each year – an estimated 13 200 tourists during the 2000-01 season (Boyd 2001). Headland (1994) calculated that when the annual number of tourism person days on the continent is compared to governmental activity, tourism accounts for an estimated 0.52% of the time spent ashore. Most Antarctic tourism is currently ship-based and the waste generated is ship-contained (Tracey 2001). It is a requirement of the International Convention for the Prevention of Pollution from Ships (known as MARPOL 73/78) that vessels over 400 t have waste management plans containing procedures for the collection, storage, processing and disposal of garbage generated on board. Furthermore, faith has been attached to the fact than many operators are members of the International Association of Antarctica Tour Operators (IAATO) which imposes a range of obligations on its members, including requiring compliance with the provisions of the Madrid Protocol and visitor guidelines that IAATO has developed at its own volition.

Finally, this research makes greatest use of Australian sources of information and experience. This is due to the earlier-mentioned difficulties in sourcing the in-house documents of other programs, and is an inevitable consequence of the author's employment. It is not considered inappropriate however in view of the fact that Australia claims sovereignty, and presumably therefore assumes a management role over, much of the continent.

1.6 Chapter outline

This thesis consists of six chapters. The introduction provides a summary of the research task, defines key terms used in the text, and summarises the aims, objectives, methodology and limitations of the research. Antarctica's physical environment and the known or likely impacts of poor waste management practices are described in order to provide readers with an understanding of the challenges involved in conducting operations in the region, and the environmental significance of the issue.

Adopting a qualitative approach, Chapter 2 surveys scientific and technical literature, and national Antarctic program and ATS documents in order to establish the nature of the waste generated and in existence in the region, and the manner in which solid wastes have been handled since the 1940s. The legacy of past practices is also discussed. While some of the ensuing management issues are daunting, it is apparent that attitudes to waste handling on the continent have changed markedly; one can cautiously take heart.

Chapter 3 discusses the obligation on Antarctic Treaty Consultative Parties (ATCPs) to manage their waste in accordance with the requirements of the Madrid Protocol, the key AT agreement on environmental protection. The Madrid Protocol's waste management annex, and the limited means currently available to examine ATCP compliance with its provisions, are reviewed.

Chapter 4 explores the functional elements of ISWM systems in the Antarctic context. Waste minimisation, storage and processing practicalities; incineration practices; contaminated site management; and the transport of waste from the AT area are among issues discussed.

In Chapter 5, the waste management policies and practices of programs currently operating in the sector known as East or Greater Antarctica are described in order to identify factors likely to support or hinder the development of coordinated, regional, waste management arrangements.

The final chapter re-assesses the research question and the aims of the research, and concludes with recommendations for future investigations. It is noted that an active and targeted program of data collection is critical to developing longer-term, cost-effective and environmentally sound strategy choices. Nevertheless it is suggested that a trans-national shipping arrangement for the removal of waste from coastal East Antarctic sites has the potential to offer environmental, practical and economic benefits to operators in the area.

Chapter Two – A history of Antarctic waste management

2.1 Introduction

In this chapter the literature is reviewed to provide an overview of the composition, generation and management of solid waste generated in Antarctica since the late 1940s. The 1940s and 1950s are considered to be the beginning of the 'contemporary' or 'modern era' of Antarctica's history. The International Geophysical Year (IGY), from July 1957 to December 1958, marked a period of significant increase in Antarctic activity; some 60 research stations were established by the 12 nations operating on the continent at that time.

2.2 Change in thought and practice

While there are many detailed published accounts of operational issues attached to the establishment and occupation of the first Antarctic stations (see, for example, Law 1967, Law 1983, Law and Bechervaise 1957, Muller 1968 and Smith 1968) the cursory or complete lack of references to waste handling suggest that for the most part, waste management was not regarded as being a matter of import. At Brown (Argentina), for example, it was noted that 'Garbage elimination ... does not offer any trouble since it is placed near the sea coast' (Muller 1968, p. 8). Similarly, Thomson (1971, p. 60) described the New Zealand station Vanda (now decommissioned and removed) as being:

> One base that from its inception has been kept from polluting its environs ... Rubbish disposal and drainage have required special planning for the station's location, 18 miles inland on a snow-free surface, precludes drainage into the sea or the ice cap. We have overcome these problems by burning all combustible rubbish in an incinerator. Other rubbish – cans, bottles, human waste – is sealed in drums and transported by helicopter to the Scott Base dump on the annual sea ice',

the inference being that moving materials to a different site represents an environmentally acceptable outcome.

From 1940 to at least 1980, the practices employed throughout Antarctica were, typically; (i) disposal on land or in crevasses in the vicinity of stations, (ii) disposal in the near shore marine environment, (iii) deposition on sea ice in anticipation of the ice melting and drifting out to sea, and the waste sinking – a process known as 'sea icing', (iv) disposal to the deep ocean, and (iv) open burning. It has been suggested (AAD 2003a, ICSU 1989), and seemingly widely accepted, that these practices were consistent with attitudes to waste management existing outside Antarctica at that time. Such tacet sanctioning appears to be inconsistently applied. The majority of coastal Antarctic stations still release untreated sewage into the near shore marine environment (Hughes 2003). While permissible under the Madrid Protocol (Annex III, Article 5), it is unlikely, though a matter of conjecture, that this practice would be positively viewed outside the ATS community.

Perhaps the first reference to waste handling in this period of Antarctica's human habitation is that described in the 1955 *Australian National Antarctic Research Expeditions (ANARE) Operations Manual* for Mawson (Australia):

> Men should remember that odd fragments discarded in winter and tidily hidden beneath snow drifts become very noticeable when the snow thaws in the spring. In winter, particularly, therefore, the disposing of rubbish, the dumping of cases, the jettisoning of drums, should be carefully organized and carried out at places where the dumps are desired to be found in the summer when the snow has disappeared (Department of External Affairs 1954).

While in Sir Vivian Fuchs' and Sir Edmund Hillary's *The Crossing of Antarctica: the Commonwealth Trans-Antarctic Expedition 1955-58* reference is made to the handling of 'gash', a term for rubbish of unknown origin and in use as naval slang from 1925:

> The most important feature was the 'gash' pit ... Now we made a deep waste pit by digging a small hole about 18 inches deep in the snow and pouring into it a pint of petrol. When this had soaked in and was ignited it burned slowly, melting a cavity (Hince 2000, p. 142).

A decade later, the shipment south of heavy vehicles facilitated the adoption of more aggressive approaches:

> waste water is allowed to run out over nearby rocks where it freezes to form 'glaciers' [which were] ... periodically scraped into the sea by bulldozers. ... Pits for waste are bottomless as regards fluids, which melt their way down into the neve. For solids, new pits can be dug easily as old ones fill up (Law 1967, p. 151).

Although emerging in the early 1970s, accounts criticising Antarctic waste management practices, particularly from outside the ATS community, came to the fore in the 1980s. The following condemnations of poor waste and site management at McMurdo (USA) and Wilkes (USA and Australia) are representative:

> truck tires, sections of pipe, and drums of oil are scattered haphazardly about – some are punctured and leaking into the porous Antarctic soil. Pieces of discarded trucks and other metal materials lie along the shoreline which surrounds an ocean floor littered with the refuse of 30 years of ocean dumping (Bogart 1988, p. 104).

> [Wilkes appears] as it did when it was abandoned in 1969 ... tinned and bottled food, machine parts, buildings, chemicals (including more than 200 boxes of tinned caustic soda spilling their contents on to the snow) metal drums, flares and even explosives were scattered ... [nearby] Casey's rubbish tip ... was a serious ecological hazard ... no separation of toxic materials from other non-combustible wastes. Skuas were found dead around the tip and scavenging birds have removed food scraps and dropped parts of them over a wide area (Ron Lewis Smith cited in May 1988, p. 134).

> the sordid vision of Wilkes base ... Here were acres of accumulated rubbish and God knows what else, buried in ice and snow, the detritus of fifteen years of squalid existence by groups of men (Murray-Smith 1988, p. 101).

By comparison, the literature of the late 1980s and early 1990s is characterised by seemingly detached and analytical observations. Agraz et al. (1998) summarise the legacy of waste practices employed by their national program's activities at Marambio (Argentina) on Seymour Island in the Antarctic Peninsula:

> Wastes were not evacuated from Antarctica, and therefore accumulated over the surrounding areas forming large waste deposits. Some of these wastes remained there (mainly construction material) and some – particularly fuel drums – were transported away from the Station Area by gravity force. Eventually part of them, after sliding through valleys and gullies, reached the shoreline ... a great abundance of 200 litre-fuel drums filled with human faeces, half-buried into the slope and/or into the ice-foot ... in the past, since no standardized drum disposal methods existed, most of them were accumulated on the edge of the plateau. Water stream action as well as backward erosion gradually pushed drums down the slope.

Similarly:

> Drums dumped at this site [ie lakes above and to the south of Marsh, King George Island] have leaked thick deposits of oil: more oil was clearly visible on the surface of the stream draining the catchment ... The partly enclosed bay into which the stream drains is important for wildlife. A third waste disposal site was at the Chinese station in a catchment which also drains into

> this bay. Though efforts have been made to clean up this area, material remaining has contaminated a small lake (Harris 1991, p. 199).

About this time, references to measures taken to mitigate the degradation of aesthetic values associated with accumulating waste made increasing appearances. The techniques employed reflect that the sea was considered to be a zone of no consequence and no ecological significance. The sinking of waste bulldozed onto the sea ice near Casey was assisted by explosives (Deprez et al. 1999). Waste accumulated in a consolidated mass on the shoreline at McMurdo in the 1970s and failing to breakout and sink for three consecutive seasons was relocated to an inland hollow where it was covered with fill material and graded (Chiang et al. 1997). (A multi-million dollar clean up of this site has since recovered and returned to America, 1800 bales of scrap metals, 1000 m^3 of large bulk metal, 57 m^3 of wood, 200 m^3 of cardboard, 40 m^3 of construction debris, 40 m^3 of asbestos waste, and 700 drums of liquid waste and chemicals.)

The French program is reported to have used a conveyor-belt system to dump waste into the sea (Greenpeace International 1990). In the report of a 1989 inspection of the site at Dumont d'Urville, Greenpeace note the existence of an ongoing concern for aesthetics over and above the pollution of the marine environment:

> Plastics, metals and sections of discarded pipe littered the hillside from years of use. Houssin [the station's officer in charge] informed the [inspection] group that a high pressure hose would be used to sweep this litter off the hillside and into the sea (Greenpeace International 1990, p. 51).

The decommissioning of Hallett (USA/New Zealand) in northern Victoria Land in the 1980s also amounted to the transfer of material from land to sea. Dumped were:

> metal cans, empty fuel containers, drums, tanks, rubber fuel lines, steelwork from buildings, a whole wannigan, metal sheets, bearers, trusses and floor joints, small non-burnables packed in drums, various building fittings and vehicles (Waterhouse 2001, p. .38).

Although published in 1993, the following description is posed, without judgement, as the likely current approach to site clean-up throughout Antarctica:

> Where removal has been proven impractical at this stage, the land surface is being cleared to the maximum possible extent and top-dressed to minimise visual pollution. The sites will continue to be monitored and materials which emerge as a result of erosion or melt will be progressively cleared (Sayers 1993, p. 135).

2.3 Independent commentary

An ostensibly independent source of information on current waste management practices and issues is the reports of inspections made by ATCPs (under Article VII of the AT, and Article 14 of the Madrid Protocol) of the stations of other countries. Seven inspections have been conducted since 1994, the most recent by Norway in January 2001, and USA in February 2001. A standard checklist has been developed for this purpose (Appendix I). The Norwegian inspection of six sites in Dronning Maud Land (Maitri, India; Novolazarevskaya, Russia; Georg Forster, Germany; Sanae IV, South Africa; Troll, Norway; and Epica Drill Site, Germany) found that the appropriate management and disposal of waste was given high priority at most of the areas visited in that the stations had comprehensive schemes for separating, storing and back-loading materials (Ministry of Foreign Affairs 2001). The American inspection of 11 Antarctic Peninsula stations (Arctowski, Poland; Ferraz, Brazil; Vernadsky, Ukraine; Juan Carlos I, Spain; St Klimont Ochridiski, Bulgaria; Bellingshausen, Russia; Presidente Eduardo Frei, Chile; Great Wall, China; Artigas, Uraguay; King Sejong, Korea; and Teniente Jubany, Argentina) also made favourable observations of station practices in general although reported that waste from Bellingshausen was being stockpiled in a holding on the beach covering an estimated 1 hectare (United States Department of State 2001).

It appears that ATCPs have adopted an attitude of mutual forbearance with respect to the environmental management of others' programs, evidenced, for example, by apparent ATCP acceptance versus public outrage at the construction of an 1100 m airstrip linking three islands near Dumont d'Urville. Similarly, while the Norwegian inspection (above) found that waste was disposed of into the Antarctic environment at one of the stations, the final report of ATCM XXIV says 'The inspection team had observed no violations of the basic provisions of the Antarctic Treaty and it was also noted that there was a high awareness of the provisions relating to the Environmental Protocol at the stations visited' (ATCM 2001). Hansom and Gordon (1998) acknowledge that to achieve the present 'status quo' and in order to adopt even the most basic environmental management measures, ATCPs have had to negotiate a complex course around issues of sovereignty, jurisdiction, and economic and political interests. Indeed, seven states claim sovereignty over parts of the continent while the claims of three overlap and are mutually contested. Some ATCPs do not make claims or recognise those of others.

Non government organisations (NGOs) including Greenpeace International, the Antarctic and Southern Ocean Coalition and Mission Antarctica (now known as 'INSPIA') have helped bring information on Antarctic waste management activities and the deteriorating condition of disused stations into the public arena, i.e. outside scientific, specialist, ATCP-exclusive or otherwise difficult to source, literature. Achievements aside, the focus of 'activist' NGO groups tends to be on reporting information likely to attract news and current affairs attention. As such there is a risk that these commentaries may not improve the public's knowledge and understanding of the issues involved. Sensationalist tactics may also be directed at publicising the writers' cause – as may be necessary to maintain NGO existence – rather than providing a useful appraisal of contemporary practices; ATCPs may well view NGO activities as a threat to the achievement of program plans.

Commercial tour operators and individuals participating in tourist ventures are a potential, source of independent, qualitative, information on ATCP operations. Tourism operators who wish to provide their clients with experiences of stations, or to visit sensitive areas including historic sites, may feel constrained though, by the need to maintain a high level of goodwill with national Antarctic programs. (The logistical support of national programs is also a likely significant source of funding for some operators.) When invited to comment on this theory, IAATO (Landau 2003) declined although a stated objective of the organisation is 'To enhance public awareness and concern for the conservation of the Antarctic environment and its associated ecosystems' (IAATO 2003), and although IAATO's website notes that 'Experienced naturalist staff, many trained as researchers, can collect data following standard protocols … IAATO members are particularly interested in contributing to CCAMLR surveys of beached marine debris.' IAATO member vessels have been involved in the repatriation of waste from Arctowski and Bellingshausen (IAATO 2003).

2.4 Waste types and quantities

Even at the broadest level, analyses of the nature of Antarctica's waste vary. SCAR's Panel of Experts described wastes generated by Antarctic operations as being generally narrower in their compositional range and having lower toxicity levels that those of the industrialised and heavily populated areas of the world (ICSU 1989). Others, including Canale et al. (1990), maintain that the types of wastes generated in Antarctica are diverse and analogous to the waste management problems facing any modern society. That the waste generated is the result of a diverse combination of policy and practices, rather than of a single activity, may be the only point of agreement.

Arrens' itemisation of solid waste produced as a result of AAP activities is likely to be representative of the range of wastes generated by stations with significant research programs. Materials include adhesives and sealants, ferrous metal, defective mechanical equipment and vehicles, piping, wiring, batteries, empty fuel drums, packaging materials, bio-hazards, rubber, glass, plastic, paper, obsolete and defective science equipment, timber, clothing, cardboard, sewage sludge, ash, food scraps, explosives, paints, concrete pieces, old building components, fibreglass, and cement and plasterboard sheeting (Arrens 1994). The list incorporates 20 types of waste classed as hazardous under the Australian National Environment Protection Measures (NEPM).

In practice though, waste materials are unlikely to be conveniently sorted. Deprez et al. (1999, p. 301) found Wilkes and a nearby 1965 to 1986-operated tip site in Thala Valley to contain a cocktail of:

> environmentally hazardous substances, including: rusting drums of fuel, oil and lubricants, detonators, blasting caps, caustic soda, ferrous silicate, sulphur, gas cylinders, burnt plastic explosives, explosive charges, other chemical powders, bitumen, linseed oil, aluminium shot, and other items of rubbish spread over the station area of a few square kilometres ...
>
> ash, gravel, vehicle parts, batteries, rusted cans and other metal objects, glass, plastics, paper and cardboard, wood, rope, clothing, construction materials, asbestos and/or cement sheeting, rubber, cement, mattress springs, insulation batts and kitchen items (such as toasters).

Chemical analysis of this site, and, one could extrapolate, similar sites, indicated 'extremely high concentrations of copper, lead, zinc, and to a lesser extent cadmium and arsenic, present in the sediment in forms that are actively able to leach' (Snape and Riddle 1998, p. 7).

Waste has been categorised and quantified in a wide range of ways throughout the world, e.g. according to its nature – chemical composition (inorganic, organic) and physical state (gaseous, liquid, solid); properties, e.g. solubility, biodegradability, infectiousness, persistence in the environment, reactivity with other substances; treatment or disposal method – incineration, deposition in freshwater environments, deposition in the marine environment, landfill; and source – industrial, domestic and/or institutional. Article 8 of Annex III of the Madrid Protocol only requires waste to be allocated to one of five groupings:

1 – sewage and domestic liquid wastes;
2 – other liquid wastes and chemicals, including fuels and lubricants;
3 – solids to be combusted;
4 – other solid wastes; or
5 – radioactive material.

The ATCP accepted inspection protocol seeks to obtain production rates per person day, though this information is rarely found in the reports that have been submitted to ATCMs. The Spanish program at Juan Carolos I on Livingston Island produces organic waste 0.1 to 1.5 kg per person per day, glass 0.3 kg, metal cans 0.1 kg, and plastics 0.05 kg (United States Department of State 2001) while at a German station, 1.8 kg of solid wastes are (or were) generated per person day (Stephan 1990). The United States Antarctic Program (USAP) most frequently publishes total annual generation, which at McMurdo for the years when data have been available, has ranged between 2400 and 4000 t. The 1995 figure of 2476 t, excluding sewage, is considered to represent a typical recent year (Waterhouse 2001).

A study by SCAR, estimated the annual production of solid wastes in Antarctica to be approximately 4 m^3 per person per year, excluding fuel drums and building waste – reducing to about 1.3 m^3 per person per year after allowing for the high temperature incineration of the combustible component (SCAR and COMNAP

1986). Fuel drums and building waste could, however, account for as much as 80% of waste produced on the continent.

2.5 Summary

Antarctic waste handling practices have received scant attention in polar literature, past and present. The popular early methods of handling waste materials were variations of local dumping, an activity conducted with little apparent regard to the likely environmental impacts. While there has been considerable development in approach to waste management and environmental protection, the ongoing practice of accumulating waste, which is evident at some stations, is likely to differ only in the assumption that greater consideration is now being given to the placement and containment of materials.

Information on the nature, volume or weight, and sources of waste generated and accumulated in Antarctica continues to be scarce and is typically presented in only narrative form. The means by which independent analyses of waste management practices currently adopted at stations can be obtained are limited.

Chapter 3 provides an overview of the ATS and, in particular, the Madrid Protocol. The Protocol entered into force in 1998, marking a heightened ATCP commitment to environmental protection. The waste management annex to the Protocol is examined in detail and with a focus on compliance issues.

3.1 Introduction

This chapter considers the adequacy of the Madrid Protocol's waste management annex and its provisions related to source reduction, recycling, waste storage, and the disposal and removal of waste from the AT area. An outline of the environment protection framework existing prior to the Protocol is included to provide a context for discussing the current regime. Reports on waste management practices made by ATCPs conducting operations in East Antarctica are reviewed, and compliance issues are discussed.

3.2 The early framework

Environmental management generally, and waste management specifically, were afforded little attention when the first research stations were established in Antarctica. The literature of the day and recently recorded oral histories indicate that Antarctica was thought of as a continent to be 'conquered' and exploited – a hostile force that should be made obedient to human purpose and direction. Phillip Law, the first head of ANARE lamented that Antarctica held 'no known valuable exploitable resources' and asked what might be done to contribute to its development (Law 1963, p. 7). These attitudes are later qualified; 'You have to understand the spirit of the day. We were still in the times of colonial attitudes, expansionist attitudes, territorial acquisition, gains from possessions' (Phil Law in Clark and Wishart 1993, p. 11). Schatz (1988, p. 101) comments similarly on the change in values and 'needs', but in relation to science; compromising science was not a significant issue given that early science did not depend on fine point, parts-per-billion measurements – 'Little harm was seen in local trash dumping; the areas of human impact were few and small; and the principal problems were those of access and survival.'

When the AT came into force in 1961, the focus of ATCPs was on sovereignty issues, freedom of scientific research and avoiding militarisation of the continent rather than environmental management. Only the prohibition of the disposal of radioactive waste is mentioned – in Article V. The Agreed Measures for the Conservation of Antarctic Fauna and Flora and conventions for the Conservation of Antarctic Seals and Antarctic Marine Living Resources (CCAMLR), which form part of the ATS, are however indicative of the acceptance of a stewardship role. Nevertheless, SCAR's encouragement of study of the EIA processes in order 'to determine the point at which changes become so significant as to require the cessation or modification of the causative activities' (SCAR 1985, p. 3) reflects a highly set impact threshold. 'Waste is a particular problem and its disposal in such a way as to avoid *severe* [emphasis added] impacts requires further consideration' (SCAR 1985, p. 9).

The AT's continuing operation is largely enacted through ATCMs. The increasing number of environmental protection-related recommendations, measures, decisions or resolutions that are developed indicate that environmental concerns are firmly on the agenda. Measures contain provisions intended to be legally binding when adopted by all ATCPs; decisions are made on internal organisational matters; resolutions are hortatory (Hansom and Gordon 1998). A list of post-1991 ATCP recommendations, measures and resolutions related to waste management activities is at Table 1. The table shows that while waste management requirements are included in protected area management plans; there are currently no measures focussed on the implementation of Annex III.

