that exceeded the CCME R/P criteria. The results are discussed in greater detail in Section G of Chapter V.

It was considered advisable to conduct further tests in the north end of the dump to ascertain the extent of the sub-surface contamination. Therefore the north end of the dump site was not included in the plans for the new landfill. Proposals for development of the new landfill included constructing two berms and two discharge control points to prevent migration of contaminated leachate off-site. It was recommended that leachate collected at the discharge control points should be analyzed for a suite of contaminants and discharged following consultation with local regulatory agencies. This proposal was subsequently modified to include only one discharge control point during the final planning and construction phase in the fall of 1994; site development is discussed in detail in Chapter V.

3. Environmental Studies

i. PCB and Trace Metal Pollution from a Former Military Waste Disposal Site at Iqaluit, NWT (Haertling 1988)

This work is contained in a Master's thesis from the geography department at Queen's University and deals only with the Sylvia Grinnell Park Dump in the West 40 (Dump Site #1). In contrast to the engineering consultants' reports, the thesis provides detail about background items such as geology of the area, the influence of climate and the geochemistry of bottom sediments in ponds near the site.

Samples collected at the base of the dump and from ponds between it and Sylvia Grinnell River were analyzed for metals and PCBs. The report concluded that relatively high levels of some metals were present at the toe of the landfill, but that these decreased rapidly with distance from the dump. A single plume of contamination spreading from the centre of the dump was found to be effectively stopped from migrating further towards the river by bedrock outcrops.

PCB concentrations found in this study were all below 1 ppm. These results were contrasted with higher concentrations reported previously by the Environmental Protection Service. The author makes an attempt to develop a transport model for PCBs at the site, which indicates a release of up to 40% of PCBs from the dump to the Sylvia Grinnell River. However, he concludes that "due to the large number of assumptions and

rough estimates in applying the model, this can only be considered a guess". A level of 11.1 ppb of PCBs was detected in ponding underneath some electrical equipment; this level is misquoted is some subsequent reports as 11.1 ppm.

ii. Upper Base Communications Building S-28 PCB Cleanup (Sanexen 1989)

In October 1989, PCB-containing equipment was removed from Communications Building S-28 at the Upper Base by the engineering firm Sanexen International. The electrical components were placed in drums which were themselves placed in vaults in a DIAND PCB registered storage facility. A review of the report by the Water Resources Division, DIAND points out many deficiencies regarding the manner in which sampling was conducted, analyses run and results interpreted. In particular, surrogate recovery of many samples was very poor and the sample numbering system was confusing, leaving doubt as to the location of samples. The highest concentration of PCBs detected in the five soil samples collected outside the building was 2.3 ppm, but the exact location and depth of these samples is not given. The report recommended that soil from an area of 5 meters by 3 meters to a depth of 30 cm (9 m^3) be removed from next to both front and rear doors, and that this soil be placed in the registered PCB storage vault. The reasoning behind this recommendation requires explanation, but none was provided. It was also recommended that the floors of the building be washed three times with decontaminating agent and then sampled. Results of dioxin and furan analyses of wall swabs were reported, and an unsuccessful attempt was made to calculate 2,3,7,8-TCDD toxic equivalencies (TEQs) for the swab dioxin concentrations. The report was to have included information concerning the dioxin to PCB ratio in surface swabs to determine whether dioxins were generated during a fire that had occurred inside the building, but this was not possible as no samples were analyzed for both constituents.

iii. Environmental Site Assessment & Remediation Options for an Abandoned U.S. Air Force Base and Five Waste Sites at Iqaluit, NWT. (Avati 1993a, b, c)

This report, comprising three volumes, describes an environmental assessment of the Upper Base, North 40 Dump and the four West 40 dumps. The assessment was conducted according to the National Contaminated Sites Classification System (NCSCS) for determining levels of environmental risk, as developed under the National Contaminated Sites Remediation Program. The NCSCS uses a numerical procedure which assigns scores to an extensive list of site characteristics including overall levels of contamination in an area, its topography, potential for contaminant migration, and known

impact of any contamination on humans. Although the score sheets are appended to the document, very little information is available on how scores were arrived at. Studies conducted by the ESG suggest that the NCSCS system is not appropriate for application to contaminated sites in the Arctic, as many factors which form part of the scoring system are unknown.

This work suffers from a lack of continuity between volumes, likely as a result of their production by several different groups: sample locations for the field portion of the investigation were designated by Public Works Canada - Environmental Services, and sampling was carried out by Norecol Environmental Management Ltd., who also wrote the first draft of the site assessment volume which was edited by Komex International Ltd. The Remediation Options volume (Avati 1993b) was prepared by Komex International Ltd. Preparation of the summary volume was subcontracted by Avati (1993c) to Acres International Ltd.

