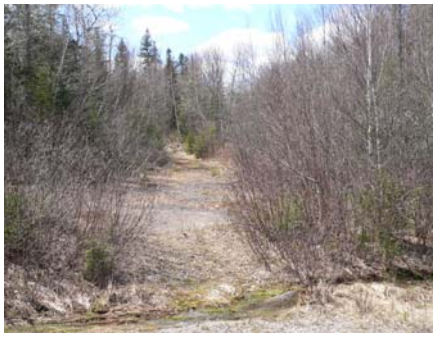
HEALTH CANADA SAFE ENVIRONMENTS PROGRAMME

FACT-FINDING TASK 3A-2

HUMAN HEALTH RISK ASSESSMENT FOR CURRENT EXPOSURES TO HERBICIDES & HERBICIDE-RELATED CHEMICALS CFB GAGETOWN, OROMOCTO, NEW BRUNSWICK

FINAL REPORT



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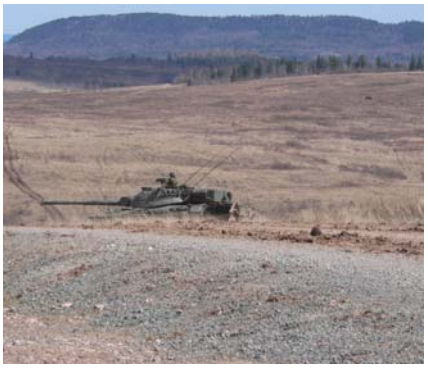

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DILLON CONSULTING LIMITED REFERENCE NO. 05-4212-0800 JULY 14, 2006

Health Canada
Safe Environments Programme

Fact-Finding Task 3A-2
Human Health Risk Assessment for Current Exposures to Herbicides & Herbicide-Related Chemicals
CFB Gagetown, Oromocto, New Brunswick

Submitted by

Dillon Consulting Limited &
RBR Consulting Inc

File #: 05-4212-0800

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Executive Summary

This risk assessment addresses the potential for adverse health effects associated with potential exposures to herbicide residues at Canadian Forces Base (CFB) Gagetown. Health Canada has commissioned Dillon Consulting and RBR Consulting to prepare this risk assessment to address concerns that those who currently might work at, or otherwise come into contact with the base might be exposed to residuals of herbicides and herbicide-related compounds such as polychlorinated dibenzo-p-dioxins and furans (PCDD and PCDF) associated with the spraying of Agent Orange and related herbicides there decades ago.

CFB Gagetown occupies approximately 110,000 hectares with its main offices located adjacent to the community of Oromocto, New Brunswick. A range training area (RTA), which is used for live-fire training, accounts for about 30,000 hectares of this land and is closed to public access. The remaining 80,000 hectares are used for military training, but also accommodate a number of non-military activities including forest management, hunting, fishing and other recreational activities. The current land uses for CFB Gagetown are not expected to change in the foreseeable future.

The Federal Government has launched an initiative that will report on the facts surrounding the use of Agent Orange, Agent Purple and other herbicides and herbicide-related chemicals during the specific test periods in June 1966 and June 1967. The initiative also encompasses the identification and reporting of facts surrounding the use of herbicides and herbicide-related chemicals used as CFB Gagetown between 1952 to the present day. This *Human Health Risk Assessment* (HHRA) represents Fact-Finding Task 3A-2, and evaluates potential human exposures to current levels of herbicides and herbicide-related chemicals for people who could be expected to be on the site currently or in the future. It addresses potential exposure and the associated hazards and/or risks for military personnel and members of the general public who may access the base for recreational purposes and who may come into contact with residual levels of herbicides and herbicide-related chemicals while on the base.

In order to develop exposure scenarios that adequately describe potential exposures for the various user groups, it was necessary to identify distinct exposure *Subject Areas* (SAs) across the base that reflect the variation in exposure potential that exists across the Base. The SAs included in the HHRA and the receptors considered on each are listed below.

Subject Area	Receptors
SA 1– 1966 Test Area	Soldiers & Recreational Users
SA 2 – Rippon Road	Soldiers & Timber Harvesters
SA 3 – Murphy Bivouac	Soldiers, Youth Campers & Recreational Users
SA 4 – Clones Bivouac	Soldiers
SA 5 – Base Administration and Parks	Soldiers & Recreational Users
SA 6 – Static Range Impact Area	Soldiers
SA 7 – General Manoeuvres Area	Soldiers
SA 8 – Base Perimeter and Fire Breaks	Soldiers & Recreational Users
SA 9 – Nerepis River	Anglers
SA 10 – Swan Creek Lake	Anglers
SA 11 – CFB Gagetown	Hunters

Detailed review of the environmental quality data for surface soil, groundwater, surface water, sediment and vegetation showed that polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were the only chemicals that were present in these environmental media at levels that exceed the *Environmental Quality Guidelines* (screening criteria) established by the Canadian Council of Ministers of the Environment (CCME). Thus PCDD/PCDF was the only chemical considered in the HHRA. The levels of the other chemicals evaluated in the ESA were all below their respective screening criteria and would not represent a potential concern for human health at the concentrations in the environmental media reported for the Base.

The risk assessment evaluated exposures for the relevant exposure pathways (ways that a receptor could come into contact with a chemical) for the receptors identified in each of the SA considered in the HHRA. Although the relevant exposure pathways evaluated varied between the SAs, the following exposure pathways were considered for one or more of the SAs:

- Inadvertent ingestion of soil;
- Dermal contact with soil;
- Inhalation of soil particulate;
- Inadvertent ingestion of sediment;
- Dermal contact with sediment;
- Inadvertent ingestion of groundwater;
- Dermal contact with groundwater;
- Inadvertent ingestion of surface water;
- Dermal contact with surface water;
- Ingestion of deer or moose;
- Ingestion of fish; and
- Ingestion of berries.

The results of the HHRA showed that for all receptors, except the angler, the Hazard Indices (HI) calculated for base-related exposures are well below the hazard acceptability benchmark of 0.2 (20% of the Toxicity Reference Value (TRV), established by Health Canada (Health Canada, 2004). In most cases, the HIs are 100 to 1,000-fold lower than the 0.2 benchmark.

For the general population background exposures to PCDD/PCDF from food and other sources range between 1.32 pg TEQ/kg-day for the adult to 5.92 pg TEQ/kg-day for the infant. Base-related exposures to PCDD/PCDF in soil, sediment, surface water, groundwater, deer, moose and berries represent incremental increases of less than 1% in these background exposures.

The predicted HI values for the angler exceed established benchmarks. While this by itself does not indicate that unacceptable non-cancer hazard exists, it suggests that additional consideration of this pathway may be warranted. It is important to note that the results for the angler rely heavily on food-chain (bioaccumulation) modeling that can reliably be expected to over estimate the actual concentration of PCDD/PCDF in fish tissue. As such, these results should be viewed with caution. Further consideration, possibly direct measurement of fish tissue, may be warranted.

Based on the results of the HHRA, the following recommendations can be made for the individual *Subject Areas*:

- **Subject Area 1 – 1966 Test Area**
  Exposures to PCDD/PCDF in the 1966 Test Area do not represent a potential concern for human health for either the soldier or recreational receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 2 – Rippon Road**
  Exposures to PCDD/PCDF in the Rippon Road area do not represent a potential concern for human health for either the soldier or timber harvester. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 3 – Murphy Bivouac**
  Exposures to PCDD/PCDF in the Murphy Bivouac area do not represent a potential concern for human health for the soldier, youth camper or recreational user. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 4 – Clones Bivouac**
  Exposures to PCDD/PCDF in the Clones Bivouac area do not represent a potential concern for human health for the soldier. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 5 – Base Administration and Parks**
  Exposures to PCDD/PCDF in the Base Administration and Parks area do not represent a potential concern for human health for the soldiers or recreational receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 6 – Static Range Impact Area**
  Exposures to PCDD/PCDF in the Static Range Impact Area do not represent a potential concern for human health for the soldier receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 7 – General Manoeuvres Area**
  Exposures to PCDD/PCDF in the General Manoeuvres Area do not represent a potential concern for human health for the soldier receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 8 – Base Perimeter and Fire Breaks**
  Exposures to PCDD/PCDF in the Base Perimeter and Fire Breaks do not represent a potential concern for human health for the soldier or recreational receptor. Therefore,

restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 9 – Nerepis River**
  Exposures to PCDD/PCDF in soil, sediment and surface water in the Nerepis River area do not represent a potential concern for human health for the angler receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF in soil, sediment and surface water is not warranted. Further consideration of the potential exposures to PCDD/PCDF through the ingestion of fish may be warranted.

- **Subject Area 10 – Swan Creek Lake**
  Exposures to PCDD/PCDF in soil, sediment and surface water in the Swan Creek Lake area do not represent a potential concern for human health for the angler receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF in soil, sediment and surface water is not warranted. Further consideration of the potential exposures to PCDD/PCDF through the ingestion of fish may be warranted.

- **Subject Area 11 – CFB Gagetown**
  Exposures to PCDD/PCDF in the CFB Gagetown Area do not represent a potential concern for human health for hunter receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

These results indicate that for all receptors and pathways considered, with the possible exception of the ingestion of fish caught in the Nerepis River or Swan Creek Lake, exposures to PCDD/PCDFs in soil, sediment, surface water, groundwater, moose, deer and berries clearly do not and will not represent a potential concern for human health at CFB Gagetown.

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1.0 Introduction

Health Canada has commissioned Dillon Consulting and RBR Consulting to prepare this risk assessment to address concerns that those who currently might work at or otherwise come into contact with the base might be exposed to residuals of herbicides and herbicide-related chemicals. This *Human Health Risk Assessment* (HHRA) represents Fact-Finding Task 3A-2, and evaluates potential human exposures to current levels of herbicides and herbicide-related chemicals for people who could be expected to be on the site now or in the future.

1.1 Background

Canadian Forces Base (CFB) Gagetown occupies approximately 110,000 hectares adjacent to the community of Oromocto New Brunswick. A range training area (RTA), which is used for live-fire training, accounts for about 30,000 hectares of this land and is closed to public access. The remaining 80,000 hectares are used for military training, but also accommodate a number of non-military activities including forest management, hunting, fishing and other recreational activities.

Live-fire training and other military training exercises require open areas that are free of trees, shrubs and other large vegetation, for establishment of line-of-site during training exercises and to reduce the potential for wildfires that could result from live-fire training. Although a variety of vegetation management measures have been used in the training areas since the base was established in 1952, the use of chemical herbicides has been the preferred approach. The use of herbicides on CFB Gagetown has lead to concerns over the potential environmental impacts that may have occurred as a result of the long-standing and repeated application of herbicides, particularly Agent Orange and Agent Purple, on the base.

The Federal Government has launched an initiative that will report on the facts surrounding the use of Agent Orange, Agent Purple and other herbicides and herbicide-related chemicals during the specific test periods on June 1966 and June 1967. The initiative also encompasses the identification and reporting of facts surrounding the use of herbicides and herbicide-related chemicals at CFB Gagetown between 1952 to the present day. As part of this commitment, the Federal Government, through Health Canada, has commissioned a study to examine the potential human health effects that may be related to the presence of herbicides and herbicide-related chemicals in soil, sediment, surface water, groundwater, fish, game and vegetation on CFB Gagetown.

1.2 Scope and Objectives

Human health risk assessment (HHRA) is a process that is used to quantitatively evaluate the potential for human health risks that could be associated with exposures to chemicals in the environment. The HHRA is based on the fundamental toxicological premise that a person must be able to come into contact with a chemical in the environment in order for a health risk to possibly occur. For situations in which it is reasonable to expect that a person could come into contact with a specific chemical in the environment, the HHRA is designed to estimate the amount of contact that a person could have and to use that information to determine the potential level of risk that that person could experience as a result of that contact. Regulatory guidance for the design and

implementation of the HHRA to address human health concerns related to exposures to chemicals in the environment, is well established in Canada, the United States and in developed countries around the world. Although procedural differences exist between jurisdictions, the fundamental structure of the HHRA is the same. The basic HHRA components include:

- **Site Characterization**
  The Site Characterization component of the HHRA provides an overview of the environmental sampling conducted as part of the *Environmental Site Assessment* (ESA). It serves as the foundation for the risk assessment by providing the information about the amounts of all of the substances of interest that are in the environment under study in soil, groundwater, surface water or other environmental media, and the factors (such as groundwater flow) that govern the transport of these chemicals in environmental media.

- **Problem Formulation**
  The Problem Formulation component of the HHRA builds on the information provided by the Site Characterization, to identify the chemicals that are of particular concern to human health and the people who could come into contact with the these chemicals. It also serves to identify the ways in which people could come into contact with the chemicals of concern (exposure pathways), how long the individual exposures could be (exposure duration) and how frequently these exposures could occur (exposure frequency). This section of the report includes the development of a Conceptual Site Model (CSM) that identifies the potentially complete exposure pathways and the potentially incomplete exposure pathways.

- **Exposure Assessment**
  The Exposure Assessment builds on the CSM completed as part of the Problem Formulation. For each of the potential receptors (people who could come into contact with the chemicals of concern), exposures are estimated for each of the potentially complete exposure pathways identified by the CSM. Where appropriate, combined exposure estimates (exposures for the relevant exposure pathways), are also provided.

- **Toxicity Assessment**
  The Toxicity Assessment provides a summary of the biological and toxicological effects of the identified chemicals of concern. It also identifies the *Toxicological Reference Values* (TRVs) or exposure benchmarks that are used to determine if the estimated exposures identified by the Exposure Assessment.

- **Risk Characterization**
  The Risk Characterization builds on the results of the Exposure Assessment and Toxicity Assessment to determine if the exposure estimates for the various receptors considered, represent potential concerns for human health.

- **Discussion of Uncertainties**
  The Discussion of Uncertainties component of the HHRA serves to provide perspective on the results of the Exposure Assessment, Toxicity Assessment and

Risk Characterization components of the HHRA. The Uncertainty Analysis provides an assessment of the likelihood that the factors and calculations in the risk assessment accurately reflect reality and attempts to bound these considerations which reflect their likelihood of actually occurring.

The HHRA presented in this report is based on Health Canada guidance for the completion of human health risk assessments for sites under federal jurisdiction in Canada (Health Canada, 2004). This has been augmented by guidance from other regulatory agencies including the Ontario Ministry of the Environment (MOE, 2005) and the US EPA, (USEPA, 1989), when specific guidance was not available from Health Canada.

The scope of this HHRA encompasses the evaluation of current potential human health hazards and/or risks that may be associated with the presence of herbicides and herbicide-related chemicals in the soil, surface water, groundwater, fish, game and vegetation on CFB Gagetown. The objectives of the HHRA include:

- Evaluation of potential exposures for:
  - military personnel currently on CFB Gagetown;
  - members of the general public who may use the base for recreational purposes;

- Evaluation of the potential hazards/risks associated with exposures for each group of people who could be present on CFB Gagetown lands;
- Identification of areas on CFB Gagetown where exposures to herbicide and herbicide-related chemicals may pose unacceptable hazards for one or more of the groups of people who could be present;
- Formulation of general conclusions regarding the overall potential concern for human health as a result of exposure to herbicide and herbicide-related chemicals on CFB Gagetown;
- An analysis of the potential effects that any identified data gaps could have on the conclusions of the HHRA; and
- Provision of recommendations to address potential concerns identified in the HHRA.

The scope and objectives of the HHRA do not extend to the evaluation of exposures to chemicals that are unrelated to the use of herbicides on CFB Gagetown. This HHRA also does not consider the potential human health hazards and/or risks associated with exposures to herbicides or herbicide-related chemicals that may have occurred in the past. Potential health hazards and/or risks associated with previous exposures to herbicides and herbicide-related chemicals are specifically addressed elsewhere.

1.3 Organization of Report

This report is organized in 10sections and 9 appendices including:

- **Section 1: Introduction.**

- **Section 2: Site Characterization** – summarizes the environmental and biological monitoring data available for CFB Gagetown contained in the *Environmental Site Assessment* (ESA) report completed as *Fact Finding Task 2B* (ESA, 2006b).

- **Section 3: Problem Formulation** – identifies the chemicals of concern, the potential receptors and the active or complete exposure pathways.

- **Section 4: Exposure Assessment** – presents the results of the exposure calculations.

- **Section 5: the Toxicity Assessment** – provides a listing of the toxicological reference values used to assess the potential hazards/risks associated with exposure to the chemicals of concern.

- **Section 6: Risk Characterization** – characterizes the hazards associated with exposure to non-carcinogenic chemicals and the risks associated with exposure to carcinogenic chemicals for the identified receptors.

- **Section 7: Discussion of Uncertainties** – provides an evaluation of the uncertainties associated with the hazard estimates from the *Human Health hazard Assessment* (HHRA).

- **Section 8: Conclusions and Recommendations** – provides a summary of the recommendations and conclusions stemming from the HHRA.

- **Section 9: References** – lists the citations for the reference materials used in the development of the HHRA.

- **Section 10: Glossary** – provided descriptions of the technical terms used in the report.

- **Appendix A:** provides a summary of the analytical data used in the preparation of the HHRA.

- **Appendix B:** provides the derivations of screening criteria for chemicals where criteria were not available from either Health Canada or the *Canadian Council of Ministers of the Environment* (CCME).

- **Appendix C** provides the statistical calculations used in the derivation of the *Exposure Point Concentrations* (EPCs).

- **Appendix D** provides the rationale to support the selection of receptor parameters used in this HHRA.