Primary environmental protection standards were arguably first provided for by ATCM VIII-11 (1975), which called on ATCPs to adhere, to the 'greatest extent feasible', to a *Code of Conduct for Antarctic Expeditions and Station Activities*. Subsequently, the increasing degree and level of complexity of Antarctic operations, changing attitudes to what constitutes pollution, and improvements in logistics and technology, resulted in a 1985 proposal that the code be revised. In 1986 a SCAR Panel of Experts on Waste Disposal was formed. The panel surveyed national operators, compiling data relating to 17 national programs, 34 year-round occupied stations, 28 permanent summer bases and a number of field camps. The data gathered applied to the 1986-87 and 1987–88 austral summers and encompassed all domestic and operational waste generated and liable to be discharged or disposed of to the atmosphere, marine or terrestrial environments (ICSU 1989). The panel's 27 recommendations formed the basis of a new code adopted at ATCM XV. In addition

Table 1. Waste management-related measures, resolutions and recommendations adopted at ATCMs, 1991–2002.

Meeting	Reference	Purpose
Measures		
ATCM XIX 1995	Measure 1	Management plan requiring that all non-human waste is removed from SPA 13 (Moe Island).
ATCM XIX 1995	Measure 2	Management plan requiring the removal of all waste from SSSI 11 (Mt Erebus, Ross Island) and prohibiting excreting within the area.
ATCM XIX 1995	Measure 3	Management plan requiring the removal of non-human waste from SPA 24 (Pointe-Geologie Archipelago).
ATCM XX 1996	Measure 2	Management plan requiring that all waste, including human waste, is removed from SSSI 9 (Adelaide Island).
ATCM XXI 1997	Measure 1	Management plan requiring that all waste, including human waste, is removed from SPA 5 (Beaufort Island).
ATCM XXI 1997	Measure 2	Management plan requiring that human waste and grey water are removed from SPA 25 (Cape Evans, Ross Island) and that work parties remove the waste they generate.
ATCM XXI 1997	Measure 3	Management plan requiring that all waste, including human waste, is removed from SSSI 11, 12 (Taylor Valley, Victoria Land), 13 (Potter Peninsula, King George Island), 14 (Harmony Point, Nelson Island), 15 (Danco Coast) and 37 (Cape Geology, Victoria Land), and prohibiting excretion within the sites.
ATCM XXII 1998	Measure 1	Management plan requiring that all waste generated by visitors and work parties is removed from SPA 27 (Cape Royds, Ross Island), 28 (Hunt Point, Ross Island) and 29 (Cape Adare).
ATCM XXIII 1999	Measure 1	Management plan requiring that all waste is removed from SSSI 23 (Svarmartharen).
Resolutions		
ATCM XIX 1995	Resolution 5	Provides a checklist for inspections under Article VII of the AT.
ATCM XIX 1995	Resolution 2	Restates the need to ensure other international agreements do not provide for the disposal of nuclear waste in, or transfer of nuclear material to, the AT area.
ATCM XXII 1998	Resolution 2	Provides a guide to the preparation of management plans for ASPAs. Plans for the disposal of waste are to be included in permit conditions. The requirements set out in Annex III represent the minimum standard. All waste should be removed from the site. Protocol compliant exceptions should be identified as appropriate in the Management Plan.
ATCM XXIV 2001	Resolution 4	Requests parties to review Historic Sites and monuments and confirm that listing remains appropriate.
ATCM XXIV 2001	Resolution 5	Provides interim protection of newly discovered pre-1958 sites and artefacts on the basis of possible historic significance.
Recommendations		
ATCM XVI 1991	Recommendation 10	Includes the requirement that entry permits for protected areas provide comment on waste management expectations.
ATCM XVIII 1994	Recommendation 1	Establishes guidelines for NGO activities that, amongst other things, preclude the disposal of litter or garbage on land and prohibit open burning.
ATCM XXIII 1999	Recommendation 1	Provides guidance on environmental impact assessment.

Sources: ATCM (1991), ATCM (1992), ATCM (1994), ATCM (1995), ATCM (1996), ATCM (1997), ATCM (1998), ATCM (1999), ATCM (2001), ATCM (2002) to recommending specific disposal measures, the code placed greater emphasis on waste management planning.

Stakeholders outside the ATS forum have had little opportunity to contribute to the discussion of this topic, and others. One might charitably suggest that this is because no appropriate mechanism or mandate exists or is able to be developed, or it is the product of the need being dismissed because the region shows no evidence of having supported indigenous human populations. Without such, there is no tradition of land-use at issue (science and exploration aside). It may also be that ATCPs hold the view that their activities do not impact on the community; therefore consultation is not warranted. One unprecedented act of inclusiveness saw environmentalists, service providers, tourist operators, fishing interests, educators, managers, policy advisers and business developers attend an 'Antarctic Futures Workshop' (Tetley 1988) convened by Antarctica New Zealand.

3.3 The Madrid Protocol

The need for greater environmental protection has most notably been recognised and addressed by ATCPs through the Madrid Protocol which was opened for signature in 1991 and entered into force on 14 January 1998. The Protocol provides for the protection of the Antarctic environment through five specific annexes addressing marine pollution, fauna and flora conservation, environmental impact assessment, waste management and protected area management. The waste management annex deals with waste minimisation, waste treatment and waste disposal. Conspicuously absent is reference to the core objectives of ecologically sustainable development (ESD) – a guiding principle for environmental management worldwide. The implementation of ESD principles and objectives are increasingly associated with achieving efficiencies in waste management (Harding 1998).

The text of Annex III is at Appendix II. The Protocol's overriding environmental principles are that:

> The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area (Madrid Protocol, Article 3).

To this end, activities, including waste management activities, in the AT area are expected to be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems. Such judgments are to take account of:

- the scope of the activity, including its area, duration and intensity;
- the cumulative impacts of the activity, both by itself and in combination with other activities in the AT area;
- whether the activity will detrimentally affect any other activity in the AT area;
- whether technology and procedures are available to provide for environmentally safe operations;
- whether there exists the capacity to monitor key environmental parameters and ecosystem components so as to identify and provide early warning of any adverse effects of the activity and to provide for such modification of operating procedures as may be necessary in the light of the results of monitoring or increased knowledge of the Antarctic environment and dependent and associated ecosystems; and
- whether there exists the capacity to respond promptly and effectively to accidents, particularly those with potential environmental effects.

A list of recent ATCP-prepared EIAs involving waste management installations or activities is at Table 2. All, by virtue of the EIA level at which they have been addressed, were deemed unlikely to cause no more than minor or transitory impacts. There does not appear to be a structured means within the ATS by which the actual impacts have or will be assessed and quantified against the predicted impacts. Such an analysis would be a useful aid to the planning of similar activities.

Table 2. Waste management-related Initial Environmental Evaluations prepared by ATCPs, 1991–2001.

Year	ATCP	Title
		Station removal and site clean-up activities
1991	Australia	An Initial Environmental Evaluation of the removal of old Casey station, Antarctica
1992	Germany	Removal of the research station 'Georg von Neumayer', Ekström Ice Shelf, Antarctica – Initial Environmental Evaluation
1993	New Zealand	Decommissioning Vanda station, Wright Valley, Antarctica – Initial Environmental Evaluation
1993	Germany	Dismantling and clean-up of the research station 'Georg Forster', Shirmacher Oasis, Queen Maud Land, Antarctica
1996	USA	Retrieval of fuel and other materials from Old South Pole station, Antarctica
1996	USA	Adoption of SOP for the renovation or decommissioning of USAP facilities
1996	USA	Decommissioning and removal of Byrd Surface Camp, Antarctica
1996	USA	Environmental assessment: mitigation and reclamation of former dump sites near Palmer Station, Antarctica
1997	Australia	Removal of old buildings from Mawson station
1997	USA	Adoption of standard operating procedures for placement, management, and removal of materials cached at field locations for the United States Antarctic Program
1997	USA	Removal of geophysical sampling equipment at Don Juan Pond, Wright Valley and site reclamation at Lake Vida, Victoria Land, Antarctica
1998	China	Initial Environmental Evaluation for the cleanup work of Zhongshan Station. Wastes disposal and wastes removal
1999	South Africa	Initial Environmental Evaluation for the decommissioning of the SANAE III and Sarie Marais bases in Dronning Maud Land, Antarctica
2000	Japan	Removal of observation huts that were built in 1998
		Waste management facilities and equipment installation
1993	USA	Operation of a sanitary waste disposal facility at McMurdo Station, Antarctica
1997	USA	Consolidation of facilities in the hazardous waste yard, McMurdo station, Antarctica
1998	China	Initial Environmental Evaluation for the maintenance of Zhongshan station. Installation of new incinerator
1999	Spain	Installation of a new incinerator at Juan Carlos Juan Carlos I station
1999	Japan	Construction of station facility (construction of PV panels and wind turbine / reconstruction of heliport, summer lodges, waste storage / replacement of incinerator)
2000	Japan	Construction of waste storage
2001	New Zealand	Installation of a wastewater treatment plant at Scott base
		Waste management
1991	USA	Initial Environmental Evaluation – accelerated implementation of waste management actions at McMurdo station, Antarctica
1992	USA.	Initial Environmental Evaluation of the US Antarctic Program's management of food wastes at McMurdo station, Antarctica, for 1993–1995
1993	USA	Initial Environmental Evaluation and Environmental Assessment – master permit application for materials and waste management and waste disposal
1993	USA	Temporary storage of fuel-contaminated soil at McMurdo station, Antarctica

Table 2. (cont'd).

1995	USA	Management of unreliable and unsafe explosives in Antarctica
1996	South Africa	Initial Environmental Evaluation of the proposed burning of untreated timber on the Fimbul Ice Shelf, Antarctica, during the 1996/1997 summer period
		Other
1993	USA	Initial Environmental Evaluation and environmental assessment of the National Science Foundation's Antarctic waste regulations
1993	USA	Issuance of waste permits for PolarFlite™ and Adventure Network International
1995	USA	Issuance of waste permits to Adventure Network International and Mr. Skip Novak, owner and operator of the *Pelagic*

Sources: ATCM (2001), Netherlands (2000)

Article 2 of Annex III lists specific wastes to be removed from the AT area 'if generated after entry into force of this Annex' – a qualifier that weakens the General Obligations. The wastes involved are:

(a) radioactive materials;

(b) electrical batteries;

(c) liquid and solid fuel;

(d) wastes containing harmful levels of heavy metals or acutely toxic or harmful persistent compounds;

(e) PVC, polyurethane foam, polystyrene foam, rubber and lubricating oils, treated timber and products that could produce harmful emissions if incinerated;

(f) plastic wastes other than low density polyethylene containers;

(g) fuel drums; and

(h) other solid, non-combustible wastes.

While on the one hand the requirements are viewed as tough (Hansom and Gordon 1988), Czech (1992, p. 32) submits that the waste management annex is less stringent than the 1989 code 'due to the fact that in the wording of the annex there are, in many cases, added phrases or allowances which enable the provisions to be widely interpreted.' Phrases such as 'to the maximum extent practicable', 'as far as practicable', and 'wherever practicable' are routinely used. Similarly, Article 1 (General Obligations) only calls for ATCPs to give *consideration* to waste source reduction, recycling, waste storage, disposal and removal from the AT area in the planning and conduct of activities.

Bastmeijer (2000, p. 296) also notes the Protocol's inclusion of 'vague formulations and lacunas' that make it difficult to formulate the minimum requirements with regard to the Madrid Protocol's key elements. Czech however ventures further, concluding that the Madrid Protocol's 'ambiguities and generalisations do not provide for wide scale protection of the Antarctic environment ... and ought to be eliminated.' Indeed, one of the Madrid Protocol's negotiators, AAD Policy Manager Andrew Jackson, acknowledges that the speed with which the Protocol was drafted resulted in a document:

> full of legal loopholes, vague language and 'weasel words' – ways out of your obligations ... the Madrid Protocol is a political document full of broad objectives and intentions, but very thin on detail about how things would actually happen (Bowden 1997, p. 417).

While acknowledging that the text is full of value-laden terms such as 'adverse impacts', 'significant changes' and 'further jeopardy', Riddle (2000) submits that the vagueness was not accidental; the intention was that the standards that must be maintained should be set by agreed usage. Whether this has occurred is difficult to gauge. The CEP established under Article 11 to provide advice and formulate recommendations to ATCPs in connection with implementing the Madrid Protocol, including the operation of the Protocol's annexes, has so far focussed on environmental impact assessment (EIA) and activities related to area protection and the conservation of flora and fauna (CEP 2003), although a rolling review of the annexes is planned (ATCM 2001).

3.3.1 The quantification of values

The CEP makes reference to areas potentially having environmental, scientific, historic, aesthetic or wilderness values, or a combination thereof, and the quality of these as being thought of as an overall degree of excellence in terms of the values they contain (CEP 2002a). Although the subject of academic critiques (Summerson and Riddle 1998, Summerson and Riddle 2000 and Codling 1998), the means by which the continent's aesthetic and wilderness values can be determined and applied have yet to be established by Antarctic operators (Bishop 2003). Developing a rigorous and defensible methodology is likely to be a particular challenge for ATCMs given the unease with which the forum appears to deal with issues that are not informed by what is deemed 'scientific objectivity'. Schatz (1988) and others argue that sentiment is not sufficient as a call to action for the clean-up of past waste disposal sites, a position that is likely to have ATCP support.

The process of evaluating values is likely, although not in Codling's view, to rely on many subjective considerations. Codling's attempt at an analytical approach to landscape assessment fails to acknowledge that even the process of scoping the project (e.g. selecting the attributes to be used and the way they are assigned) involves making subjective-based choices. Nevertheless her motives are well founded; the degree of success in achieving acceptance of the assessment results is likely to be relative to the perceived objectivity of the methodology. And while the CEP establishes representativeness, distinctiveness, ecological importance and scientific usefulness as appropriate quality criteria, this approach is also unlikely to encourage a holistic consideration of Antarctica as a place; a landscape is more than the sum of its component parts (Lucas 1992). One aspect of this is the potential for natural heritage values to be a component of a country's cultural heritage (AHC 1999) a concept even further distanced from rational comprehensive planning models of likely ATCP appeal.

3.3.2 Abandoned sites and Annex III, Article 1

Annex III, Article 1 includes a requirement for past and present waste disposal sites and abandoned work sites to be cleaned up by the generator except where structures are designated historic, or the impacts of removal would be greater than leaving the site in its current state. The clean-up of past sites of activity is not an insignificant issue, in particular for programs with a long history of Antarctic operations. Stations located on the ice sheet (of which there were already 17 by 1989) generally have a life span of four to eight years before becoming uninhabitable and abandoned (ICSU 1989). Since 1947, the British Antarctic program and its predecessors, the Falkland Islands Dependencies Survey and Operation Tabarin, have abandoned or left unoccupied, 18 bases and two field huts (Shears and Hall 1992). Abandoned station buildings are arguably the greatest component of Antarctic waste, and the greatest source of environmental pollution in the AT area.

Reasons used or proffered to justify deferring clean-up action are listed in Table 3. Sources of information from which the table was compiled include public statements and personal communications (conversations and emails) in which the reason(s) have been variously stated or implied. The sources of each have not been cited because of an inability to satisfactorily establish whether some of the reasons are personally held or reflective of program policies; and because it is often not possible to establish an audit trail of key decisions (if consciously made) related to the management of sites. An assessment of the validity of the reasons listed has not been attempted for the same reasons and as it has not been possible to access relevant data and examine the

Table 3. Suggested and actual reasons used for deferring action on waste site and facility clean-up.

Reason	Possible situation or scenario
Practical/operational-based reasons	
Sheer complexity of the task	There are multiple sites involving a wide geographical spread, and complex historical issues have to be resolved
Scheduling demands	Clean-up activities are part of a long term strategy requiring the adoption of a staged approach
General unknowns and uncertainties	Further investigation is desirable
Lack of clean up expertise	The task needs to be outsourced
Waste retrograde issues	Uncertainties exist as to the application of the Basel Convention, quarantine processes and other requirements
Likely physical impossibility	The ice shelf on which the station was constructed has calved off into the sea
Engineering and site management issues	Approaches adopted elsewhere in the world are not appropriate to the Antarctic situation; trials need to be conducted
Negative past experience	Adverse outcomes of previous attempts (leaching from disturbed sites, discoveries of asbestos) point to the need to take a conservative approach
Artefact management difficulties	The unavoidable or inadvertent destruction of artefacts is a likely result of clean-up activities
Future program support	A change to science program direction will make the use of the site desirable for logistical reasons
Prudent project management	Ad hoc/opportunistic clean-up is unlikely to produce environmentally acceptable results
Human health and safety risks	The site contains hazardous materials and/or is physically unstable
Tourism-related reasons	
Emergency response support	The site provides ship-based tourism activities with shore-based refuge or supporting infrastructure
Value as a destination	The site's status as an early Antarctic settlement makes it one of Antarctica's most popular tourist destinations
Concentration of impacts	Tourism focussed at heavily impacted sites will reduce the spatial range of impacts
Science-supported reasons, and impacts on science	
Interference with ongoing research	Clean-up would result in a pollution load from ships, and flights which would interfere with long-term, sensitive atmospheric measurements and monitoring
Interference with environmental science contributing to clean-up	Clean up would interfere with contaminant research being undertaken and intended to assist future management decisions for the site
Science funding issues	Funding the clean up will reduce the funding available to science and science support
Development of monitoring programs	Processes for monitoring the impacts of clean-up need to be developed and implemented
Environment protection-related reasons	
Unknown consequences / the precautionary principle	Site disturbance may cause greater environmental harm than leaving the material in situ
Disturbance to wildlife	Wildlife have recolonised the site; clean up would cause disturbance
Application of environmental standards	Selection of the appropriate clean up method is dependant on a decision being made on the remediation endpoint
Questionable environmental benefit	Personnel support, transport of materials, fossil fuel usage etc. in the clean up represents environmental burdens greater than those related to the sites abandonment

Table 3 (cont'd).

Treaty/political reasons	
Provisions of the Madrid Protocol	The Protocol says the clean up obligation shall not be interpreted as requiring the removal of any structure or waste material in circumstances where the removal by any practical option would result in greater adverse environmental impact than leaving the structure or waste material in its existing location.
Management plan restrictions	The site falls within an ASPA or an ASMA and clean-up is contrary to the relevant management plan
Liability issues	Well intended but inappropriate clean up actions may have unacceptable legal consequences.
Potential heritage value	The site's heritage value has yet to be determined
Status as a Historic Monument	The site has been declared an Historic Monument; a protection obligation exists
Requirement to consult	A Comprehensive Environmental , and EIA under domestic legislation, is being prepared
Institution/program-specific reasons	
Program goals	The program responsible for the site is developing an in-house capability for site clean up, with the intention of transferring knowledge to other ATCPs and enhancing its influence in the ATS
Unresolved internal conflicts	Agreement on an appropriate approach has yet to be reached
Abandoned status is not established	The site is a recreational area and field refuge for program personnel; an ad hoc repair and maintenance program is in place
Low environmental priority	The management of other environmental issues warrants more urgent attention
Potential heritage value	A heritage strategy is being developed
Low program priority	A reduction in science resulting from the diversion of funds to clean-up operations is unacceptable
Strategic planning	Sites requiring attention are still being identified and assessed
Ownership issues	Site has been owned or occupied by other programs; further consultation is warranted
Stakeholder consultation	Public input is being sought on the clean up project proposal and associated EIA
Philosophical/subjective reasons	
Comparable actions of other ATCPs	The management of the site is no worse than the management of other sites by other ATCPs
Public criticism	Clean-up would be perceived as sentimental and indulgent in the context of worldwide environmental and social issues
Negligible gains	Removal of the site simply results in the transfer of a problem from one continent to another
Absence of scientific justification	According to the scientific community the site does not carry any environmental risks, clean-up is not justified and is irrational
Absence of appropriate data	Quantitative data relevant to the issue is necessary and does not exist

sites alongside field personnel with appropriate technical expertise. In any case, the reasons given are unlikely to remain static, and may not apply beyond the short-term. Although broadly categorised in the table, many of the reasons are entwined. An emerging theme though, is that not 'writing off' a facility in the first instance is likely to hold considerable ATCP appeal for resource-related reasons. Sites may therefore be 'maintained' on the basis of value as an emergency refuge or recreational site, or because of possible interest, real or otherwise, in occupation by programs not previously involved in the site's construction or management.

3.3.3 Historic values and Annex III, Article 1

The potential for ATCPs to declare buildings to be historic sites rather than face the expensive and logistically difficult problem of their removal, has been flagged by Hughes and Davis (1995), and indirectly in the final report of ATCM XXIV of 2001 (CEP 2001), which discusses the need to establish the distinction between historic artefacts and waste. The relatively short period in which Antarctica has been continuously occupied is likely to mean that anything built in the forties and fifties could be considered worthy of consideration and protection. This is reflected in a document accepted at CEP IV, *Guidelines for handling of pre-1958 historic remains whose existence or present location is not known* (Appendix III).

Wilkes, established in 1957 as part of the IGY program, is among stations viewed as having heritage values. Although partially buried and crushed, deemed a fire hazard due to fuel seepage and vacated in 1969, Wilkes is listed as an 'indicative place' on the Australian Heritage Commission (AHC) Register of the National Estate on the basis of it being:

> one of the few Antarctic stations to retain its integrity as a station built specifically for the International Geophysical Year ... The buildings and artefacts are still in their original context ... The physical remains, including those hidden under snow have considerable potential in the information they can tell about the lifestyle of expeditioners who lived and worked at Wilkes (AHC 2002).

An AHC-drafted document *Policy on Wilkes Station* reproduced in Clark and Wishart (undated, c. 1989) recommends:

> Clean up but do not remove Wilkes station and carry out limited restoration on the transmitter building and radome for use as refuge and display ... Allow the remaining buildings to decay under the effect of the elements. Clean up the area from time to time.

The ruins of BSE Pedro Aguirre Cerda (Chile) on Deception Island have recently been listed as a monument and accorded the protection of an AT Historic Site. The station was destroyed by a volcanic eruption in 1967. The basis for the listing is the significance of the ruins to Chilean Antarctic history, to early meteorological and volcanological recordings in Antarctica; and the site's existence as an example of historic damage to a base by natural phenomena (Chilean Antarctic Program 2001, CEP 2001). The motives behind the site's nomination have been viewed with cynicism (Anon. 2002).

