During Phase I a review of the available documentation pertaining to each site was undertaken. Included in these documents were asbestos, PCB, and hazardous materials inventories for each of the sites as well as spill reports and retrograde histories for hazardous wastes. Subsequent to this initial record search, the study team undertook a literature search with the goal of providing background information on the environmental setting within each particular ecoclimatic region. The scope of this environmental overview included descriptions of the physiography, geology, hydrology, vegetation, wildlife, fisheries and marine mammals, heritage resources and land use. In addition, an initial examination and evaluation into available clean up technologies and methodologies were carried out. The final part of this review included an overview of the then present Canadian Federal and Provincial clean up standards, criteria, guidelines and regulatory framework.

The following outlines the results of this initial study:

- Hazardous materials (as defined by the Canadian *Transportation of Dangerous Goods Act*) that were identified on the sites included Class 1 (explosives), Class 2 (compressed gas cylinders), Class 3 (flammable liquids), Class 5 (oxidizing substances), Class 6 (poisonous and infectious substances), and Class 8 (corrosives).

- Various materials were identified that are not classified as hazardous but may be considered as a cause for concern includes diesel, grease, oil, lubricants, and hydraulic fluids.

- There was very little information available on fuel spills at each of the sites.

- A detailed survey of the biophysical environment (i.e. climate, geology, hydrology, flora and fauna survey, heritage resources, and land use) was obtained.

Phases II and III were combined into a field investigation program in accordance with the *Guidelines* referenced above. Field and laboratory work was carried out by the study team to:

- Collect and analyse soil, water, cooling oil, asbestos and paint samples;

- To determine site specific environmental parameters for a baseline risk assessment;

- To note sites of historical and archaeological significance; and

- To locate and determine the extent of contamination associated with landfills.

The results of the Phase II/III study are summarised below:

- Facilities overview: The design of the structures (including buildings and miscellaneous towers) for each of the 15 sites is essentially the same. Facility layout, however, is site specific. All sites were constructed on granular pads over the natural ground. All site activity centred around the main building, referred to as the 'modular train', which housed the majority of activities, including radar and communications operations, offices, workshops,

power generation, and accommodation of personnel. Other facilities included vehicle and equipment maintenance/storage areas, petroleum facilities, communication dishes and ancillary facilities (i.e. storage, weather stations, etc). Each site also had an airstrip and, in some cases, a hangar. The types and quantities of facilities being demolished as part of this project varies for each site as there are varying requirements for these facilities as part of the new North Warning System.

- Asbestos surveys found that asbestos was located at all 15 sites in sheet and pipe forms. Analysis found that the typical samples were chrysolite.

- Paint samples identified several heavy metals (lead was of greatest concern) and PCB's.

- PCB's were also found in a variety of equipment, including communications and lighting equipment.

- Analytical results from laboratory testing were reviewed and compared with applicable soil and drinking water guidelines as well as background values from both literature and off site samples. Analysis was carried out in two stages. In most cases, a first round of samples was analysed for a full suite of compounds. The results of the first round were reviewed and, in sample locations where the results exceeded the guidelines, a second round of down gradient (or below) samples were taken. Contaminants that were analysed include inorganic (i.e. metals) and organic (i.e. PCB's) compounds.

- Landfills were assessed for contents and leachate potential. Landfills were found to contain a variety of materials and, in some cases, are the source of contaminated leachate. In addition, many open dump sites were found at each location. These dumps contained scrap metals (i.e. barrels), wire, and paper remains. In some cases, old equipment was found around the site. The majority of waste materials were, however, either located within landfills or in pallet lines awaiting disposal.

At the same time as this initial study, the Canadian Department of National Defence conducted a second, parallel study of the sites. In 1989/90, an environmental study of ten of the 21 sites provided a detailed physical and chemical inventory of the stations and considered the impact of chemical contaminants on the Arctic ecosystem. This first part also presented a basis for the general approach to the clean up of the DEW Line, as well as specific clean up recommendations for each station. This was followed up, in 1992, by an assessment program, including the provision of recommendations for clean up, for the remaining eleven sites. In conjunction with these studies, an overview document discussing the environmental impact of the DEW Line on the Arctic. This report proposed the major migration pathways by which chemical contamination from these sites was distributed throughout the Arctic ecosystem.

In conjunction with the station assessments, several Canadian government departments conducted two studies in 1993/1994 designed to assess the impact of the historically common practice of disposing debris into the ocean through the ice. The first study, which took place in

the waters of Cambridge Bay and the second study, which took place along the east coast of Baffin Island, included assessing the marine environment adjacent to three DEW Line sites, including the Cambridge Bay site. The first of these ocean disposal studies concluded that there was a large variety and amount of debris on the ocean floor but that there were no significant chemical effects arising from its presence (i.e. it was concluded that PCB contamination emanated from anthropogenic sources near the study site and not the ocean disposed equipment). The second historic ocean disposal study reported that very little debris in each of the study areas were present and that there is no evidence that historic ocean disposal activities have contributed to contamination of the near shore marine environment.