- **Appendix E** provides the detailed exposure dose and hazard index calculations for the HHRA.

- **Appendix F** provides the uptake modelling used to estimate chemical concentrations in fish, game and vegetation on the base

- **Appendix G** provides the toxicity assessment for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans.

- **Appendix H** provides the peer review comments received from Health Canada and the Peer Review Panel.

- **Appendix I** provided the Dillon Team responses to the peer review comments.

1.4 Limitations

Risk assessments, by their nature, have inherent limitations and uncertainties. It is believed that these uncertainties have been addressed through the conservative interpretation of site-specific data and parameter selection, and in the conservatism inherent in existing toxicity information. The quantitative estimates of risk provided by this process are valid only for the assumptions and exposure scenarios outlined in this report. However, should knowledge of the site conditions or toxicity information change, the risk posed by the site may differ from that presented in this report.

This report was prepared exclusively for the purposes, project, and site location outlined in the report. The report is based on information provided to, or obtained by Dillon as indicated in the report, and applies solely to site conditions existing at the time of the site investigation. Where the risk assessment has relied on information provided to Dillon by the other parties, Dillon has, within the scope and expectations of the risk assessment process, reviewed this data but Dillon does not warrant the accuracy, completeness and representativeness of this information. Dillon's report represents a reasonable review of available information within an established work scope, work schedule, and budget.

This report was prepared by Dillon for the sole benefit and use of the Health Canada. The material in it reflects Dillon's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decision made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

2.0 Site Characterization

2.1 Site Description and Land Use

CFB Gagetown land use totals approximately 110,000 hectares (ha), including 65 lakes, 365 wetlands, and 251 permanent and intermittent streams (ESA, 2006a) (Figure 2-1, Figure 2-2). The active ranges in the Range Training Area (RTA) represent approximately 30,000 ha of this land use. A variety of non-military land uses occur within the approximately 80,000 ha of non-RTA land, including forest management, hunting, fishing, camping, and various other recreational activities. Based on the information provided by Base personnel, the current land-uses for CFB Gagetown are not expected to change in the foreseeable future. For the purpose of health and safety of individuals coming into the RTA, non-military land uses are controlled by CFB Gagetown Range Control (ESA, 2006a). Non-military land uses are also restricted to areas outside RTA Impact Areas and active ranges. Civilians and military personnel wishing to enter these areas must obtain clearance through Range Control so that designated areas can be selected away from military activities and allow for safe use of the land.

The Base administrative area is located in the northern sector and includes administrative and training facilities as well as the personnel married quarters and singles quarters. The personnel married quarters include parks and recreational areas. The RTA contains active ranges of all types (for land training), general manoeuvre areas, bivouacs, and undisturbed forest.

The Lindsay Valley Conservation Area, in the northwest corner of CFB Gagetown, near the main entrance of the Base, was developed as part of a comprehensive natural resources management program for CFB Gagetown (ESA, 2006a). A variety of recreational activities take place here, including cross-country skiing, snowmobiling, snowshoeing, hiking, biking, and biathlon training.

The topography of the RTA varies from north to south (ESA, 2006a). The north part of the RTA is within the Grand Lake Basin subdivision of the New Brunswick Lowlands and is characterized by gently undulating terrain, generally at elevations below 45 meters. The south part of the RTA is within the Nerepis Highlands division of the St. Croix Highlands and is characterized by hilly to mountainous terrain and elevations generally ranging from 90 m to 200 m. However, the lowest elevations in the entire RTA are found within the south part of the RTA, along the Nerepis River watershed.

There are a minimum of two weather stations located in the vicinity of CFB Gagetown and Environment Canada records weather data from these stations. Based on these stations, annual precipitation at the RTA includes approximately 900 mm of rainfall and 252 cm of snowfall (ESA, 2006a). Mean annual temperatures range from 5.4 to 6.1 °C. Prevailing winds are from the southwest during the summer months (months of herbicide applications).

2.1.1 Overview of Reasons for Herbicide Use at CFB Gagetown

CFB Gagetown houses an 110,000-ha training area where a significant amount of live-fire military training occurs within designated RTA Impact Areas (ESA, 2006a). This activity and the areas used for it are tightly controlled; however, the live fire training exercises in the Impact Areas occasionally result in fires in areas where there is an abundance of combustble material (e.g., dry

grass, stumps, shrubs, and forest re-growth). As a result, there is a requirement to keep open areas free of softwoods and hardwoods to reduce the risk of wildfires resulting from live firing. Reducing the amount of vegetation in the Impact Areas and on the Ranges in turn reduces material that could be ignited. Controlling vegetation growth is a major component of the CFB Gagetown Fire Prevention Plan (ESA, 2006a). Firebreak roads must be kept clear of vegetation to maintain effective fire barriers.

The RTA must also provide the military with line-of-sight during operations. In some cases targets must be visible from distances as far as 4 kilometres. In order for this visibility to be achieved, vegetation height and type has to be controlled. CFB Gagetown uses a variety of methods to manage vegetation growth in the training areas, including mechanical methods (e.g., cutting, crushing, or grubbing), burning, or chemical methods such as spraying herbicides through ground or aerial applications (ESA, 2006a). Chemical vegetation control has generally been the preferred method to manage secondary vegetation in the Impact Areas and firebreak roads because of personnel safety, its effectiveness, and cost per hectare.

2.1.2 Description of Herbicides

The term herbicide is a generic name for chemicals used for the control of plant growth, or killing of plants and plant parts. Mechanisms of action by which herbicides accomplish their role include a reduction or cessation of photosynthetic activity, respiration, growth, and cellular function (ESA, 2006a).

Commercial formulations of herbicide products (referred to herein simply as herbicides) are given a trade or commercial name by the companies that manufacture them, and each product is a mixture of active ingredients (AIs) that has the herbicidal property, and other ingredients such as carriers (which act as a vehicle for more effective transmission), dilutants, and adjuvants (which modify the action of the principal ingredient (ESA, 2006a). For example, the herbicide product Dycleer is manufactured by Syngenta Crop Protection Canada Inc., and contains the AIs Dicamba and 2,4-D, along with proprietary carriers and adjuvants.

In some cases, manufacturing impurities are also found in herbicides as a result of the production of the active ingredient. For example, 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD) is a manufacturing impurity associated with the production of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). A comprehensive list of the herbicides, and AIs is provided in the ESA report (ESA, 2006a).

2.1.3 Surficial Geology

The surficial geology around the periphery of CFB Gagetown from the northwest to the south (i.e., along the banks of the Saint John River), as well as along the banks of the Oromocto River to the west and the Nerepis River in the south, mostly consists of terraces and floodplains made up of sand, gravel, some silt, minor clay and organic sediments, generally more than 2 m thick, and deposited as channel, overbank, and flood basin deposits (ESA, 2006a). The surficial geology of the central portion of the RTA is fairly consistent and comprises clay, silt, sand, gravel, and block deposits forming discontinuous to continuous layers varying from 0.5 metre to 3 metres in thickness. The northwest portion of the RTA contains some organic sediment, including bogs, fens, swamps and peat, with minor silt and fine sand, generally 1 to 5 m thick, deposited in shallow

basins on poorly drained surfaces. The surficial geology of the southeastern portion of the mountainous region of the RTA mostly consists of bedrock outcrops of various lithologies and ages. The bedrock surface is generally weathered and shows glacial erosion features (ESA, 2006a)

2.1.4 Hydrogeology and Groundwater Use

The regional aquifer underlying CFB Gagetown is primarily a fractured bedrock aquifer (ESA, 2006a). The hydraulic property of the bedrock aquifer is fairly variable and related to the diverse lithology of the area. Reported horizontal hydraulic conductivities varied from 10^{-3} cm/s to 10^{-4} cm/s. It should be noted that it is possible in the highly fractured bedrock or permeable conglomerate horizons to encounter localized high horizontal hydraulic conductivities within the bedrock aquifer. Reported average water table depth corresponds approximately to the mean depth to bedrock value of 4.7 m, indicating that the flow within the aquifer is influenced by the bedrock topography to a certain extent in addition to the surface topography.

The extent and nature of bedrock aquifers underlying CFB Gagetown is not fully known (ESA, 2006a). Confined or semi-confined bedrock aquifers reportedly exist throughout CFB Gagetown. The southern portion of CFB Gagetown area covering Rockwell Wood North range and part of the Rockwell Impact Area were reportedly unconfined. Reportedly unconfined conditions were also identified in Lawfield Impact Area, Greenfield Impact Area, and in the north part of the Wellingdon and Grenade ranges. Unconfined portions of the bedrock aquifer could be more vulnerable to surficial contamination depending upon the water table depth and surficial material thickness and composition.

Although the main water supply to CFB Gagetown and the Town of Oromocto is obtained from the Saint John River (ESA, 2006a), all other villages and residents located around the perimeter of CFB Gagetown rely on private water wells for their potable water supply. There are also several wells located at CFB Gagetown that provide potable water supplies to select areas; however, it is reported that these wells are not used for consumption purposes, but rather as water supplies for showers and other non-comestible uses within the RTA bivouac areas as well as for the Petersville guard shack.

2.1.5 Surface Water

CFB Gagetown lies within the Saint John River watershed, lying to the south and west of the Saint John River. All surface waters drain directly, or indirectly through major tributaries (the Oromocto and Nerepis Rivers), into the lower Saint John River.

CFB Gagetown encompasses a drainage area of approximately 1,060 km^2 (ESA, 2006a). This area is divided almost equally among the three major watersheds. The sizes of these drainage areas are:

- The Oromocto River drainage - 318 km^2
- The Nerepis River drainage - 365 km^2
- The Saint John River drainage - 378 km^2

The direction of drainage in a particular watershed varies with the local topography; however, in general, the western regions of CFB Gagetown drain to the Oromocto River, the northern and eastern regions drain directly to the Saint John River, and the central and southern regions drain to

the Nerepis River (ESA, 2006a). Map No. 1-3 from the ESA report, provides details on the Base plan with key water features as well as training areas, including bivouacs and location of water wells (ESA, 2006a).

As indicated in Section 2.1.4, the main water supply for CFB Gagetown and the Town of Oromocto, is obtained from the St John River. Based on communications with the Base Environmental Officer, Mr. Tom McLaughlan, the Water Treatment Plant, located at CFB Gagetown, provides treatment of the surface water, consisting of coagulation, flocculation, sedimentation, and rapid sand filtration (ESA, 2006a). The water undergoes complete treatment and continuous chlorination. The capacity of the plant is 13,600 m^3/day (ESA, 2006a).

2.2 Identification of Human Health Risk Assessment Subject Areas

In assessing potential human exposures to chemicals in soil, surface water, groundwater and vegetation on the base it is necessary to understand the various groups of people who could be present on the base (soldiers, members of the public *etc*.), the areas of the base each group of people are likely to frequent and the types of activities that each group could be engaged in. In order to develop exposure scenarios that adequately describe potential exposures for the various user groups, it is necessary to identify distinct exposure zones or areas across the base that reflect the variation in exposure potentials that exist across the Base.

The identification of *Subject Areas* (SAs) for the human health risk assessment considered both the potential presence of COCs, typical activities for the given SAs and the various user groups who could be present in the individual SAs. Based on these considerations, eleven (11) SAs were identified for inclusion in the HHRA. The location of each SA is provided in Figure 2-3. Rationales to support the selection of each of the SAs are provided below.

2.2.1 Subject Area 1 – 1966 Testing Area

Subject Area 1 is defined as the 1966 Trial Area and is located to the west of Highway 7 within Area 50 of CFB Gagetown (see Figure 2-3). This area was selected as a distinct area due to the potential for exposure to PCDD/PCDFs in soil resulting from the 1966 herbicide trials.

2.2.2 Subject Area 2 – Rippon Road

Subject Area 2 is identified as the 1967 Trial Area along Rippon Road from the gate east of Highway 7 to Clones Bivouac and forms the boundary between Area 30 and Area 31 of CFB Gagetown (Figure 2-3). This area was selected as a distinct area due to the potential for exposure to PCDD/PCDFs in soil resulting from the 1967 herbicide trials.

2.2.3 Subject Area 3 – Murphy Bivouac

Subject Area 3 is defined as the Murphy Bivouac area located on the south-eastern edge of the base adjacent to Hamilton Wood Static Impact Range and Area 38 of CFB Gagetown (Figure 2-3). The levels of PCDD/PCDF in soil were found to exceed CCME guidelines in one sample taken from this area. This was selected as a distinct area to address the specific use of this area by youth groups

and by local residents who cross base property at the Murphy Bivouac to access summer cottages on Murphy Lake.

2.2.4 Subject Area 4 – Clones Bivouac

Subject Area 4 is defined as the Clones Bivouac area located at the intersection of Clones Road and Rippon Road. Area 18, Area 30 and Area 31 of CFB Gagetown bound the Clones Bivouac area (Figure 2-3). PCDD/PCDF levels were found to exceed CCME guidelines in soil samples from Clones Bivouac area. This area was identified as a distinct area to address the specific use of the area as a bivouac area for soldiers on training manoeuvres.

2.2.5 Subject Area 5 – Base Administration and Parks

Subject Area 5 is defined as the Base Administration area and recreational facilities on the base. It also includes the park areas within the community that provides housing for the base (Figure 2-3). This area was identified as a distinct area to address potential concerns related to potential exposures for base personnel and their families who may use recreational facilities in the community and Base Administration area.

2.2.6 Subject Area 6 – Static Range Impact Area

Subject Area 6 is defined as the Static Range Impact Area and includes the Grenade Range, Wellington Range, Tow Tracking Range, anti Armour Range, Argus Impact, Greenfield Impact, Hersey Impact, Coy Defensive Position, Argus Wood, Dinge Wood, Rockwell Impact, Rockwell Wood North, Rockwell Wood South, Lawfield Impact, Drummond DML and South Boundary DML (Figure 2-3). Subject Area 6 also included Area 2 and Area 3 of CFB Gagetown. This area was identified as a distinct area to reflect the limited access to area by soldiers and the limited potential for contact with the soil while on training manoeuvres in the area.

2.2.7 Subject Area 7 – General Manoeuvres Area

Subject Area 7 is defined as the General Manoeuvres Area. The General Manoeuvres of CFB Gagetown covers the remainder of the base area east of Highway 7 outside the Static Range Impact Area (Figure 2-3). However, for the purposes of the human health risk assessment, SA 7 has been limited to those areas where soil sampling was conducted as part of the ESA. For the human health risk assessment SA 7 has been considered to include Area 8, Area 11, Area 12, Area 20, Area 21, Area 28 and portions of Area 26, Area 27, Area 29 and Area 33 of CFB Gagetown. The other areas within the General Manoeuvres Area, including Area 13, Area 14, Area 15, Area 16, Area 17, Area 18, Area 19, Area 30, Area 31 and portions of Area 29, Area 32 and Area 36 were not identified as *Areas of Potential Concern* by the ESA either due to the lack of herbicide application or very limited indications of herbicide application (ESA, 2006a). Therefore, sampling data is not available for these areas. Although these areas cannot be quantitatively evaluated in the HHRA, the fact that these areas lie outside the areas of general herbicide application suggests that the levels of herbicide and herbicide-related chemicals in the soil would be similar to those found in background areas. Thus, exposures that occur in these areas can be expected to reflect background exposures.

2.2.8 Subject Area 8 – Base Perimeter and Fire Breaks

Subject Area 8 is defined as the lands that form the perimeter of the base and those areas identified in the ESA as fire breaks (Figure 2-3). Based on information provided by Base personnel, the perimeter lands of the base are the areas where local residents would have the greatest access to the base and where recreational activities such as hunting, hiking and collecting berries would likely be the highest. For the purposes of the human health risk assessments SA 8 has been considered to include Area 6, Area 7, Area 9, Area 10, Area 22, through Area 25, Area 34, Area 35, Area 37, and Area 38 through Area 53 of CFB Gagetown. Subject Area 8 also includes a portion of Area 33.

2.2.9 Subject Area 9 – Nerepis River

Subject Area 9 is defined as the Nerepis River and the lands immediately adjacent to the river (Figure 2-3). This area represents one of the two areas on the base where environmental sampling data are available for surface water and sediment. It also represents an area with reasonable fishing access for the general population. For the purposes of this assessment, SA 9 has been considered to include the lands from Area 32, Area 33, Area 36, Area 37, Area 40 and Area 41 that are immediately adjacent to the Nerepis River (100 m either side of the river).

2.2.10 Subject Area 10 – Swan Creek Lake

Subject Area 10 is defined as Swan Creek Lake and the lands immediately adjacent to the lake (Figure 2-3). This area represents one of two areas on the base where environmental sampling data are available for surface water and sediment. For the purposes of this assessment SA 10 has been considered to include parts of the Engineering Skills Training Area and the northern portion of Area 4 of CFB Gagetown.

2.2.11 Subject Area 11 – CFB Gagetown

Subject Area 11 is defined as the entire area of CFB Gagetown. This area is intended to reflect potential exposures for people who hunt moose and deer. Information provided by Base personnel indicated that moose and deer are the only animals that are actively hunted on the Base. Hunters can be expected to move over many areas of the base during a hunting season in pursuit of game. Thus, assessing exposures to chemicals in the soil on an area-by-area basis will greatly over estimate potential exposures for this receptor group. To compensate for this over estimation, SA 11 was established to provide reasonable exposures for hunters.