The main limitation of the study outlined in the Avati report lies in the recommendations for remediation of each of the sites. Excavation of partially filled dump sites as recommended by Avati for all of the dump sites investigated is not advisable, particularly for areas immediately adjacent to water courses. Removing potentially hazardous wastes from within a landfill represents both a financial and environmental liability. Excavation of landfills and dumps as outlined in the DEW Line Cleanup Protocol (see Chapter IV) should be limited to those sites with compromised stability and with erosion occurring in a manner that cannot be corrected. In addition, inappropriate criteria were applied to the results in some cases and the same data compared to different criteria between volumes.

The results of analyses included in the Avati site assessment volume (1993a) have been reviewed in detail for each site in Chapter V. The data have been compared to the appropriate criteria where this was not done in the report.

iv. Preliminary Report on Cleanup of Waste Disposal Sites Near the Town of Iqaluit, NWT (UMA 1994a)

This preliminary report provides an outline of proposed cleanup and stabilization plans for five waste disposal sites near Iqaluit including the four dumps in the West 40 and the Apex Dump. Information concerning the physical characteristics of each site is detailed, including aesthetic characteristics, natural surface features, operations and waste

disposal history, geotechnical stability, surface and sub-surface drainage, access, site sensitivity and safety.

The report discusses the cleanup of the sites in terms of the six phases described in the 1991 CCME National Guidelines for the Decommissioning of Industrial Sites. The report addresses phase 1 only and outlines requirements for completion of the other five phases. Chemical contamination at the sites was not investigated. Suggestions for the preparation of cleanup plans (phase 4) are included as an appendix at the end of the report. Recommendations for cleanup of the five sites included in the UMA report have been adopted with modifications in this report (see Chapter V).

4. Literature Reviews

i. Literature Review of Abandoned and Waste Disposal Sites in the Iqaluit Area, NWT (PWC 1992)

This report summarizes available information concerning the four West 40 dumps, the North 40 Dump and the Upper Base. It includes some results of contaminant analyses, as well as 39 references and 44 colour photographs. The report was produced concurrently with the Avati report discussed above.

ii. Summary of the Solid Waste Disposal Situation in the Town of Iqaluit (Finley 1994)

A report by a water resources student from the University of Toronto summarizes much of the information contained in the Avati report (1993a,b,c). The locations of the sites, the contamination and waste materials reported in the literature, and cleanup options as presented in the Avati report are outlined. Two remediation alternatives not included in the Avati report are also presented: these involve the consolidation of wastes from all the sites into a hazardous waste site to which access would be limited, or the dumping of all non-hazardous materials into the ocean. The issue of ownership of the affected sites is addressed briefly.

IV. CLEANUP PROTOCOL

A. Introduction

1. Defining Environmental Objectives for the Arctic

The Arctic has many characteristics which distinguish it from more forgiving southern environments. The presence of permafrost and the restrictions of light and temperature contribute to limited biodiversity and a generally fragile ecology. Consequently, the approach to solving environmental problems in the South is not necessarily applicable in the Arctic. In order to take appropriate remediation measures at any Arctic site, a set of environmental objectives is required that is cognizant of the unique nature of the environment of the North.

In assessing the environmental status and recommending appropriate cleanup measures at the Iqaluit sites, an environmental basis for comparison was required. The most comprehensive model for the cleanup of an Arctic environment is that provided by the Distant Early Warning (DEW) Line Cleanup Project. Iqaluit, in addition to being similar environmentally to the DEW Line, also shares many aspects of its past. Although their histories differ somewhat, both were greatly influenced by the American military presence. For these reasons, the assessments and the cleanup recommendations proposed for Iqaluit are based on the objectives outlined in the protocol developed for the DEW Line, the DEW Line Cleanup Protocol.

Investigations have been carried out at six solid waste disposal sites and a former military installation at Iqaluit. The environmental assessment of these sites addresses visible debris, landfills, and contaminated soil; cleanup of these sites should ensure that contaminants in soil, sediment and water do not pose a threat to living organisms (including humans) in the future. **This chapter describes the approach used by the Environmental Sciences Group in the establishment of cleanup strategies.**

2. How is Environmental Impact Assessed?

While it is generally agreed that the effect of contaminants on the environment must be minimized, defining the level at which contamination risks to the environment become acceptable is a subject of some contention. The question of "how clean is clean?" or "what constitutes an acceptable level?" is a complex one. Two approaches are used to evaluate environmental quality - absolute and relative.

An "absolute", or criteria-based, method defines numerical values or limits that can be compared with measured environmental contaminant concentrations. It establishes baseline concentrations for various substances below which the impact on the environment is assumed to be minimal. When environmental samples contain concentrations above this limit, there is a need for further investigation and/or remediation of the sampling area, depending on the amount by which the baseline value is exceeded. This approach has certain advantages: it is relatively easy to use and administer, it provides a common base for communication between interested parties, and it minimizes confusion. The approach suffers, however, from the *assumption* that the concentration limits apply equally in all circumstances.