3.3.4 Compliance

A difficulty in reviewing ATCP compliance with the Madrid Protocol's waste management provisions results from Antarctic operations not being readily subject to scrutiny by parties external to the ATS, principally by virtue of the remoteness of sites. A heavy reliance must, therefore, be made on information exchanges, an obligation arising from Articles III, VII and adopted recommendations under Article IX, in particular Recommendation VIII–6 of the 2001 ATCM; and Articles 8 and 9 of Annex III of the Madrid Protocol. One of the reasons why parties are encouraged to annually exchange information about their activities in Antarctica is to demonstrate their compliance with the AT, with measures adopted under the AT and the Madrid Protocol (Antarctic Exchange of Information 2003).

Annex III, Articles 8 and 9 call upon parties to prepare waste management plans specifying clean up programs, current and planned waste management arrangements and current and planned arrangements for analysing the environmental effects of waste and waste management – and to circulate the plans. ATCPs are expected to provide copies of their waste management plans, and reports on the plans' implementation and review, to the CEP. It appears that only 12 of the 45 ATCPs submitted annual reports to CEP V of 2002.

Table 4. Waste management reporting (2000 – September 2002) by national programs operating in East Antarctica.

Treaty requirement	Australia	France	China	Russia	Japan
Waste management information is exchanged *Madrid Protocol, Annex III*	yes, via the AAD's website (AAD 2000b, 2002a)	yes (IFRTP 2001)	yes, through the CEP (CEP IV: IP 45 – Chinese Antarctic Program 2001)	yes, through the CEP (CEP III: IP 25; CEP IV: IP 46 & 50 – Russian Federation 2000, 2001a, 2001c)	yes, through the CEP (CEP III: IP 60; CEP IV: IP 14 - JARE 2001, 2002a, 2002b)
Waste management plans are included *Madrid Protocol, Annex III, Article 9(1)*	yes	no	no	under development; planned introduction 2002-03	no (although are reported to exist)
Waste reduction, storage and disposal are included in plans *Madrid Protocol, Annex III, Article 8(2)*	yes	yes	yes (storage and disposal)	plans under development	yes (storage and disposal)
Each fixed site is addressed in plans *Madrid Protocol, Annex III, Article 8(2)*	yes	yes	yes	plans under development	no
Field camps are addressed *Madrid Protocol, Annex III, Article 8(2)*	no	n/a?	n/a?	plans under development	n/a?
Ships that are part of the operation of fixed sites are addressed *Madrid Protocol, Annex III, Article 8(2)*	no	no	no	Vessel plans are in accordance with MARPOL 73/78	no
Programs for cleaning up existing waste disposal sites and abandoned work sites are included *Madrid Protocol, Annex III, Article 8(2)*	yes	yes (site monitoring only)	no	no	it is reported there are no plans
Current and planned waste management arrangements, including final disposal are included *Madrid Protocol, Annex III, Article 8(2)*	yes (current arrangements) yes (planned arrangements) no (final disposal)	yes (current arrangements) no (planned arrangements) no (final disposal)	yes (current arrangements) no (planned arrangements) no (final disposal)	plans under development	yes (current arrangements) no (planned arrangements) yes (destination)
Current and planned arrangements for analysing the environmental effects of waste and waste management are included *Madrid Protocol, Annex III, Article 8(2)*	yes	yes (current arrangements)	yes (current arrangements)	plans under development	no

Table 4. (cont'd).

Treaty requirement	Australia	France	China	Russia	Japan
Inventories of the location of past activities are annually exchanged *Madrid Protocol, Annex II Article 8(3) (Article 9)*	no	yes	no	no (database of sites to be completed in 2003)	yes
Information is publicly available *2001 ATCM Resolution 6*	yes	yes	yes	yes	yes
Annual exchanges (30 March to 1 April) include waste management plans issued during the year giving title including name of station/vessel/location *2001 ATCM Resolution 6, Attachment A, 2.4.4*	no	no	no	no	no
Annual exchanges (30 March to 1 April) include report on implementation of waste management plans during the year *2001 ATCM Resolution 6, Attachment A, 2.4.4*	yes	no	no	no	yes
Permanent exchanges include title of waste management plans, a copy, or contact point for printed version and brief report on implementation *2001 ATCM Resolution 6, Attachment A, 3.3*	no	no	no	no	no
Specified waste classifications are used *Madrid Protocol, Annex III, Article 8(1)*	yes; until 1999-2000	yes	no	no	yes

Table 4 lists the contents of recent (2000–02) waste management reports submitted by ATCPs conducting programs in East Antarctica, against the requirements of Resolution 6 and Articles 8 and 9. Most notable are failures to make available the actual waste management plans, and to compile and distribute information on abandoned stations and work sites. Although not reflected in the table, the information that is provided on sites and their planned clean-up is generally scant. Such incomplete reporting may be insignificant in itself, or indicative of significant forms of non-compliance. Even then, strong implementation and compliance do not necessarily mean that the environment is better protected, although it is likely to be a positive indicator. Similarly, the adoption of transparent management practices and active reporting does not necessarily correlate with high environmental standards.

A list of working papers (WPs) and information papers (IPs) submitted to ATCMs and the CEP and specifically considering waste management is at Table 5. Generally, the papers present as political statements rather than as a source of operationally useful information. One IP relates to clean up actions outside the AT area and contributes little to discussion of the Antarctic situation. Their examination indicates that: (i) there are substantial differences between parties in the development of thought and practice, and (ii) no nation is showing significant leadership in this field.

The protracted considerations by programs on the clean up or implementation of protective measures at some disposal sites is likely to attract criticism, warranted or otherwise. Brunckhorst (2000) discusses the popular existence of 'deferred action' approaches to the management of natural resources, ecosystems and landscapes, i.e. work only proceeds when the likely impacts, local environment and other issues are fully understood. It is arguably untenable given that ultimate knowledge can never be achieved, and until work begins, feedback processes are virtually non-existent. The current gaps in understanding of the Antarctic environment may necessitate that monitoring programs are designed with little or no background data.

While approaches proceeding on the basis of 'best understanding' (described by Brunckhorst as 'passive adaptive management') may be prudent, there are instances where this approach has been problematically applied outside Antarctica, e.g. in endangered species recovery programs that have been embarked upon when species

*Table 5. Information papers (IP) and working papers (WP) on waste management submitted to ATCMs and the CEP 1991–2002.**

Meeting/ Year	Paper No	Title	Submitted by
ATCM XVI 1991	IP 75	Removal of waste from the Marambio Antarctic base	Argentina
ATCM XVII 1992	IP 24	Abandoned stations and field huts: the British approach to management	United Kingdom
ATCM XVIII 1994	IP 33	Clean-up and conservation of abandoned British bases in the Antarctic Peninsula region	United Kingdom
ATCM XVIII 1994	IP 80	A waste management strategy for Australia's Antarctic operations	Australia
ATCM XIX 1995	WP 11	Nuclear waste and the Antarctic Treaty area	Netherlands
ATCM XIX 1995	WP 23	Waste dump inspection list	Australia
ATCM XIX 1995	WP 25	Incinerator emissions	SCAR
ATCM XX 1996	IP 10	Decommissioning Vanda station, Wright Valley, Antarctica	New Zealand
ATCM XXII 1998	IP 29	Pollution abatement at McMurdo station, Antarctica	USA
ATCM XXII 1998	IP 14	Handling of solid waste and waste water on board the *Humboldt* scientific research vessel	Peru
CEP I 1998	IP 35	Waste management at the Italian Terra Nova Bay station	Italy
CEP II 1999	IP 60	Waste management of Syowa station	Japan
CEP III 2000	IP 43	The report on an ecological situation at the Ukranian Antarctic station Akademik Vernadsky 1996–2000	Ukraina
CEP IV 2001	WP 23	Proposal: Guidelines for handling of pre–1958 historic remains in Antarctica	Norway
CEP IV 2001	IP 4	Antarctic activities work sites cleaning at Collins Glacier ice cap, pursuant to Annex II, Article 1, Paragraph 5 of the Protocol on Environmental Protection to the Antarctic Treaty. Years 2000–2001	Uruguay
CEP IV 2001	IP 13	Monitoring marine debris and its impact on marine living resources in Antarctic waters	CCAMLR
CEP IV 2001	IP 50	Planning of waste disposal at the Russian Antarctic stations and ships	Russia
CEP IV 2001	IP 64	Oil spill response exercise in Antarctica	United Kingdom/ Germany
CEP V 2002	IP 16	Results of the waste disposal project at Bellingshausen station	Russia
CEP V 2002	IP 22	The clean-up and removal of abandoned British stations in Antarctica	United Kingdom
CEP V 2002	IP 57	Clean up of a former subantarctic research station at Heard Island	Australia

*Excludes papers on inspections, EIA addressing station activities and programs, and annual reports and information exchange documents although these may include sections on waste management activities.

are at the brink of extinction. At this point, management mistakes are likely to carry enormous risks.

Brunckhorst's 'active adaptive approach' considers management actions as deliberate experiments which are intended to both manage effectively and to generate better information. Such 'learning by doing', is likely to lead to capacity building and may be the only solution for Antarctic operations if techniques and technologies from other areas of the world cannot be adapted or applied to the continent. It is to be expected that its opponents will condemn it as a methodology negating informed, consistent and defensible decision making – one that is inappropriate to an environment still characterised by significant scientific uncertainties with respect to the potential outcomes of activities.

3.4 Summary

While the Madrid Protocol has strengthened the legal regime for the protection of the Antarctic environment generally, its existence alone does not ensure a consistent, environmentally sound and holistic approach to waste management. The language used in the Protocol's principles and technical annexes allows ATCPs to exercise considerable latitude in responding to its provisions, and in some areas, makes the task of determining compliance problematic. Indeed, in view of the vague quality of the current articles it would be hard for ATCPs not to be found compliant. There is evidently no ATS mechanism in place whereby compliance is currently considered, through the analysis of information exchanges, or by other means. In particular, there is wide scope for ATCPs to dismiss or potentially indefinitely defer the obligation to clean-up past waste sites and abandoned infrastructure.

In Chapter 4, ISWM system theory is considered in conjunction with Antarctic operations. The focus is on the adaptation of its key elements to the Antarctic environment which present significant, and possibly unique, logistical challenges in the waste management arena.

4.1 Introduction

Waste management in Antarctica is drastically different from waste management in Australia (Riddle et al. 2000). Surprisingly though, the reasons and issues involved have been little examined. The functional elements of ISWM are described in industry literature as being waste handling and separation, storage and processing at the source; collection; separation, processing and transformation; and transfer, transport and disposal. In this chapter, ISWM system theory and the adaptation of its elements to Antarctic conditions and operations, is considered. The discussion draws on Tchobanoglous et al.'s (1993) description of waste handling, separation and processing management issues as centring on the identification of the waste components to separate; the selection of the type, number and capacity of on-site containers to hold separated wastes; and changing waste storage habits, particularly where other options may have been more convenient.

4.2 Waste minimisation

If waste generation can be significantly reduced, many of the problems addressed by this thesis are made more manageable or even negated. Waste minimisation and diversion occurs when materials that would normally be destined for landfill are removed from the disposal system. The implementation of a fully integrated waste minimisation program necessitates an investigation or audit of each component of the waste generation cycle. A less thorough but practical approach involves targeting activities generating 'problem wastes'; items comprising a significant volume of the waste stream (in Antarctica, fuel drums and packaging) or of a highly toxic nature. Waite (1995) and Liu and Liptak (2000) report that packaging contributes to between 30 and 40% by volume and weight of domestic waste generated by so called modern economies. Items sent to Antarctica typically receive additional packaging to provide protection from an expected higher level of potential physical damage. Packaging materials could therefore be expected to comprise a far greater component of the waste streams of Antarctic communities than they are elsewhere.

Packaging waste may be reduced by using reusable packing materials such as air bladders and plastic pallets in preference to timber dunnage which on removal from Antarctica may need to be destroyed or deep buried to comply with quarantine controls; and PVC liners and plastic boxes for food. Using standard dimension and standard strength packaging to enhance consolidation and reduce the need to 'pack out' larger cargo units; removing wrappings designed for sales appeal rather than serving product protection functions; and supplying personal and household products in bulk and concentrated forms, are also likely to help.

Other expedition planning strategies with the potential to reduce the amount of solid waste generated include:

- procuring equipment that can be readily repaired or easily upgraded on site;
- procuring consumables with long shelf lives;
- procuring equipment that has been designed for longevity rather than planned obsolescence;
- adopting computerised inventory systems to avoid over supplying, enable re-use planning, and to minimise product expiration and spoilage;
- the pre-preparation of food, and judicious menu planning;
- reducing the range of food types and other products supplied;
- the non-supply of disposable or single use products; and
- conducting education programs aimed at enhancing the awareness of waste minimisation strategies amongst expedition personnel.

The implementation of waste minimisation strategies is likely to require significant cultural change and modification of consumer habits. While 'making do' – resourcefulness, improvisation and innovation – was once characteristic of Antarctic expeditions, present-day scientific and support personnel have been known to demand standards of living that exceed those they experience outside Antarctica. These standards have been viewed as entitlements or compensation for hardships and privations attached to Antarctic living. Conversely, expedition personnel are essentially a 'captive audience' limited to using the products with which they are supplied. Purchasing policies that determine the implementation of waste management strategies are likely to reside with program managers remote from the work site.

4.3 On site management

For many years there has been considerable debate as to whether Antarctica is an appropriate place to trial new or prototype equipment. For a long time it has been held that in the interests of efficiency, safety and economy, only proven equipment should be commissioned. Mainstream waste handling practices are at any rate likely to require significant modification or adaptation for Antarctic application. The foundations of incinerators, storage areas or other installations considered necessary to stockpile or process materials may need to be built on sediment or ice, depending on the required location of the facility. Constant low temperatures may mean that the ground remains frozen except for a shallow top layer in the middle of summer. The inside climates of buildings may need to be adjusted to produce warm, moist air compared with the outside cold and dryness, and measures may need to be put in place to prevent vapour penetrating structures and ice forming inside building shells. 'Wet' trades, such as bricklaying and rendering, may not be feasible as water can be difficult to keep in a liquid state. Materials such as plastics and metals can become brittle in low temperatures. In these conditions, machinery is likely to be difficult to start and lubricate, and outside workers need to be especially well-protected. Ideally, engineering solutions will therefore be prefabricated, simple to transport and erect, and constructed from easily handled materials.

The need to maintain flexibility and adaptability in order to apply on site, the demands of evolving environmental protection expectations and views with respect to minimising human impacts, is increasingly evident. SCAR (1985) 'simply' encouraged waste removal and suggested that, in general, unnecessarily sophisticated technology should be avoided since processing plants using energy, materials and staff are liable to increase the net impact. In recent years, however, the consideration of treating large quantities of sewage through Rotating Biological Contactor Systems has been actively encouraged within the ATS. Similarly methods that were once considered viable or even ingenious would now be highly unacceptable. For example, a novel system developed 20 years ago for adoption at Mizuho (Japan) involved freezing waste water in cubic ice blocks and sealing garbage and faeces in the blocks: 'By applying this system, we can dispose the waste materials without diffusing pollution' (Hayashida et al. 1981, p. 49). Risebrough and McLaughlin

(1972) suggested compacting incinerator ash and other solid waste into blocks that could be used for local landfills and extend the area available for penguin rookeries – a plan proposed with good intentions having acknowledged that the building of Hallett station displaced several thousand birds. More recently, the commissioning of units that detoxify medical and laboratory wastes by physically grinding them and mixing them with an iodine solution; and in-vessel (ship) or closed system composting; have been given consideration. It is possible that some programs will seek to adopt 'best practice' techniques and technology for political-type reasons rather than accurately quantified environmental benefits.

It is important to note that even where appropriate technologies have been embraced and the preferred facilities are in place, compliance with waste management routines and the proper operation of equipment relies entirely on the actions of on-site personnel. Accordingly there must be a high level of commitment to educating, training and motivating personnel to enable them to conduct their activities in an environmentally responsible manner. Antarctic stations typically have an annual turnover of on-site managers potentially leading to loss of information, practical expertise (e.g. in correct incinerator operation) and momentum for continuous improvement.

4.3.1 Processing

There are many types of specialised processing equipment designed to macerate, compact, crush, bale, grind, shred, dehydrate and pelletise selected materials, principally to reduce the volume of waste needing to be handled. On the basis of Duston's (1993) overview of waste processing options, balers appear to be the most versatile choice of processing equipment for Antarctic use. Most balers handle a variety of materials including cardboard, plastic bottles, paper, tin and aluminium cans. The bales produced may weigh over a tonne and therefore cement floors, a small forklift and storage for materials insufficient to complete a bale are minimum infrastructure requirements. According to Duston, attempts to crush glass without specialised equipment are unlikely to result in adequate densification without a strenuous level of effort and significant occupational health and safety risks. While granulators are an option for PET and HDPE plastics, granulated plastic can be easily contaminated and unacceptable to recyclers. Small plastic particles are also a potential environmental hazard and, if accidentally released, are less readily located and retrieved than larger units. Plastic matter has been found in the stomachs of sea surface feeding petrels breeding on the continent (van Franeker and Bell 1988).

4.3.2 Incineration

Open burning as a solid waste management technique was phased out throughout Antarctica in the 1998–99 summer. At the time of the planned phase-out, loose recommendations were made on the subsequent conduct of incineration practices. Waste was to be burnt in incinerators which to the maximum extent practicable reduced harmful emissions – a statement that obviously demands no specific commitment. Emissions standards and equipment guidelines have not been developed for Antarctica although there is a Madrid Protocol expectation that the solid residues generated by burns will be removed from the AT area.

Incineration remains a widespread practice in Antarctica. Its key attraction in this setting is its usefulness in reducing waste volumes – potentially 90% of the volume and 75% of the weight of materials going to landfill (Pett 1994), rather than its potential to render certain wastes more suitable for final disposal, destruct the organic component of biodegradable waste or to replace fossil fuel in energy generation. Materials typically burnt at Antarctic stations include putrescible kitchen waste, medical sharps, laboratory cultures and avian products. SCAR (ICSU 1989) found that an estimated 70% of all solid waste generated, excluding fuel drums, was potentially combustible. At that time, only five of the 59 sites where waste was incinerated conducted emission-controlled burns. While generally pro-incineration in 1989, SCAR found that the emissions that may be produced as a result of incinerating wastes (i.e. nitrogen oxides, sulphur dioxide, hydrogen chloride, carbon monoxide, carbon dioxide, fine particulate matter, toxic heavy metals, fluorides and organic compounds including dioxins and furans) to be the second biggest source of atmospheric emission in Antarctica – the main source being the burning of fossil fuels.

Some of the main arguments making incineration an unattractive option in other areas of the world are not applicable in the Antarctic context. There are no caps on landfill volumes, and land remote from communities is not difficult to find. While public concerns over incinerator emissions are often linked to human health risks underpinned by the reaction of communities in the area of existing and proposed facilities, these concerns are also not likely to be issues in Antarctica. One may nevertheless speculate that anti-incineration views will eventually contribute to the demise of this practice as an Antarctic waste management technique.

Many of the newly appearing alternatives are likely to be focussed on addressing the massive problems of urban areas. The adaptation of equipment and technology to comparatively small Antarctic applications is likely to render them prohibitively expensive.

4.3.3 Accumulation and storage

Waste that has been in Antarctica for more than one season is often referred to as 'accumulated waste.' While on-site management is implied, accumulated waste is unlikely to be found appropriately prepared, ready for removal. Removal is likely to be with the caveat that it will be undertaken as opportunity presents. Indeed it may never, unless the task is assigned program priority.

The strength and frequency of winds in Antarctica necessitates the use of protected storage areas for all but the bulkiest and heaviest accumulated industrial-type wastes. As well as preventing the dispersal of materials by wind, containment facilities must be impervious to water which may dissolve or leach substances and prevent recycling, e.g. by causing cans to rust. The need to make optimal use of space may mean that containers or other units have to be packed with wastes of different types, or that waste materials are transported in the same containers as general cargo. Handling and separation standards that are the norm outside Antarctica may not be achieved; a concern because some materials, if mixed, may become combustible, explosive, or release toxic gases or leachate.

As indoor space at Antarctic stations is usually at a premium, the most practical option for waste storage is likely to be some form of containerisation. The standard 20' shipping unit – TEU or 'C' container – is at many stations considered unwieldy to handle when packed. USAP and the New Zealand program use thick cardboard boxes on pallets known as 'triwalls' (Antarctica New Zealand 1999) while the AAP makes greatest use of three certified but non-standard shipping container formats –

'E boxes' (one third of a TEU), '½-heights' (a TEU halved horizontally) and '¼-heights' (four of which make up a TEU). Factors needing consideration when designing or determining a container's suitability for Antarctic application are outlined at Table 6.

Material balance and material flux analysis techniques described by Moore and Shin-Yu Tu (2002) and others have recently been used to attempt to quantify Antarctic waste generation and accumulation rates. In a study of Scott (New Zealand), Klee (2001) found that the weight of solid material introduced into Antarctica in one year (217 t) as opposed to removed (94 t) pointed to approximately 123 t accumulating at the station that year. He concluded (p. 14) that the 'total solid material burden on the ice increases by some 100 t per year.' In comparison, between 1997 and 2001 Australia shipped to Antarctica between 641 and 752 t of cargo per year with a total of 2867 t over four summers. In the same period, the weight removed ranged between 501 and 1043 t per year, with a total for the four seasons of 2959 t. It is suggested, however, that these figures reflect intensive clean-up campaigns and shipping opportunities rather than being indicative of waste generation trends. As such, conclusions should be drawn with care, particularly where short sampling periods are involved.

4.3.4 Contaminated sites

The management of contaminated sites in Antarctica presents particular and significant challenges. A 'contaminated site' is one where the concentrations of hazardous substances in soil and associated sediments, surface water or groundwater are above background concentrations, and a site assessment indicates that the substances pose, or are likely to pose, an immediate or long term risk to human health or the environment. In some definitions, reference is made to the site assessment taking into account potential site usage. This could be a significant factor in determining management methods in Antarctica given that there is no comparable area from which an Antarctic land-use praxis can be readily drawn.