2.2.12 Overlay of HHRA Subject Areas with ESA APECs

The identification of SAs for the risk assessment has been based, in part, on the availability of sampling data from the ESA. In order to properly assess potential exposures for the relevant receptors in each of the SAs, it was necessary to group the sampling data from the ESA into the SAs identified for the risk assessment. The following summary shows how the ESA data has been grouped for incorporation into the risk assessment.

The ESA also defined APEC 19 as *"10 small areas located around the base"* (ESA Stage 2, Table 2-1, 2006a). The information provided in the ESA indicates that two of these sample locations are

in SA 7 while the majority are situated around the perimeter of the base (8 of 10 locations). Two of these 8 sample points are located in SA 5, and one is located in SA 10. The remaining 7 locations are situated within SA 8. Because the majority of the samples locations within APEC 19 are situated within SA 8, the data from APEC 19 has been included as part of SA 8.

HHRA Subject Area		Applicable ESA Areas	HHRA Subject Area		Applicable ESA Areas
SA-1	1966 Test Area	A1	SA-7	General Manoevers Area	A11, A12, A13
SA-2	Rippon Road	A2	SA-8	Base Perimeter & Fire Breaks	A3, A14, A17, A18, A19
SA-3	Murphy Bivouac	A16			
SA-4	Clones Bivouac	A15	SA-9	Nerepis River	A21
SA -5	Base Administration & Parks	A4 & A20	SA-10	Swan Creek Lake	A22
SA-6	Static Range Impact Area	A5, A6, A7, A8, A9, A10	SA-11	CFB Gagetown	A1 – A22

2.3 Discrete and Composite Samples

The ESA (ESA, 2006b) applied a strategy that included the use of composite and discrete samples to provide an overall picture of the concentrations of herbicide and herbicide-related chemicals in the soil across the base. The design and implementation of the sampling program is described in detail in the ESA final report.

In brief, each APEC identified in the ESA was divided into six sectors and six randomly selected sample locations were identified within each sector, yielding a total of 36 discrete sample locations within each APEC (ESA, 2006b). These sample locations were used to create composites. Single samples from each sector were combined to form a single composite sample. The process was repeated 6 times in each APEC to provide a total of 6 composite samples from each APEC. Sampling of soil focused on the 0 – 10 cm horizon excluding roots and surface vegetation (ESA, 2006b). Six composite samples were collected from most APECs, sixteen composite samples were collected in APEC 3. It should be noted that this general compositing process did not apply to APEC 15 through APEC 22. Twelve composite were collected in APEC 15 (one for each of the twelve bivouac areas with no water supply), and ten composite samples were collected from each of APEC 17, APEC 18 and APEC 19 (ESA, 2006b). Six composite samples were collected from each of APEC 21 and APEC 22.

For APECs in which the PCDD concentration (expressed as *Toxic Equivalents* or TEQ) in one or more composite samples exceeded the CCME screening criterion of 4 pg TEQ PCDD/PCDF/g soil, discrete samples from each of the sectors within the APEC were submitted for analysis. The results from the discrete samples were used to identify the individual sectors within the APEC in which the PCDD/PCDF concentration exceeded the screening criterion. A total of 295 soil samples (159 composite and 118 discrete) collected from the APECs were submitted for analysis (ESA, 2006b). An additional eighteen composite samples were collected from the background areas within the base perimeter (ESA, 2006b). A summary of the number of composite and discrete samples in each of the SAs considered in the HHRA is provided below.

Summary of Composite and Discrete Soil Samples by Subject Area

Subject Area	Number of Composite Samples	Number of Discrete Samples	Total Number of Samples
SA 1	6	18	24
SA 2	6	36	42
SA 3	16	6	22
SA 4	12	7	19
SA 5	11	18	29
SA 6	36	8	44
SA 7	18	0	18
SA 8	42	25	67
SA 9	6	0	6
SA 10	6	0	6
Background Locations	18	0	18
Totals	177	118	295

The composite samples provide estimates of chemical concentrations across each of the APECs considered in the ESA. However, compositing samples can result in a potential dilution of samples with elevated levels of chemicals and thus result in an under-estimation of the potential maximum concentrations within each APEC. This was identified as an issue in the ESA (ESA, 2006b). The discrete samples reported in the ESA can aid in the delineation of areas within each APEC in which chemical concentrations may be elevated. The inclusion of the discrete samples in the data set used for the HHRA ensures that areas in which chemical concentrations could be higher are adequately considered both in the chemical screening process and in establishing *Exposure Point Concentrations* (EPCs) as inputs to the exposure assessment.

For the purposes of this HHRA, no distinction has been made between composite and discrete samples. Both composite and discrete samples have been evaluated as individual values. This approach supports a consistent approach to consideration of each SA.

The use of composites was limited to soil samples. For other environmental media, including surface water, groundwater, sediment and vegetation, only discrete samples were collected and used in the risk assessment.

2.4 Summary of Available Data

The focus of the ESA was to evaluate the presence of herbicide and herbicide-related chemicals in soil, groundwater, surface water, sediment and vegetation on CFB Gagetown. A summary of the analytical data from the ESA is provided in Appendix A. These data present the environmental sampling from the ESA grouped into the SAs considered in the HHRA. The data are presented on a dry-weight basis for soil and sediment and on a wet-weight basis for vegetation samples.

The various individual isomers and congeners of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) all have the same biological mechanism of action (*ie.* they all work on the body in the same way). Thus, PCDDs and PCDFs are generally assessed as a group.

For the purposes of this assessment, the term *PCDD/PCFCs* will be used to represent the group of common acting chemicals.

Although the individual PCDD/PCDF isomers and congeners have the same biological mechanism of action they differ in their level of toxicity. The World Health Organization (WHO) has developed *Toxic Equivalency Factors* (TEFs) that rank the toxicities of the individual isomers and congeners to the most potent dioxin in the group (2,3,7,8-TCDD) which is assigned a potency of 1.0. A summary of the WHO TEFs assigned to each of the PCDD/PCDF isomers and congeners is provided below. It should be noted that the WHO TEFs are not the only TEFs available for ranking the potencies of the various PCDD/PCDF compounds. However, the WHO TEFs represent the most recent evaluation of these compounds and is widely used internationally and is the approach sanctioned by Health Canada.

The concentrations of PCDD/PCDF isomers and congeners for the various SAs are presented in Appendix A. These data are presented as the *Toxicity Equivalent Concentration* (TEQ) for each of the individual isomers and congeners. The TEQ concentrations are calculated by multiplied the concentration reported by the analytical lab, by the respective TEFs to provide a toxic equivalent concentration or TEQ. For example if the soil concentration of octachlorodibenzo-p-dioxin (OCDD) is reported as 500 pg/g, this is converted to a TEQ concentration by multiplying the reported concentration by the TEF for OCDD (500 pg/g x 0.0001 = 0.5 pg TEQ/g). Similar calculations are completed for each PCDD and PCDF and the TEQ concentrations are summed to provide a total or overall TEQ for the sample. These overall TEQ concentrations are then used in the HHRA to estimate exposure and potential hazards.

Summary of World Health Organization Toxic Equivalency Factors for PCDD/PCDFs

PCDD Congeners	WHO TEF Factor	PCDF Congeners	WHO TEF Factor
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0.1
1,2,3,7,8-PnCDD	1	1,2,3,7,8-PnCDF	0.05
1,2,3,4,7,8-HxCDD	0.1	2,3,4,7,8-PnCDF	0.5
1,2,3,6,7,8-HxCDD	0.1	1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDD	0.1	1,2,3,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDD	0.01	1,2,3,7,8,9-HxCDF	0.1
OCDD	0.0001	2,3,4,6,7,8-HxCDF	0.1
		1,2,3,4,6,7,8-HpCDF	0.01
		1,2,3,4,7,8,9-HpCDF	0.01
		OCDF	0.0001

2.4.1 Data Verification

An independent *Toxic Equivalency* (TEQ) calculation check was performed on a random ten percent of the ESA (ESA, 2006b) data set and on all samples with a TEQ greater than or equal to 4.0 pg/g. The samples from the ESA were compared to the values calculated for the risk assessment. In selecting samples to be checked, an initial TEQ calculation check was performed on all samples. This initial TEQ calculation check showed agreement with the ESA data set for all samples that did not have congeners with non-detect values. The final TEQ calculation check was performed on a random ten percent of samples that had congeners with non-detect values. The TEQ calculation check was performed on the following samples:

D3-C6;	A8-C6;	A16-MUR-SS2;	B1-C2;	A8-S1-SW1;
A3-S2-SS5;	A10-C2;	A17-BB1-C1;	B1-C3;	A13-S3-SW1;
A4-S2-SS1;	A10-C4;	A18-F5-C1;	DB3-C4;	A22-SCL6-SW1;
A4-S3-SS4;	D10-C6;	A19-MSA8-C1;	A8-S1-SD1	B1-S6-SW1;
A4-S4-SS6;	A13-C2;	A19-MSA10-SS1;	A8-S6-SD1;	B3-S5-SW1;
A6-C5;	A15-CLOSS3;	A20-G3-C1;	D22-SCL6-SD1;	B3-S6-SW1;
A6-S1-SS6;	A15-CLOSS5;	D21-NR1-C1;	B1-S1-SD1;	A15-BLI-GW1;
A6-S2-SS6;	A15-LAW-C1;	A22-SCL2-C1;	B1-S6-SD1;	A15-COO-GW1;
A7-C5;	A16-COR-C1;	A22-SCL5-C1;	B2-S2-SD1;	D15-LYO-GW1.

The TEQ calculation was performed using blank corrected data and was conducted in the following steps.

1. The first step, blank correction was performed in the following manner. If an individual congener was detected and the sample blank was non-detect, zero was used as the blank and no blank subtraction was used. If an individual congener was detected and the sample blank was also detected, the sample blank was subtracted from the congener result. If an individual congener was non-detect, one-half the method detection limit was used, and no blank correction was performed.

2. In the next step, the blank subtracted value for each congener was multiplied by the *Toxicity Equivalent* Factor (TEF) for that particular congener. In the final step, the calculated values (blank subtracted value * TEF) were summed to calculate the TEQ.

The results of the TEQ calculation check showed agreement between the data and the calculated values for the ten percent of the data set and all samples with a TEQ greater than or equal to 4.0 pg/g.

2.4.2 Data Available for Soil

Surface soil data are available for SA 1 through SA 10. The combined data sets from SA 1 through SA 10 have been used to represent soil conditions for SA 11 (CFB Gagetown). The ESA soil data for SA 1 through SA 10 are provided in Table 1 through Table 10 in Appendix A. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration, calculated from the blank subtracted isomer and congener concentrations, is also provided. A summary of the ESA soil samples included in the risk assessment is provided in Table 2-1.

2.4.3 Data Available for Groundwater

Groundwater data is available only for SA 4. These data are presented in Table 11 in Appendix A. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration, calculated from the blank subtracted isomer and congener concentrations, is also provided. A summary of the ESA groundwater data collected from Clones Bivouac, included in the risk assessment is provided in Table 2-2.

2.4.4 Data Available for Sediment

Sediment Data is available for SA 9 and SA 10. Summaries of the ESA sediment data for SA 9 and SA 10 are provided in Table 12 and Table 13 in Appendix A. These represent sediments collected from the Nerepis River and Swan Creek Lake respectively. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration, calculated from the blank subtracted isomer and congener concentrations, is also provided. A summary of the ESA sediment data included in the risk assessment is provided in Table 2-1.

2.4.5 Data Available for Surface Water

Surface water data are available for SA 6, SA 9 and SA 10. Summaries of the ESA surface water data for SA 6, SA 9 and SA 10 are provided in Table 14 through Table 16 in Appendix A. These represent surface water samples collected from ponds and puddles in SA 6 (ESA, 2006b) and from surface waters in the Nerepis River (SA 9) and Swan Creek Lake (SA 10) respectively. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration, calculated from the blank subtracted isomer and congener concentrations, is also provided. A summary of the ESA surface water data included in the risk assessment is provided in Table 2-2.

2.4.6 Data Available for Vegetation

Vegetation data is available for SA 1, SA 2 and SA 8. Summaries of the ESA vegetation data for SA 1, SA 2 and SA 8 are provided in Table 17 in Appendix A. These represent leaf, root and stem samples collected from all three locations. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration is also provided. A summary of the ESA vegetation data included in the risk assessment is provided in Table 2-3.

2.4.7 Data Available for Background Locations.

Soil, sediment, surface water and vegetation samples were collected from three background locations on CFB Gagetown. Summaries of the soil, sediment, surface water and vegetation data are provided in Table 18, Table 19, Table 20 and Table 21 respectively in Appendix A. For PCDD/PCDFs, the raw analytical concentrations and the blank subtracted concentrations are provided for each of the 17 PCDD and PCDF isomers and congeners. The PCDD/PCDF TEQ concentration, calculated from the blank subtracted isomer and congener concentrations, is also provided.

2.4.8 Adequacy of the Data for Completing the Risk Assessment

The data were collected as part of the ESA. This task was designed to provide data that was suitable as inputs to a human health risk assessment. The design and implementation of ESA was subject to extensive review prior to and during the implementation of the sampling program. The process used

in the ESA was deemed acceptable by the reviewers of that work. As part of the risk assessment, the Dillon Team reviewed the data to confirm its adequacy for inclusion in a human health risk assessment. The data was considered to be adequate to meet the objectives of the risk assessment as outlined in the Scope of Work.

3.0 Problem Formulation

3.1 Identification of Chemicals of Concern

The objective of the chemical screening process is to determine which chemicals are present in the environment at levels that may pose a potential hazard or risk to human health or the environment. The identification of chemicals of concern is based on a comparison of chemical concentrations and applicable screening guidelines. Guidelines have been established for several environmental media including soil, groundwater, surface water and ambient air. These guidelines are established using very conservative assumptions that over estimate exposures. As a result the guidelines represent chemical concentrations that do not pose a hazard or risk to human health or the environment. Chemicals that are present at concentrations that are lower than their respective guideline concentration are not considered to pose a hazard or risk to humans or the environment. If the concentration of a chemical exceeds the guideline value, it does not mean that the chemical poses a hazard or risk to humans or the environment. A case in which the amount of a chemical in the environment exceeds a guideline is an indication that additional work must be undertaken to determine if site-specific exposures to chemicals pose a potential hazard or risk. This additional work is usually undertaken as a risk assessment. Thus, chemicals that are present at concentrations that exceed their respective guidelines are identified as chemicals of concern and are carried through to a quantitative risk assessment.

Guidelines have been established by regulatory agencies such as the Canadian Council of Ministers of the Environment (CCME), Health Canada, the Ontario Ministry of the Environment, and the U.S. Environmental Protection Agency. It is important to note that most agencies develop guidelines that are based on human health and ecological effects. Where both values are available, the lower of the two values is selected as the generic or common guideline value. This approach provides protection for both human and ecological receptors. Because the focus of the risk assessment is human health, the screening guidelines selected from the various agencies are those that are based on the protection of human health. The CCME was used as the primary source of guidelines (CCME, 2004). When guidelines were not available from either the CCME, screening guidelines from the Ontario Ministry of the Environment (MOE) *Guideline for Use at Contaminated Sites in Ontario* (MOE, 2004) were used. If human health based guidelines were not available from these Canadian sources, the US EPA Region III *Risk Based Concentration Tables* (USEPA, 2004) was used as an additional source of human health based screening guideline values. A summary of the screening guidelines used in the human health risk assessment is provided in Appendix B.

The chemical screening process to identify the chemicals of concern (COCs) for the human health risk assessment has been based on information provided as part of Fact Finding Task 2B, Stage 2 (ESA 2006a) and Stage 3 (ESA, 2006b). The information provided in the ESA report and the associated databases have been used to screen for COCs. It should be noted that the primary focus of the ESA was the evaluation of herbicide use on CFB Gagetown. As a result, chemical analysis of soil, sediment, surface water, groundwater and vegetation focused on herbicide and herbicide-related chemicals that may have been used on the base. Information on other chemical constituents was outside of the scope of the ESA and analyses for non-herbicide related constituents were not provided in the ESA and have not been considered in the HHRA.

The screening tables used to identify the chemicals of concern in soil and sediment, groundwater and surface water are provided in Table 3-1 through Table 3-17. The data compiled from the information provided in the ESA are grouped under the various analytical packages used in the ESA. This approach to presenting the data was used to facilitate comparison and validation of the data between the ESA and the HHRA. The data presented in Table 3-1 through Table 3-17 only list those chemicals for which the ESA reported analysis results. Chemicals that are listed in the ESA but for which analyses have not been reported have not been included in the screening tables. The following information is provided in the screening tables:

- Chemical Name (PCDD/PCDF samples are listed as Package B and are identified as TEQ);
- Frequency of detection (number of detection per number of samples submitted for analysis);
- Minimum detected concentration;
- Maximum detected concentration;
- Sample with maximum detected concentration (provides ESA sample number);
- Minimum detection limit;
- Maximum detection limit;
- Screening values;
- Retained for Risk Evaluation (indicates which chemicals exceed screening values); and
- Rationale for selection for or exclusion from the HHRA.

For soil and sediment samples, soil screening values for residential and industrial land-uses have been provided in the screening tables. Potable water screening values have been used to identify chemicals of concern in groundwater and surface water.