The "relative" strategy of environmental monitoring also begins with the determination of the concentration of a contaminant in field samples. The focus, however, is not on the comparison of this result with a baseline criterion, but on an assessment of the potential for the movement of the contaminant from the substrate in which it is contained, to humans or other parts of the environment. In order to make this assessment it is necessary to examine the pathways for this movement in a *site-specific* context and to gauge the resulting impact. Not surprisingly, the same concentration of a contaminant can display very different effects under different circumstances. The US Environmental Protection Agency uses this approach for the Superfund program (*Superfund Risk Assessment Guide* US EPA 1989); mathematical models are used to estimate exposures/dose and the results are then combined with toxicological information to obtain site-specific risk. This methodology has some inherent difficulties such as applying the procedures correctly, having all the toxicological information and defining acceptable risk levels.

A bridging of the two methods can be achieved by modifying absolute - or criteria-based - assessments by taking into account factors at the contaminated site which affect the fate of the contaminant. This is the approach that has been used in the development of the DEW Line Cleanup Protocol.

B. Development of the DEW Line Cleanup Protocol

1. The DEW Line

The DEW Line was an air traffic detection and warning system constructed in the 1950s as part of the North American Air Defence project to warn of potential attack from

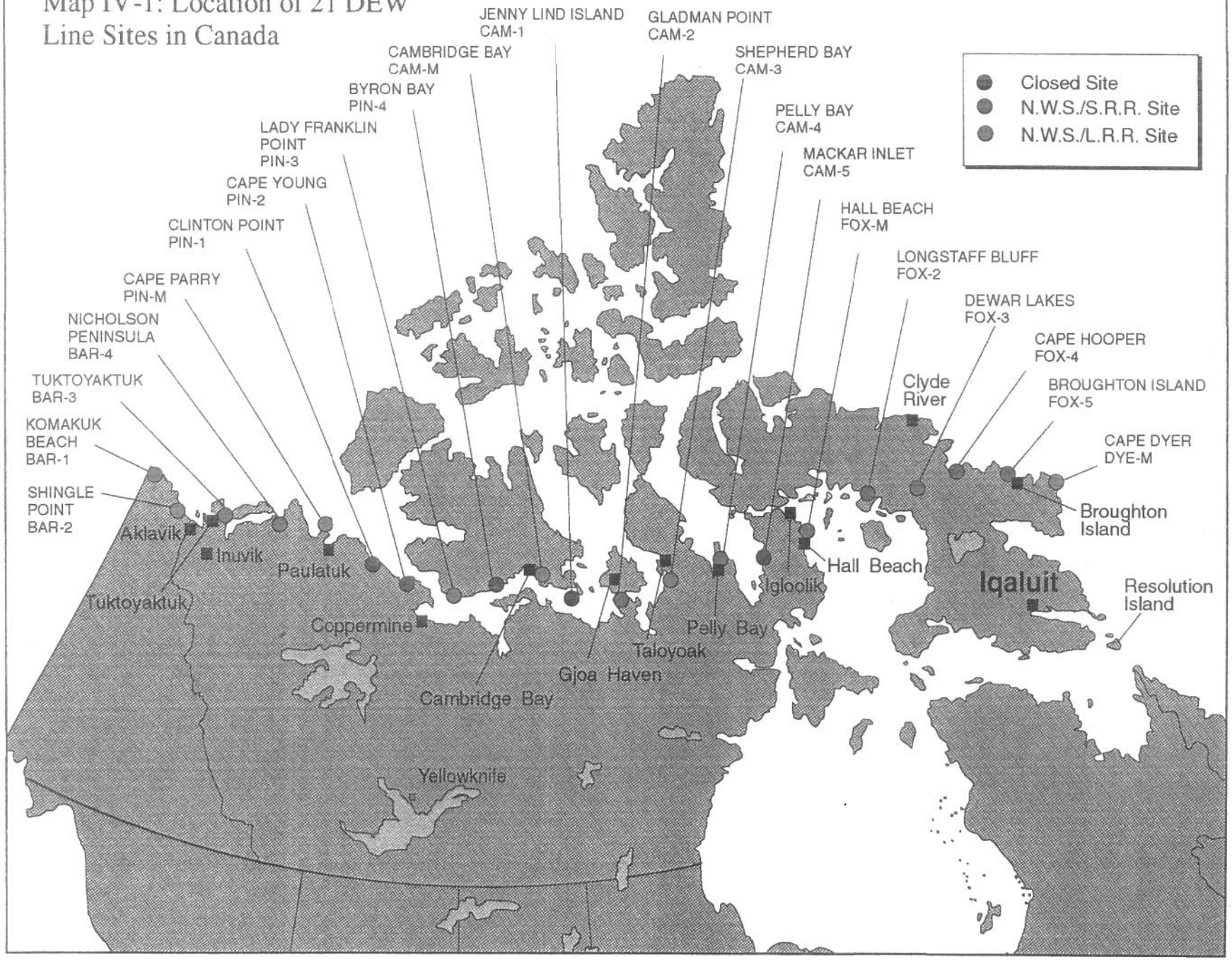
the Soviet Union. It consisted of a network of radar stations strung along the 66th parallel from Alaska to Greenland and became fully operational on July 31, 1957. The DEW Line was the northernmost of three radar chains across the continent including the Pine Tree Line situated along the US-Canada border, and the Mid-Canada Line constructed along the 55th parallel (Fletcher 1990).