Given the small amount of historical data on contaminant disposal for the study teams for both studies, this second scientific study of the DEW Line sites sampled all areas of the sites and analysed for a wide suite of contaminants. During the initial stages of this study, patterns of waste disposal common to all of the sites became evident. This was supported by the following observations:

- Debris in varying quantities were found scattered over the sites and often included hazardous materials (i.e. batteries, waste oils, and asbestos);

- The contents of some landfills were exposed, the result of erosion and spring runoff;

- Fuel handling and storage facilities were often the sites of spills. In addition, contamination was consistently found at less obvious locations (i.e. PCBs that were found in older household products which were believed to have been dumped outside buildings or down drains);

- Chemical analyses showed the following patterns of contaminant dispersal:

  (1) PCBs and inorganic elements such as copper, lead and zinc were found to be the contaminants of primary concern in soil and water. Pesticides, polyaromatic hydrocarbons, phthalates and chlorinated compounds were either absent or in low concentrations,

  (2) Inorganic element contamination was, in general, confined to outfalls and landfills, and in the case of lead, to fuel spills,

  (3) PCBs were present in elevated levels around outfalls and, to a lesser degree, in landfills and stained areas near pallet lines and buildings,

  (4) Leachate waters and soils collected at the base of some landfills contained detectable concentrations of contaminants, indicating a more concentrated source within the landfill, and

(5) The remaining contamination appeared to be restricted to isolated spills within the station area.

Future sampling was based on the knowledge gained from the initial sampling and the distribution parameters discussed above.

Evidence was found at many of these sites that showed the migration of contaminants (primarily copper, lead, zinc and PCBs) along adjacent water systems or, in the case of PCBs, by aerial transport. Point sources for such migration were identified for remediation action.

While the DEW Line sites were operational, barrels (i.e. 45/55 gallon drums) were used extensively to transport petroleum products. As a result, some sites have up to several thousand barrels remaining, many of which were simply discarded onto the surrounding landscape. In most cases these barrels are empty but some contain unidentified residues. In addition, initial studies indicate that barrels are buried in landfills. The status of these barrels is unknown but information can be extrapolated from the analytical results of the surface barrels (i.e. types of contaminants, etc). Random sampling of barrels at the stations showed the following:

- Most of the discarded barrels were empty but some contain waste oil, water, or remnants of the original contents (or a combination of these three);
- A small proportion of the barrels contain glycols, fuel and lubricants, waste oils or PCBs; and
- In most cases barrel contents can be incinerated on-site, but some contain substances (i.e. cadmium, chromium, lead, chlorine and/or PCBs) in excess of regulations and, as such, must be disposed of in southern disposal facilities.

The results that were obtained from both DEW Line Clean Up scientific assessment studies were subsequently reviewed using an impact, or risk, assessment philosophy. The mere presence, or input, of a chemical contaminant is not alone cause for concern; an impact on the ecosystem must be assessed. Chemical contaminants are considered to have an adverse effect on the environment if a negative impact can be demonstrated (i.e. levels of chemical contamination that may affect reproductive success). Specifically, an adverse effect was defined as the significant introduction of a chemical contaminant into the terrestrial or marine food chains. The initial part of the risk assessment evaluated contaminant persistence and mobility and determined the circumstances under which they would be a potential threat to the environment.

As part of the ecological risk assessment process, both terrestrial and marine impacts were examined. In examining terrestrial impact, the study team used plants (a primary food source in the Arctic ecosystem) as an indicator to determine to what extent contaminants had entered the food chain. As a result of these studies, the study team was able to determine the maximum concentration of contaminants that could be present in soils without posing a significant effect on higher levels of the food chain. This evaluation was a key assessment factor in determining the Arctic soil remediation criteria for contaminants found on the DEW Line sites. In determining

marine impact, the results of a historic ocean disposal studies concluded that evidence for biomagnification of PCBs in bottom dwelling marine organisms, which act as food sources for larger organisms such as birds and marine mammals, suggest that low level inputs have a significant impact on the ecosystem. As a result of this conclusion, it was determined that it is important that contaminants be prevented from entering the ocean, even at low concentrations. As such, contaminant flow must be contained at the source. Furthermore, assessment of the underwater debris found during this study concluded that, despite the extensive nature of the debris, chemical contamination was insignificant when compared to shoreline runoff and, as such, clean up actions should be restricted to the land and foreshore areas and not deep waters unless there is evidence to the contrary.

As a result of these studies, three reports were completed which presented the conclusions that arose from these investigations along with practical recommendations for remediation strategies appropriate to the Arctic. Supporting information was provided through other reports, including a specific study on archaeological resources. These reports were supplied to a number of libraries throughout Canada (including a number throughout the Northwest Territories).

Environmental Working Group

In 1997, the Department of National Defence and Nunavut Tunngavik Incorporated (NTI) agreed to form an **Environmental Working Group** (EWG). The EWG is comprised of scientific and technical experts representing both the Inuit (NTI) and DND. The purpose of the EWG is to examine environmental issues related to the DEW Line Clean Up project and to provide recommendations to a joint DND/NTI core group consisting of senior management from both organisations. Specific tasks that have been assigned to the EWG included:

- Development of a landfill risk evaluation matrix;
- Evaluation of, and recommendations for, a post-construction/remediation landfill monitoring program;
- Identification of hydrocarbon clean up requirements;
- Establishment of confirmatory testing protocols; and
- Preparation of a list of items suitable for landfilling at the DEW Line sites.

Pre-clean up Activities

Prior to the clean up of each site, the Department of National Defence undertakes a final site assessment. The aim of these site visits is several-fold, including:

- To fully delineate the extent of contaminated areas in order to prepare accurate construction drawings;