3.1.1 Identification of Chemicals of Concern in Soil

The screening tables to identify the chemicals of concern in soil in SA 1 through SA 11 are provided in Table 3-1 through Table 3-11 respectively. The data for SA 11 represents the combined data sets from SA 1 through SA 10. The results of the screening show that for SA 1 through SA 5 and SA 7 through SA 10, the maximum detected concentrations of all chemicals except PCDD/PCDF (TEQ) are below their respective residential land-use screening values. As noted in Appendix B, screening values are not available for several of the chemicals listed. However, none of these chemicals were reported as being detected in any of the samples collected from the various SAs considered in the HHRA. Therefore, these chemicals have not been identified as chemicals of concern and have not been evaluated in the HHRA.

At SA 6 the maximum detected concentration of 1,2,3,4-tetrachlorobenzene exceeded the surrogate screening value of 4.7 µg/g for residential land-use in two of 36 samples (Table 3-6). However, SA 6 defines the Static Range Impact Area (Figure 2-3) and is an area where access is strictly controlled and members of the general public would not be expected to have access to this area of the base. The frequency with which people could be expected to be present in SA 6 is significantly less than the frequency with which they could be expected to be on a residential property. Therefore, the application of a residential screening criterion to SA 6 is inappropriate. The frequency with which soldiers could be expected to frequent SA 6 is better reflected by an commercial or industrial land-use. Therefore, the industrial land-use criterion for 1,2,4,5-tetrachlorobenzene of 61 µg/g has been used as a surrogate screening criterion for 1,2,3,4-tetrachlorobenzene. The maximum detected concentration of 1,2,3,4-tetrachlorobenzene in SA 6

was 37 µg/g. This is below the industrial land-use screening criterion. Therefore, 1,2,3,4-tetrachlorobenzene has not been identified as a chemical of concern at SA 6. It should also be noted that the maximum detected concentration of 1,2,3,4-tetrachlorobenzene reported for SA 11 is the same sample that was listed for SA 6.

Based on the results of the chemical screening the following chemicals have been identified as chemicals of concern in soil:

- PCDD/PCDFs

A summary of the number of samples in each SA where PCDD/PCDF levels exceed the soil screening criterion is provided below.

PCDD/PCDF Exceedances in Soil

Subject Area	Number of Exceedances	Subject Area	Number of Exceedances
SA 1	1	SA 7	2
SA 2	10	SA 8	3
SA 3	3	SA 9	0
SA 4	2	SA 10	0
SA 5	1	SA 11	25
SA 6	3		

3.1.2 Identification of Chemicals of Concern in Groundwater

The screening table to identify the chemicals of concern in groundwater at Clones Bivouac is presented in Table 3-12. The results of the screening show that the maximum detected concentrations of all chemicals except PCDD/PCDF (TEQ) are below their respective groundwater (drinking water) screening values. As noted in Appendix B, screening values are not available for several of the chemicals listed. However, none of these chemicals were reported as being detected in any of the samples collected from the various SAs considered in the HHRA. Therefore, these chemicals have not been identified as chemicals of concern and have not been evaluated in the HHRA.

Based on the results of the chemical screening the following chemicals have been identified as chemicals of concern in groundwater at Clones Bivouac:

- PCDD/PCDFs

A summary of the number of samples in each SA where PCDD/PCDF levels exceed the groundwater screening criterion is provided below.

PCDD/PCDF Exceedances in Groundwater

Subject Area	Number of Exceedances
SA 4	14
SA 11	14

3.1.3 Identification of Chemicals of Concern in Sediment

The mechanisms that govern human exposure to sediments do not differ from those that govern human exposure to soil and standard risk assessment practice assesses human exposures to sediments in the same manner as human exposures to soil. Therefore the soil screening criteria have been used to screen for chemicals of concern in sediments. The screening tables to identify the chemicals of concern in sediment in SA 9 and SA 10 are provided in Table 3-13 and Table 3-14 respectively. The results of the screening show that for SA 9 and SA 10 the maximum detected concentrations of all chemicals except PCDD/PCDF (TEQ) are below their respective residential land-use screening values. As noted in Appendix B, screening values are not available for several of the chemicals listed. However, none of these chemicals were reported as being detected in any of the samples collected from the various SAs considered in the HHRA. Therefore, these chemicals have not been identified as chemicals of concern and have not been evaluated in the HHRA.

Based on the results of the chemical screening the following chemicals have been identified as chemicals of concern in sediments:

- PCDD/PCDFs

A summary of the number of samples in each SA where PCDD/PCDF levels exceed the soil screening criterion is provided below.

PCDD/PCDF Exceedances in Sediment

Subject Area	Number of Exceedances
SA 9	0
SA 10	4
SA 11	4

3.1.4 Identification of Chemicals of Concern in Surface Water

The screening tables to identify the chemicals of concern in surface water in the Static Range Impact Area, the Nerepis River and Swan Creek Lake are presented n Table 3-15, Table 3-16 and Table 3-17 respectively. The results of the screening show that the maximum detected concentrations of all chemicals except PCDD/PCDF (TEQ) are below their respective groundwater (drinking water) screening values. As noted in Appendix B, screening values are not available for several of the chemicals listed. However, none of these chemicals were reported as being detected in any of the samples collected from the various SAs considered in the HHRA. Therefore, these chemicals have not been identified as chemicals of concern and have not been evaluated in the HHRA.

Based on the results of the chemical screening the following chemicals have been identified as chemicals of concern in surface water:

- PCDD/PCDFs

A summary of the number of samples in each SA where PCDD/PCDF levels exceed the groundwater screening criterion is provided below.

PCDD/PCDF Exceedances in Surface Water

Subject Area	Number of Exceedances
SA 6	3
SA 9	11
SA 10	7
SA 11	21

3.1.5 Identification of Chemicals of Concern in Vegetation.

Screening guidelines have not been established for vegetation samples. For the purposes of this HHRA, chemicals identified as a concern in one or more of the other environmental media have been included as chemicals of concern for vegetation.

3.2 Identification of Potential Receptors

Although the Base is primarily used for military operations and training, portions of the base are also used for non-military purposes such as timber harvesting. In addition, residents from surrounding communities are able to use areas of the base for recreational activities such as fishing, hunting, hiking and the collection of blueberries. Although the public is able to make use of base lands, access is controlled by base personnel and is limited to areas of the base that are not in active use. In order to properly assess potential human exposures to chemicals in soil, surface water, groundwater and/or vegetation within a particular SA, it is necessary to understand who can reasonably be expected to be present within each SA. The following sections provide a summary of the potential people who could reasonably be expected to be present in each of the SAs established for the HHRA. The identification of groups of people (*ie* receptors) and estimates of the length of time that each could be expected to spend in each of the SAs has been based on information provided to the risk assessment team by personnel at CFB Gagetown and on information collected during the preliminary site visit conducted by the risk assessment team. The relevant receptors for each of the subject areas are provided in the following sections.

The focus of this HHRA is the assessment of current exposures to herbicide and herbicide related compounds on CFB Gagetown. It does not address exposures that could have occurred as a result the historic application of herbicides and herbicide related compounds on CFB Gagetown. The chemical screening identified PCDD/PCDF as the only chemical of concern in all environmental media examined in the ESA. PCDD/PCDFs are tightly bound to environmental media such as soil or sediment and are not generally mobile in the environment. Therefore, the potential for off-site migration of the chemicals of concern is not considered to be an issue for the current exposures being considered in this assessment. The potential for members of the local community to be exposed to PCDD/PCDFs is addressed through the assessment of potential exposures experienced by members of the general population while on the Base.

3.2.1 Receptor Identification for SA 1 – 1966 Test Area

Subject Area 1 is used for training purposes. Therefore, soldiers were identified as potential receptors for SA 1. In addition, members of the local community may use the area for recreational activities. Therefore, it is reasonable to expect that local residents could spend some time within SA1. A summary of the identified receptors and the length of time that each has been assumed to be present on SA 1 is provided below.

SA 1 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	8	2
Recreational Users	8	70

Based on information provided by Base personnel, SA 1 is not used for training purposes on a regular basis and its use varies from year to year. In addition, the area is densely wooded and does not lend itself to the typical training activities that occur in the General Manoeuvres Area. Soldiers can be expected to pass through the area during day-training exercises on an infrequent basis and would not necessarily be in the area from year to year. In addition, the area is not used as a bivouac and therefore, soldiers would not camp in the area. For the purposes of this risk assessment it has been assumed that soldiers would be present within SA 1 for a period of 8 hours per day 2 days per year. This is felt to provide a conservative estimate of the potential exposure duration for soldiers engaged in training activities at CFB Gagetown.

The frequency with which members of the local community make use of SA 1 is unclear. However, camping is not allowed in the area. Therefore, community members would only be expected to be in the area during daylight hours or 8 hours per day. The primary concern for exposure on SA 1 is contact with chemicals in the soil. During the winter when the ground is frozen and/or covered with snow, community members on the site would have no access to the soil and exposures would not occur. Exposures to chemicals in the soil could be expected to occur during the frost-free period of the year. For the purposes of this assessment it has been assumed that the ground would be free of frost and/or snow cover from mid-March through mid-November (35 weeks per year). For the purposes of this assessment it has been conservatively assumed that community members could spend up to two days per week 35 weeks per year (70 days per year) engaged in recreational activities on SA 1. This is expected to be a conservative estimate that will over-estimate potential exposures for SA 1.

Although hunters could also be expected to spend time in SA 1, they are expected to move around to a greater extent than other recreational receptors and would also be expected to spend time in other SAs. Subject Area 11 was developed specifically to address the differences in exposure potentials that exist between hunters and other recreational receptors. Therefore, activity patterns used to assess potential exposures for hunters are discussed in Section 3.2.11.

3.2.2 Receptor Identification for SA 2 – Rippon Road

Rippon Road is used for training purposes. In addition, it serves as a communications corridor for the base. Soldiers engaged in training manoeuvres and soldiers who are involved in the

maintenance of the communications line would be expected to be present on Rippon Road (SA 2). Although Rippon Road is open to hunters, it is restricted to the general public. Therefore, community members would not be expected to be present in SA 2. The areas adjacent to Rippon Road have recently been used for timber harvesting (in 2004) and there is a potential for similar activities in the future. Therefore, timber harvesters have been identified as potential receptors for SA 2. A summary of the identified receptors and the length of time that each has been assumed to be present on SA 2 is provided below.

SA 2 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	8	12
Timber Harvester	8	30

The estimate of the length of time that soldiers could be on SA 2 has been based on information provided by Base personnel. The area is not used as a bivouac and soldiers would typically be in the area for a six-hour period approximately 12 days per year. Linemen inspecting, maintaining and/or repairing communications cables are typically on-site for 1 to 2 days every other month over the course of a year. For the purposes of this assessment, it has been assumed that soldiers would spend up to 12 days per year in the Rippon Road area (SA 2).

Assumptions related to the length of time a timber harvester could be expected to spend on-site are based on information provided by contractors engaged in previous timber harvesting events in the area.

3.2.3 Receptor Identification for SA 3 – Murphy Bivouac

The Murphy Bivouac (SA 3) is used as housing facilities for several training exercises over the course of the year. It is also used as a youth camp for children aged 10 –12 for a 5-day period during the summer. The Murphy Bivouac site serves as the access point for several residences located on Murphy Lake. A summary of the identified receptors and the length of time that each has been assumed to be present on SA 3 is provided below.

SA 3 Receptors		Time Spent On-site	
		Hrs/day	Days/year
Soldiers	Field Artillery School	8	7
	Armour School	8	64
	Military Engineering	8	25
Youth Campers	Children ages 10- 12	24	5
Recreational Users	All ages	1	30

Murphy Bivouac is used as accommodation for military training three times over the course of a year, for periods that last between 7 days (Field Artillery School) and 64 days (Armour School). Based on information provided by Base personnel, Murphy Bivouac is used for sleeping and eating meals for a period of 8 hours per day. The remainder of the day is spent off the bivouac site. Thus, it has been assumed that a soldier would spend 8 hours per day on the Murphy Bivouac site. The

longest duration of occupancy (64 days) has been used to assess potential exposures for soldiers using Murphy Bivouac.

Youth campers are assumed to spend 5-days per year on the Murphy Bivouac site. For the purposes of this assessment it has been assumed that youth campers would spend a full 24 hours per day on the bivouac site while at camp. People who reside in the summer cottages on Murphy Lake would only be expected to be present on Murphy Bivouac while going to or leaving the cottages. Thus, for these receptors, exposures are expected to occur twice per week during the summer months as people access and leave the cottage sites.

3.2.4 Receptor Identification for SA 4 – Clones Bivouac

The Clones Bivouac (SA 4) is used for several training exercises over the course of the year for periods that range between 9 days (Army Reserves) and 57 days (Infantry School). A summary of the identified receptors and the length of time that each has been assumed to be present on SA 4 is provided below. Base Personnel provided the duration of occupancy information for each training group. The longest duration of occupancy (57 days) has been used to assess potential exposures for soldiers using Clones Bivouac.

SA 4 Receptors		Time Spent On-site	
		Hrs/day	Days/year
Soldiers	Air Defence Regiment	8	23
	Infantry School	8	57
	Army Reserves	8	9

3.2.5 Receptor Identification for SA 5- Base Administration and Parks

Subject Area 5 includes both the Base Administration complex and recreational facilities on the base and parks and green spaces in the housing complex to the west of the Administration complex. Soldiers and other base personnel have the potential to come into contact with chemicals in the soil while on the base during the frost and snow-free period of the year (35 weeks). For the purpose of the human health risk assessment it has been assumed that soldiers and other base personnel could come into contact with soil on SA 5 175 days per year (5 days per week for 35 weeks per year).

People who live in the community adjacent to the base also have the potential to come into contact with soil, both on the Administration complex and in the parks and green spaces within SA 5. For the purposes of this assessment it has been assumed that young children could spend every day during the summer (9 weeks) and two days per week during the school year when the ground is free of frost and/or snow cover (26 weeks per year (35 weeks – 9 weeks)), for a total of 115 days per year. While it is possible that young children could spend more than two days per week in local parks during the school year, particularly during the late spring and early fall, it is unlikely that they would do this on a regular basis in the early spring and late fall when the weather is poorer. In addition, the assumption of 115 days per year assumes that a child will spend every day during the summer months in local parks. This is a conservative assumption that is likely to over estimate the length of time a child would spend in this area during the summer. Thus, the assumption that a child

could spend 115 days per year in the parks and recreational facilities on the Base and in the surrounding community is felt to be conservative.

The following occupancy assumptions have been used to estimate potential exposures for soldiers and recreational users of SA 5.

SA 5 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	8	175
Recreational Users	4	115

3.2.6 Receptor Identification for SA 6 – Static Range Impact Area

Access to SA 6 is strictly controlled and is limited to soldiers involved in range training exercises. The length of time a soldier could spend in SA 6 is unclear. The area is not used as a bivouac and therefore exposures would be limited to approximately 8 hours per day on the days when soldiers are present in SA 6. For the purposes of the human health risk assessment, it has been assumed that soldiers could spend up to 30 days per year on SA 6.

SA 6 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	8	30

3.2.7 Receptor Identification for SA 7 – General Manoeuvres Area

The General Manoeuvres area is used for training exercises throughout the year. The length of time that soldiers could spend in the area depends on the types of exercises being conducted. For the purposes of the human health risk assessment, it has been assumed that the longest period a soldier would spend in SA 7 in a year would be equivalent to the longest time spent at the Clones Bivouac (64 days per year). The information provided by base personnel indicated that soldiers could spend up to eight hours per day at the Clones Bivouac with the remaining 16 hours per day being spent in training exercises. Therefore, it has been assumed that soldiers could spend up to 16 hours per day in SA 7 engaged in training activities.

SA 7 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	16	64

3.2.8 Receptor Identification for SA 8 – Base Perimeter and Fire Breaks

The areas that form the perimeter of the base and the firebreak areas (SA 8) are used for training purposes. Therefore, soldiers were identified as potential receptors for SA 8. In addition, members of the local community use the area for recreational activities. Therefore, it is reasonable to expect

that local residents could spend some time within SA 8. A summary of the identified receptors and the length of time that each has been assumed to be present on SA 8 is provided below.

SA 8 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Soldiers	16	2
Recreational Users	8	70

Although SA 8 is used for training, it is not used as often as the General Manoeuvres Area. From information provided by Base personnel, the frequency of use of this area varies from year to year. Although this area does contain bivouac areas, their frequency of use is unclear. For the purposes of this risk assessment it has been assumed that soldiers would be present within SA 8 for a period of 8 hours per day 2 days per year.

The frequency with which members of the local community make use of SA 8 is unclear. However, camping is not allowed in the area. Therefore, community members would only be expected to be in the area during daylight hours or 8 hours per day. The primary concern for exposure on SA 8 is contact with chemicals in the soil. During the winter when the ground is frozen and/or covered with snow, community members on the site would have no access to the soil and exposures would not occur. Exposures to chemicals in the soil could be expected to occur during the frost-free period of the year. For the purposes of this assessment it has been assumed that the ground would be free of frost and/or snow cover from mid-March through mid-November (35 weeks per year). For the purposes of this assessment it has been conservatively assumed that community members could spend up to two days per week 35 weeks per year (70 days per year) engaged in recreational activities on SA 8. This is expected to be a conservative estimate that will over-estimate potential exposures for SA 8.

Although hunters could also be expected to spend time in SA 8, they are expected to move around to a greater extent than other recreational receptors and would also be expected to spend time in other SAs. Subject Area 11 was developed specifically to address the differences in exposure potentials that exist between hunters and other recreational receptors. Therefore, activity patterns used to assess potential exposures for hunter are discussed in Section 3.3.11.