The DEW Line was made up of 6 Main stations, 26 Auxiliary sites and 31 Intermediate sites (I-sites); 42 of the stations were located in Canada. The I-sites, which were situated every 80 km along the line, consisted of a Doppler radar which transmitted signals that would deflect off any object in its path and then trigger alarms at the nearest Auxiliary site. Auxiliary sites - approximately 160 km apart - had rotating long range search radars in addition to the Doppler radars. The Main stations, which were 800 km apart, performed the same functions as the Auxiliary sites. In addition, they provided supply and maintenance services for the smaller sites as well as southward communication. The 42 sites in Canada comprised 20 I-sites, 18 Auxiliary sites and 4 Main sites.

The I-sites became obsolete due to advances in technology and were abandoned in 1963. Responsibility for the administration of the 21 sites abandoned in Canada was transferred to Indian and Northern Affairs Canada (DIAND). The remaining 21 *active* DEW Line sites in Canada (shown on Map IV-1) continued to be operated by the United States Air Force (USAF) and the Canadian Department of National Defence (DND).

A Memorandum of Understanding, signed by both Canada and the United States in March 1985, described an agreement to modernize the North American Air Defence project. This memorandum indicated the requirements to replace the then active DEW Line with an upgraded system to be called the North Warning System (NWS). The NWS facilities have since been constructed and consist of 15 long-range radars (LRR), 11 in Canada, and 39 short-range radars (SRR), 36 of which are in Canada. In 1993, the NWS system became fully operational and the DEW Line was officially closed.

Map IV-1: Location of 21 DEW Line Sites in Canada



2. *Environmental Studies*

The requirements for the *physical restoration* of the 21 decommissioned (DND) DEW Line sites in Canada (Map IV-1 preceding this section), are outlined in a *Memorandum of Understanding for the Restoration of Distant Early Warning and North Warning Sites*, signed by DND and DIAND in 1989 (see Annex A in Reimer et al 1991).

It became apparent during the summer of 1989 that investigations were needed in order to establish the requirements for *chemical remediation* at these sites. To accomplish this, a two year study was conducted on behalf of DND by the Environmental Sciences Group (ESG) at Royal Roads Military College (RRMC). A report, *North Warning System Environmental Study,* Volumes One to Three (Reimer et al. 1991) describing overall environmental objectives, as well as specific cleanup plans for ten of the sites, was submitted to the Director of the North Warning System Office (DNWSO) in 1991. Results from this report formed the basis for a *General Protocol for DEW Line Cleanup*[1] developed at a government workshop, chaired by the Director General Environment, DND, held in October 1991 at RRMC. The protocol was agreed upon by representatives from Indian and Northern Affairs, Environment Canada, the Government of the Northwest Territories, the Department of Fisheries and Oceans and the Department of National Defence.

In the summer of 1991, the ESG carried out an environmental investigation of three additional LRR sites located on the east coast of Canada to evaluate the success of previous cleanup activities, and to act as a quality control check on current NWS operational practices. Results of the study were presented in Volume Four of the *North Warning System Environmental Study* (Dodd and Reimer 1992).

During the summer of 1992, the ESG conducted investigations of the remaining 11 DEW Line sites for which DND is responsible. The final report, *Environmental Study of Eleven DEW Line Sites* (Reimer et al. 1993b), was submitted to the DNWSO in 1993. Results and recommendations in this report were reviewed and accepted at the 2nd DEW

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[1]DEW Line Cleanup (DLCU) is the physical restoration and chemical remediation of those parts of the DEW Line sites no longer required for the operation of the North Warning System. Cost-sharing for DLCU has to be negotiated between the governments of Canada and the United States.

Line Cleanup Environmental Workshop held at RRMC between March 30 and April 1, 1993.

UMA Engineering Ltd., in association with Jacques Whitford Environment Ltd. and Sheppard Green Engineering & Associates Ltd., were contracted to develop the engineering design needed to accomplish the cleanup objectives for all 21 active sites. Drawings and specifications for the environmental cleanup and demolition work, solutions for the disposal of hazardous and non-hazardous waste and cost estimates to the 95% design phase were completed in November 1994.