Contaminated site management has been the subject of a series of conferences, the most recent being the *Third International Contaminants in Freezing Ground*

Table 6. Desirable Antarctic waste container features.

Tapered sides

Tapered sides allow tightly packed refuse to be readily dislodged and for bins to be partially nested during storage and transport.

Robust construction

Corrugated sides are stronger than smooth sides for a given gauge.
A disadvantage is that they are more difficult to clean.

Large openings and lids

Large openings are necessary to facilitate mechanical filling, particularly of bulky materials. Lids or covers of some sort are necessary to keep waste contained. Tarpaulins must be able to be well secured if they are not to tear in high winds.

Ability to be drained

Containers must be capable of being drained of melted snow or washing water, and able to be sealed to prevent the leakage of materials during transport.

Corrosion resistance

Galvanised sheet, while relatively cheap, is susceptible to corrosion. Fabricating containers from mild steel, and galvanising them after construction may be a better option.

Multiple securing points

Lashing bars, rings or other means may be needed to secure the contents and the containers themselves.

Permanent unique identifiers

Containers should be uniquely numbered and identifiable from a distance, four sides and above. They may also need to be plated or certified for shipping.

Quarantine friendliness

Containers need to be devoid of gaps, holes and crannies that have the potential to harbour soil, plant material and fauna of quarantine concern.

Provision for multiple lifting methods

To have greatest versatility, containers should be capable of being top-lifted, and forked from at least two directions.

Acceptability to multiple modes of transport

The size and weight need to be appropriate to the handling equipment and modes of transport to be used; potentially helicopters, fixed wing aircraft or ships.

Conference held in Hobart, Tasmania in 2002 (AAD 2002b). Coverage in the literature includes: contaminated site management tools and issues (e.g. Babicka et al. 2000, Snape et al. 2001a, Deprez et al. 1999); specific remediation techniques (Snape et al. 2001c, Northcott et al. 2001, Morris et al. 2000); toxicological studies and the impacts of contaminants on the local environment (Kennicutt et al. 1995, Lenihan and Oliver 1995, Lenihan et al. 1990, King and Riddle 2001, Lenihan et al. 1995); and physical, chemical and biological characteristics of the environment influencing contaminant dispersal and remediation (Snape et al. 2000, Cole et al. 2000).

Whereas there is a tendency to assess the significance of sites where waste is stockpiled on the basis of visual criteria (Snape and Riddle 1998), expanses of decaying buildings, surplus equipment and timber may have less impact on the physical and biological environment than a far smaller area of material that is toxic, environmentally persistent or has a tendency to bioaccumulation. Not unexpectedly, many sites are problematic on both accounts. Harris (1991) reports the existence of waste disposal sites in and around lakes and catchments, and West (2000), a site where 50 t of aluminium hydroxide powder have been dumped on a mountainside and allowed to wash on to the tundra below, and where 36 500 L of diesel, oil and paint products are stored in hundreds of corroded and leaking barrels. Contaminated sites may also be given low management priority because of the technical difficulties they present.

Management options may include (i) no action, (ii) treatment in situ, (iii) removal of contaminated soils and treatment, and (iv) removal and disposal without treatment (Deprez et al. 1999). Option (i) has occasionally translated to the burial of dumps, either through ignorance or in the hope that burial beneath sediment or ice equates to containment (Snape et al. 2001c). Option (ii) is generally considered to be a preferable approach as it has the potential to deliver significant environmental and financial benefits relative to the more traditional practices of excavation and removal (Snape et al. 2001c). A particular appeal of in situ treatments is their avoidance of the high costs, technical difficulties and environmental risks involved in transporting large quantities of hazardous materials to treatment facilities in or remote to Antarctica. Obstacles to adopting some in situ techniques include handling difficulties posed by the low temperatures, the lack of available water, the low levels of nutrients in Antarctica reducing the efficacy of bioremediation-based processes, and operations being limited to the short austral summer between November and February (Northcott et al. 2001). In situ methods are also less likely to mitigate the degradation of wilderness and aesthetic values.

If the contaminated site happens to be an abandoned, or 'deactivated' as occasionally appears in the literature, repair and maintenance as an emergency refuge, or restoration and conservation as a historic monument with a requirement for future management, may be considered. The latter may be a greater expense and undertaking than the removal option.

Clean-up issues are summarised by Riddle et al. (2000) as including:

- in winter, removing material that is virtually impenetrable to all but the most powerful excavation techniques;
- in summer, negotiating melt conditions which turn valleys (a common location of tip sites) into river beds;
- estimating the volume of waste involved when it is buried by snow;
- handling the large volumes of soils that can be impacted as a result of contaminant dispersal; and
- satisfying quarantine conditions at receiving destinations.

Snape et al. (2001c) believe that the technical capability to remediate contaminated sites does not presently exist because of environmental challenges that are unique to the cold regions. Similarly, containment structures designed for temperate regions have been assessed as neither practical nor suitable for the Antarctic environment (Snape et al. 1998). Whatever the method employed, it is highly unlikely that a site's return to a 'pristine' condition is achievable.

4.4 Waste removal from Antarctica

As noted in Chapter 3, the Madrid Protocol requires the removal from Antarctica of specific types of waste. The removal of other material is discretionary. Whereas communities elsewhere may enjoy an 'at the door' collection service or access to local waste placement facilities provided by their local government, there are two options for waste removal from Antarctica – by ship or by air – the costs of which are likely to be the single greatest waste management expense. For shipping, the waste volume is significant. For air operations, the weight is likely to be the greatest issue.

Weight rather than volume is the waste management industry preference for record keeping and calculations. Potentially enormous variations in specific weights are likely to be encountered in Antarctica as they are elsewhere. Tchobanoglous et al. (1993) found mixed food waste to vary between 13 and 485 kg/m^3 (a typical figure being 294 kg/m^3), paper 42–132 kg/m^3 (a typical figure being 51 kg/m^3), plastics 42–132 kg/m^3 (a typical figure being 66 kg/m^3), aluminium 66–243 kg/m^3 (a typical figure being 162 kg/m^3), and dirt and ash 324–1011 kg/m^3 (a typical figure being 486 kg/m^3). Programs that do not have weighing facilities in Antarctica must resort to reporting their waste by volume, at best supplemented by descriptors such as; 'loose', 'as found in containers', 'uncompacted', or 'compacted'. SCAR (ICSU 1989) similarly recognised that the composition of waste in Antarctica varies so much between sites that it is not possible to accurately transform weight into volume units. They suggested that a reasonable indicative figure may be obtained by assuming that 1000 t of waste, including some ash, will occupy 2–3 m^3.

4.4.1 Retrograde by sea

Antarctic shipping operations typically involve one of three arrangements: the use of icebreakers during summer to cut channels through the pack in which ships of more conventional design can proceed; the use of multi-purpose vessels incorporating reasonable ice-breaking qualities and having passenger, cargo and scientific capacities; and the summer use of ice-strengthened ships. Even ice-strengthened ships may be threatened by heavy ice that is under pressure. Icebreakers are similarly not immune to ice-induced damage. It is desirable that ships operating in Antarctic waters in summer have:

- the ability to penetrate ice over 1.5 m at a speed of at least 1 m/sec;
- an endurance of between 30 and 60 days, with half of these being in ice;
- helicopter capability;
- laboratory space appropriate to scientific program requirements;

- a dry cargo capacity of at least 2000 m^3 or 7000 t;
- accommodation for more than the ship's crew;
- the ability to carry bulk fuel to stations; and
- officers with Antarctic ice pilotage experience.

Most ice-breaking cargo vessels currently used in Antarctic waters:

- vary in length between 60 and 120 m;
- have a beam between 13.8 and 24.8 m (the beam being their determining dimension with respect to icebreaking capability);
- have a displacement of between 2000 and 15 000 t; and
- have a speed of less than 16 knots (Makinen et al. 1994).

4.4.2 Retrograde by air

Twenty-seven stations, operated by 16 ATCPs, have landing facilities for helicopters or fixed-wing aircraft (Rosenberg 2003). The transportation of waste by air is less attractive than shipment however, as the use of aircraft in Antarctica can be prohibitively expensive. Figures produced by USAP (Fowler 1988) point to the cost of air freight being one hundred times greater than sea freight. The in-Antarctica value of a drum of air-transported aviation turbine kerosene has been costed at US$6000/drum (US$24 000 landed at the South Pole) by Kershaw (1998).

Helicopters are used between ship and shore, and helicopters and fixed wing aircraft between inland sites and the coast. Helicopters currently in service include UH-1N Huey, Bell 212, Bell 206B Jetrangers, Hughes 500D, Aerospatiale AS 350, Sikorsky S76 and MIL Mi8 (Lyons 1996). Loads are carried internally or externally, depending on cargo sizes and weights. Fixed wing aircraft used include Lockheed LC 130 Hercules, De Havilland DHC-7 Dash 7, De Havilland DHC-6 Twin Otters, Dornier 228-100, Antonov AN 2/3 and Pilatus Porters.

While the carriage of waste by aircraft (especially helicopters) within Antarctica is not unusual, reports of flights moving waste to other continents are rare. Inter-continental aircraft currently servicing Antarctica include: Lockheed LC and C130 Hercules, Lockheed C141 Starlifters, Lockheed C5A Galaxies, Ilyushin Il 18 and 76, Antonov AN 72/74, De Havilland DHC-7 Dash 7 and Douglas DC-6. Desirable characteristics for cargo carrying aircraft are: a strong airframe, high wings, engines and tail; a low belly; a flat floor fuselage; large doors; multiple gas turbine engines; and rough field landing gear, i.e., with wide stance, short legs, multiple wheels and large, soft tyres.

In developing Antarctic air transport systems, planners must take account of the:

- aircraft's payload and range restrictions;
- distance south at which flights must commit or return to their originating airport (for inter-continental operations);
- need and ability for aircraft to refuel on the ice (for inter-continental operations);
- availability of alternate runways for emergency use;
- available runway types (possibilities are crushed rock, sea ice, snow-free glacial ice, compacted snow, groomed snow or open field) and their preparation requirements;
- matching of aircraft to runway type;
- availability or establishment of on-ground support facilities; and
- aircraft cold weather performance and service requirements.

Blue ice (snow ablated) landing sites are the most attractive because they are, in their unmodified state, suitable for conventional wheeled aircraft which, compared to ski-equipped aircraft, are more readily available, cheaper to buy and operate, and have a greater range (Mellor 1993). Antarctic airfield locations, including potential blue ice sites, are listed in Tracey (2001).

4.5 Waste handling on removal

Potential southern, Southern Hemisphere gateways for inter-continental aircraft operations or the receipt of waste transported by ship are, in order of decreasing latitude, Argentina, Chile, the Falkland Islands (Islas Malvinas), Argentina, New Zealand, Australia (Hobart and Melbourne), South Africa and Australia (Perth). In addition to needing to be able to handle waste carried as cargo, useable ports must be able to manage the discharge of ship-generated wastes such as sludge, tank washing water and other oily residues.

Most of the waste currently shipped to Australia from Australian Antarctic Territory (AAT) is discharged at the Port of Hobart. Hobart also receives, or transits to France, waste from French-claimed Antarctic territory. In the 1999–2000 summer shipping season, this involved 150 t of solid waste including plastics, glass, steel from cans, ash, empty kerosene drums, copper and electrical wires, and materials classed 'infectious substances' and 'ecotoxic' (Riddle 2001).

Tasmanian Government requirements associated with importing waste into Tasmania from other than Australian Antarctic stations are described in the Tasmanian Department of Primary Industries, Water and the Environment (DPIWE) publication *Protocol for Acceptance of Wastes from the Antarctic to Tasmania* (Deprez 2000). This document is intended to assist in negotiating the entry of waste into Tasmania. Wastes identified as problematic or potentially problematic to import are PCBs, organochlorine pesticides and related compounds, radioactive substances, ozone depleting substances, hazardous chemicals, soil, disease agents and pests. In addition to DPIWE and local council requirements, Environment Australia (EA), AQIS, Quarantine Tasmania, the Australian Customs Service (ACS) and the Australian Maritime Safety Authority (AMSA) have specific requirements with respect to the import, export and transit of waste. EA administers the *Hazardous Waste (Regulation of Exports and Imports) Act* 1989 and is responsible for implementing Australia's national and international environmental obligations including the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

Waste from South African, Norwegian and German Antarctic stations is imported into South Africa (el Naggar and Schoppe 1994). Cape Town is a major city in global shipping and has extensive cargo handling facilities. Metals, oil and glass are amongst recyclables that are able to be processed. There are no restrictions of a quarantine nature that would impact on the acceptance and handling of waste from anywhere in Antarctica (Kaliazin 2002).

Along with waste from Scott Base, Lyttelton in New Zealand receives kitchen wastes from US and Italian stations in the Ross Sea (Cervellati et al. 1990). The entry of food waste, soil and biohazards requires a permit issued by the Ministry of Agriculture and Forestry (Roper-Gee 2002).

South America is, as the nearest mainland to Antarctica, a popular transit area for national programs and tourist operators. An estimated 90 tourist vessels depart for or arrive from Antarctica via Ushuaia, Argentina each year, amounting to the annual transit of over 9000 tourists (Moser 2001). Other ports used include Stanley (the Falkland Islands/Islas Malvinas), Valpariso (Chile), Rio de Janiero (Brazil), Buenos Aires (Argentina) and Punta Arenas (Chile). Chile receives solid, non-hazardous American Antarctic waste while Argentina receives empty fuel drums from Great Wall Station (China).

Article 1 of Annex III of the Madrid Protocol calls upon countries, as a general obligation, to remove their waste, to the maximum extent practicable, 'to the country from which the activities generating the waste were organised, or to any other country in which arrangements have been made for the disposal of such wastes in accordance with relevant international agreements.' Often this will not be the most logistically efficient option.

The desire as well as the ability of communities to receive and process waste from Antarctica is an important planning consideration, noting that there may even be barriers to countries accepting waste from their own Antarctic stations. With respect to Australian states receiving waste from AAT, Cripps (1995, p. 23) found that:

> There appears to be no basis on which the Commonwealth can legislate to force a state to take waste from the AAT; as once waste has been removed from the Antarctic Treaty Area, the international obligations on Australia may have been satisfied.

While waste may be welcomed as an income-generating activity, communities may dislike the perception of being a 'dumping ground' even though they may in turn export locally-generated medical, radioactive and other hazardous wastes. The importation of waste may need to be tolerated by communities seeking to position themselves as a major Antarctic gateway, able to supply materials and specialist services to expedition organisers. Nevertheless, environmental and waste management legislation and court decisions have established that unless waste legally changes ownership during the off site transport and disposal process, the waste remains the property and responsibility of the waste generator forever (Brown et al. 2001).

Unless contractors are specifically directed otherwise, it is likely that most will dispose of waste in the least technological manner (landfill). Many of the materials listed for removal from Antarctica are not suitable for landfill disposal and require special handling and processing. Also, the removal of originally benign wastes from cold to warm climates may result in the creation of new hazards. Food waste that is not transported frozen, for example, may become putrid and raise sanitation and associated health concerns.

The need for appropriate waste composition studies has been mentioned elsewhere in this thesis. For materials destined for landfill, analyses will need to be made of the wastes' density and potential for compaction. For waste to be incinerated, the critical parameters are its chemical composition, heat value and the proportion of the combustible component. Co-mingled recyclables separated from non-recyclables before shipment and delivered to a materials recovery facility (MRF) may be separated in assembly-line fashion by a series of magnets, screens, air blowers and/or hand labour. MRFs are, however usually found in large population centres rather than close to likely gateway ports. Factors varying the market prices for sorted recyclables include changes in demand, technological advances the creation of interest in particular materials, the degree of processing necessary, the purity of materials and the volumes available.

The potential for the sale of Antarctic recovered waste materials to offset Antarctic waste handling costs is, at best, negligible – an observation supported by the results of a recent Australian-based study. Brah (2003) found that the collection, transport, waste processing and disposal costs of collected municipal solid waste (MSW) amounts to $160/t whereas the revenue raised from the sale of recyclables is about $20/t of collected MSW. Economically, a much more substantial gain from recycling is that described by Duston (1993) as the 'cost avoided gain' i.e., the savings in landfill fees (for non-hazardous wastes, currently $30/t in Tasmania, and as high as $100/t on the Australian mainland and $200/t in Europe) that occur every time a tonne of material is removed from the waste stream. Duston's analysis of a municipal recycling program found that the cost avoided savings can amount to 75% of the total gain from recycling. Even then, in most situations, reduction in landfill is likely be less important than the benefits of reduced use of virgin resources, reduced throughput of matter and energy resources, and reduced pollution and environmental degradation.

It appears that many of the protocols that have been developed for waste stream sampling (refer Liu and Liptak 2000) would have difficult practical or statistical application in the Antarctic context, for a large part because of the diversity of operators (nationalities) and sites involved. And Moore and Shin-Yu Tu (2002) warn against relying on a single method of obtaining data on waste generation and handling because of the potential for the approach to mask significant omissions because of bias inherent in the method.

4.6 Summary

Mainstream ISWM system approaches require considerable adaptation and ingenuity to accommodate Antarctica's operating conditions, and to elicit the system's on site ownership by transient populations. The need to address the on-site storage of waste for extended periods emerges as a significant element. The containerising of cargo is expected to simplify the removal of rubbish as ship time is a major cost associated with waste removal.

Adopted approaches need to be sensitive to economic realities and be readily modifiable to accommodate evolving technology with potential application. An efficient Antarctic system will give particular emphasis to waste volume reduction and be informed by reliable information on the waste expected to be handled so that the current logistics infrastructure can be appropriately tailored, or new systems developed. In Chapter 5, the waste management-related policies and operations of national programs with stations in East Antarctica are summarised insofar as they might point to factors in determining trans-national strategies transferable to other areas of the continent.

5.1 Introduction

Article 6 of the Madrid Protocol encourages liaison in the planning and conduct of Antarctic activities. To this end, ATCPs are to endeavour to promote cooperative programs concerning the protection of the Antarctic environment and dependent and associated ecosystems. While a history of cooperative activities exists in the scientific arena where joint expeditions, science exchange programs, and international meetings are commonplace, references to collaborative waste management programs are rare, and detailed information on the planning behind such activities has proven difficult to obtain.

In this chapter issues in the development of consistent and regional approaches to waste management are examined using East Antarctica as a case study. The institutions, policies, and logistic framework of programs in the area are described with the intention of establishing whether any significant incompatibilities exist. East Antarctica (Figure 2) comprises territory claimed by Australia, France and Norway, and includes Australian, French, Norwegian, Japanese, Chinese, German, South African, Indian and Russian stations. The Norwegian claim, Dronning Maud Land, extends from 20°W to 45°E. Australia's claim extends from 45°E to 160°E, excluding Terre Adelie (136°E to 142° E) which is claimed by France. While Georg von Neumayer (Germany), SANAE (South Africa), Dakshin Gangotri (India) and Novolazerevskaya (Russia) are in East Antarctica, they form a distinct group to the west of the current areas of Australian, French, Chinese and other Russian interest. This discussion has therefore been restricted to the coastal sites extending from Syowa (Japan) at 30°E, to the Dumont d'Urville (DDU) / Commonwealth Bay area at around 142°E.

Table 7 lists key sites of human activity in East Antarctica, past and present. The greatest concentration of sites is in the Larsemann Hills where Australian, Chinese and Russian program facilities are in close proximity. The identification and description of the full suite of human-impacted areas in the region is beyond the scope of this study.

Table 7. East Antarctic sites.

Site	Country	Location	Est.	Summer – winter pop.	Approx. no. of buildings	Aspect	Height ASL	Comments
Syowa	Japan	69°00'S, 39°35'E	1957	110—40	47	coastal	29 m	
Mizuho	Japan	70°3'S, 44°20'E	1986	n/a	6	inland	2230 m	closed 1991; buried under snow
Molodezhnaya	Russia	67°40'S, 45°51'E	1962	n/a	70	coastal	68 m	closed 1999
Mawson	Australia	67°36'S, 62°52'E	1954	49—12	35	coastal	5 m	
Druzhnaya 4	Russia	69°45'S, 73°43'E	1987	50	17	coastal	6 m	summer only
Zhongshan	China	69°37'S, 76°37'E	1998	60—15	5	coastal	11 m	
Progress II	Russia	69°36'S, 76°35'E	1988	60—15	13	coastal	64 m	
Law	Australia	69°38'S, 76°38'E	1986	20	7	coastal		summer only
Progress I	Russia	69°04'S, 76°40'E	1985	16	1	coastal	58 m	partially removed 1991-92
Davis	Australia	68°35'S, 77°58'E	1957	70—23	29	coastal	15 m	
Mirny	Russia	66°33'S, 93°01'E	1956	170—60	37	coastal	39 m	
Edgeworth David	Australia	66°15'S, 100 36'E		20	4	inland		summer only
Dobrowolski/Oaziz	Poland/ Russia	66°16'S, 100°45'E	1956	5-0		inland		unmanned observatory, Soviet-built then Polish then Russian managed
Vostok	Russia	78 28'S, 106 48'E	1957	37—29	4	Inland	3488 m	currently unoccupied
Casey, 'new'	Australia	66°17'S, 110°32'E	1988	70—20	22	coastal	30 m	
Wilkes	Australia	66°15'S, 110°31'E	1959	n/a	40	coastal	10 m	originally American; partially buried under snow
Concordia (Dome C)	France/ Italy	75°06'S, 123°23'E	1997	50—16	3	inland	3200 m	year-round occupation expected from 2003
Cap Prudhomme	France/ Italy	66°41'S, 139°54'E		10		coastal		staging post for Concordia
Dumont d'Urville	France	66°40'S, 140°01'E	1956	80—35	49	island	42 m	
Port Martin	France	66°49'E, 141 23'E	1950	17	1	coastal	15 m	burnt out in 1952 and abandoned
Cape Denison	Australia	67°00'S, 142°30'E	1912	n/a	4	coastal	3 m	historic site; Mawson's hut

Sources: AAD (2002c), COMNAP (2000), Guichard (2003), Hemmi (2002), IFRTP (2001), JARE (2001), May (1988), RAE (2001b), Rubin (1996), McIvor (undated), Stonehouse (2002).

Table 8. Ship access to occupied or maintained sites on the coast of East Antarctica.