3.2.9 Receptor Identification for SA 9 – Nerepis River

The Nerepis River (SA 9) represents one of two areas where there can be considered to be reasonable access for fishing. The assessment of potential exposures in this area has focused on potential exposures experienced by anglers that fish in the Nerepis River. The fishing season on the Nerepis River runs for approximately 18 weeks between May 15th and September 15th. For the purposes of this assessment it has been assumed that anglers would regularly fish in the Nerepis River three days per week over the 18-week period. It has also been assumed that anglers could spend an additional 10 to 15 days during the summer months fishing in the river. Therefore, it has been assumed that anglers could spend up to 70 days per year fishing in the Nerepis River (SA 9). Camping is not allowed in SA 9. Therefore, anglers would not be expected to spend more than 8 hours per day fishing in the Nerepis River in SA 9.

SA 9 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Anglers	8	70

Although soldiers and hunters could also be expected to spend some time per year in SA 9, they would not be expected to be engaged in fishing activities. For soldiers and hunters, exposures to chemicals in SA 9 would be limited to exposures to soil. The maximum PCDD/PCDF concentration reported in SA 9 was 0.671 pg TEQ/g soil (Table 3-9), which is below the screening criterion of 4 pg TEQ/g. Therefore, PCDD/PCDFs exposures are addressed for these receptors in other SAs considered in the risk assessments (SA 1 through SA 8 for soldiers and SA 11 for hunters). Therefore, these receptors have not been incorporated into quantitative evaluation of SA 9.

3.2.10 Receptor Identification for SA 10 – Swan Creek Lake

The Swan Creek Lake (SA 10) represents one of two areas where there can be considered to be reasonable access for fishing. The assessment of potential exposures in this area has focused on potential exposures experienced by anglers that fish in Swan Creek Lake. The fishing season on Swan Creek Lake runs for approximately 18 weeks between May 15th and September 15th. For the purposes of this assessment it has been assumed that anglers would regularly fish in Swan Creek Lake three days per week over the 18-week period. It has also been assumed that anglers could spend an additional 10 to 15 days during the summer months fishing in the lake. Therefore, it has been assumed that anglers could spend up to 70 days per year fishing in Swan Creek Lake (SA 10). Camping is not allowed in SA 9. Therefore, anglers would not be expected to spend more than 8 hours per day fishing in Swan Creek Lake in SA 10.

SA 10 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Anglers	8	70

Although soldiers and hunters could also be expected to spend some time per year in SA 10, they would not be expected to be engaged in fishing activities. For soldiers and hunters, exposures to chemicals in SA 10 would be limited to exposures to soil. These exposures are addressed for these receptors in other SAs considered in the risk assessments (SA 1 through SA 8 for soldiers and SA 11 for hunters). Therefore, these receptors have not been incorporated into quantitative evaluation of SA 10.

3.2.11 Receptor Identification for SA 11 – CFB Gagetown

As noted in Section 3.2.11 SA 11 was defined to address the potential exposures that could be experienced by hunters across the base. The length of time that hunters could be expected to spend on SA 11 has been determined as the combined durations of the deer and moose hunting seasons on the base. Information provided by base personnel indicates that moose hunting on the base is limited to a 3-day period every year. Provincially the deer hunting season runs between October 3rd and November 19th (47 days). Information provided by Base personnel indicates that on the base the

season is restricted to a 27-day period that over laps the moose hunting season. Based on this information it has been assumed that hunters would not be on-site for more than 27 days per year.

SA 11 Receptors	Time Spent On-site	
	Hrs/day	Days/year
Hunters	8	27

3.3 Site Conceptual Model and Problem Formulation Summary

In evaluating possible exposures to the chemicals of concern in a human health risk assessment, only pathways that are considered to be potentially complete are considered. Pathways that are considered to be incomplete are not included. An incomplete exposure pathway is one whereby there is no mechanism by which a receptor could come into contact with the chemical in a given environmental media. For example, if a chemical that is not volatile, is present in subsurface soil (greater than 2 meters below ground) people on the surface could not come into contact with the chemical and potential exposures to that chemical in the subsurface soil would be considered as an incomplete exposure pathway and would not be included in the human health risk assessment. The rationales to support the inclusion of potentially complete exposure pathways are provided below.

- Direct Contact with Soil.

  Direct contact with soil is possible for soldiers and recreational users of CFB Gagetown who may be in any of the SAs considered in the HHRA. Therefore, the following exposure pathways are considered to be potentially complete for soldiers, recreational users, timber harvesters, angler and hunter:

  - Inadvertent ingestion of soil;
  - Dermal contact with soil;
  - Inhalation of soil particulate;

- Direct Contact with Sediment and Surface Water

  Direct contact exposures to sediments and surface water are considered to be potentially complete for anglers who may be present in SA 9 and/or SA 10. Therefore, the following pathways are considered to be potentially complete for anglers:

  - Inadvertent ingestion of sediment;
  - Dermal contact with sediment;
  - Inadvertent ingestion of surface water;
  - Dermal contact with surface water;

- Direct Contact with Groundwater

  Direct contact exposures to groundwater are considered to be potentially complete exposure pathways for soldiers in SA 4 where groundwater is used for showering. Therefore, the following pathways are considered to be potentially complete for SA 4.

  - Inadvertent ingestion of groundwater;
  - Dermal contact with groundwater.

- Indirect Exposures

  Indirect exposures through the consumption of fish, game and berries are considered to be potentially complete exposure pathways for angler, hunters and recreational respectively. Therefore the following indirect exposure pathways are considered to be potentially complete:

  - Consumption of fish (complete for anglers in SA 9 and/or SA 10);
  - Consumption of game (moose or deer, complete for hunters in SA 11);
  - Consumption of berries (complete for recreational users SA 1 and SA 8)

A summary of the potentially complete exposure pathways for the relevant receptors in each SA is provided below. The *Site Conceptual Models* (SCM) for each SA are provided in Figures 3-1 through Figure 3-11.

The focus of the HHRA is the evaluation of potential exposures to herbicides and herbicide-related chemicals present in soil, sediment, surface water and groundwater as a result of the historical use of these chemicals at CFB Gagetown. The chemical screening process identified PCDD/PCDFs as the contaminants of concern for the HHRA. These compounds are not volatile and do not generally considered to be mobile in the environment. Thus, the the inhalation of chemical vapours, or the migration of chemicals from environmental media on the Base to the surrounding communities do not represent potentially complete exposure pathways and have not been included in the assessment. In addition, indirect exposure to PCDD/PCDF through the consumption of backyard garden produce does not represent a potentially complete exposure pathway and has not been included in the assessment.

Summary of Potentially Complete Exposure Pathways

Subject Area	Receptors	Exposure Pathways											
		Soil			Ground Water		Surface Water		Sediment		Biota Consumption		
		Inadvertent Ingestion	Dermal Contact	Particulate Inhalation	Inadvertent Ingestion	Dermal Contact	Inadvertent Ingestion	Dermal Contact	Inadvertent Ingestion	Dermal Contact	Game	Fish	Berries
SA 1	Soldiers	X	X	X									
	Recreational Users	X	X	X									X
SA 2	Soldiers	X	X	X									
	Timber Harvesters	X	X	X									
SA 3	Soldiers	X	X	X									
	Youths	X	X	X									
	Recreational Users	X	X	X									
SA 4	Soldiers	X	X	X	X	X							
SA 5	Soldiers	X	X	X									
	Recreational Users	X	X	X									
SA 6	Soldiers	X	X	X									
SA 7	Soldiers	X	X	X									
SA 8	Soldiers	X	X	X									
	Recreational Users	X	X	X									X
SA 9	Anglers	X	X	X			X	X	X	X		X	
SA 10	Anglers	X	X	X			X	X	X	X		X	
SA 11	Hunters	X	X	X							X		

4.0 Exposure Assessment

4.1 Calculation of Exposure Point Concentrations

Statistical analysis of the soil, sediment, surface water and groundwater data was undertaken to identify the *Exposure Point Concentrations* (EPCs) to be used as concentration inputs into the exposure assessment calculations. Individual data sets were tested for several potential distributions including; normality, log-normality, gamma and non-parametric distributions using ProUCL® (Version 3) software available from the US EPA. ProUCL tests datasets for several potential distributions including; normality; log-normality; and a gamma distributions, and provides recommendations regarding the best fit for the data (ProULC, 2004). A detailed summary of ProUCL and the various statistical approaches it applies to the calculation of UCL can be found in the ProUCL User Guidance Manual (ProUCL, 2004) available through the US EPA. Summaries of the recommended 95% UCLs for soil, groundwater, sediment, surface water and vegetation are presented in Table 4-1 through Table 4-5. The recommended 95% UCLs were selected as the EPCs for input into the exposure assessment calculations. In cases where the recommended 95% UCL was greater than the maximum reported value, the maximum reported value was selected as the EPC. The detailed statistical analyses for outlining the recommended 95% UCL for each medium for each SA are provided in Appendix C.

The concentrations of PCDD/PCDFs in fish, game and berries were developed using a US EPA bioaccumulation food chain model that estimated the accumulation of PCDD/PCDF from soil, sediment and surface water into fish, game and vegetation (see Appendix F). The EPCs for berries, fish and game are presented in Table 4-6 through Table 4-8.

4.2 Physical and Physiological Factors

Physical and physiological factors such as body weight and inhalation rate and behavioural factors such as the consumption of soil all affect the potential daily exposures experienced by each of the receptors considered in the HHRA. Physical and physiological parameters are available from a number of sources including the Health Canada, and the US EPA. Receptor parameters recommended by Health Canada have been used as the primary source of values for the HHRA. Where these parameters were not available from Health Canada, values from the US EPA were used. A summary of the receptor parameters used to estimate exposures for each of the receptors considered in the HHRA is provided in Table 4-9. A discussion of the selection of the receptor parameters used in the HHRA is provided in Appendix D.

4.3 Receptor Activity Patterns

The level of exposure that a person could experience on CFB Gagetown depends on the amount of time a person spends on Base lands while engaged in military training or recreational activities. The length of time a person could be expected to be present on Base lands is determined by the activity patterns that are assumed for each of the identified receptor groups. Health Canada provides generic exposure duration and exposure frequency assumptions for several land-use categories including; agricultural, residential, commercial and industrial sites (Health Canada, 2004). However, this

guidance does not adequately describe the amount of time that people from the various receptor groups could spend on Base lands. Therefore, it was necessary to develop exposure frequency and duration assumptions for the various receptor groups considered in the HHRA. The estimates of time spent on site for the various receptor groups have been based on information provided by personnel from CFB Gagetown and on information collected during a visit to the Base in April 2006. A summary of the exposure frequency and duration estimates for each receptor group for each of the SAs considered in the HHRA is provided below. The information used to develop these estimates and the rationales to support them are provided in Section 3.

Summary of Receptor Group Activity Patterns

SA	Soldier		Timber Harvesters		Recreational Users		Hunters		Anglers	
	Hrs/Day	Days/Year	Hrs/Day	Days/Year	Hrs/Day	Days/Year	Hrs/Day	Days/Year	Hrs/Day	Days/Year
SA 1	8	2			8	70				
SA 2	6	12	8	30						
SA 3	8	64			1[1]	30				
					24[2]	5				
SA 4	8	57								
SA 5	8	175			4	115				
SA 6	8	30								
SA 7	16	64								
SA 8	16	2			8	70				
SA 9									8	70
SA 10									8	70
SA 11							8	27		

1: Recreational users for SA 3 include residents using the Base to access local cottages
2: Recreational users at Murphy Bivouac represent youth campers (ages 10 –12)

4.4 Inadvertent Ingestion of Soil and/or Sediment

Exposure to chemicals in soil depends on the concentration of the chemicals in the soil, the amount of soil ingested on a daily basis and the number of days per year that exposures are likely to occur. The estimated daily intake of chemicals through the incidental ingestions of soil is calculated as shown in Equation 4-1. For the purposes of this assessment it has conservatively assumed that on the days when people are on the one of the areas of interest, all soil ingested on that day comes from that area. The mechanisms that govern human exposure to sediments do not differ from those that govern human exposure to soil and standard risk assessment practice assesses human exposures to sediments in the same manner as human exposures to soil.

Eq 4-1:

$$EDI_{si} = \frac{C_s \times IR_s \times CF1 \times AF_{GIT} \times ET_1}{BW}$$

Where:

Parameter	Description	Units
EDI_{si}	= Estimated daily intake from incidental ingestion of soil/sediment	pg/kg-day
C_s	= Concentration of chemical in soil/sediment	pg/g
IR_s	= Daily soil/sediment ingestion rate	mg/day
CF1	= g to kg conversion factor	0.001 g/mg
AF_{GIT}	= Bioaccessibility factor	Unitless
ET_1	= Exposure term (days of exposure/days per year)	Days/365 days (unitless)
BW	= Receptor body weight	kg

A sample calculation of exposure through the inadvertent ingestion of soil is provided below. The factors and calculations used to estimate exposures through the inadvertent ingestion of soil and sediment are provided in Table 4-10 and Table 4-11 respectively. Detailed calculations of the estimated exposure to PCDD/PCDF through the inadvertent ingestion of soil and/or sediment are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-12.

Sample Exposure Calculation for the Inadvertent Ingestion of Soil/Sediment: Soldier SA 1

Receptor	Concentration in Soil	Soil Ingestion Rate	CF1	AFgit	ET1	Body Weight	Estimated Daily Intake
	pg/g	mg/day	g/mg	Unitless	Unitless	kg	pg/kg-day
Soldier: SA 1	1.28	100	0.001	1	0.01	70.7	9.9E-06

4.5 Dermal Contact with Soil and/or Sediment

The uptake of chemicals from soil or sediment through the skin depends on the concentration of the chemical in the soil/sediment, the surface area of skin exposed on a daily basis, the amount of soil/sediment that adheres to the skin and the permeability of the skin to the chemical. The estimation of the daily exposures to chemicals from dermal contact with soil/sediment is calculated as shown in Equation 4-2. For the purposes of this assessment it has been conservatively assumed that on the days when a person is in one of the areas of interest, all dermal contact with soil/sediment is derived from the soil/sediment on the site.

Eq 4-2:
$$EDI_{dc} = \frac{C_s \times SA \times SL \times CF1 \times AF_{skin} \times ET1}{BW}$$

Where:

Parameter	Description	Units
EDI_{dc}	= Estimated daily intake from dermal contact with soil/sediment	mg/kg-day
C_s	= Chemical concentration in soil/sediment	mg/kg
SA	= Surface area of exposed skin	cm^2/day
SL	= Soil/Sediment loading factor	g/cm^2
AF_{skin}	= Dermal absorption factor	unitless
CF1	= kg to g conversion factor	0.001
ET1	= Exposure term (days of exposure/days per year)	unitless
BW	= Receptor body weight	kg

The soil/sediment loading factor represents the amount of sediment that adheres to the skin over a given surface area. The calculated sediment loading factors used in the present assessment are provided in Table 4-9. The loading factors are based on soil adhesion to the skin. It is reasonable to expect that a greater amount of sediment could adhere to the skin given that, in general, sediment would be expected to be wetter than soil. Although a thicker layer of sediment may adhere to skin than soil, the area covered by soil and sediment can be expected to be the same. The uptake of chemicals from soil or sediment through the skin is governed by the layer of soil/sediment that is in direct contact with the skin. Chemicals in soil/sediment that are not in direct contact with the skin do not contribute to dermal uptake. Therefore, using soil loading factors to estimate uptake from sediments will provide reasonable estimates of potential exposure.

The uptake of chemicals through the skin is chemical-specific. The dermal absorption factor of 0.03, recommended by the US EPA, has been used to estimate dermal exposures to PCDDs/PCDFs (USEPA, 2001).

A sample calculation of exposure through the dermal contact with soil is provided below. The factors and calculations used to estimate exposures through dermal contact with soil and sediment are provided in Table 4-13 and Table 4-14 respectively. Detailed calculations of the estimated exposure to PCDD/PCDF through dermal contact with of soil and/or sediment are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-15.

Sample Exposure Calculation for Dermal Contact with Soil/Sediment: Soldier SA 1

Receptor	Concentration in Soil/Sediment (mg/kg)	Skin Surface Area Exposed (cm^2)	Soil/Sediment Loading to Exposed Skin (g/cm^2/day)	Conversion Factor (kg/g)	Dermal Absorption Factor (unitless)	Exposure Term (d/y / d/y)	Body Weight (kg)	Estimated Daily Intake (mg/kg-d)
Soldier: SA 1	1.28E-06	3390	3.36E-04	0.001	0.03	0.0055	70.7	3.38E-15

4.6 Inhalation of Soil Particulates

Inhalation exposure to chemicals on re-entrained soil and dust particles depends on the concentration of the chemical bound to the soil/dust particle and on the concentration of the particles in the air column. Exposure to chemicals through the inhalation of re-entrained soil and dust particles is calculated as shown in Equation 4-3.

Eq 4-3:

$$EDI_{Inhal} = \frac{C_s \times P_{air} \times IR_a \times ET2 \times AF_{Inhal} \times ET1}{BW}$$

Where:

Parameter	Description	Units
EDI_{inhal}	= Estimated daily intake from particulate inhalation	mg/kg-day
C_s	= Chemical concentration in soil	mg/kg
P_{air}	= Particulate emission factor	kg/m^3
IR_a	= Inhalation rate	m^3/hour
ET2	= Daily exposure time	hours/day
AF_{inhal}	= Inhalation absorption factor	Unitless
ET1	= Exposure term (days of exposure/days per year)	unitless
BW	= Body weight	kg

The particulate concentration in air of 7.6×10^{-10} kg/m^3 recommended by Health Canada was used to estimate chemical concentrations in the air column (Health Canada, 2004). Inhalation absorption factors for all chemicals were assumed to be 1, representing 100% absorption. Daily inhalation rates for all receptors were based on the values recommended by Health Canada as outlined in Table 4-9.