Since the ESG was involved in ongoing DEW Line evaluation and cleanup work, DIAND and Environment Canada's National Contaminated Sites Remediation Program tasked ESG with conducting environmental studies of the I-sites. In 1992, five sites - Atkinson Point (BAR-D), Horton River (BAR-E), Pearce Point (PIN-A), Bernard Harbour (PIN-C) and Matheson Point (CAM-C) - considered to be representative of the 21 abandoned facilities, were studied (Reimer et al. 1993c). Investigations of the remaining 16 I-sites were completed over the following two years (Reimer et al. 1994, 1995).

Collectively, these studies have provided a detailed physical and chemical inventory of the DEW Line sites - the results from the analyses of over 6000 soil, water and biota samples represents the world's largest data base on contaminants in the Arctic. The conclusions from these investigations lend support to the initial protocol.

3. *Updates to the Protocol*

The DEW Line Cleanup Protocol has been continually updated since the workshop in 1991 when it was adopted. The protocol and the evolving cleanup design have undergone periodic review by elected officials of the Northwest Territories Legislative Assembly as well as by residents of northern communities. Briefings to the Legislative Assembly took place in January and March 1992, February 1993, March 1994 and, more recently, in March 1995. In 1992 and 1993, the protocol was presented for approval to a total of twelve Arctic communities including Aklavik, Broughton Island, Clyde River, Igloolik, Hall Beach, Taloyoak (Spence Bay), Pelly Bay, Gjoa Haven, Coppermine, Cambridge Bay, Inuvik and Paulatuk. In May 1994, the Cambridge Bay Hamlet Council was consulted regarding the DLCU Protocol and the issue of historical ocean dumping. Meetings to discuss the protocol were held in Cambridge Bay in October,

1994 with the Nunavut Planning Committee and again in November of that year with the Kitikmeot Inuit Association.

Following further scientific studies, public consultations, engineering design, field testing and a 2nd DEW Line Cleanup Environmental Workshop held at Royal Roads Military College, Victoria in 1993, the protocol was updated. The current protocol is presented as Annex A located at the end of this chapter.

4. General Protocol

The DEW Line Cleanup Protocol provides a comprehensive method for the assessment of former DEW Line facilities, and it establishes practical environmental objectives and corresponding cleanup plans that will be protective of the Arctic environment. No other such strategies have been developed for the Arctic. It should be stressed that the general protocol is designed to prevent the migration of contaminants from sources (either in landfills, sewage outfalls and lagoons or stained areas) to other parts of the Arctic ecosystem (vegetation, watercourses and the ocean). In each case where contaminant migration is detected, at any concentration, specific measures are designed to deal with it.

It can be noted from Annex A that three categories of waste/contamination are targeted when cleanup operations are implemented: visible debris (both hazardous and non-hazardous), landfills and contaminated soils. Details of these categories and features most relevant to the investigations presented in this report are discussed in Section C.

C. Overview of the DEW Line Cleanup Protocol

The DEW Line Cleanup Protocol was developed specifically for the remediation of those parts of former (DND) DEW Line sites that are no longer required for the operation of the North Warning System. The object of the Protocol, however, is the protection of the environment, largely through the removal or containment of contaminant sources. It is reasonable to apply the protocol to the Pole Vault sites and military communications facilities since they were operated in conjunction with the DEW Line prior to abandonment and are located in the same general ecosystem. Therefore, the cleanup plans that have been recommended for Iqaluit are consistent with the DEW Line Cleanup Protocol.

Three categories of waste/contamination are targeted when the DEW Line Cleanup Protocol is implemented: visible debris, landfills and contaminated soils.

1. Visible Debris

During cleanup of the seven sites investigated at Iqaluit, all visible debris should be collected and sorted into hazardous and non-hazardous components. Debris from the demolition of facilities no longer required should be dealt with in the same manner as other debris. Prior to demolition, materials containing asbestos, PCB ballasts and other electrical equipment should be removed. Barrels should be treated in accordance with the DEW Line Cleanup Protocol for Barrels. Any creosote-treated timbers/poles may require removal from the site or burial in an engineered landfill on site.

i. Non-Hazardous Debris

Non-hazardous debris including kitchen waste, pieces of wood, scrap metal and miscellaneous materials can be buried in a suitable landfill. Incineration of this material is not recommended. It was found that incineration of structural debris (for example, painted woods) could result in the production of ash containing high concentrations of leachable inorganic elements (Reimer et al. 1991, Volume One, Chapter VII). This does not preclude the burning of some non-hazardous materials, such as unpainted, non-creosote-treated wood, but if incineration is the only practical alternative to burial in an engineered landfill, then the ash should be treated as hazardous waste unless shown to be otherwise by leachate tests. The procedure for burial in landfills is outlined in the landfill section (below).