Site	Average time of sea ice breakout	Average time sea ice is fast	Distance of anchorage from coast	Typical vessels visits each summer*	Usual/preferred resupply timing	Ship/shore transport	Nearest port outside Antarctica
Syowa (Japan)	remains fast	remains fast	2 km	1	vessel remains between late December and mid-February	vehicles over sea ice	Cape Town
Mawson (Australia)	late January	early April	50 m	3	January	barge	Cape Town
Druzhnaya 4 (Russia)	late December	mid-February	150 m	1			
Zhongshan (China)	highly variable	early April	5 nm	1		helo/surface transport	Perth
Progress II (Russia)	highly variable	April/May	5 nm		April/May	helo/surface transport	Hobart/Perth
Law (Australia)	highly variable	highly variable	5 nm	2	variable/flexible	helicopter	Hobart/Perth
Davis (Australia)	late January			2-3	November	vehicles over sea ice	Hobart/Perth
Mirny (Russia)	early February	early April	400 m	1-2	February		Hobart/Perth
Casey and Wilkes (Australia)	late December		500 m	2-3	December	barge	Hobart
Dumont d'Urville (France)	Early December	early March		5		barge/helo/ surface transport	Hobart

*excludes tourist vessels
Sources: COMNAP (2000), Hemmi (2002), Kaliazin (2002), McIvor (undated)

The logistic arrangements applying to sites that are occupied year-round, or visited infrequently yet considered 'maintained', are outlined at Table 8. The earliest resupply visit is often in November to Davis (Australia) in the seasons when over ice resupplies are programmed. At the other extreme, Progress II (Russia) is often resupplied in April or May.

5.2 National program policy and operations

5.2.1 Australia

Australia operates three permanently occupied stations in East Antarctica; Mawson (MacRobertson Land), Davis (Ingrid Christensen Coast, Princess Elizabeth Land) and Casey (Budd Coast, Wilkes Land). Some other sites are occupied continuously over most summers, the waste being flown by helicopter to Davis or Mawson, or directly to resupply vessels transiting the coast. The AAP also assumes responsibility for the American-built Wilkes, 3 km due north of Casey. Wilkes has a landfill site estimated at 12 500 m^3 by Snape et al. (1998) and 14 000–21 000 m^3 by Arrens (1994). These estimates do not include the abandoned buildings and a likely similarly large volume of petroleum-hydrocarbon-contaminated sediments.

Mawson, Davis and Casey each house approximately 20 personnel over winter. The stations are equipped with tracked tractors and loaders, Hagglunds, utilities, trucks, forklifts and cranes, and resupplied by barge or using vehicles and sleds over the ice from one of two AAD-chartered vessels – RSV *Aurora Australis* (a 94 m, 3900 t, Australian-built ice-breaker) and the ice-strengthened MV *Polar Bird* which is to end its AAP service at the end of the 2002–03 season.

In the 1999–2000, 2000–01 and 2001–02 seasons, an estimated 119, 213 and 348 t net of waste respectively were returned to Tasmania (RTA'd) from AAT. Over this period, 36% of the waste removed was reused or recycled. Details of the wastes composition are reported on the AAD's website (AAD 2003b).

Incinerators are operated at Mawson, Davis and Casey, ostensibly to dispose of putrescible waste. Unpublished and incomplete incineration statistics for 1997–2000 indicate that in the order of 53 t of waste are incinerated at the three stations each year (O'Brien 2001). O'Brien also reported that current

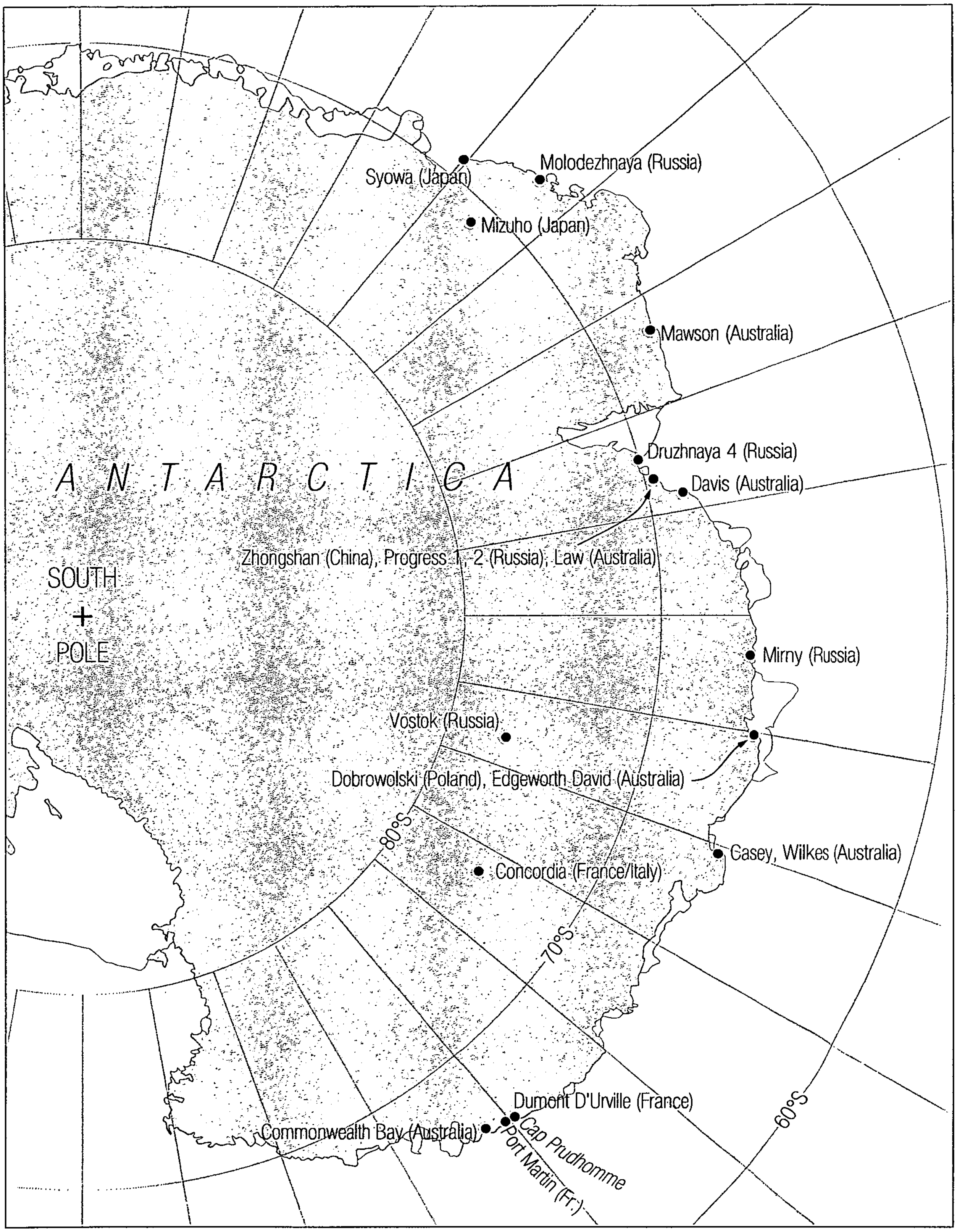

Figure 2. Sites of activity in East Antarctica.

incineration practices produce emissions that exceed environmental best practice guidelines.

The AAP is administered by the AAD, an agency of EA. The AAD seeks to advance Australia's Antarctic interest or vision of having 'Antarctica valued, protected and understood' (AAD 2000b). The four goals of the AAP are to:

- maintain the ATS and enhance Australia's influence in it;
- protect the Antarctic environment;
- understand the role of Antarctica in the global climate system; and
- undertake scientific work of practical, economic and national significance.

The stated means of achieving the first two goals include:

- maintaining a strong presence at ATS meetings, taking the lead on issues and developing initiatives for international consideration;
- complying with the requirements of the ATS;
- cooperating with AT partners;
- developing ways to minimise impacts; and
- remediating past work sites (AAD 2000b).

These goals are also articulated via the AAD's environmental policy (AAD 2001b) which commits the AAD to:

- encouraging compliance with the environmental principles and agreements of the ATS by other national operators, organisations and individuals in the Antarctic; and
- developing and implementing measures and technology to prevent or minimise pollution, waste and other human impacts on the Antarctic environment.

The Madrid Protocol is adopted under domestic legislation, namely the *Antarctic Treaty (Environment Protection) Act* 1980, amended 1996. In some areas, the AAD's management of activities exceeds Protocol requirements, e.g. the sludge byproducts of the stations' sewerage systems are returned to Australia.

The AAD recently attained certification of its environmental management system to ISO 14001. It also has a 1994-published waste management strategy. The success or otherwise of the strategy's implementation has not been reported upon publicly. It aims 'To minimise, as far as practicable, the environmental impacts caused by wastes generated from past, present and future activities associated with Australian's Antarctic and sub-Antarctic operations' (Arrens 1994, p. 2). Specific objectives, in abbreviated form include to:

- establish a waste minimisation program;
- establish a waste reuse program;
- ensure all potentially recyclable wastes are recycled on return to Australia;
- transport, store and dispose of waste in accordance with Australian legislation and best practice;
- identify and manage contaminated sites;
- clean up abandoned work sites;
- encourage, develop and improve waste collection and streaming practices;
- adopt a uniform waste classification and manifest system;
- ensure the stations are provided with appropriate containers for waste handling;
- develop an identification scheme that facilitates waste streaming;
- conduct a waste management education program;
- develop a waste management resource document; and
- establish a waste monitoring program and set targets.

5.2.2 Russia

Russia usually has a year-round presence at three sites in the study region; Progress II in the Larsemann Hills (typically 15 wintering personnel), Mirny (60 wintering personnel) on the coast of Wilhelm II Land, and an inland station Vostok (29 personnel). Progress is the planned site of an airdrome for flights of IL-76 aircraft between Russia, Africa, Antarctica and Australia. Druzhnaya, to the west, is occupied in summer. Molodezhnaya, also in the region, was closed in 1999. The coastal stations are resupplied using the Russian vessel RV *Akademik Fedorov* and, when required, MI-8 helicopters. Heavy caterpillar tractors and carriers, bulldozers, skidders, amphibian carriers and truck cranes provide ground transport. Vostok is typically accessed using USAP aviation support or by an annual tractor train from Mirny, 1260 km distant.

The main goals of the Russian Antarctic Expeditions (RAE) are, in summary, to:

- maintain a presence on the continent and conduct scientific research relevant to the economic conditions and geopolitical interests of Russia in the area;
- operate winter stations and field bases in 'the regime of minimum permissible parameters';
- conduct a program of environmental monitoring, including of the anthropogenic impact on the environment;
- undertake seasonal expedition studies and engineering activities; and
- carry out nature protection measures aimed and making expedition activities comply with the requirements of the Madrid Protocol (Russian Federation 2001b).

The Madrid Protocol was adopted by Russia through the Decision of the Government of the Russian Federation of 18 December 1997 No. 1580 *on ensuring the implementation of the Protocol on Environmental Protection to the Antarctic Treaty.* The Federal Services of Russia for Hydrometeorology and Environmental Monitoring (Roshydromet) is responsible for administering a permit system-based implementation program.

RAE submitted an information paper (IP–50) to the fourth CEP meeting held in Russia in 2001; *Planning of waste disposal at the Russian Antarctic stations and ships*. The document 'presents a basic guidance in preparing waste management plans and handbooks for RAE stations, bases, inland traverses and ships to be issued in 2001–2002' (Russian Federation 2001a, pages not numbered). It acknowledges that 'the most significant impact by the number of sources will result from the activity of waste disposal at the stations' whereby 'a secondary pollution of the environment is possible by garbage, dust and accidental spills of used fuel stored in old corroded containers ... these impacts will occur within the limits of stations, namely in non-recoverable areas.'

RAE waste disposal policy is described in that document as including:

- reduction of waste introduced to Antarctica;
- appointments of waste disposal officials to develop and monitor waste disposal at each site;
- waste separation (in a specially equipped room), with an emphasis on managing chemical waste;
- storage of waste in environmentally safe and marked containers; and
- waste removal from the AT area and the safe disposal or recycling *with due regard to cost efficiency* [emphasis added].

In a multi-season EIA covering all RAE activities it is noted that:

> A document was prepared on planning waste disposal at the Russian Antarctic stations and ships. At present, garbage disposal at the stations and ships is carried out with the existing instructions that temporarily substitute the Waste Disposal Plans ...
>
> Specific conditions for implementation of activity:
>
> The RAE activity is carried out under the conditions of untimely and insufficient funding during the non-optimal time frame for the seasonal logistic operations (Russian Federation 2001b, p. 78).

In reading the program documents it is difficult to differentiate between practices that are proposed and practices that are currently adopted. The statement that 'Regular removal of the day-to-day expedition activity waste is to become a common practice' (Russian Federation 2001a, pages not numbered) implies that waste removal is not currently undertaken – an observation supported by recent ATCP inspections. As the only waste management related paper RAE submitted to CEP V concerns a clean-up project at Bellingshausen station on the Antarctic Peninsula, an assessment of post-2001 advances in routine waste handling practices has not been possible.

RAE's receptivity to collaborative arrangements and external assistance is established in CEP (2002d) which describes successful experiences of joint clean-up projects; with the Alfred Wegener Institute in Germany involving waste removal from Schirmacher Oasis, Novolazarevskaya; with the Canadian NGO View Foundation at Bellingshausen in the 1995–96 summer; and with Mission Antarctica between 1998 and 2001–02. During the final season of Mission Antarctica's involvement, more than 800 t of waste were repatriated, destination unspecified, as well as metal scrap from Artigas (Uruguay), Frei (Chile) and Arctowsky (Poland). Page 3 of the Russian-submitted paper concludes that:

> In this way it was obtained a positive experience of international cooperation on cleaning up Antarctic territories which could be recommended to Antarctic community in order to draw additional fund sources to environment protection measures and to speed up their implementation (CEP 2002d).

5.2.3 China

Under the umbrella of the Chinese Antarctic Research Expeditions (CHINARE), China operates one year-round East Antarctic station, Zhongshan in the Larsemann Hills. The station is typically manned by 15 personnel in winter, and resupplied using the 167 m Chinese vessel *Xuelong* (Chinese Arctic and Antarctic Administration, undated). Cargo is transferred ashore by barge, helicopters, and sleds towed behind traverse vehicles, depending on the time of the season. Tracked vehicles on site include a front-end loader, bulldozer, and a truck with a crane. A new living building containing accommodation, offices, a mess, kitchen, storage and hospital facilities is planned (Chinese Antarctic Program 2001) and can be expected to generate a significant volume of construction waste.

In *Document of the State Oceanographic Administration, Peoples Republic of China* cited in Kriwoken (1992, p. 24) it is reported that:

> The Peoples Republic of China stresses and adheres to the relevant regulations on environmental protection within the Antarctic Treaty System .... Waste material must be kept in hermetically sealed containers according to its type. Those materials that are incombustible, or not allowed to be burnt off in the Antarctic, must be carried back to China. Other materials must be burnt off periodically in the incinerator ... Every member of the field party must bring rubbish bags to return waste (including packing material, cigarette ends, and human waste) to the station for proper disposal.

In the *2000–01 Chinese Antarctic Environment Report* (Chinese Antarctic Program 2001, pages not numbered), waste management activities are described as follows:

> The solid waste materials were divided into four catalogues (sic) and treated in different ways ...
> – Combustible materials [food scraps, cardboard, some timber, miscellaneous items and field/human wastes – McIvor undated] were not permitted to store

in the station for a long time. They were burned in the incinerator after being recorded. The remains were put in case and would be transported back to China.
– Metal, plastic and other non-combustible materials were collected and piled to be transported back to China.
– materials were smashed into pieces and put into cases to be transported back to China.
– Battery useless was collected into cases and would be transported back to China.

No new information is provided in CHINARE's CEP V submission.

An AAD environment officer observed that waste is 'separated into three types, with combustible material burnt in a high temperature incinerator and glass and metal stockpiled in the lee of a hill north-east of station' and that 'Non-combustible wastes are sorted into waste categories (glass, plastic, metal, wood, other) and stored in a distinct area south of the power house, with empty drums utilised for small items wherever possible, for removal by ship at the next opportunity' (McIvor undated, p. 12).

Australia, China and Russia have undertaken to jointly seek the indefinite designation of the Larsemann Hills (Figure 3) as an Antarctic Specially Managed Area (ASMA) under Annex V (Article 4) of the Madrid Protocol (McIvor undated). A management plan has been drafted and seeks to provide a reference guide for the parties so that the values of the area are maintained and environmental impacts are minimised through the appropriate planning and conduct of activities. A stated objective of the plan is to prevent contamination of the environment through the implementation of comprehensive waste management practices and the appropriate handling and storage of harmful substances; waste disposal and management activities are to comply, as a minimum, with Annex III to the Madrid Protocol.

5.2.4 Japan

Japan, under the Japanese Antarctic Research Expeditions (JARE), operates Syowa on the northern coast of the East Ongul Islands in Lutzow-Holm Bay. Mizuho, a facility approximately 270 km south-east of Syowa, lies in a severe katabatic wind region and has been buried and is no longer occupied (Hemmi 2002). Mizuho is

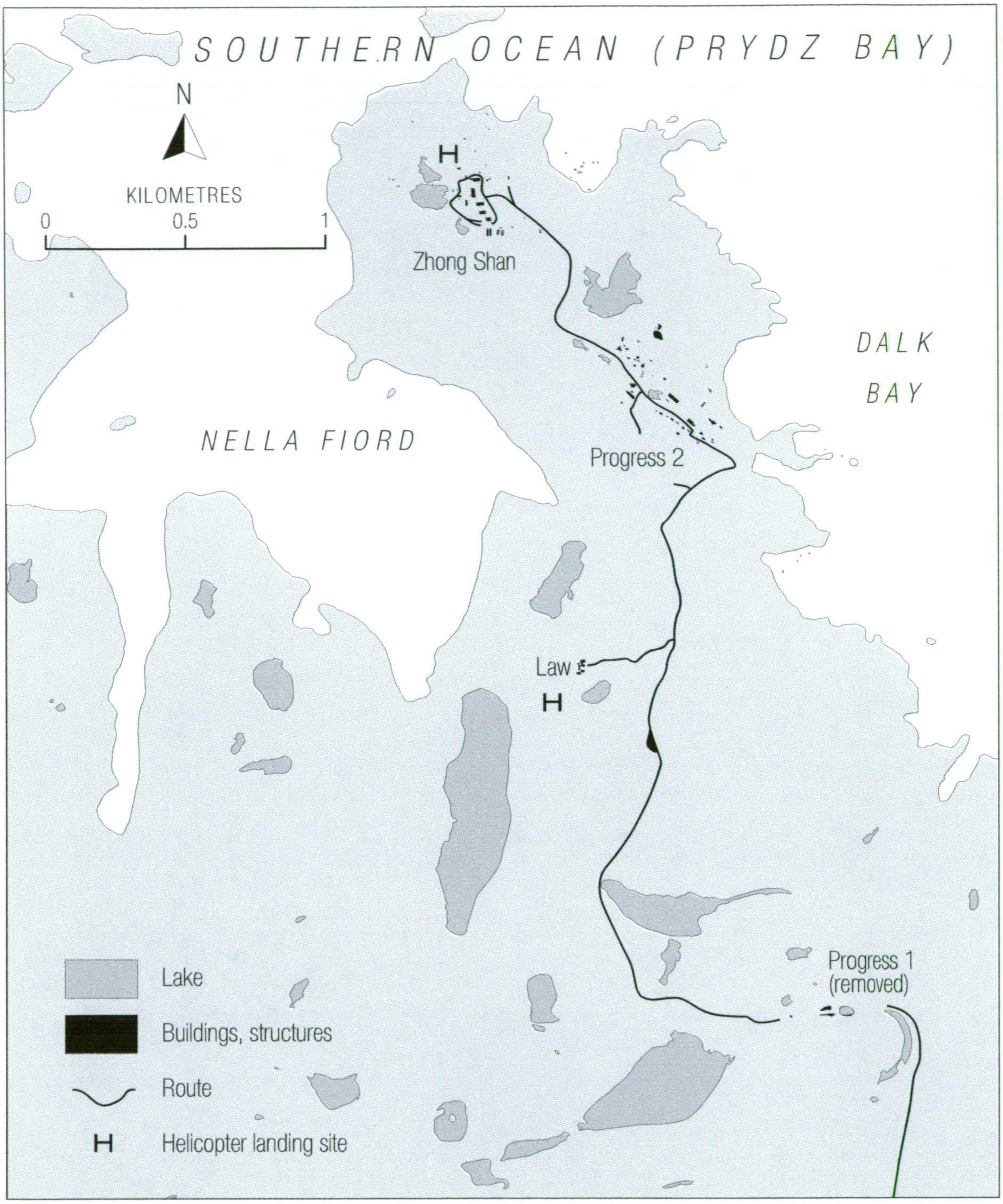

Figure 3. Larsemann Hills area.

still visited for the purposes of undertaking scientific observations (JARE 2002a) and there are no plans for its removal. The main building at Syowa is elevated to prevent snow drifts.

Vehicles for materials handling at Syowa include numerous traverse/field tracked tractors, trucks, crane trucks, dump trucks, rough terrain forklifts, cranes, loaders and excavators. The station is typically occupied over winter by 40 personnel, and serviced by the 134 m ship *Shirase* which normally sails with two Sikorsky S-61A helicopters and one OH-6 helicopter for ship-shore transportation and research (National Institute of Polar Research, undated).

Japanese law enacting the Madrid Protocol, the *Law Relating to Protection of the Environment in Antarctica (Antarctic Environment Law)* entered into force at the same time as the Protocol and was preceded by *The Cabinet Ordinance for Enforcing the Antarctic Environment Law and the Prime Minister's Office Ordinance for Enforcing the Antarctic Environment Law* (JARE 2001). It is administered by the Environment Agency (Tracey 2001).

In Japan's *Annual Report under the Protocol on Environmental Protection to the Antarctic Treaty* (JARE 2001, pages not numbered) it is reported that a waste management plan has been introduced, and:

> Some combustible wastes are incinerated and sewage is treated by the biological treatment plant. The ash and sludge are brought back to Japan. Other wastes [cited later as being photographic chemicals, lubricants, untreated wood, plastics, rubber, cloth, clinical waste, glass, metal cans, aluminium, building waste, batteries, incinerator residue, unopened waste food, fluorescent light bulbs] are removed from Antarctic Treaty area for proper disposal.