In estimating potential exposures to chemicals on re-entrained particles, it has been assumed that the re-entrainment of soil particles will occur every day that the ground is frost-free. Because the re-

entrainment of soil and dust particles only occurs when the ground is dry, it is unlikely that wind action will suspend particles into the air during the spring and fall or during summer rain events when the ground is wet. Therefore, assuming that soil/dust re-entrainment occurs every day that the ground is frost-free will over estimate potential exposures by this route.

A sample calculation of exposure through the inhalation of soil particulate is provided below. The factors and calculations used to estimate exposures due to the inhalation of soil particulate are provided in Table 4-16. Detailed calculations of the estimated exposure to PCDD/PCDF through the inhalation of soil particulate are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-17.

Sample Exposure Calculation for Inhalation of Soil Particulate: Soldier SA 1

Receptor	Concentration in Soil/Sediment (mg/kg)	Particulate Emission Factor (kg/m^3)	Inhalation Rate (m^3/h)	Daily Exposure Time (h/d)	Inhalation Absorption Factor (unitless)	Exposure Term (d/y / d/y)	Body Weight (kg)	Estimated Daily Intake (mg/kg-d)
Soldier: SA 1	1.28E-06	7.60E-07	0.66	8	1.00	0.0055	70.7	3.97E-16

4.7 Inadvertent Ingestion of Groundwater and/or Surface Water

The inadvertent ingestion of groundwater is considered to be the amount of water that could enter the mouth while showering. The inadvertent ingestion of surface water is considered to be the amount of water that a person could swallow while swimming or wading. Exposure to chemicals as a result of the inadvertent ingestion of groundwater or surface water depends on the concentration of the chemical in the water and on the amount of water consumed while showering, swimming or wading. Exposures to chemicals through the inadvertent ingestion of groundwater or surface water are calculated as shown in Equation 4-4.

Eq 4-4:

$$EDI_W = \frac{C_w \times IR_w \times AF_{GIT} \times ET1}{BW}$$

Where:

Parameter	Description	Units
EDI_w	= Estimated daily intake from inadvertent ingestion of water	mg/kg-day
C_w	= Chemical concentration in water	mg/L
IR_w	= Inadvertent water ingestion rate	L/day
AF_{GIT}	= Gastrointestinal absorption factor	Unitless
ET1	= Exposure term (days of exposure/days per year)	unitless
BW	= Body weight	kg

A sample calculation of exposure due to the inadvertent ingestion of water while showering, swimming or wading is provided below. The factors and calculations used to estimate exposures as a result of the inadvertent ingestion of groundwater and surface water are provided in Table 4-18 and Table 4-19. Detailed calculations of the estimated exposure to PCDD/PCDF through the inadvertent ingestion of water are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-20.

Sample Exposure Calculation for the Inadvertent Ingestion of Water: Soldier SA 4

Receptor	Concentration in Ground Water (mg/L)	Ground Water Ingestion Rate (L/d)	Gastrointestinal Absorption Factor (unitless)	Exposure Term (d/y / d/y)	Body Weight (kg)	Estimated Daily Intake (mg/kg-d)
Soldier: SA 4	9.06E-10	0.05	1	0.16	70.7	1.00E-13

4.8 Dermal Contact with Groundwater and/or Surface Water

Exposures to chemicals as a result of dermal contact with water depends on the concentration of the chemical in the water and the area of exposed skin that comes into contact with the water and the length of time a person spends in contact with the water. Exposures to chemicals through dermal contact with water are calculated as shown in Equation 4-5.

Eq 4-5:

$$EDI_w = \frac{C_w \times SA \times CF2 \times K_p \times ET2 \times ET1}{BW}$$

Where:

Parameter	Description	Units
EDI_w	= Estimated Daily intake from dermal contact with water	mg/kg-day
C_w	= Chemical concentration in water	mg/L
SA	= Skin surface area	cm^2
CF2	= Conversion factor 2	L to cm^3
K_p	= Dermal permeability coefficient	cm/hour
ET2	= Daily exposure time	Hours/day
ET1	= Exposure term (days of exposure/days per year)	unitless
BW	= Body weight	kg

A sample calculation of exposure due to dermal contact with water while showering, swimming or wading is provided below. The factors and calculations used to estimate exposures due to dermal contact with groundwater and surface water are provided in Table 4-21 and Table 4-22. Detailed calculations of the estimated exposure to PCDD/PCDF through dermal contact with groundwater or surface water are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-23.

Sample Exposure Calculation for the Inadvertent Ingestion of Water: Soldier SA 4

Receptor	Concentration in Ground Water (mg/L)	Skin Surface Area Exposed (cm^2)	Conversion Factor (L/cm^3)	Dermal Permeability Coefficient (cm/h)[1]	Daily Exposure Time (h/d)	Exposure Term (d/y / d/y)	Body Weight (kg)	Estimated Daily Intake (mg/kg-d)
Soldier: SA 4	9.06E-10	18940	0.001	0.81	0.17	0.16	7.1E+01	5.13E-12

1: USEPA 2004

4.9 Ingestion of Fish, Game and Berries

Exposures to chemicals through the consumption of country foods such as fish, game and berries depends on the levels of chemicals in the foods consumed, the amounts consumed in a given meal and the number of meals consumed over the course of a year. For the purposes of this assessment, the food consumption rates presented in Table 4-9 are considered to represent yearly-averaged daily consumption rates (*ie*, these represent the amounts of fish, game or berries consumed on a daily basis during the year). Exposures to chemicals through the consumption of fish, game or berries are calculated as shown in Equation 4-6.

Eq 4-6:

$$EDI_{fgb} = \frac{C_{fgb} \times IR_{fgb} \times CF1 \times AF_{GIT} \times ET1}{BW}$$

Where:

Parameter	Description	Units
EDI_{fgb}	= Intake from consumption fish, game &berries	mg/kg-day
C_{fgb}	= Concentration of chemical in fish, game & berries tissue	mg/kg (freshweight)
IR_{fgb}	= Yearly averaged daily consumption rate	g/day
CF1	= Conversion factor	kg/g
AF_{git}	= Gastrointestinal absorption factor	unitless
ET1	= Exposure term (days of exposure/days per year)	unitless
BW	= Receptor body weight	kg

A sample calculation of exposure due to the consumption of fish, game or berries is provided below. The factors and calculations used to estimate exposures due to the consumption of fish, game or berries are provided in Table 4-24, Table 4-25 and Table 4-26 respectively. Detailed calculations of the estimated exposure to PCDD/PCDF through the fish, game or berries are provided in Appendix E. A summary of the estimated exposures for the receptors considered in each SA, is presented in Table 4-27.

Sample Exposure Calculation for the Consumption of Berries: Recreational Adult SA1

Receptor	Chemical Concentration in Berries (mg/kg fresh weight)	Annual Averaged Berry Ingestion Rate (g/d)	Conversion Factor (kg/g)	Gastrointestinal Absorption Factor	Exposure Term (d/y / d/y)	Body Weight (kg)	Estimated Daily Intake (mg/kg-d)
Recreational Adult: SA 1	8.51E-08	1.99	0.001	1	1	70.7	2.40E-12

5.0 Toxicity Assessment

At the request of Health Canada, the toxicological review presented herein has been closely adapted from a toxicological profile prepared by Cantox Environmental (Cantox, 2006a) which is based on USEPA and ATSDR summary documentation.

5.1 General Information

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) constitute a group of highly persistent ubiquitous chlorinated organic chemicals (Haws, 2006; WHO, 2000). They have been found to be persistent, bioaccumulative toxicants and have been found in fish, birds and animal tissue and in human adipose tissue and milk (Haws, 2006). They are generally unwanted chemicals that have no known industrial use but are by-products of industrial operations and combustion processes, including chlorine bleaching of paper and pulp, production of chlorinated phenols and their derivatives, burning of wastes and fuels and metal smelting (CEPA, 1990; ATSDR, 1998; Haws, 2006). The largest source of PCDDs and PCDFs in Canada is the large-scale burning of municipal and medical waste (Health Canada, 2005).

The effects attributed to PCDDs and PCDFs include dermal toxicity, immunotoxicity, reproductive effects and teratogenicity, endocrine disruption and carcinogenicity (WHO, 2000). Epidemiological studies of PCDD and PCDF exposed workers have not found effects beyond prolonged chloracne (CEPA, 1990).

Structurally related compounds that bind to the aryl hydrocarbon receptor (AhR), the ligand-activated transcription factor, are commonly referred to as dioxin-like compounds (DLCs) or PCDDs and PCDFs. Due to their persistence, tendency to biomagnify through the food chain and lipophilicity, once consumed they accumulate in humans potentially causing chronic lifetime human exposure. Since the mechanism of action is the same and because they are commonly found in the environment as a mixture, the Toxic Equivalency Factor (TEF) methodology has has been developed to assess exposures to PCDD/PCDF mixtures (NTP, 2004abcd).

The TEFs assigned to the various PDCF isomers and congeners are provided in Section 2.5. For the evaluation of PCDDs and PCDFs, it is important to consider the contributions of the entire mixture. However, for the benefit of this report the toxicological profile outlines the physical and chemical properties and toxicological data specifically focusing on TCDD, the most toxic and well studied of the PCDDs and PCDFs. Where it is necessary this document refers to relevant data related to other PCDDs and PCDFs that are essential in the development of appropriate guidelines and limits. For a complete toxicological profile for PCDDs and PCDFs please refer to ATSDR (1998).

5.2 Regulatory Exposure Limits

In deriving a tolerable intake of a particular chemical, regulatory agencies typically rely on both toxicological data from laboratory studies in animals and epidemiological data from exposed human populations to determine the most sensitive adverse effect observed after exposure. The World Health Organization defines a tolerable daily intake (TDI) as:

"an estimate of the amount of a substance in food or drinking water, expressed on a body weight basis that can be ingested on a daily basis over a lifetime without appreciable risk" (WHO, 2003).

A TDI for a particular chemical is generally derived from either a no-observed-adverse-effect-level (NOAEL) or a lowest-observed-adverse-effect level (LOAEL) that has been identified in animal toxicity studies demonstrating the most sensitive effect; i.e., the adverse health effect occurring at the lowest dose of chemical tested. This NOAEL or LOAEL is then adjusted downwards by dividing by uncertainty factors to account for things like inter-species differences (between the test species and humans) and intra-species differences (among individuals within the population). Accordingly, exposure at, or below, the TDI is expected to pose no health risks, even in sensitive people who may be more susceptible. Although TDIs are typically derived from laboratory animal studies, careful consideration is also given to available studies of human exposure (ECSCF, 2001). The sections that follow for PCDD/PCDFs first describe briefly the health effects observed in exposed human populations and then the basis of the various TDIs recommended by regulatory agencies are described.

5.3 Animal Toxicology

Numerous effects have been reported in multiple animal studies following exposure to PCDDs and PCDFs. The most sensitive toxic and biochemical endpoints on a body burden basis are: endometriosis, developmental neurobehavioural (cognitive) effects, developmental reproductive (sperm counts, female urogenital malformations) effects, and adult and developmental immunotoxic effects (WHO, 2000). Of these endpoints, development of reproductive system in rats was identified by JECFA (2001) to be the most sensitive endpoint in male rat offspring of treated females. The most sensitive reproductive endpoints in male rat offspring were effects on sperm counts and ventral prostate weight (JECFA, 2001). In female rat offspring studies, whose effects included vaginal thread abnormalities, the doses were somewhat higher than those that induced effects in male rat offspring. A wide range of dose-dependent health effects have been documented in laboratory animals exposed to TCDD. The most sensitive indicators of TCDD toxicity appear to be the effects on the developing reproductive systems of male rat fetuses exposed in utero (COT, 2001). Several studies have reported these effects at various doses but the key study on which the evaluations by JECFA, ECSCF and COT (JECFA, 2001; ECSCF,2001; COT 2001) were based was a study reporting developmental effects in male rats following repeated subcutaneous exposure to the dams (Faqi et al., 1998). This study had not been published when WHO conducted its consultation regarding the reevaluation of the TDI for PCDDs and PCDFs in 1998.

5.4 Human Health Effects

Human health effects from exposure to PCDDs and PCDFs are primarily from occupational, epidemiological studies and only a few intentional poisonings. Populations exposed to the highest levels of PCDDs and PCDFs include occupationally exposed workers, for example herbicide producers. Accidentally exposed populations may be exposed via contamination of the environment or food as was the case for the local population in Seveso, Italy was exposed to

substantial quantities of PCDDs and PCDFs in 1976 following a chemical plant explosion (Bertazzi et al., 1989). Studies of highly exposed populations suggest various non-cancer health effects are associated with dioxin exposure; for example, chloracne (a skin condition), increases in liver enzymes, increased cardiovascular disease and developmental effects. However, most of these effects, such as chloracne, appeared only at doses several orders of magnitude greater than the general public receives from background contamination in food (JECFA, 2001). The pattern of exposure in these studies does not reflect long-term dietary exposure (COT, 2001).

5.5 Opinions of Various Regulatory Agencies

TCDD does not affect genetic material and there is a level of exposure below which cancer risk would be negligible (WHO, 1999).

U.S. EPA's reassessment of PCDD and related compounds may place too much confidence in the ability to accurately predict cancer risks at low doses. This approach dramatically increases cancer risk estimates that are not based on compelling new data but rather on the application of statistical models applied to results of occupationally exposed cohorts that have been associated with significant uncertainty regarding actual exposure. This is further confounded by the fact that these models are not yet fully validated and that we still have knowledge gaps with respect to the mechanism of action and interaction for the PCDD and PCDF group of chemicals (ATSDR scientists; Pohl et al., 2002).

In the Priority Substance List assessment, Health Canada concluded that there is no adequate demonstration that human populations exposed to PCDDs and PCDFs have suffered excess cancer. However, based on the results of studies in animals, it was assumed that PCDDs and PCDFs are non-genotoxic carcinogens and reproductive toxicants with a threshold, and therefore a tolerable daily intake for human exposure was derived (CEPA, 1997). Based on JECFA (2001), Health Canada (2004; 2005) has adopted a tolerable level of 70 picograms per kilogram body weight per month or approximately 2.3 picograms per kilogram of body weight per day. The Health Canada tolerable daily intake of 2.3 pg/kg body weight/day has been adopted for the current study.

6.0 Risk Characterization

The risk characterization stage of the HHRA process compares the exposures to the chemicals of concern for each of the receptors, with the toxicity reference values to determine if site-related exposures exceed the identified benchmarks. For non-genotoxic chemicals, such as PCDD/PCDFs, the potential for exposures to result in adverse human health effects is based on the ratio between the estimated exposure and the identified toxicity reference value. This ratio is called the *Hazard Index* (HI) and is calculated as shown in Equation 6-1. A HI of less than 1.0 indicates that exposures are below the toxicity reference value and the likelihood of adverse human health effects is neglibible. Because of the conservative assumptions used by regulatory agencies in the development of toxicity reference values, HI values greater than 1.0 do not indicate that adverse human health effects will occur, but suggest that a more refined analysis is warranted.

Eq: 6-1:

$$HI = \frac{\sum_{1}^{n} EDI_i}{TRV}$$

Where:

Parameter	Description	Units
HI	= Hazard index	unitless
EDI_i	= Estimated daily intake for pathway i	mg TEQ/kg-day
TRV	= Identified toxicological reference value	mg TEQ/kg-day

A summary of the HIs calculated for each of the receptors considered in each of the SAs is provided in Table 6-1. The risk characterization results for each of the SAs considered in the HHRA are discussed in greater detail in Sections 6-1 through 6-11.

6.1 Characterization of Risk for SA 1 – 1996 Test Area

The exposure doses and hazard indices for the soldier and recreational adult, teen, child and toddler receptors are provided in Table 6-2 through Table 6-6 respectively. The results show that for all receptors considered, the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier and recreational receptors, exposures to PCDD/PCDF in SA 1 would not represent a potential concern for human health.

6.2 Characterization of Risk for SA 2 – Rippon Road

The exposure doses and hazard indices for the soldier and timber harvester receptors are provided in Table 6-7 and 6-8 respectively. The results show that for all receptors considered, the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier and timber harvester, exposures to PCDD/PCDF in SA 2 would not represent a potential concern for human health.

6.3 Characterization of Risk for SA 3 – Murphy Bivouac

The exposure doses and hazard indices for the soldier, youth camper and recreational adult, teen, child and toddler receptors are provided in Table 6-9 through 6-14 respectively. The results show that for all receptors considered, the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier, youth camper, and recreational receptors, exposures to PCDD/PCDF in SA 3 would not represent a potential concern for human health.

6.4 Characterization of Risk for SA 4 – Clones Bivouac

The exposure doses and hazard indices for the soldier are provided in Table 6-15. The results show that the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier receptor, exposures to PCDD/PCDF in SA 4 would not represent a potential concern for human health.

6.5 Characterization of Risk for SA 5 – Base Administration and Parks

The exposure doses and hazard indices for the soldier and recreational adult, teen, child and toddler receptors are provided in Table 6-16 through 6-20 respectively. The results show that for all receptors considered, the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier and recreational receptor, exposures to PCDD/PCDF in SA 5 would not represent a potential concern for human health.