ii. Hazardous Debris

Hazardous items must be packaged, labelled, stored in a secured location, manifested and shipped off-site to an appropriate disposal facility, in accordance with all applicable regulations. The hazardous fraction at these sites may include, but is not limited to:

- radioactive materials;
- electrical batteries;
- wastes containing toxic chemicals at potentially harmful levels;

- any petroleum product containing in excess of 2000 ppb (2 ppm) of PCBs, 1000 ppm of chlorine, 2 ppm of cadmium, 10 ppm of chromium, or 100 ppm of lead;
- ash produced by the combustion of waste material;
- POL tank sludge; and,
- sludge in waste oil collection tanks or garage floor collection trays.

iii. Barrels

Almost all abandoned military installations in the North, including the Pole Vault System and the DEW Line, contain barrels which were used predominantly to transport fuel to the Arctic, and barrels are still used for the transport of solvents to northern communities like Iqaluit. In Iqaluit, barrels from the military era and from other origins have found their way into the North 40 Dump. Although historically most barrels encountered have been empty, some contain products such as mixtures of used lubricants, fuel, cleaning solvents, alcohols (methanol and ethanol), degreasers (methylene chloride and tetrachloroethylene) and antifreeze (usually ethylene glycol). Polychlorinated biphenyls (PCBs), used as dielectric fluids in electrical equipment and as an additive in lubricating fluids and other chemicals such as antifreeze agents (propylene glycol and methoxypropanol), on occasion have found their way into the waste oil stream.

Although barrels were not specifically addressed in the original DEW Line Cleanup Protocol, the large number of barrels present at most sites and the variety of their contents made it apparent that a protocol for their disposal was required. Following the results of studies at Cape Dyer (DYE-M) in 1991 and Cambridge Bay (CAM-M) in 1992 (Reimer et al. 1993a; ESG et al. 1994), a methodology for dealing with barrels and their contents at the DEW Line sites was proposed. This proposal was presented at the 2nd DEW Line Cleanup Environmental Workshop at RRMC in March 1993. The general approaches were discussed by representatives of the government agencies present: Indian and Northern Affairs Canada (DIAND), the Department of National Defence (DND), Environment Canada (EC) and the Government of the Northwest Territories (GNWT). The methodology presented at this workshop was employed in the sampling and analyses of barrel contents at some North Warning System Sites during July and August 1993 (*Collection and Analysis of Samples from Barrels at Eleven North Warning System Stations*, Poland 1994).

The proposed DEW Line Cleanup Protocol for Barrels was reviewed and updated at a meeting held at RRMC in April 1994. Participants, including representatives from DIAND, GNWT, Environment Canada, ESG and Queen's University Analytical Services Unit endorsed the protocol. Additional information pertaining to the development of the protocol may be found in a report prepared for the Action on Waste Program, Indian and Northern Affairs Canada (Poland 1994).

The DEW Line Cleanup Protocol for Barrels was used by the Inuvialuit Projects Inc. during the cleanup of the Horton River Intermediate DEW Line Site (Inuvialuit Projects Inc. 1994 & Dodd et al. 1994). The consolidation, the cleaning and crushing of barrels, as well as the analyses and disposal of barrel contents, were undertaken in accordance with the protocol. The protocol was also used for the consolidation and sampling of barrels at Resolution Island, NWT (Poland 1995). Modifications regarding the practical aspects of the protocol were made during field work at Horton River and Resolution Island; these changes were incorporated into the protocol and endorsed in January 1995 by representatives from DIAND, GNWT, Environment Canada and DND. The current protocol consisting of a Flow Chart, Methods and Criteria is given in Annex. A brief description of its implementation is presented below.

Barrels are considered as visible debris and clean, empty barrels are classified as non-hazardous. It is suggested that all empty barrels should be either crushed or shredded and placed in an appropriate landfill or shipped south to be recycled. Barrel contents must undergo chemical analyses and identification, however, before they can be classified and then sorted according to their contents. Barrel contents comprising water only (less than 2% glycols or alcohols) should be transferred to an open vessel, such as a utility tub or half-barrel, and any organic material removed by agitation with an oil-absorbent pillow or a segment of other oil-absorbent material. The water may then be discarded on to the ground at a minimum of 30 metres distance from natural drainage courses.