The significant components of the approximately 190 t of solid waste repatriated to Japan in the 2000–01 season were: untreated wood (20 t), building waste (27 t), vehicles (34 t) and 'other solid wastes' amounting to 69 t. Only paper products and wooden fragments (4 t in 2001–02) are incinerated (JARE 2002b). Stockpiled are approximately 300 t of scrapped vehicles and used materials. Under a program for the clean-up of existing waste disposal sites and abandoned work sites, approximately 100 t are removed every year (JARE 2002a).

5.2.5 France

France operates a coastal station, Dumont d'Urville (DDU), with a wintering population of around 35. Situated on the ice-free Ile des Pétrels in French-claimed territory on the Adélie Coast of East Antarctica, DDU is serviced from Hobart by the 65 m, 1700 t *L'Astrolabe*. A smaller station, Port Martin, 50 km to the east, was occupied for one winter before being abandoned in 1952 (Guichard 2003). Its fate has yet to be determined (Godon 2003). Concordia, a joint French/Italian inland station is resupplied each year by three summer tractor train traverses, and by air from DDU and Terra Nova Bay (Italy), approximately 1200 km distant in the Ross Sea area.

Since 1992, the administrative framework and human, technical and logistic resources for the French Antarctic program have been provided by the Institut Français pour la Recherche et la Technologie Polaires (IFRTP), a public interest group involving several government ministries and public and private sector institutions. The program's environmental policy and related instructions are communicated to expedition personnel via *Instructions Pratiques Concernant le Tri et la Gestion des Dechets a Dumont D'Urville* (Godon 2003).

In the 2001–02 summer, solid wastes removed from the AT area included 30 m^3 of plastic and rubber, 10 kg medical waste, 2 m^3 glass, 0.1 m^3 aluminium, 5 t iron, 2 t other metals, 0.1 t batteries, 100 to 200 fuel drums and 2 m^3 incinerator residue. Seventeen cubic metres of paper products, and treated and untreated wood were incinerated. Food scraps (5 m^3) were disposed of onto the sea ice or into the sea (IFRTP 2001). A 'programmes planned during the reporting year [1 October 2001 to 31 September 2002] to clean up waste disposal and abandoned work sites' is the 'monitoring of bacteriological quality of sea water at DDU' (IFRTP 2001, p. 41).

5.3 Strategy development

In view of the commonality of waste management issues in Antarctica, the logistical constraints discussed earlier, and the escalation of interest over the last decade in holistic and collaborative approaches to environmental planning and management (see, for example, Margerum and Born 1995, Brunckhorst 2000 and von Droste 1995), it is surprising that there is little evidence of anything more than passing consideration being given to the merits of collaborative operational activities, let alone their physical progression. Discoveries of synthetic organochlorine pesticides, radioactive fallout and introduced species in the Antarctic environment have reduced the 'tyranny of distance,' highlighting the fact that Antarctica is not as notionally isolated or ecologically discrete as many might suggest. With this perspective in mind, to give consideration to environmental management issues on a more than station-by-station or national program scale does not seem an unreasonable or overly ambitious proposition.

The propensity for strategies intended to cope with major collective concerns to be decomposed and redefined into 'micro issues' needs to be taken into consideration when proposing an operational framework, because as this occurs, projects invariably look increasingly less attractive or urgent. Another factor unconducive to the promotion of change is the potential, in the early planning-stage, for disproportionate attention to be given to issues likely to limit or preclude successful collaborative operations rather than the identification of environmental benefits. Regardless of these obstacles, it is suggested that the shared use of a dedicated cargo vessel for the removal of waste from East Antarctica is potentially attractive for environmental, economic and practical reasons.

As discussed in Chapter 4 and further explored in Table 8, the timing of Antarctic shipping arrangements is largely determined by the seasonal formation and decline of sea ice. Ideally therefore, a vessel chosen to service East Antarctica would be an icebreaker able to support cargo operations using ground transport over sea ice, and by barge. An operation reliant on helicopters, and even more so, long-range flights, would place significant restrictions on the characteristics of the waste able to be retrieved. For this reason, mid-summer shipping operations are indicated.

Also emerging from this case study is the requirement for strong leadership. Underdal (1998) explores the mechanism through which leadership can be exercised and the capabilities required to succeed in a leadership role in international environmental negotiations. He identifies a number of modes of leadership, and their advantages and disadvantages. A blend of what he describes as 'unilateral action' and 'instrumental leadership' shows particular promise with respect to the present study. Underdal (p. 105) suggests that unilateral action is exercised whenever an actor moves to solve a collective problem by his own efforts. The actor requires sufficient capabilities to accomplish alone, significant results in a given system of activities: 'Even actions that by themselves make no substantial contribution towards solving the basic problem itself can indirectly make a significant difference by helping to persuade others to follow.' In other words, a degree of influence in progress towards a coordinated activity may be achieved by a party singularly demonstrating an amount of sacrifice during the project's early development.

Instrumental leadership is described by Underdal as a matter of finding means to achieve common ends, based on the assumption that actors may enter international negotiations with incomplete and imperfect information and tentative or vague preferences; one party's guidance becomes accepted by others. Skill, energy and status are summarised as conditions considered necessary for success in designing politically feasible solutions.

By virtue of its territorial claim of 42% of the continent, Australia would seem to be 'morally' obliged, to take a highly proactive role in developing initiatives aimed at protecting the Antarctic environment. An Australian-led initiative would be consistent with the Australian Government's aim of encouraging compliance by other national operators with the environmental principles and agreements of the ATS. Australia too, is an attractive processing point for waste from East Antarctica on the basis of its proximity to the region and likely ability to handle waste in an environmentally appropriate, safe and legal manner.

5.4 Summary

A wide range of logistical approaches have been adopted by the managing institutions of programs in East Antarctica in response to the dictates of their scientific interests, station locations, political framework, available technology and priorities. While there are points of operational and policy commonality, collaborative operations have been little explored. Shared shipping arrangements may provide the impetus for concerted action and greater uniformity of approach to waste management operations, noting that not all of the ATCPs working in East Antarctica have developed a pro-active and long-term strategic plan for the removal of materials and the identification and clean-up of sites of past activities.

Chapter Six – Conclusions

This study sought to examine whether there is potential to enhance solid waste logistics in Antarctica through the adoption of practices aligned with ISWM system principles. This has been achieved through: (i) a literature review establishing changing attitudes to the Antarctic environment, and specifically, waste management therein; (ii) a review of current ATCP obligations arising from Annex III of the Madrid Protocol; (iii) an analysis of the functional elements of ISWM systems in an Antarctic setting, allowing the identification of key issues for operations in the region; and (iv), an examination of East Antarctic operations and Protocol compliance which indicates there is value in working towards greater uniformity in approach to waste management, and the adoption of regional logistical arrangements.

Although compliance with the Madrid Protocol represents a shared ATCP purpose, it is apparent that parties to the AT attach varying importance to waste management as a task. The methods by which Annex III's provisions have been operationalised reflect differing logistic support preferences and requirements, available resources, and varying knowledge bases and capabilities that are likely linked to the technical expertise and experiences that countries have in implementing environmental protection regimes at home. While high problem similarity exists, it is unlikely any one approach would be ecologically, logistically or economically acceptable for all geographical areas and national Antarctic programs. Regional arrangements such as those discussed in Chapter 5 are, however, likely to enhance waste management practices, both on practical and policy-related levels by:

- opening up the behaviour of players to greater scrutiny and discussion – providing the necessary incentive and climate for ATCPs to prioritise waste management as an issue of importance;
- stimulating momentum for improved environmental performance in the 'lull' after the Madrid Protocol's initial acceptance by ATCPs;
- assisting to overcome the 'economies of scale' applying to the handling of wastes generated by a single station or program;
- capitalising on the benefits of adopting some measure of uniformity in waste management practices; and

- reducing the need for programs to combine marine science, expeditioner transfer and cargo functions typical of current operations allowing a reduction in program operator costs through attracting cheaper, and a greater number of, shipping charter options.

For as long as science continues to be the currency of the ATS, science-based analyses of the impacts of waste handling techniques are likely to be the key driver in the adoption of improved practices. Scientific investigations also offer the potential to reduce program operator conflicts on the basis of their actual or perceived level of reason and objectivity over reactions to waste issues that may be considered emotional, or against the prevailing interests of ATCPs whose value commitments are disparate. The Madrid Protocol is, however, about the management of *human activities* – activities that impact on the environment. The importance therefore of ethics, politics, sociology, aesthetics, evolving ideologies and the like, and their complex interconnections, including those involving attitudes sourced from outside the traditional ATS forum, must receive far more than their current cursory ATS attention. A more holistic and inclusive approach to the consideration of environmental issues is needed.

Some ATCPs will have a strong intention to improve their waste management practices, and a similarly strong capacity to do so. Others will have the capacity but not the strong intention, strong intention but limited capacity, or limited intention and limited capacity. For each ATCP, the mix of intent and capacity is unlikely to remain static. It is this fluidity that makes the formulation of strategies especially engaging.

The key findings associated with each of the research objectives follow.

Describe the nature of Antarctic waste and examine contemporary solid waste handling practices

A lack of sufficiently-detailed, reliable, and consistently-recorded data on the nature, location, accessibility, volume and production rates of waste generated by programs, operating in Antarctica, and the likely range of variations that can be expected, currently precludes the planning of optimal ISWM systems on a regional, and in many cases local, level. In order to make longer-term, cost-effective and environmentally-sound waste management strategy choices it is necessary for decision-makers to plan a coordinated, active and targeted program of data collection.

Review the provisions of the waste management annex of the Madrid Protocol, and the responses of national Antarctic program operators

Annex III of the Madrid Protocol provides only a broad framework for waste management activities. The Protocol's loose terminology allows considerable flexibility of response to its provisions. This lack of precision complicates assessment of the level of ATCP compliance and of whether practices have improved since its adoption. Particularly evident is that the waste reporting system currently adopted by ATCPs is unlikely to advance the stated aim of facilitating studies directed at evaluating the environmental impacts of scientific activities and their associated logistic support. Fundamental to the development of integrated waste handling arrangements and continuous improvement, is agreement on specific and measurable waste management objectives and goals.

Using an ISWM system framework, analyse logistical issues peculiar to the on-site handling, removal and processing of solid waste from Antarctica

This research points to waste storage being the most significant ISWM issue in Antarctica due to the potential for waste to be accessed by scavenging birds, generate leachate, be dispersed by high winds or be irrevocably buried, and because of the limited number of removal opportunities that exist due to shipping constraints. Tailored logistical approaches are needed too for the extraction of iced debris, the programmed demolition of facilities, and the handling of annually-generated domestic-type waste. On a practical level, the choice of on-site waste handling methods for accumulated materials will vary accordingly to the wastes' accessibility (i.e. topographic features determining ease of retrieval and assembly at an inter-continental transfer point), the degree of ice or snow encasement (superficial, half-buried or totally enclosed) and the waste type (principally hazardous or non-hazardous).

Examine East Antarctic activities as a case study for the development of cooperative waste management operations

The waste management practices of East Antarctic operators reflect a wide range of influences including the economic status of the home country, government agendas, attitudes to resource ownership, the dictates of domestic legislation, administrative arrangements including the terms of reference of the managing institutions, and the implications of change. Nevertheless the adoption of a trans-national shipping arrangement warrants investigation as one element of a regional approach to waste management. Among critical scoping questions are:

- the expectations of the project that each party will have;
- how much each party is prepared to contribute;
- factors on which participation is conditional; and
- the maximum, credible, uncontrollable project risk, and its acceptability to the participating parties.

Already some common themes emerge and are relevant to operations throughout Antarctica. They are that an appropriate course of action:

- will not be significantly different from the 'business as usual' scenario of each program because of the substantial commitment of resources that has already been made by many Antarctic programs;
- will, because of variations in the timing and ease of physical access, need to involve logistic arrangements that are able to allow for considerable adjustment and flexibilities; the coupling or decoupling of issues, and the adding or subtracting of participants;
- will ideally provide scope for cooperation to evolve incrementally; and
- will see each party entering into the arrangement assume at least some responsibility for the outcome.

The complexity of the ATS has the potential to impede the progression of a co-ordinated approach to waste management operations. Detailed discussion on an environmental liability annex to the Madrid Protocol, for example, commenced at ATCM XVII in 1992, and while the proposed annex has been discussed at every meeting following, it is far from finalised. Similarly, while consensus on the need to establish an AT secretariat was reached at ATCM XVI in 1991, agreement on its location was not reached until 2001 (ATCM XXIV) while constitutional and operative instruments have yet to be established. Accordingly, dialogue at an institutional level, with nominated countries leading negotiations is recommended as an approach most likely to produce timely results.

It is suggested that waste management planning may be advanced initially, by research into:

- the effectiveness of Annex III of the Madrid Protocol in addressing the problems that it was designed to ameliorate;
- the accuracy of EIA predictions with respect to waste and site clean up programs conducted to date;
- the design of a protocol for sampling and characterising Antarctic wastes, and the development of an associated standardised classification system and reporting format; and
- the social, economic, political and legal issues attached to the potential use of Australia (Hobart, Tasmania) as a processing point for Antarctic waste, in particular from foreign stations within and outside AAT.

References

AAD (2000a). *Antarctic Treaty exchange information—particulars for the Australian National Antarctic Research Expeditions (ANARE) exchange information under Article VII(5).* http://www.antdiv.gov.au/environment/wasteman.html [Accessed 22 July 2002]. Australian Antarctic Division, Hobart, Australia.

AAD (2000b). *Looking south: the Australian Antarctic Program into the 21st century.* Australian Antarctic Division, Hobart, Australia. 46 pp.

AAD (2001a). *Report on the open-ended intersessional contact group on diseases of Antarctic Wildlife. Report 1: Review and risk assessment.* XXIV ATCM Working Paper; CEP IV Agenda Item 4D. Australian Antarctic Division, Hobart, Australia. 35 pp.

AAD (2001b). *The AAD environmental policy: our vision; Antarctica valued, protected and understood.* http://www.aad.gov.au/environment/policy/policy.asp [Accessed 5 August 2002]. Australian Antarctic Division, Hobart, Australia.

AAD (2002a). *Antarctic Treaty exchange information 2000–2001 — particulars for the Australian National Antarctic Research Expeditions (ANARE) exchange information under Article VII(5).* http://www.antdiv.gov.au/environment/ wasteman.html [Accessed 22 July 2002]. Australian Antarctic Division, Hobart, Australia.

AAD (2002b). *Contaminants in freezing ground.* http://www.aad.gov.au/science/ cfg3/default.asp [Accessed 1 July 2002]. Australian Antarctic Division, Hobart, Australia.

AAD (2002c). *Search Antarctic names.* http://aadc-maps.aad.gov.au/aadc/gaz/ search_names.cfm [Accessed 27 November 2002]. Australian Antarctic Division, Hobart, Australia.

AAD (2003a). *Contaminated sites*. http://www.aad.gov.au/default.asp?casid=3109 [Accessed 2 January 2003]. Australian Antarctic Division, Hobart, Australia.

AAD (2003b). *State of environment*. http://www-new.aad.gov.au/default.asp?casid=3808 [Accessed 3 February 2003]. Australian Antarctic Division, Hobart, Australia.

Adamson, E., Adamson, H. and Seppelt, R. (1994). Cement dust contamination of *Ceratodon purpureus* at Casey, East Antarctica: damage and capacity for recovery. *Journal of Bryology 18*:127–137.

Agraz, J.L., Sanchez, R.A., Rinaldi, C.A. and Acero, J.M. (1998). *Environmental review of Argentine activities at Marambio station*. Instituto Antartico Argentiono, Buenos Aires. 67 pp.

AHC (1999). *Natural heritage places handbook; applying the Australian Natural Heritage Charter to conserve places of natural significance.* Australian Heritage Commission, Canberra, Australia. 56 pp.

AHC (2002). *Register of the National Estate Database – Wilkes station, Casey station database number: 016100 File number: 9/01/002/0002.* http://www.environment.gov.au/cgi-bin/heritage/register/site.pl?016100 [Accessed 24 April 2002]. Australian Heritage Commission, Canberra, Australia.

Anderson, I. (1998). With people come plagues: tourists and scientists could be bringing deadly diseases to Antarctica's wildlife. *New Scientist* 5 September 1998, p. 4.

Anon. (1989). Tips on keeping Antarctica clean. *Australian Geographic 15*:120.

Anon. (personal communication 2002). Environment Officer, Australian Antarctic Division, Hobart, Australia.

Antarctic Exchange of Information (2003). *Background.* http://www.infoantarctica.org.ar/index.htm [Accessed 10 March 2003]. Site hosted by Argentine Antarctic program.

Antarctica New Zealand (1999). *Antarctica New Zealand waste management handbook* (2nd edition, draft). Antarctica New Zealand, Christchurch, New Zealand.

Arrens, M. (1994). *A waste management strategy for Australia's Antarctic operations.* Australian Antarctic Division, Hobart, Australia. 44 pp.

ATCM (1991). *Final report of the XVI Antarctic Treaty Consultative Meeting, 7–18 October, Bonn, Federal Republic of Germany.*

ATCM (1992). *Final report of the XVII Antarctic Treaty Consultative Meeting, 11–20 November 1992, Venice, Italy.*

ATCM (1994). *Final report of the XVIII Antarctic Treaty Consultative Meeting, 11–22 April 1994, Kyoto, Japan.*

ATCM (1995). *Final report of the XIX Antarctic Treaty Consultative Meeting, 8–19 May, Seoul.*

ATCM (1996). *Final report of the XX Antarctic Treaty Consultative Meeting, 29 April – 10 May 1996, Utrecht, Netherlands.*

ATCM (1997). *Final report of the XXI Antarctic Treaty Consultative Meeting, 19–39 May 1997, Christchurch, New Zealand.*

ATCM (1998). *Final report of the XXII Antarctic Treaty Consultative Meeting, 25 May – 5 June 1998, Tromso, Norway.*

ATCM (1999). *Final report of the XXIII Antarctic Treaty Consultative Meeting, 24 May – 4 June 1999, Lima, Peru.*

ATCM (2001). *Final report of the XXIV Antarctic Treaty Consultative Meeting, 9–20 July 2001, St Petersburg, Russia.*

Babicka, N.A., Snape, I. and Goldsworthy, P.M. (2000). GIS – a tool for managing contaminated sites and abandoned stations in Antarctica. *2000 Contaminated site remediation conference, Melbourne, 4–8 December 2000.* 5 pp.

Bastmeijer, K. (2000). Implementing the environmental protocol domestically: an overview. In: Vidas, D. (Ed.). *Implementing the environmental protection regime for the Antarctic.* Kluwer Academic Publishers, Dordrecht, The Netherlands. Pp. 287–307.

Bishop, I. (2003). *Antarctic Science Project No. 2250: Development of a GIS of wilderness and aesthetic values for the AAT.* http://its-db.aad.gov.au/proms/public/report_project_public.cfm?project_no=2250 [Accessed 28 February 2003]. Australian Antarctic Division, Hobart, Australia.

Bogart, P.S. (1988). Environmental threats in Antarctica. *Oceanus 31*(2):104–107.

Bowden, T. (1997). *The silence calling.* Allen & Unwin, New South Wales, Australia. 594 pp.

Boyd, D. (2001). After the protocol: Problems and prospects for Antarctica. In: Jabour-Green, J. and Haward, M. (Eds). *The Antarctic: past, present and future.* Antarctic CRC Research Report 28. University of Tasmania, Hobart, Australia. Pp. 105–111.

Brah, N. (2003). Alarm bells ring the changes. *Waste management and the environment 14*(6): 38–39.

Brown, G.A., Clarke, N.C., Laurenson, R.A. and Lenton, R.M. (2001). *Initial Environmental Review for the Australian Antarctic Division June 2001 (Prepared in accordance with Section 4.1.3 of ISO 14004 Environmental management systems – general guidelines on principles, systems and supporting techniques).* Graham A. Brown & Associates, Sydney, Australia. 407 pp.

Brown, G.A. and Black, I. (2002). *The waste management and minimisation guidebook.* Thomson Legal and Regulatory Limited, Victoria, Australia.

Brunckhorst, D.J. (2000). *Bioregional planning: resource management beyond the new millennium.* Harwood Academic Publishers, Amsterdam, The Netherlands. 162 pp.

Cameron, R.E. (1972). Pollution and conservation of the Antarctic terrestrial ecosystem. In: Parker, B.C. (Ed.). *Proceedings of the colloquium on conservation problems in Antarctica held on 10–12 September, 1971, Blacksburg, Virginia 24061.* Allen Press Inc, Kansas, USA. Pp. 267-307.

Canale, G., Fulford, B. and Quilligan, H. (1990). *Waste minimisation at Casey station, Australian Antarctic Territory.* Unpublished thesis, Graduate School of Environmental Science, Monash University, New South Wales, Australia. 155 pp.

Cervellati, R., Metalli, P. and Testa, L. (1990). Current developments in environmental protection at Terra Nova Bay station. In: Kohnen, H., Teixeira, A.J. and Fowler, A.N. (Eds). *Proceedings of the fourth symposium on Antarctic logistics and operations, Sao Paulo, Brazil, 16 to 18 July 1990.* Standing Committee on Antarctic Logistics and Operations of the Council of Managers of National Antarctic Programs in conjunction with the Scientific Committee on Antarctic Research. 14 pp.

Chiang, E., Chang, S.C. and Brown, A.J. (1997). Pollution abatement at McMurdo Station, Antarctica. *Proceedings of the seventh international offshore and polar engineering conference, Honolulu, USA, May 25-30, 1997.* Pp. 572-578.

Chilean Antarctic Program (2001). *Proposal to include the ruins of BSE Pedro Aguirre Cerda on the Historic Sites and Monuments List.* Committee for Environment Protection IV, Working Paper WP-34. 2 pp.

Chinese Antarctic Program (2001). 2000/2001 *Chinese Antarctic environmental report.* Committee for Environment Protection IV, Information Paper IP-45.

Chinese Arctic and Antarctic Administration (undated). *China's Arctic and Antarctic research*. Chinese Arctic and Antarctic Administration, Beijing, China. 25 pp.