6.6 Characterization of Risk for SA 6 – Static Range Impact Area

The exposure doses and hazard indices for the soldier are provided in Table 6-21. The results show that the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier receptor, exposure to PCDD/PCDF in SA 6 would not represent a potential concern for human health.

6.7 Characterization of Risk for SA 7 – General Manoeuvres Area

The exposure doses and hazard indices for the soldier are provided in Table 6-22. The results show that the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). Thus, for the soldier receptor exposures to PCDD/PCDF in SA 7 would not represent a potential concern for human health.

6.8 Characterization of Risk for SA 8 – Base Perimeter and Fire Breaks

The exposure doses and hazard indices for the soldier and recreational adult, teen, child and toddler receptors are provided in Table 6-23 through 6-27 respectively. The results show that for all receptors considered, the exposure doses are well below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9}

mg TEQ/kg-day). Thus, for the soldier and recreational receptors, exposures to PCDD/PCDF in SA 8 would not represent a potential concern for human health.

6.9 Characterization of Risk for SA 9 – Nerepis River

The exposure doses and hazard indices for the angler receptor in the Nerepis River are provided in Table 6-28. A number of exposure pathways were considered including:

- inadvertent ingestion of soil;
- dermal contact with soil;
- inhalation of soil particulate;
- inadvertent ingestion of sediment;
- dermal contact with sediment;
- inadvertent ingestion of surface water;
- dermal contact with surface water, and
- fish ingestion.

The results show the individual exposure estimates for each pathway are below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). For all pathways except fish ingestion, estimated exposures are two to five orders of magnitude (100-fold to 100,000-fold) lower than the TRV. Thus, for the angler, exposures to PCDD/PCDF in soil, sediment and surface water in SA 9 would not represent a potential concern for human health.

The HI for fish ingestion exceeds the hazard acceptability benchmark of 0.2 established by Health Canada. These results suggest that exposures to PCDD/PCDF through the consumption of fish caught in the Nerepis River within SA 9 warrant additional consideration.

6.10 Characterization of Risk for SA 10 – Swan Creek Lake

The exposure doses and hazard indices for the angler receptor in Swan Creek Lake are provided in Table 6-29. A number of exposure pathways were considered including:

- inadvertent ingestion of soil;
- dermal contact with soil;
- inhalation of soil particulate;
- inadvertent ingestion of sediment;
- dermal contact with sediment;
- inadvertent ingestion of surface water;
- dermal contact with surface water, and
- fish ingestion.

The results show the individual exposure estimates for each pathway are below the TRV of 2.3 pg TEQ/kg-day (2.3×10^{-9} mg TEQ/kg-day). For all pathways except fish ingestion, estimated exposures are two to five orders of magnitude (100-fold to 100,000-fold) lower than the TRV. Thus,

for the angler, exposures to PCDD/PCDF in soil, sediment and surface water in SA 10 would not represent a potential concern for human health.

The HI for fish ingestion exceeds the hazard acceptability benchmark of 0.2 established by Health Canada. These results suggest that exposures to PCDD/PCDF through the consumption of fish caught in the Nerepis River within SA 10 warrant additional consideration.

6.11 Characterization of Risk for SA 11 – CFB Gagetown

The exposure doses and hazard indices for the hunter receptor on CFB Gagetown (SA 11) for deer and moose consumption are provided in Table 6-30 and Table 6-31 respectively. A number of exposure pathways were considered including:

- inadvertent ingestion of soil;
- dermal contact with soil;
- inhalation of soil particulate; and
- consumption of deer **or** moose.

The results show that for the hunter who consumes deer, the total Base-related exposure, including deer consumption was 2.50×10^{-12} mg TEQ/kg-day (Table 6-30). Thus, for the hunter receptor, exposure to PCDD/PCDF in SA 11 would not represent a potential concern for human health.

6.12 Consideration of Background Exposures

In addition to evaluating Base-related exposures to PCDD/PCDFs, the risk characterization also considers background exposures that may be experienced by the general Canadian population. This provides an important perspective on the Base-related PCDD/PCDF exposures estimated for the various receptor groups considered in this risk assessment. Estimated daily intakes (EDIs) of PCDD/PCDFs for the general Canadian population have been calculated as part of Fact-Finding Task 3A-1 (Cantox, 2006b). This report has developed EDI estimates for five different age groups within the Canadian population (infants, toddlers, children, teens and adults). The EDI rates for these receptor age groups were calculated by combining media-specific and age-specific intake rates with reported background concentrations of PCDD/PCDFs in various environmental media (air, water, food, soil *etc*.) in Canada. A detailed discussion of the development of the EDI values can be found in Fact Finding Report 3A-1 (Cantox 2006b). A summary of the EDI values is provided below.

Summary of Estimated Daily Intakes from Background Sources (from Cantox, 2006b)

Receptor	Infant (0 to 6 months)	Toddler (7 months to 4 yrs)	Child (5 to 11 years)	Teen (12 to 19 years)	Adult (>20 yrs)
EDI in pg TEQ/kg-day	5.92	4.71	2.73	1.65	1.32

For the purposes of this HHRA, the EDI values developed by Cantox have been used in conjunction with the estimated Base-related exposures to PCDD/PCDF to demonstrate the contribution that

Base-related exposures make to the total yearly-averaged daily exposures experienced by the various receptors considered in the HHRA. The contribution that base-related exposures make to the total daily exposure for each receptor is calculated as shown in Equation 6-2. Base-related exposures are expressed as a percentage of the total daily exposure. A summary of Base-related contributions to the total daily exposures is provided in Table 6-32.

Eq 6-2:

$$\%Contribution = \left(\frac{Base-related\ \ Exposure}{EDI + Base-related\ \ Exposure} \right) \times 100$$

The results indicate that, with the possible exception of fish ingestion, Base-related exposures to PCDD/PCDF account for less than 1% of the total daily exposure experienced by the various receptors considered in the HHRA. The results for the angler warrant additional consideration.

6.13 Risk Characterization Summary

A summary of the HIs calculated for each of the receptors considered in each of the SAs is provided in Table 6-1. A review of the data shows that for all receptors, except the angler, the HIs calculated for base-related exposures are well below the hazard acceptability benchmark of 0.2 (20% of the TRV), established by Health Canada (Health Canada, 2004). In most cases the HIs are 100 to 1000-fold lower than the 0.2 benchmark. The resulting HI values for the angler exceed typical benchmarks. While this by itself does not indicate that unacceptable non-cancer hazard exists, it suggests that additional consideration of this pathway may be warranted. It is important to note that the results for the angler rely heavily on food-chain (bioaccumulation) modeling that can reliably be expected to over estimate the actual concentration of PCDD/PCDF in fish tissue. As such, these results should be viewed with caution. Further consideration, possibly direct measurement of fish tissue, may be warranted.

These results indicate that for all receptors considered, with the possible exception of the angler, exposures to PCDD/PCDFs in soil, sediment, surface water, groundwater, moose, deer and berries clearly do not and will not represent a potential concern for human health at CFB Gagetown.

7.0 Discussion of Uncertainties

Uncertainty is an inherent component of all risk assessments. The joining of multiple estimates into a coherent conclusion does not allow the exclusion of uncertainty, and attempting to understand its magnitude is an integral aspect of the risk assessment process. One goal of risk assessments is to minimize uncertainty, and not being able to eliminate it entirely, to categorize and bound it. The value of discussing the uncertainties is to understand their magnitude. That allows us to bound the uncertainties and allows us to better understand the results, to put the results in context and to define the level of confidence that we can have in our results.

If the uncertainty associated with a particular input factor is great, the range of possibilities for that specific value may produce a profound difference in the resulting risk calculation, depending on the particular value that is selected for that factor. An example of the potential impact of uncertainty on the results of the risk assessment may be illustrated by the soil ingestion factor for a child. The range of possibilities for daily soil ingestion may be anywhere from 0 to 100 milligrams per day per child. Even for a site-specific risk assessment, it is impossible to assess the amount of soil ingested by a particular child so that a unique value may be selected for each child in a study area. For this reason a value must be predicted from the scientific literature and inserted into the risk assessment calculations to represent the soil ingestion rate. If a value close to zero, such as 1 milligram per day is selected, the resulting predicted potential risk for a child will be 100-fold lower than the potential risks that would be predicted if a soil ingestion rate of 100 milligrams per day were used.

Since it is standard and customary to over-estimate the potential risks, but unacceptable to under-estimate them, regulatory guidance dictates that values from the high end of the range of factors be selected for use in estimating exposures and the associated potential hazards or risks. This section of the report presents a discussion of the uncertainties associated with many of the risk assessment factors used in this HHRA. It also includes a sensitivity analysis that provides an indication of the effect that some of the important factors have on the estimates of potential hazard and risk.

7.1 Site-Occupancy Assumptions

For the purpose of the risk assessment, it was assumed that the Soldier receptor might only be present in certain areas of the site for a limited duration. For example, it was assumed that the Soldier would only be present in areas such as SA1, for two days each year. In order to address uncertainties surrounding this assumption, an additional calculation was performed in which the Soldier was instead assumed to be present in area SA1 for 365 days per year. Increasing the occupancy assumption from 2 days per year to 365 days per year results in a 182-fold increase in the hazard indices (HI) for this receptor. In both cases, the resulting hazard quotients were well below the benchmark value indicating that the site-occupancy assumption of two days per year does not affect the outcome of the risk assessment. The results of both calculations are presented below.

Site-Occupancy Assumption	Soil Ingestion HQ	Soil Dermal HQ	Soil Inhalation HQ	Total HI
2 days per year	4.3×10^{-6}	1.47×10^{-6}	1.72×10^{-7}	5.94×10^{-6}
365 days per year	7.84×10^{-4}	2.68×10^{-4}	3.14×10^{-5}	1.08×10^{-3}

7.2 Exposure Amortization Periods

The TRV for PCDD/PCDF developed by the WHO was established as *Provisional Tolerable Monthly Intake* (PMTI). This monthly exposure limit was established to ensure that chronic daily exposures over long periods (years) remained below the thresholds established to provide protection against reproductive effects (see Section 5 and Cantox, 2006a). Calculating HIs for short duration exposures using a short duration exposure that has been amortized over a similar short period can lead to toxicological inconsistencies when the corresponding TRV for that substance is derived from toxicological studies of chronic or long-term exposure. For example, the youth camper receptor at SA 3 was assumed to be on-site for five days per year. The current risk assessment converted this five-day exposure into a yearly averaged exposure to provide a yearly-averaged daily dose that is toxicologically consistent with the derivation and proper application of the TRV, which is based on chronic exposures. Comparing the five-day exposure and a five day amortization directly to the chronic TRV does not accurately provide an indication of the acute or the chronic hazard that may be associated with this exposure because the chronic toxicity value is based on a long term duration of exposure (most chronic animal toxicity studies are two years in duration) and it cannot be confidently applied for use with a five day exposure and amortization period. An assessment of the short-term or acute potential hazards that may be associated with this short-duration exposure would require that the exposure not be amortized to a short duration, thereby retaining the integrity of the TRV derivation or that it be compared to a TRV that has been developed to reflect short term exposure scenarios.

It should be noted that the low-level Base-related exposures experienced by receptors such as the youth camper are well below the background estimated daily intake (EDI) exposures experienced by these receptors on a daily basis. Therefore, amortizing small incremental exposures of shorter periods of time to assess potentially acute or sub-acute effects has little practical toxicological value and provides no real augmentation to our understanding of the potential hazards experienced by the receptors at Gagetown. To assess the potential effect that changing the exposure amortization period from 365 days to 5 days would have on the exposure and hazard calculations, potential exposures and hazards were assessed for the youth camper using a 5-day exposure amortization period. The results below show that changing the amortization period from 5 days/365 days per year to 5 days/5 days per year, results in a 73-fold increase in the estimated HI. Despite this, the HI remains 33-fold lower than the hazard acceptability benchmark of 0.2. Thus, altering the exposure amortization factor from 0.0137 (5/365) to 1 (5/5) does not alter the conclusions of this report. It should be noted boldly however, that such an approach, given its improper linking of exposure and toxicological endpoint, if applied to the general practice of risk assessment in Canada, could have a serious negative effect on the use of risk assessment to support decision-making to resolve environmental concerns.

Amortization Period (days/year)	Soil Ingestion HQ	Soil Dermal HQ	Soil Inhalation HQ	Total HI
365	2.62×10^{-5}	4.11×10^{-5}	1.44×10^{-5}	8.17×10^{-5}
5	1.91×10^{-3}	3.00×10^{-3}	1.05×10^{-3}	5.96×10^{-3}

7.3 Use of EPC from all of APEC 15 to represent SA 4 (Clones Bivouac)

The potential hazards associated with exposure to PCDD/PCDF at SA 4 (Clones Bivouac) were assessed using soil sampling data from all of the bivouacs in which groundwater was used. The use of a 95% UCL derived from the data set from this entire area may have underestimated potential exposure at Clones Bivouac. The potential difference in exposure estimates that may result from the use of the entire APEC 16 data set to assess exposures at Clones Bivouac was evaluated by reassessing the exposure estimates for Clones Bivouac using the highest PCDD/PCDF TEQ concentration reported for APEC 16. The results, summarized below, show that there is a 3.1-fold difference between the maximum reported PCDD/PCDF concentration in soil and the EPC used to evaluate exposures. Although there is also a 3.1-fold increase in the total HI when the maximum PCDD/PCDF concentration is used, the total HI is still well below the hazard acceptability benchmark of 0.2. Thus, using the maximum reported concentration rather than the EPC calculated from the entire APEC 16 dataset would not alter the conclusions of the assessment.

Concentration in Soil (pg TEQ/g)	Soil Ingestion HQ	Soil Dermal HQ	Soil Inhalation HQ	Total HI
Maximum (9.13)	1.01×10^{-3}	3.45×10^{-4}	4.04×10^{-5}	1.39×10^{-3}
EPC (2.93)	3.23×10^{-4}	1.11×10^{-4}	1.29×10^{-5}	4.47×10^{-4}

7.4 Time Spent in Bivouacs and Time Spent in General Manoeuvres Area

The current risk assessment has considered exposures that occur in individual areas of the base. For the soldier receptor, exposures were calculated for time spent in bivouac areas independently of time spent in the general manoeuvres areas. This was done to characterize the potential hazards associated with time spent in these areas as aid to determining the need for continued use restrictions in each of these areas. However, this approach does not fully address the overall potential exposure that could potentially be experienced by a soldier who spends 16 hours per day in the general manoeuvres area and 8 hours per day at a bivouac site. The potential hazards associated with these combined exposures have been evaluated for soldiers who spend the day in the general manoeuvres area and 8 hours per day in either the Clones or Murphy Bivouac areas. The results indicate that the combined HIs for soil-related exposures are well below the hazard acceptability benchmark of 0.2. Thus, the combined exposures experienced by soldiers who spend 16 hours/day in the general manoeuvres area and 8 hours/day at a bivouac site would not be expected to result in potential concerns for human health.

Total HI Clones Bivouacs (SA4)	Total HI Murphy Bivouacs (SA3)	Total HI General Manoeuvres Area (SA7)	Combined Total HI (SA4 and SA7)	Combined Total HI (SA3 and SA7)
3.05×10^{-3}	1.08×10^{-3}	2.08×10^{-3}	5.13×10^{-3}	3.16×10^{-3}

It should be noted that current assessment has considered exposures for two of the 28 bivouac areas on the Base. The remaining bivouacs typically fall into either SA 7 or SA 8. For the soldier receptor, the HIs calculated for exposures that were assumed to last for 16 hours/day are well below the hazard acceptability benchmark of 0.2. Increasing the duration of exposure from 16 hours per day to 24 hours per day would not alter the conclusions of the risk assessment. Thus, because the

exposures experienced by soldiers in SA 7 and SA 8 are well below the level of potential concern for human health, the continued use of the bivouacs in these areas would not result in exposures to PCDD/PCDF that would be a potential concern for human health.

7.5 Screening Value for 1,2,3,4-Tetrachlorobenzene

A surrogate value of 61 µg/g (industrial land use) was used to screen 1,2,3,4-tetrachlorobenzene in soil and sediment in SA 6. Based on the selection of this screening criterion, 1,2,3,4-tetrachlorobenzene was not identified as a chemical of concern for the risk assessment. A provisional *Soil Quality Guideline* (SQG) for 1,2,3,4-tetrachlorobenzene is currently under review by Health Canada. The provisional human health SQG for direct soil contact exposure for the toddler receptor is 129 µg/g for residential land-use. The provisional SQG for the adult receptor for commercial/industrial land use is 5621 µg/g (Dillon, 2005). This latter land use better reflects the potential exposures that could occur on SA 6, where 1,2,3,4-tetrachlorobenzene was detected. Both of these provisional values are above the maximum reported concentration of 1,2,3,4-tetrachlorobenzene of 37 µg/g.

Although the use of a surrogate value for 1,2,3,4 tetrachlorobenzene may introduce potential uncertainty into the chemical screening process, the provisional screening criterion for a residential toddler would also have resulted in the removal of 1,2,3,4-tetrachlorobenzene from the list of chemicals of concern. Therefore, the use of the surrogate value will not alter the conclusions of the risk assessment.