It is recommended that the barrels containing oily residues should be initially screened for organic compounds. These organic chemicals should then be analyzed so as to subdivide them into used petroleum products (gasoline, fuel oil or lubricating oil) and other compounds such as glycols and alcohols. The contents should also be analyzed for PCBs, chlorine, cadmium, chromium and lead. Barrel contents which are composed of water with glycols and/or alcohols or organic phases and which contain less than 2 ppm PCBs, 1000 ppm chlorine, 2 ppm cadmium, 10 ppm chromium and 100 ppm lead may be disposed of by incineration. Alternatively these contents may be shipped off-site to a

licensed disposal facility. The solid residual material resulting from incineration should be subjected to a leachate extraction test. Material that is found not to generate toxic leachate should be disposed of as DCC Tier II contaminated soil (see Section 3, below). Material which does generate toxic leachate should be treated as hazardous waste, packaged in accordance with all applicable regulations and disposed of off-site at a licensed disposal facility.

Empty barrels resulting from consolidation of contaminated material should be triple rinsed with solvent (for example, varsol or diesel) prior to steam cleaning. The effluent from the steam cleaning process should be treated in the same manner as the water in barrels containing only water, as described above. Solvent washings should be added to the bulked contaminated products unless analyzed separately and shown to be suitable for incineration. Alternatively, the empty barrels may be shipped off-site.

iv. Buildings

a) Swabs

The options for disposition of site buildings are partially governed by whether their inner surfaces are contaminated with PCBs. High levels (>10,000 ng/100 cm^2) of PCBs were observed on the walls of buildings at some of the DEW Line sites studied in 1992 and 1993 (Reimer et al. 1993b, 1994). Accordingly, the examination of surface PCB contamination was included in this study.

There are no federal or territorial regulations which direct the demolition and disposal of PCB-contaminated physical structures. Environment Canada, for example, has no regulations for such cleanup (see *Environmental Study of Abandoned DEW Line Sites:* Reimer et al. 1993c). Following the DEW Line Protocol for landfills, demolished buildings may be buried in a suitable landfill. Health and Welfare Canada have provided advice to northern agencies, however, on criteria for occupied buildings. A surface cleanup standard for a residential area is 10,000 ng/100 cm^2 of PCBs while that of an electrical substation area is 100,000 ng/100 cm^2. These are based on a draft policy statement of the US EPA (Environmental Protection Agency 1985). In the absence of any regulatory policy, these levels were used to guide site-specific cleanup as follows: buildings found to contain PCBs on inner surfaces at levels exceeding 10,000 ng/100 cm^2 should not be made available for future human habitation, but they could be used as storage areas provided PCB levels do not exceed 100,000 ng/100 cm^2.

b) Asbestos

Prior to demolition, in the event that demolition is selected as a disposal option, asbestos-containing materials should be removed in a safe manner, doubly-sealed in plastic bags and buried in an engineered landfill.

2. Landfills

The term "Landfills" as used in the DEW Line Cleanup Protocol refers to all areas of garbage or refuse disposal. All landfills located in high erosion areas should be removed - otherwise natural processes will continue to expose their contents. It is otherwise undesirable to dig up buried debris, but containment procedures are recommended in instances where contaminated leachate has been identified.

i. Relocation of Landfills

Landfills located in unstable, high erosion areas must be relocated. The landfill should be excavated and all debris sorted into hazardous and non-hazardous materials. The non-hazardous debris may be placed in an engineered landfill on site; hazardous debris must be containerized and removed from the site. Excavated soils should be tested and, if contaminated, treated in accordance with the general protocol for soils. The excavated areas should be covered with gravel and regraded to restore natural drainage.

ii. Landfill Closure Without Leachate Control

Landfills located in a suitable and stable area not subject to erosion and that show no evidence of contaminated leachate can remain where they are. Exposed debris present in landfills of this sort should be removed, provided removal does not jeopardize landfill stability, and sorted into hazardous and non-hazardous materials. Hazardous debris should be containerized and removed from the sites. All non-hazardous debris should be placed within the landfills and compacted to minimize the presence of voids. After all debris has been added, landfill surfaces should be regraded and covered with sufficient gravel fill so that permafrost will eventually encapsulate the contents. The final contour of a landfill should be such that subsequent natural ponding or erosion would not occur.

iii. Landfill Closure With Leachate Control

Landfills that are located in stable areas not subject to erosion but identified as potential sources of contaminated leachate must be fully contained to prevent leachate

migration. Containment measures have been outlined in *Geotechnical Evaluation and Preliminary Design for the Cleanup of Ten DEW Line Sites* (EBA Engineering Consultants Limited, 1992). Briefly, a low permeability layer is introduced on the downhill slope portion of the landfill, keyed into the underlying permafrost and the landfill regraded to preclude ponding and water infiltration.

iv. Non-Hazardous Waste Landfills

Non-hazardous materials including untreated wood, metal, and crushed or shredded barrels should be placed in properly engineered landfills on-site. Asbestos, packaged according to regulations, and contaminated soils containing lead or PCBs below the higher of two levels of the DEW Line Cleanup Criteria, discussed in Section 3 below, may also be placed in such an on-site landfill. After all waste material has been added to the landfill, the surface should be regraded to conform to the surrounding contours, with a cap thickness sufficient to allow permafrost to be reestablished. The final landfill geometry must be such that it precludes water infiltration and ponding.