Clark, L. and Wishart, E. (undated). *Historical documentation of Wilkes Station, Antarctica 1988/89*. Queen Victoria Museum and Art Gallery, Launceston, Australia.

Clark, L. and Wishart, E. (1993). *66 degrees south*. Queen Victoria Museum and Art Gallery, Launceston, Australia. 99 pp.

Codling, R. (1998). Wilderness and aesthetic values in Antarctica. *XXII Antarctic Treaty Consultative Meeting, 25 May – 5 June 1998, Tromso, Norway. 4 pp.*

Cole, C.M., Snape, I., Gore, D.B., Revill, A.T. and Riddle, M.J. (2000). Contaminants in the Antarctic environment III: Chemical and physical processes that influence contaminants in cold regions. In: Hughson, T. and Ruckstuhl, C. (Eds). *ISCORD 2000. Proceedings of the sixth international symposium on cold region development, Hobart, Tasmania, Australia, 31 January – 4 February 2000.* Tasmania State Government, Australia. Pp. 128–131.

CEP (2001). *CEP IV Final Report Appendix 6 Measure 2.* http://cep.npolar.no/innhold/cep_archive/meetings.html [Accessed 30 December 2001].

CEP (2002a). *Guidelines for the implementation of the framework for protected areas set forth in Article 3, Annex V of the Environmental Protocol.* http://cep.npolar.no/innhold/cep_archieve/Doc/Guidelines/guideline_list.html [Accessed 12 August 2002].

CEP (2002b). *Meeting documents CEP V Poland 2002: A new waste water treatment system for New Zealand's Scott base – rationale, selection process and outcome – Information Paper 32.* (Submitted by New Zealand). http://www.cep.aq/default.asp?casid=5073 [Accessed 2 July 2003].

CEP (2002c). *Meeting documents CEP V Poland 2002: Clean up of a former subantarctic research station at Heard Island – Information Paper 57.* (Submitted by Australia). http://www.cep.aq/default.asp?casid=5073 [Accessed 2 July 2003].

CEP (2002d). *Meeting documents CEP V Poland 2002: Results of the waste disposal project at Bellingshausen station – Information Paper 16.* (Submitted by Russia). http://www.cep.aq/default.asp?casid=5073 [Accessed 2 July 2003].

CEP (2002e). *Meeting documents CEP V Poland 2002: The clean-up and removal of abandoned British stations in Antarctica – Information Paper 22.* (Submitted by United Kingdom). http://www.cep.aq/default.asp?casid=5073 [Accessed 2 July 2003].

CEP (2003a). Activities *related to environmental impact assessments (Annex I of the Protocol).* http://www.cep.aq/default.asp?casid=5083 [Accessed February 2003].

CEP (2003b). *Current CEP activities.* http://www.cep.aq/default.asp?casid=5082 [Accessed February 2003].

COMNAP (2000). *Stations and bases.* http://www.comnap.aq/comnap/comnap.nsf/P/StationsbyName [Accessed 29 July 2001]

Cripps, E. (1995). *Antarctic waste management in Australian domestic law.* Unpublished thesis, Graduate Diploma of Antarctic and Southern Ocean Studies with Honours, Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart, Australia. 87 pp.

Czech, K. (1992). *The waste disposal and waste management provisions of the Madrid Protocol.* Unpublished thesis, Graduate Diploma of Antarctic and Southern Ocean Studies with Honours, Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart, Australia. 61 pp.

Dayton, P.K. and Robilliard, G.A. (1971). Implications of pollution to the McMurdo Sound benthos. *Antarctic Journal of the United States 6*(3):53–56.

Department of External Affairs (1954). *Antarctic Research Expedition 1955 Mawson, Heard Island and Macquarie Island operations manual.* Australian Antarctic Division, Melbourne, Australia.

Deprez, P.P. (2000). *Protocol for acceptance of wastes from the Antarctic to Tasmania.* Office of Antarctic Affairs, Department of State Development, Hobart, Australia. 8 pp.

Deprez, P.P., Arens, M. and Locher, H. (1999). Identification and assessment of contaminated sites at Casey Station, Wilkes Land, Antarctica. *Polar Record 35*(195):299–316.

Duston, T.E. (1993). *Recycling solid waste: the first choice for public and private sector management.* Quorum Books, Connecticut, USA. 204 pp.

Fowler, A.N. (1988). Antarctic logistics. *Oceanus 31*(2):80–86.

Frederickson, L.H. (1971). Environmental awareness at Hallet station. *Antarctic Journal of the United States* 6(3):57.

Godon, P. (personal communication 2003). Head of Polar Logistics Department, French Polar Institute Paul Emile Victor – IPEV, Plouzane, France.

Greenpeace International (1990). Report on a visit to Dumont d'Urville, Antarctica. *Polar Record 26*(156):51–53.

Guichard, A. (personal communication 2003). Managing Director, Polar Latitudes Pty Ltd, Hobart, Australia.

Handmer, J., Wilder, M. and Dovers, S. (1993). Australian approaches to Antarctic conservation: an historical perspective. In: Handmer, J. and Wilder, M. (Eds). *Towards a conservation strategy for the Australian Antarctic Territory.* The 1993 Fenner conference on the environment. Centre for Resources and Environmental Studies, Australian National University, Canberra, Australia. Pp. 18–40.

Hansom, J.D. and Gordon, J.E. (1998). *Antarctic environments and resources: a geographic perspective.* Addison Wesley Longman Limited, Essex, UK. 402 pp.

Harding, R. (Ed.). (1998). *Environmental decision-making.* The Federation Press, Victoria, Australia. 366 pp.

Harris, C.M. (1991). Environmental effects of human activities on King George Island, South Shetland Islands, Antarctica. *Polar Record 27*(162):193–204.

Hayashida, S., Mae, S. and Murayama, M. (1981). A treatment and disposal system of waste materials at Mizuho station. *Antarctic Record 72*:49–60.

Headland, R. (1994). Historical development of Antarctic tourism. *Annals of Tourism Research 21*(2):269–280.

Hemmi, K. (personal communication 2002). Environment Section, National Institute of Polar Research, Tokyo, Japan.

Hemmings, A.D. (1990). Human impacts and ecological constraints on skuas. In Kerry, K.R. and Hempel, G. (Eds). *Antarctic ecosystems: ecological change and conservation.* Springer-Verlag, Berlin, Germany. Pp: 224–230.

Hince, B. (2000). *The Antarctic dictionary: a complete guide to Antarctic English.* CSIRO Publishing and Museum of Victoria, Melbourne, Australia. 393 pp.

Hughes, J. and Davis, B. (1995). The management of tourism at historic sites and monuments. In: Hall, C.M. and Johnston, M.E. (1995). *Polar tourism: Tourism in the Arctic and Antarctic regions.* John Wiley & Sons, West Sussex, UK. Pp. 235–255.

Hughes, K.A. (2003). A simple method to reduce discharge of sewage microorganisms from an Antarctic research station. *Marine Pollution Bulletin 46*:353–357.

IAATO (2003). *Antarctic tourism: a resource for science. Select IAATO papers to the Antarctic Treaty Consultative Meetings.* http://www.iaato.org/reports.html [Accessed 22 January 2003]. International Association of Antarctica Tour Operators.

ICSU (1989). *Waste disposal in the Antarctic: Report of the Scientific Committee on Antarctic Research, panel of experts on waste disposal in response to Recommendation 4 of the XIII Antarctic Treaty Consultative Meeting 1985 (ATCM XIII–4).* Australian Antarctic Division, Hobart, Australia. 53 pp.

IFRTP (2001). *Activites Francaises en Antarctique notification 2001–2002. Echange di'informations conforement aux articles II (1) et VII (5) due traite sur l'Antarctique.* IFRTP – Technopole Brest-Iroise, France. 44 pp.

JARE (2001). *Annual report under the Protocol on Environmental Protection to the Antarctic Treaty.* CEP IV Information Paper IP–14.

JARE (2002a). *Annual report under the Protocol on Environmental Protection to the Antarctic Treaty.* CEP V Information Paper IP–66.

JARE (2002b). *Japanese Antarctic activities for 2002–2003. Exchange information under Article VII(5) of the Antarctic Treaty.* Headquarters for Japanese Antarctic Research Expedition Ministry of Education, Culture, Sports, Science and Technology, Tokyo, Japan.

Kaliazin, V. (personal communication 2002). Director, Antarctic Logistics Centre International, Cape Town, South Africa.

Kennicutt, M.C., McDonald, S.J., Sericano, J.L., Boothe, P., Oliver, J., Safe, S., Presley, B.J., Liu, H., Wolfe, D., Wade, T.L., Crockett, A. and Bockus, D. (1995). *Environmental Science and Technology 29*:1279–1287.

Kerry, K.R. (1993). Terrestrial flora and fauna of the AAT: biological background and conservation issues. In: Handmer, J. and Wilder, M. (Eds). *Towards a conservation strategy for the Australian Antarctic Territory.* The 1993 Fenner

Conference on the Environment. Centre for Resources and Environmental Studies, Australian National University, Canberra, Australia. Pp. 53–74.

Kershaw, A. (1998). Antarctica and tourism in 2010. In: Tetley, G. (Ed.). *Antarctica 2010: a notebook: proceedings of the Antarctic futures workshop 28–30 April 1998.* Antarctica New Zealand, Christchurch, New Zealand. Pp. 78–82.

King, C.K. and Riddle, M.J. (2001). Effects of metal contaminants on the development of the common Antarctic sea urchin *Sterechinus neumayeri* and comparisons of sensitivity with tropical and temperate echinoids. *Marine Ecology Progress Series 215*:143–154.

Klee, R.J. (2001). Industrial metabolism on ice: a case study of industrial materials flows and environmental management alternatives for Scott base, New Zealand's Antarctic research station. *The Journal of the Royal Society of New Zealand.*

Knowles, B. (1989). *The green, white wilderness: applying ecophilosophical principles to the management of Antarctica's wilderness.* Unpublished thesis, Graduate Diploma in Environmental Studies, University of Tasmania, Hobart, Australia. 70 pp.

Kriwoken, L.K. (1992). Chinese at Zhongshan focus on environmental protection. *ANARE News* (Autumn). Pp. 24–25. Australian Antarctic Division, Hobart, Australia.

Landau, D. (personal communication 2003). Executive Director, Office of the Secretariat, International Association of Antarctica Tour Operators, Colorado, USA.

Law, P.G. (1963). *Resources of Australian Antarctica.* Public Address on the Occasion of the Celebration of the Golden Jubilee of the Commonwealth Public Service Professional Association, Wilson Hall, University of Melbourne, 4th October, 1962. Reprinted from *The P.O.A. Chronicle Number 187*, August.

Law, P.G. (1967). Development of techniques of logistic support for expeditionary activities. *Annals of the International Geophysical Year XLIV Antarctic.* Pergamon Press, Oxford, UK. Pp. 145–155.

Law, P.G. (1983). *Antarctic odyssey.* Heinemann, Melbourne, Australia. 284 pp.

Law, P.G. and Bechervaise, J. (1957). *ANARE: Australia's Antarctic outposts.* Oxford University Press, Melbourne, Australia. 152 pp.

Lenihan, H.S. and Oliver, J.S. (1995). Anthropogenic and natural disturbances to marine benthic communities in Antarctica. *Ecological Applications 5*(2):311–326.

Lenihan, H.S., Kiest, K.A., Conlan, K.E., Slattery, P.N., Konar, B.H. and Oliver, J.S. (1995). Patterns of survival and behaviour in Antarctic benthic invertebrates exposed to contaminated sediments: field and laboratory bioassay experiments. *Journal of Experimental Marine Biology and Ecology 192*:233–235.

Lenihan, H.S., Oliver, J.S., Oakden, J.M. and Stephenson, M.D. (1990). Intense and localized benthic marine pollution around McMurdo Station, Antarctica. *Marine Pollution Bulletin 21*(9):422–430.

Liu, D.H.F. and Liptak, B.G. (2000). *Hazardous waste and solid waste.* Lewis Publishers, Washington D.C., USA. 272 pp.

Lucas, P.H.C. (1992). *Protected landscapes: a guide for policy-makers and planners. IVth World congress on national parks and protected areas, Caracas, Venezuela.* Chapman and Hall, London, UK. 297 pp.

Lyons, D. (1996). *Polar and environmental technology.* Unpublished course notes, of the Institute of Antarctic and Southern Ocean Studies. IASOS, University of Tasmania, Hobart, Australia.

Makinen, E., Arpiainen, M. and Heideman, T. (1994). *The diversity of modern Antarctic vessels.* SCALOP, Rome, Italy, August, 1994.

Margerum, R.D. and Born, S.M. (1995). Integrated environmental management: moving from theory to practice. *Journal of Environmental Planning and Management 38*(3):371–391.

May, J. (1988). *The Greenpeace book of Antarctica.* Child & Associates Publishing Pty Ltd, New South Wales, Australia. 192 pp.

McIvor, E. (undated). *Draft Antarctic Specially Managed Area management plan for the Larsemann Hills, East Antarctica.* Australian Antarctic Division, Hobart, Australia. 26 pp.

Mellor, M. (1993). *Notes on Antarctic aviation.* CRREL Report 93–14. US Army Cold Regions Research and Engineering Laboratories, Hanover, USA.

Ministry of Foreign Affairs (2001). *Antarctic Treaty report of the Norwegian Antarctic inspection under Article VII of the Antarctic Treaty and Article 14 of the Protocol on Environmental Protection to the Antarctic Treaty.* Ministry of Foreign Affairs, Oslo. 52 pp.

Moore, S. and Shin-Yu, Tu (2002). *Waste minimisation performance monitoring: an Australian perspective.* http://www.civeng.unsw.edu.au/water/awdb/Iswa4.thm/ [Accessed 8 July 2002]. Cooperative Research Centre for Waste Management and Pollution Control Limited.

Morris, C.E., Cole, C.M., Snape, I. and Deprez, P. (2000). Contaminants in the Antarctic environment. IX. Overcoming problems of contaminated site clean-up using engineering solutions. In: Hughson, T. and Ruckstuhl, C. (Eds). *ISCORD 2000. Proceedings of the sixth international symposium on cold region development, Hobart, Tasmania, Australia, 31 January – 4 February 2000.* Tasmania State Government, Australia. Pp. 151–154.

Moser, D. Ed. (2001). *Antarctic non-government activity news 58.* Australian Antarctic Division, Hobart, Australia.

Muller, F.W. (1968). Establishment of the scientific station Almirante Brown in Paradise Harbour, Antarctic Peninsula. *Records of the Antarctic Treaty meeting of experts on logistics.* Ministry of Education, Tokyo, Japan. 69 pp.

Murray-Smith, S. (1988). *Sitting on penguins: people and politics in Australian Antarctica.* Century Hutchinson, New South Wales, Australia. 249 pp.

El Naggar, S. and Schoppe, S. (1994). Waste management concept at the German winter station Neumayer. *Proceedings of the sixth symposium on Antarctic logistics and operations, Rome, Italy 29 to 31 August 1994.* Standing Committee on Antarctic Logistics and Operations of the Council of Managers of Antarctic Programs in conjunction with the XXII Meeting of the Scientific Committee on Antarctic Research. Pp. 13–23.

National Institute of Polar Research (undated). *Japanese Antarctic activities.* National Institute of Polar Research, Tokyo, Japan. 30 pp.

Netherlands (2000). *List of Initial and Comprehensive Environmental Evaluations prepared by the state parties to the environmental protocol.* Information Paper 39, XII Special Antarctic Treaty Consulative Meeting, The Hague, Netherlands.

Northcott, K.A., Snape, I., Connor, M.A. and Stevens, G.W. (2001). Chemical engineering in Antarctica: contaminated site remediation in a challenging environment. *Sixth world congress of chemical engineering, Melbourne, Australia, 23–27 September 2001.*

NSF (1979). *U.S. Antarctic Program draft environmental impact statement.* Division of Polar Programs, National Science Foundation, USA.

O'Brien, J.S. (2001). *Incinerator emissions at Casey Base, Antarctica.* Unpublished thesis, Graduate Diploma in Environmental Studies (Honours), School of Geography and Environmental Studies, University of Tasmania, Hobart, Australia. 140 pp.

Olivier, F. and Woehler, E.J. (2002). A report on the collection of rubbish at Casey during the 2001–2002 summer. Unpublished report to the sixtieth meeting of the Australian Antarctic Division environment committee, 12 December 2002. 6 pp.

Parker, B.C. (1971). The case for conservation in Antarctica. *Antarctic Journal of the United States* *6*(3):50–62.

Pett, J. (1994). Incineration as a waste management option. In: Hester, R.E. and Harrison, R.M. (Eds). *Waste incineration and the environment – issues in environmental science and technology*. Royal Society of Chemistry, Cambridge. Pp. 1–25.

Pfenningwerth, S. (2001). Disease in Antarctic wildlife: An assessment of risk. *Cooperative Research Centre for Antarctica and the Southern Ocean, Research Report 21*. Antarctic CRC, Hobart, Australia. 99 pp.

Quilty, P.G. (2002). Influences on the future directions of Australian Antarctic Research. In: Marchant, H.J., Lugg, D.J., and Quilty, P.G. (Eds). *Australian Antarctic science: the first 50 years of ANARE*. Australian Antarctic Division, Hobart, Australia. Pp. 579–588.

Riddle, M.J. (2000). Scientific studies of Antarctic life are still the essential basis for long-term conservation measures. In: Davidson, W., Howard-Williams, C. and Broady, P. (Eds). *Antarctic ecosystems: models for wider ecological understanding*. Pp. 297–302.

Riddle, M.J., Snape, I., Maggs, T. and Stark, J. (2000). Waste disposal and marine pollution from Antarctic stations. http://gpanews.unep.org [Accessed 25 May 2000]. *UNEP/GPA News Forum*.

Riddle, S. (2001). *Imports of hazardous wastes into Australia*. Environment Australia presentation at a seminar on the regulatory requirements on importing waste from the Antarctic, Office of Antarctic Affairs, Hobart, Australia, March 2001.

Risebrough, R.W. and McLaughlin, D.J. (1972). A proposal for the construction of a model Antarctic base. In: Parker, B.C. (Ed.). *Proceedings of the colloquium on conservation problems in Antarctica held on 10–12 September, 1971, Blacksburg, Virginia 24061.* Allen Press Inc, Kansas, USA. Pp. 247–266.

Roper-Gee, R. (personal communication 2002). Environment Officer, Antarctica New Zealand, Christchurch, New Zealand.

Rosenberg, M. (2003). *Geography: Antarctica.* http://geography.about.com/library/cia/blcantarctica.htm?once=true&. [Accessed 20 January 2003].

Rubin, J. (1996). *Antarctica: a travel survival kit.* Lonely Planet, Victoria, Australia. 362 pp.

Russian Federation (2000). *Annual report pursuant to the Protocol on Environmental Protection to the Antarctic Treaty.* CEP Document Archive. http://cep.npolar.no//innhold/cep_archive/meet_doc.htm [Accessed 23 August 2002]. Norwegian Polar Institute, Polar Environmental Centre, Tromsø, Norway.

Russian Federation (2001a). *Planning of waste disposal at the Russian Antarctic stations and ships.* CEP IV Information Paper IP–50. Russian Federation, St Petersburg, Russia.

Russian Federation (2001b). *Russian Antarctic Expedition Environmental Impact Assessment (Preliminary Stage).* CEP IV Working Paper WP–32. Russian Federation, St Petersburg, Russia.

Russian Federation (2001c). *Report of the Russian Federation on implementing the Protocol on Environmental Protection to the Antarctic Treaty (in compliance with Article 17.* CEP IV Working Paper WP–46. Russian Federation, St Petersburg, Russia.

Sayers, J. (1993). Infrastructure development and environmental management in Antarctica. In: Handmer, J. and Wilder, M. (Eds). *Towards a conservation strategy for the Australian Antarctic Territory.* The 1993 Fenner conference on the environment. Centre for Resources and Environmental Studies, Australian National University, Canberra, Australia. Pp. 109–147.

SCAR (1985). *Man's impact on the Antarctic environment: a procedure for evaluating impacts from scientific and logistic activities.* Scientific Committee on Antarctic Research, Scott Polar Research Institute, Cambridge, United Kingdom. 56 pp.

SCAR (2002). *Some Antarctic statistics.* http://www.scar.org/Antarctic%20 Info/Ant%20stats.html [Accessed 3 July 2002].

SCAR and COMNAP (1996). *Monitoring of environmental impacts from science and operations in Antarctica.* http://www.comnap.aq/comnap/comnap.nsf/P/ Pages/Environment?Open [Accessed 10 February 2003].

Schatz, G.S. (1988). Protecting the Antarctic environment. *Oceanus 31*(2):101–103.

Schofield, E. (1972). Preserving the scientific values of cold desert ecosysems: past and present practices and a rationale for the future. In: Parker, B.C. (Ed.). *Proceedings of the colloquium on conservation problems in Antarctica held on 10–12 September, 1971, Blacksburg, Virginia 24061.* Allen Press Inc, Kansas, USA. Pp. 193–225.

Shears, J.R. and Hall, J. (1992). Abandoned stations and field huts: The British approach to management. In: Melander, O. and Fontana, L.R. (Eds). *Proceedings of the fifth symposium on Antarctic logistics and operations, San Carlos de Barioloche, Republica Argentina, 8 to 10 June 1992.* Standing Committee on Antarctic Logistics and Operations of the Council of Managers of National Antarctic Programs in conjunction with the Scientific Committee on Antarctic Research.

Shurley, J.T. (1972). Pollution in Antarctica: I. The island stations with remarks on some emerging psycho-ecological viewpoints. In: Parker, B.C. (Ed.). *Proceedings of the colloquium on conservation problems in Antarctica held on 10–12 September, 1971, Blacksburg, Virginia 24061.* Allen Press Inc, Kansas, USA. Pp. 257–263.

Skare, M. (2000). Liability annex or annexes to the environmental protocol: a review of the process within the Antarctic Treaty System. In: Vidas, D. (Ed.). *Implementing the environmental protection regime for the Antarctic*. Kluwer Academic Publishers, Dordrecht, The Netherlands. Pp. 163–180.

Smith, G.D.P. (1968). Project planning, programming and site-construction of an Antarctic station. *Records of the Antarctic Treaty meeting of experts on logistics.* Ministry of Education, Tokyo, Japan. Pp. 140–158.