7.6 Consumption Rates for Game

The consumption rates for game used in the current assessment are based on guidance provided by Health Canada (Health Canada, 2004). It should be noted that these consumption rates reflect game consumption rates in First Nations populations in northern Canada and are likely to over predict game consumption rates in the general population, even amongst people who hunt on a regular basis. Estimates of game consumption in the US population are substantially lower than the rates used in the present report. However, as noted in Appendix D, the US consumption rates include food items other than game animals and therefore, were not considered appropriate for use in the current assessment.

The results of the assessment show that even using game consumption rates that are expected to over predict potential exposures, exposures to PCDD/PCDF through the consumption of deer or moose would not result in exposures that would be a potential concern for human health.

7.7 Consumption Rate for Berries

The yearly-averaged daily berry consumption rates used in the current risk assessment represent a yearly berry intake of approximately 245 g/year for the infant and toddler, 365 g/year for the child, 551 g/year for the teen and 726 g/year for the adult. As noted in Appendix D, these consumption rates are based on Nutrition Canada Surveys conducted in the early 1970's. Although the current

exposure assessment suggests that berry ingestion makes a significant contribution to the base-related daily exposures experienced by recreational receptors, the total base-related exposures experienced by recreational receptors are between 100-fold and 1000-fold below the Hazard Acceptability Benchmark of 0.2. Berry consumption would have had to increase by a minimum of 100-fold before total site-related exposures would begin to approach the Hazard Acceptability Benchmark of 0.2. This translates into annual berry consumption rates of 24,500 g/year (24.5 kg) for the infant and toddler and 36,500 g/year, 55,100 g/year and 72,600 g/year for the child, teen and adult receptors respectively. These values approach or exceed the body weights of these receptors.

While changes in berry consumption rates in the general population may have occurred between the time when these values were derived and the present, it is unlikely that increases in berry consumption would be sufficient to result in a measurable increase in exposures. Nor would any likely increases in berry consumption alter the conclusions of the risk assessment. In addition, it should be noted that the fact that the exposure estimates for berries are 100-fold to 1000-fold lower than the Hazard Acceptability Benchmarks suggests that the current approach adequately addresses vegetarians and other dietary variants.

7.8 Result for Fish Consumption

While Health Canada provides guidance on fish consumption rates for the general population (Health Canada, 2004), the values listed in this guidance are based on data from Richardson, 1997 and represent fish consumption rates for First Nations populations and reflect rates for “Eaters” only and therefore, do not reflect consumption rates in the general Canadian population. The value used in the current assessment (21.3 g/day) is based on recent surveys of sport fish consumption in the Great Lakes area and is similar to the combined consumption rate for fish eaters and non-eaters (48 g/day) in First Nations populations as reported by Richardson (Richardson, 1997) (see Appendix D). These values better reflect consumption rates in the general population.

The current value is approximately equal to 35 fish-meals per year based on a 225 gram per meal (1/2 lb) consumption rate. Given that the fishing season is approximately 26 weeks, this accounts for approximately1.5 fish-meals per week during the fishing season. The value used in the assessment to evaluate sport fish consumption is assumed to provide a reasonable estimate of exposure through the consumption of fish.

The results of the hazard calculations suggest that exposures to PCDD/PCDF through the consumption of fish caught in the Nerepis River within SA 9 and Swan Creek Lake within SA 10 could result in hazard values for the angler receptor that exceed the benchmark. It should be noted that exposure estimates for fish ingestion are not based on PCDD/PCDF tissue concentrations measured in fish taken from either water body. Rather, these exposure estimates are based on predicted PCDD/PCDF concentrations in fish tissue that were developed through the use of food chain modelling (see Appendix F). These models are known to generally over-predict PCDD/PCDF concentrations in fish tissue and as result they are anticipated to over predict potential exposures through this route. Thus, current results indicate that additional consideration of this pathway may be warranted. It should also be noted that modelling PCDD/PCDF concentrations in fish tissue does not consider potential additional uptake through the consumption of benthic invertebrates and thus, may under estimate potential exposures through this pathway.

The consumption of fish by young children would be expected to result in exposures that are greater than those experienced by adults due to the greater level of assumed consumption on a per-body-weight basis. Estimates of PCDD/PCDF exposure through fish consumption for a toddler who consumes fish caught from the Nerepis River (SA 9) range between 1.5 pg/kg-day using the linear scaling factors provided in Appendix D and 4.3 pg TEQ kg/-day using the toddler fish consumption values suggested by Health Canada (see Appendix D).

It may be further noted that as fish consumption is identified as a potential concern, increasing the consumption rate assumed for the receptors will not change the conclusion of the risk assessment or the value added by actual measured data on PCDD/PCDF concentrations in fish tissue. The collection of additional information related to sport fish consumption rates in the local community could be considered as part of this data collection.

7.9 Consumption of Fish, Game and Berries by Single Receptor

Concomitant exposures to fish, game and berries are unlikely but not impossible. Because of the relatively slow depuration rate of PCDDs and PCDFs from the human body, the possibility that these concomitant exposures could occur was considered. The potential effects can be estimated for a hypothetical receptor by summing the HQs from game and berry in order to get an overall HI. The combined HI, shown below, was calculated using the HI for the adult moose hunter and the HI for the adult recreational user from SA 8. The combined HI of 0.00419 is well below the hazard acceptability benchmark of 0.2.

It should be noted that the HIs provided below represent the HI calculated for site-related exposures for the hunter and recreational user and thus, include direct contact exposures to PCDD/PCDFs in soil and other environmental media in each of the SAs. Thus, the combined HI of 0.00419 represents the total hazard index that would be associated with multi-media exposures for an adult who spent time on-site collecting blueberries and hunting moose and who also consumed both the blueberries and game. These results indicate that, even the combination of exposures considered in this scenario would not result in exposures that exceed the hazard acceptability benchmark.

Game Ingestion HQ	Berry Ingestion HQ	Combined HI
3.13×10^{-3}	1.09×10^{-3}	4.19×10^{-3}

As was the case for SA 9 and SA 10, ingestion of fish from SA 9 and SA 10 with or without the other pathways for a single receptor predicts hazard values that exceed benchmarks. The considerations mentioned in Section 7.7 apply here as well.

7.10 Game and Berry Consumption by Younger Receptors

As noted in Section 7.8, potential exposures for the adult hunter, anglers and berry pickers were considered. This does not address the potential exposures that could be experienced by family members who do not enter the base when the foods are brought home. In order to address this set of receptor considerations, the calculated HQs for the adult were translated to HQs for other age groups based on ingestion rate and body weight ratios. For example, HQs for a toddler can be calculated as shown in Equation 7-1.

EQ 7-1:

$$HQ_{Toddler} = \frac{HQ_{Adult} \times BW_{Adult} \times FIR_{Toddler}}{FIR_{Adult} \times BW_{Toddler}}$$

Where:

Parameter	Description	Units
BW_{Adult}	= Adult body weight	kg
$BW_{Toddler}$	= Toddler body weight	kg
FIR_{Adult}	= Adult food ingestion rate	kg
$FIR_{Toddler}$	= Toddler food ingestion rate	kg

Based on this equation, HQs from the ingestion of berries and game were calculated for a toddler receptor. Results are presented in the table below. Both HQs are below 0.2.

Receptor	Body Weight (kg)	Berry Ingestion Rate (g/d)	Game Ingestion Rate (g/d)	HQ from Ingestion of Berries	HQ from Ingestion of Game
Adult	70.7	1.99*	270*	1.20×10^{-3}	3.02×10^{-3}
Toddler	16.5	0.67*	85*	1.73×10^{-3}	4.07×10^{-3}

* Age-specific ingestion rates recommended by Health Canada (see Appendix D)

7.11 Use of SA 11 to Assess Exposures for Hunters

The possibility that Hunter exposures to PCDD/PCDF in individual SAs could be higher than those estimated based on a Base-wide assessment was considered in the HHRA. The issue of using the entire base (SA 11) as the exposure area for the Hunter receptor rather than individual SAs within the Base boundaries is related to the estimation of exposure due to direct exposures to PCDD/PCDF in soil (incidental ingestion, dermal contact and inhalation of soil particulate). It does not relate to intakes from the consumption of moose or deer meat as these values were developed using food-chain modelling. A review of the *Exposure Point Concentrations* (EPCs) used to estimate exposures (Table 4-1) shows that the highest EPC (84.9 pg TEQ/g) was calculated for SA 2 which is defined as Rippon Road and the ditches on either side of the roadway. While hunters may traverse this area, it would be unreasonable to expect that they would spend the entire time on the roadway while hunting. Thus, using SA 2 to estimate potential exposures to PCDD/PCDF in soil would greatly over-estimate potential exposures for the Hunter receptor. Using data from across the Base to calculate an EPC for the Hunter receptor results in an EPC of 15.2 pg TEQ/g, which is higher than the EPCs calculated for any of the remaining SAs (with the noted exception of SA 2). Thus, using data from across the Base provides a reasonable upper bound estimate on the potential for hunters to

come into contact with PCDD/PCDF while on the base. The results of the risk assessment indicate that direct exposures to PCDD/PCDF in soil are not a concern for the Hunter receptor regardless of whether hunting takes place in a specific area of the base or if the entire base is utilized.

7.12 Consideration for Home Ranges for Moose and Deer

With respect to the issue of Range Area, the three areas where PCDD/PCDF concentrations were measured in vegetation include (APEC 1, APEC 2 and APEC 3). APEC 2 (SA 2) is defined as Rippon Road and the ditches on either side of the roadway. Thus, while deer and moose may browse along the edges of the subject area, they would not be expected to spend the majority of their time within the boundaries of SA 2. APEC 3, represents a very small area of less than 100 ha and therefore, deer or moose would not be expected to spend their entire time within this area. APEC 1 (SA 1) represents an area larger than 100 ha, so there is a potential for deer or moose to spend a large part of the year within the area of the 1966 Test Area. Before the relevance of assessing potential body burdens for moose or deer in SA 1 can be assessed it is necessary to compare PCDD/PCDF concentrations in vegetation taken from this area with the levels reported in vegetation from the background locations assessed in the ESA.

The data from the APECs and background locations were used to calculate the 95% UCL concentrations in the whole plants from the APECs and background areas. Using the data from all 3 APECs, the 95% UCLs were calculated for:

- All three APECs
- APECs 1 & 3 (APEC 2 was removed because this area does not represent a significant browse area)
- Background Locations.

Vegetation	95% UCL pg TEQ/g (wet weight)		
	All APEC data	APEC 2 (SA 2 Removed)	Background Locations
Whole Plant	1.76	0.94	1.33

The 95% UCL is used as the exposure point concentration rather than the maximum detected concentration because deer or moose would not browse exclusively in the areas where the highest concentrations were found, but would browse over a wider area. The use of the 95% UCL statistical value provides a reasonable but highly conservative estimate of the potential for intake. The data show that the differences in PCDD/PCDF concentrations in whole plants do not differ appreciably between the background areas and the APECs considered in the ESA. The PCDD/PCDF concentrations in the whole plant are higher in the background areas than in the combined APEC 1 and APEC 3. The intakes of PCDD/PCDF by deer or moose in APEC 1 and 3 would not differ from the intakes in the background areas or across the wider Base area. Thus, the consideration of range area is not warranted in the current risk assessment.

7.13 Consideration of Maximum Concentration as Exposure Point Concentration

A comparison of the 95% UCLs and the maximum reported concentrations for each SA is provided in Table 7-1. The data show that for all SAs expect SA 11, the maximum concentration is less than 10-fold higher than the 95% UCL concentration used in the study. In most cases the difference is less than 5-fold. Given that there is a direct linear relationship between concentration in the soil and the potential risks associated with direct exposure to soil (incidental ingestion, dermal contact and inhalation of soil particulate), the use of the maximum concentration rather than the 95% UCL would result in a concomitant increase in the estimated exposures. The increases in HI that would result from the use of the maximum soil concentration in each SA are shown as the *Adjusted* HI values in the right-most column of Table 7-1.

These *Adjusted HIs* for direct soil contact were combined with the HIs calculated for other routes of exposure for the receptors for whom additional exposures were assessed. The results are presented in the *Total Adjusted HI* column in Table 7-2. A comparison between the Total Adjusted HI and the Total HI based on the 95% UCL soil concentration is provided in the right-most column of Table 7-2. The data show that the use of the maximum reported concentration results in increases in the Total HI of less than five-fold in most cases. The largest increase was noted for the deer hunter in SA 11 where the use of the maximum soil concentration as the EPC, resulted in an eighteen-fold increase in the HI (from 1.06×10^{-3} to 1.96×10^{-2}). This increased HI is still ten-fold lower than the Hazard Acceptability Benchmark of 0.2. Thus, the use of the maximum soil concentration does not alter the conclusions of the report. In addition, the *Total Adjusted HIs* for all other receptors except the angler are well below the Hazard Acceptability Benchmark of 0.2. The data presented in Table 7-2 shows that the use of the maximum soil concentration does not alter the total HI for the angler receptor.

It should be noted that the maximum reported concentration in SA 11 is associated with SA 2 which is defined as Rippon Road and the ditches on either side of the roadway. While hunters may traverse this area, it would be unreasonable to expect that they would spend the entire time on the roadway while hunting. Thus, using SA 2 to estimate potential exposures to PCDD/PCDF in soil would greatly over-estimate potential exposures for the Hunter receptor. Using data from across the Base to calculate an EPC for the Hunter receptor results in an EPC of 15.2 pg TEQ/g, which is higher than the EPCs calculated for any of the remaining SAs (with the noted exception of SA 2). Thus, using data from across the Base provides a reasonable upper bound estimate on the potential for hunters to come into contact with PCDD/PCDF while on the base. The results of the risk assessment indicate that direct exposures to PCDD/PCDF in soil are not a concern for the Hunter receptor whether hunting takes place in a specific area of the base or if the entire base is utilized.

8.0 Conclusion and Recommendations

A review of the results shows that for all receptors, except the angler, the HIs calculated for base-related exposures are below the hazard acceptability benchmark of 0.2 (20% of the TRV), established by Health Canada (Health Canada, 2004). In most cases the HIs are 100 to 1,000-fold lower than the 0.2 benchmark. For the general population background exposures to PCDD/PCDF from food and other sources range between 1.32 pg TEQ/kg-day for the adult to 5.92 pg TEQ/kg-day for the infant. Base-related exposures to PCDD/PCDF in soil, sediment, surface water, groundwater, deer, moose and berries represent incremental increases of less than 1% in these background exposures.

The predicted HI values for the angler exceed established benchmarks. While this by itself does not indicate that unacceptable non-cancer hazard exists, it suggests that additional consideration of this pathway may be warranted. It is important to note that the results for the angler rely heavily on food-chain (bioaccumulation) modeling that can reliably be expected to over estimate the actual concentration of PCDD/PCDF in fish tissue. As such, these results should be viewed with caution. Further consideration, possibly direct measurement of fish tissue, is warranted.

Based on the results of the HHRA, the following recommendations can be made for the individual *Subject Areas*:

- **Subject Area 1 – 1966 Test Area**
  Exposures to PCDD/PCDF in the 1966 Test Area do not represent a potential concern for human health for either the soldier or recreational receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 2 – Rippon Road**
  Exposures to PCDD/PCDF in the Rippon Road area do not represent a potential concern for human health for either the soldier or timber harvester. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 3 – Murphy Bivouac**
  Exposures to PCDD/PCDF in the Murphy Bivouac area do not represent a potential concern for human health for the soldier, youth camper or recreational user. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 4 – Clones Bivouac**
  Exposures to PCDD/PCDF in the Clones Bivouac area do not represent a potential concern for human health for the soldier. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 5 – Base Administration and Parks**
  Exposures to PCDD/PCDF in the Base Administration and Parks area do not represent a potential concern for human health for the soldiers or recreational receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 6 – Static Range Impact Area**
  Exposures to PCDD/PCDF in the Static Range Impact Area do not represent a potential concern for human health for the soldier receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 7 – General Manoeuvres Area**
  Exposures to PCDD/PCDF in the General Manoeuvres Area do not represent a potential concern for human health for the soldier receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

- **Subject Area 8 – Base Perimeter and Fire Breaks**
  Exposures to PCDD/PCDF in the Base Perimeter and Fire Breaks do not represent a potential concern for human health for the soldier or recreational receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for these receptors is not warranted.

- **Subject Area 9 – Nerepis River**
  Exposures to PCDD/PCDF in soil, sediment and surface water in the Nerepis River area do not represent a potential concern for human health for the angler receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF in soil, sediment and surface water is not warranted. Further consideration of the potential exposures to PCDD/PCDF through the ingestion of fish may be warranted.

- **Subject Area 10 – Swan Creek Lake**
  Exposures to PCDD/PCDF in soil, sediment and surface water in the Swan Creek Lake area do not represent a potential concern for human health for the angler receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF in soil, sediment and surface water is not warranted. Further consideration of the potential exposures to PCDD/PCDF through the ingestion of fish may be warranted.

- **Subject Area 11 – CFB Gagetown**
  Exposures to PCDD/PCDF in the CFB Gagetown Area do not represent a potential concern for human health for hunter receptor. Therefore, restricting access to this area to limit potential exposures to PCDD/PCDF for this receptor is not warranted.

These results indicate that for all receptors and pathways considered, with the possible exception of the ingestion of fish caught in the Nerepis River or Swan Creek Lake, exposures to PCDD/PCDFs in soil, sediment, surface water, groundwater, moose, deer and berries clearly do not and will not represent a potential concern for human health at CFB Gagetown.

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