3. Chemical Contamination

There is a lack of reliable information regarding the total range of materials that has been used at the northern defence sites - like the Pole Vault station located at the Upper Base - over their period of operation. Under such circumstances, there is normally a requirement to conduct a screen for a wide range of substances designated as priority pollutants by Environment Canada and/or the United States Environmental Protection Agency (US EPA). Such a screen includes polychlorinated biphenyls (PCBs), inorganic elements, pesticides, volatile organics, and phenolic compounds, phthalates, chlorinated hydrocarbons, polychlorinated dibenzodioxins and furans, and ketones. Some of these compounds are assessed using an acid/base/neutral (ABN) analytical scheme.

Over the course of six DEW Line environmental studies (Reimer et al., 1991, 1993a, 1993b, 1993c, 1994, 1995) a selected group of samples has been screened for the above substances. The samples were collected from locations most likely to contain contaminants, such as outfalls, pallet lines and POL storage areas. The results indicate that inorganic elements and PCBs are the primary substances of concern. ABNs and volatile organics were either not detectable or present at very low concentrations. It was therefore concluded that ABNs or volatile organics have had a minimal impact on the environmental status of the DEW Line sites. This conclusion was further substantiated by

results obtained in a study conducted at the Auxiliary and Main sites of the DEW Line on behalf of United States Air Force (USAF); the levels of ABNs, volatiles and pesticides in soil samples were either below the detection limits or very low (UMA Engineering Ltd. 1991a). The marginally detected parameters were mostly PAHs and phenols. In all instances, these samples were from locations which also had high levels of PCBs and/or inorganic elements. The DEW Line Cleanup Criteria, a component of the overall protocol, therefore addresses levels of only PCBs and inorganic elements including arsenic, cadmium, chromium, cobalt, copper, lead, nickel and zinc.

i. DEW Line Cleanup Criteria (DCC)

When the Environmental Sciences Group began the environmental study of the North Warning System in 1989, there were no environmental criteria specific to the Canadian Arctic. One of the most comprehensive sets of environmental quality indicators were those produced by the Québec government (MENVIQ 1988). These were therefore employed during the initial interpretation of data obtained from the study of the first ten NWS Long Range Radar and DEW Line sites.

During the course of the NWS Study, the Canadian Council of Ministers of the Environment Interim Environmental Quality Criteria for Contaminated Sites were prepared (CCME 1991). In anticipation that there would be considerable interest in applying *national* criteria to the NWS sites, cleanup recommendations for the NWS sites were reviewed in the context of the new CCME criteria and included in the *North Warning System Environmental Study* (Volumes One - Three, Reimer et al. 1991).

Vegetation samples were analyzed in order to determine potential uptake of contaminants into the food chain, and the results of these analyses were correlated with soil results and used to determine the concentrations of contaminants in soil which caused an impact on the food chain. The consideration of results obtained from these analyses of Arctic vegetation and the tendency of certain contaminants (lead and PCBs) to undergo aerial transport indicated a need to combine features of the Québec and the CCME criteria. This combination was designated the DEW Line Cleanup Criteria, DCC.

The DCC define two tiers in the context of treatment of contaminated soils: substrates containing contaminants between Tier I and Tier II may be placed in an appropriate landfill at the site; soils contaminated in excess of Tier II must be removed and must be disposed of in a manner that precludes contact with the Arctic ecosystem

The DCC Level II Criteria (or DCC-II) and CCME Residential/Parkland Criteria (or CCME R/P) are identical to each other for inorganic element and PCB concentrations in soils. The DCC-II and CCME R/P Criteria are also identical to Québec "B" Criteria (MENVIQ, 1988) for those substances included in the DCC. The DEW Line Cleanup Criteria, however, dictate a more rigorous trigger for the removal of two substances from the Arctic environment: lead and PCBs. Previous research by the ESG, as well as other scientific studies, led to the inclusion of another tier of soil criteria for these two contaminants, the DCC Level I (or DCC-I). Both lead and PCBs, unlike many other contaminants, tend to migrate from a source to surrounding areas (including the surfaces of plant leaves) through the air. Both substances are also known to exert chronic (long term) - as opposed to acute (short term) - toxicological effects on animals in association with long-term bioaccumulation (in the case of lead) or food-chain related biomagnification (in the case of PCBs).

The primary objective of the DEW Line Cleanup Protocol is to mitigate the impact on the environment, including humans, of contaminants by containing persistent chemicals and preventing migration into the food chain. The DEW Line Cleanup Criteria identify contaminants in soils that have the potential to migrate into the food chain and, based on the vegetation studies (Reimer et al. 1993), the DCC criteria appear to be reasonable indicators of ecosystem impact at the radar sites.