Snape, I. and Riddle, M. (1998). *A technical report to consider extraction techniques and logistic arrangements for future removal of contaminated waste from the Thala Valley and Wilkes tip sites, Australian Antarctic Territory.* Unpublished report to the Australian Antarctic Division, Hobart, Australia. 27 pp.

Snape, I., Riddle, M., Gore, D. and Cole, C. (1998). *Interim report on the contaminated sites of the 'old' Casey tip and abandoned Wilkes station.* Unpublished report (6 February 1998, amended 8 February 1998) to the Environmental Management Section, Australian Antarctic Division, Hobart, Australia. 13 pp.

Snape, I., Riddle, M.J and Pitt, K. (2000). Overcoming problems of contaminated site clean-up using engineering solutions. In: Shiraishi, K. (Ed.). *Proceedings of the IX SCALOP Symposium, Tokyo, Japan, July 12, 2000.* Pp. 25–33

Snape, I., Gore, D.G., Cole, C.M. and Riddle, M.J. (2001a). Contaminant dispersal and mitigation at Casey station: an example of how applied geoscience research can reduce environmental risks in Antarctica. *Proceedings of the eighth international symposium on Antarctic earth sciences, Wellington, New Zealand.*

Snape, I., Riddle, M.J., Stark, J.S., Cole, C.M., King, C.K., Duquesne, S. and Gore, D.B. (2001b). Management and remediation of contaminated sites at Casey station, Antarctica. *Polar Record 37*(202):199–214.

Snape, I., Morris, C.E. and Cole, C.M. (2001c). The use of permeable reactive barriers to control contaminant dispersal during site remediation in Antarctica. *Cold Regions Science and Technology 32*(2001):157–174.

Stephan, B. (1990). Recycling and optimized utlization of materials at Antarctic research stations. In: Kohnen, H., Teixeira, A.J. and Fowler, A.N. (Eds). *Proceedings of the Fourth symposium on Antarctic logistics and operations, Sao Paulo, Brazil, 16 to 18 July 1990.* Standing Committee on Antarctic Logistics and Operations of the Council of Managers of National Antarctic Program in conjunction with the Scientific Committee on Antarctic Research. Pp. 41–51.

Stonehouse, B. (2002). *Encyclopedia of Antarctica and the Southern Oceans.* John Wiley & Sons Ltd, West Sussex, England.

Summerson, R. and Riddle, M.J. (1998). Assessing wilderness values of Antarctica. *New Zealand Natural Sciences 23*:196.

Summerson, R. and Riddle, M.J. (2000). Assessing wilderness and aesthetic values in Antarctica. In: Davison, W., Howard-Williams, C. and Broady, P. (Ed.). *Antarctic ecosystems: models for wider ecological understanding.* New Zealand Natural Sciences, University of Canterbury, New Zealand. Pp. 303–307.

Tchobanoglous, G., Theisen, H. and Vigil, S. (1993). *Integrated solid waste management: engineering principles and management issues.* McGraw-Hill, Inc., USA. 978 pp.

Tetley, G. (1998). (Ed.). *Antarctica 2010: a notebook. Proceedings of the Antarctic futures workshop 28–30 April 1998.* Antarctica New Zealand, Christchurch, New Zealand. 96 pp.

Thomson, R.B. (1971). United States and New Zealand cooperation in environmental protection. *Antarctic Journal of the United States VI*(3):59–62.

Tracey, P.J. (2001). *Managing Antarctic tourism.* Unpublished thesis, Doctor of Philosophy, Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart, Australia. 436 pp.

Underdal, A. (1988). Leadership in international environmental negotiations: designing feasible solutions. In: Underdal, A. (Ed.). *The politics of international environmental management.* Kluwer Academic Publishers, Dordrecht. Pp. 101–127.

United States Department of State (2001). *Report of the United States Antarctic inspection February 2 to February 16, 2001.* Team report of the inspection conducted in accordance with Article VII of the Antarctic Treaty and Article XIV of the Protocol under the auspices of the United States Department of State. 77 pp.

Van Franeker, J.A. and Bell, P.J. (1988). Plastic ingestion by petrels breeding in Antarctica. *Marine Pollution Bulletin 19*(12):672–674.

Von Droste, B. (1995). Biosphere reserves: a comprehensive approach. In: McNeely, J.A. (Ed.). *Expanding partnerships in conservation.* Island Press, Washington DC, USA. Pp. 58–62.

Waite, R. (1995). *Household waste recycling.* Earthscan Publications Limited, London, UK. 230 pp.

Waterhouse, E. (2001). *Ross Sea region 2001: A state of the environment report for the Ross Sea Region of Antarctica.* New Zealand Antarctic Institute, Christchurch, New Zealand.

West, M.H. (2000). Wasting away. *Geographical 72(6)*:54–55.

Appendix I
Checklist for inspections under Article VII of the Antarctic Treaty

(ATCM XIX: Resolution 5)

For waste management at permanent Antarctic stations and associated installations

19.1 Waste management plan for the separation, reduction, collection, storage and disposal of wastes
19.2 Responsibility for waste management on the station
19.3 Production of an annual waste management report
19.4 Training of personnel in waste management and the need to minimize the impact of wastes on the environment
19.5 Publicly displayed notices concerning waste management
19.6 Current waste disposal methods:
a) Radioactive materials
b) Electrical batteries
c) Fuel (both liquid and solid) and lubricants
d) Wastes containing harmful levels of heavy metals or acutely toxic or harmful persistent compounds
e) Poly-vinyl chloride (PVC), polyurethane foam, polystyrene foam, rubber
f) Other plastics
g) Treated wood
h) Fuel drums
i) Other solid, non-combustible wastes
j) Organic wastes
k) Sewage and domestic liquid wastes
1) Waste produced by field parties
19.7 Production of waste per person day
19.8 Use of open burning; Disposal of ash; Alternatives planned for
19.9 Use of incineration; Disposal of ash; Control and monitoring of emissions
19.10 Treatment of sewage and domestic liquid wastes; Monitoring of effluent
19.11 Use of landfill or ice pit
19.12 Recycling of wastes
19.13 Measures taken to prevent wastes which are to be removed from the Treaty area being dispersed by wind or accessed by scavengers
19.14 Inventory of the locations of past activities (abandoned bases, old fuel depots, etc.)
19.15 Clean-up of past activities and future plans

For abandoned Antarctic stations and associated installations

This checklist is designed for abandoned Antarctic stations and associated installations which are considered to be stations which have been given up altogether and are now unused. The checklist does not cover stations which are operated each summer or infrequently used over a number of years.

1.1 Name of station visited
1.2 Location
1.3 Nation responsible, if known
1.4 Date established, if known
1.5 Date abandoned, if known
1.6 Reason for abandonment, if known
1.7 Plans for future use of the station, if known
1.8 Plans to clean up the station, if known

3.1 Area covered by station
3.2 Number and type of buildings
3.3 Sketch or map of buildings
3.4 Age and state of buildings (structural damage, state of roofing, state of fittings and fixtures, condition of internal walls and floors, internal accumulation of snow, ice, etc.)
3.5 Hazards to visitors (dangerous buildings, materials or wastes)
3.6 Notable historic buildings, facilities or artefacts
3.7 Evidence of measures to conserve notable historic buildings, facilities or artefacts
3.8 Signs of theft or vandalism, including graffiti
3.9 Use of information signs (interpretation, unsafe buildings, toxic waste, etc.)
3.10 Major aerial antennae systems (structural damage, etc.)
3.11 Landing or dock facilities
3.12 Roads
3.13 Airstrips and associated facilities (markers, windsocks, hangars, tie-downs; etc.)
3.14 Helipads and associated facilities (markers, windsocks, hangars, tie-downs, etc.)
3.15 Nearby facilities (refuges, field huts, etc.)

5.1 Types, quantities and location of hazardous substances (e.g., chemicals)
5.2 Type and condition of storage facilities buildings, drums, tanks, etc.)
5.3 Evidence of leaks and spills and their environmental impact

9.1 Types, quantities, condition and location of wastes (empty fuel drums, etc
9.2 Type and quantities of scattered debris
9.3 Evidence of measures to maintain the site and prevent dispersal of wastes
9.4 Evidence of clean-up activities or the removal of structures

For waste disposal sites

1.1 Name of site (if any)
1.2 Location (geographical coordinates)
1.3 Map or sketch of site in relation to nearby landmarks

1.4 Description of waste disposal site (include general topography and area covered)
1.5 Estimate of total area and volume of the waste disposal site
1.6 Description of substrate of the waste disposal site
1.7 Nation responsible for site, if known

3.1 Is the site marked? How?
3.2 Has the waste been covered by soil or rock?
3.3 Are there any unused or unusable buildings at the site?
3.4 Areas of water around waste disposal site, including distance of the site from sea and freshwater bodies and possible drainage into these
3.5 Distribution and description of flora near waste disposal sites
3.6 Distribution and description of fauna near the waste disposal site (seabird colonies, skua and other scavengers' nests, seal haul-out sites)
3.7 Scientific research carried out near the waste disposal site
3.8 Means of containment, including means of avoiding scattering by wind and run off

4.1 Estimate of contents
4.2 Age and state of contents
4.3 Types and quantities of:
a) radioactive materials
b) electrical batteries
d) fuel drums
e) gas cylinders
f) wastes containing heavy metals or toxic substances
g) polyvinyl chloride (PVC), foam, polystyrene, rubber, plastics
h) treated wood
i) other hazardous materials (medical wastes, broken glass, wire, etc.)
j) other solid non-combustible wastes
k) organic wastes (bones, non-native plant material, etc.)
1) sewage and domestic liquid wastes
m) indications of soil from outside Antarctica
n) fuel (both liquid and solid) and lubricants

5.1 Current impacts, e.g.:
a) birds scavenging
b) contamination of soil
c) wind scattered debris
d) run-off, seepage, oils slicks
e) smell
f) dead vegetation
g) dead, injured, sick or contaminated native birds or other animals
h) Potential for microbial contamination
5.2 Possible future impacts, e.g. oil seeping into the ground
5.3 Are there any sensitive sites nearby, that may be vulnerable to impacts? E.g. wildlife habitat

6.1 Is the site included in a Waste Management Plan?
6.2 What measures have been taken to rehabilitate the site or prevent dispersal of wastes? Written or physical evidence of these measures.

6.3 Has a contaminated site assessment been done on the waste disposal site; Is the report available?
6.4 Has an EIA or EIAs been prepared on removal of the waste disposal site (clean-up, removal of toxic materials, etc.)
6.5 Is the waste disposal site and nearby areas being monitored to verify that no hazardous substances are being dispersed and its contents do not pose a hazard to human health or the environment (e.g. monitoring hydrocarbon, heavy metal or microbial contamination of soil, ground water or melt water)?

7.1 Future plans for the site, for cleaning up, analysing environmental effects and minimising environmental effects
7.2 Heritage/historic considerations which might need to be taken into account before removal
7.3 Priority of action, that is, urgency of clean-up action
7.4 Recommendations for additional steps that should be taken to manage the impacts of the waste disposal site and protect adjacent areas

ANNEX III
TO THE PROTOCOL ON ENVIRONMENTAL PROTECTION TO THE ANTARCTIC TREATY
WASTE DISPOSAL AND WASTE MANAGEMENT

Article 1
General Obligations

1 This Annex shall apply to activities undertaken in the Antarctic Treaty area pursuant to scientific research programs, tourism and all other governmental and non-governmental activities in the Antarctic Treaty area for which advance notice is required under Article VII (5) of the Antarctic Treaty, including associated logistic support activities.

2 The amount of wastes produced or disposed of in the Antarctic Treaty area shall be reduced as far as practicable so as to minimise impact on the Antarctic environment and to minimise interference with the natural values of Antarctica, with scientific research and with other uses of Antarctica which are consistent with the Antarctic Treaty.

3 Waste storage, disposal and removal from the Antarctic Treaty area, as well as recycling and source reduction, shall be essential considerations in the planning and conduct of activities in the Antarctic Treaty area.

4 Wastes removed from the Antarctic Treaty area shall, to the maximum extent practicable, be returned to the country from which the activities generating the waste were organised or to any other country in which arrangements have been made for the disposal of such wastes in accordance with relevant international agreements.

5 Past and present waste disposal sites on land and abandoned work sites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites. This obligation shall not be interpreted as requiring:

(a) the removal of any structure designated as a historic site or monument; or
(b) the removal of any structure or waste material in circumstances where the removal by any practical option would result in greater adverse environmental impact than leaving the structure or waste material in its existing location.

Article 2
Waste Disposal by Removal from the Antarctic Treaty Area

1 The following wastes, if generated after entry into force of this Annex, shall be removed from the Antarctic Treaty area by the generator of such wastes:

(a) radio-active materials;

(b) electrical batteries;
(c) fuel, both liquid and solid;
(d) wastes containing harmful levels of heavy metals or acutely toxic or harmful persistent compounds;
(e) poly-vinyl chloride (PVC), polyurethane foam, polystyrene foam, rubber and lubricating oils, treated timbers and other products which contain additives that could produce harmful emissions if incinerated;
(f) all other plastic wastes, except low density polyethylene containers (such as bags for storing wastes), provided that such containers shall be incinerated in accordance with Article 3 (1);
(g) fuel drums; and
(h) other solid, non-combustible wastes;
provided that the obligation to remove drums and solid non-combustible wastes contained in subparagraphs (g) and (h) above shall not apply in circumstances where the removal of such wastes by any practical option would result in greater adverse environmental impact than leaving them in their existing locations.

2 Liquid wastes which are not covered by paragraph 1 above and sewage and domestic liquid wastes, shall, to the maximum extent practicable, be removed from the Antarctic Treaty area by the generator of such wastes.

3 The following wastes shall be removed from the Antarctic Treaty area by the generator of such wastes, unless incinerated, autoclaved or otherwise treated to be made sterile:
(a) residues of carcasses of imported animals;
(b) laboratory culture of micro-organisms and plant pathogens; and
I introduced avian products.

Article 3
Waste Disposal by Incineration

1 Subject to paragraph 2 below, combustible wastes, other than those referred to in Article 2 (1), which are not removed from the Antarctic Treaty area shall be burnt in incinerators which to the maximum extent practicable reduce harmful emissions. Any emission standards and equipment guidelines which may be recommended by, *inter alia*, the Committee and the Scientific Committee on Antarctic Research shall be taken into account. The solid residue of such incineration shall be removed from the Antarctic Treaty area.

2 All open burning of wastes shall be phased out as soon as practicable, but no later than the end of the 1998/1999 season. Pending the completion of such phase-out, when it is necessary to dispose of wastes by open burning, allowance shall be made for the wind direction and speed and the type of wastes to be burnt to limit particulate deposition and to avoid such deposition over areas of special biological, scientific, historic, aesthetic or wilderness significance including, in particular, areas accorded protection under the Antarctic Treaty.

Article 4
Other Waste Disposal on Land

1 Wastes not removed or disposed of in accordance with Articles 2 and 3 shall not be disposed of onto ice-free areas or into fresh water systems.

2 Sewage, domestic liquid wastes and other liquid wastes not removed from the Antarctic Treaty area in accordance with Article 2, shall, to the maximum extent practicable, not be disposed of onto sea ice, ice shelves or the grounded ice-sheet, provided that such wastes which are generated by stations located inland on ice shelves or on the grounded ice-sheet may be disposed of in deep ice pits where such disposal is the only practicable option. Such pits shall not be located on known ice-flow lines which terminate at ice-free areas or in areas of high ablation.

3 Wastes generated at field camps shall, to the maximum extent practicable, be removed by the generator of such wastes to supporting stations or ships for disposal in accordance with this Annex.

Article 5
Disposal of Waste in the Sea

1 Sewage and domestic liquid wastes may be discharged directly into the sea, taking into account the assimilative capacity of the receiving marine environment and provided that:

(a) such discharge is located, wherever practicable, where conditions exist for initial dilution and rapid dispersal; and
(b) large quantities of such wastes (generated in a station where the average weekly occupancy over the austral summer is approximately 30 individuals or more) shall be treated at least by maceration.

2 The by-product of sewage treatment by the Rotary Biological Contacter process or similar processes may be disposed of into the sea provided that such disposal does not adversely affect the local environment, and provided also that any such disposal at sea shall be in accordance with Annex IV to the Protocol.

Article 6
Storage of Waste

All wastes to be removed from the Antarctic Treaty area, or otherwise disposed of, shall be stored in such a way as to prevent their dispersal into the environment.

Article 7
Prohibited Products

No polychlorinated biphenyls (PCBs), non-sterile soil, polystyrene beads, chips or similar forms of packaging, or pesticides (other than those required for scientific, medical or hygiene purposes) shall be introduced onto land or ice shelves or into water in the Antarctic Treaty area.

Article 8
Waste Management Planning

1 Each Party which itself conducts activities in the Antarctic Treaty area shall, in respect of those activities, establish a waste disposal classification system as a basis for recording wastes and to facilitate studies aimed at evaluating the environmental

impacts of scientific activity and associated logistic support. To that end, wastes produced shall be classified as:

(a) sewage and domestic liquid wastes (Group 1);
(b) other liquid wastes and chemicals, including fuels and lubricants (Group 2);
(c) solids to be combusted (Group 3);
(d) other solid wastes (Group 4); and
(e) radioactive material (Group 5).

2 In order to reduce further the impact of waste on the Antarctic environment, each such Party shall prepare and annually review and update its waste management plans (including waste reduction, storage and disposal), specifying for each fixed site, for field camps generally, and for each ship (other than small boats that are part of the operations of fixed sites or of ships and taking into account existing management plans for ships):

(a) programs for cleaning up existing waste disposal sites and abandoned work sites;
(b) current and planned waste management arrangements, including final disposal;
(c) current and planned arrangements for analysing the environmental effects of waste and waste management; and
(d) other efforts to minimise any environmental effects of wastes and waste management.

3 Each such Party shall, as far as is practicable, also prepare an inventory of locations of past activities (such as traverses, field depots, field bases, crashed aircraft) before the information is lost, so that such locations can be taken into account in planning future scientific programs (such as snow chemistry, pollutants in lichens or ice core drilling).

Article 9

Circulation and Review of Waste Management Plans

1 The waste management plans prepared in accordance with Article 8, reports on their implementation, and the inventories referred to in Article 8 (3), shall be included in the annual exchanges of information in accordance with Articles III and VII of the Antarctic Treaty and related Recommendations under Article IX of the Antarctic Treaty.

2 Each Party shall send copies of its waste management plans, and reports on their implementation and review, to the Committee.

3 The Committee may review waste management plans and reports thereon and may offer comments, including suggestions for minimising impacts and modifications and improvement to the plans, for the consideration of the Parties.

4 The Parties may exchange information and provide advice on, *inter alia*, available low waste technologies, reconversion of existing installations, special requirements for effluents, and appropriate disposal and discharge methods.

Article 10
Management Plans

Each Party shall:

(a) designate a waste management official to develop and monitor waste management plans; in the field, this responsibility shall be delegated to an appropriate person at each site;
(b) ensure that members of its expeditions receive training designed to limit the impact of its operations on the Antarctic environment and to inform them of requirements of this Annex; and
(c) discourage the use of poly-vinyl chloride (PVC) products and ensure that its expeditions to the Antarctic Treaty are advised of any PVC products they may introduce into that area in order that these products may be removed subsequently in accordance with this Annex.

Article 11
Review

This Annex shall be subject to regular review in order to ensure that it is updated to reflect improvement in waste disposal technology and procedures and to ensure thereby maximum protection of the Antarctic environment.

Article 12
Cases of Emergency

1 This Annex shall not apply in cases of emergency relating to the safety of human life or of ships, aircraft or equipment and facilities of high value or the protection of the environment.

2 Notice of activities undertaken in cases of emergency shall be circulated immediately to all Parties and to the Committee.

Article 13
Amendment or Modification

1 This Annex may be amended or modified by a measure adopted in accordance with Article IX (1) of the Antarctic Treaty. Unless the measure specifies otherwise, the amendment or modification shall be deemed to have been approved, and shall become effective, one year after the close of the Antarctic Treaty Consultative Meeting at which it was adopted, unless one or more of the Antarctic Treaty Consultative Parties notifies the Depositary, within that time period, that it wishes an extension of that period or that it is unable to approve the amendment.

2 Any amendment or modification of this Annex which becomes effective in accordance with paragraph 1 above shall thereafter become effective as to any other Party when notice of approval by it has been received by the Depositary.

Appendix III
Guidelines for handling of pre–1958 historic remains whose existence or present location is not known

(Adopted at CEP IV and appended to Resolution 5)

1. These guidelines apply to pre–1958 historic artefacts/sites whose existence or location is not known.

2. These guidelines should be applied, as far as possible, to provide interim protection of pre–1958 historic artefacts/sites until the Parties have had due time to consider their inclusion into the protection system under Annex V to the Protocol on Environmental Protection. This interim protection should not extend beyond three years after the discovery of a new historic artefact/site has been brought to the attention of the Parties.

3. Historic artefacts/sites for the purpose of these Guidelines, include but are not necessarily limited to:

– Artefacts with a particular association with a person who played an important role in the history of science or exploration of Antarctica;
– Artefacts with a particular association with a notable feat of endurance achievement;
– Artefacts representative of, or which form part of, some wide–ranging activity that has been important in the development of knowledge of Antarctica;
– Artefacts with particular technical or architectural value in its materials, design or method of construction;
– Artefacts with the potential, through study, to reveal information or which have the potential to educate people about significant human activities in Antarctica;
– Artefacts with symbolic or commemorative value for people of many nations.

4. Any person/expedition who discovers pre–1958 historic remains should notify the appropriate authorities in their home country. The consequences of removing such remains should be duly considered. If items nonetheless are removed from Antarctica, they should be delivered to the appropriate authorities in the home country of the discoverer.

5. If historic artefacts/sites are discovered during construction activities, all construction should be discontinued to the greatest extent practical until the artefacts have been appropriately recorded and evaluated.

6. The Party whose nationals have discovered pre–1958 historic artefacts/sites should notify the other Treaty Parties about the discovery, indicating what remains have been found, and where and when.

7. If there is uncertainty as to the age of a newly discovered historic artefact/site it should be treated as a pre–1958 artefact/site until its age has been established.