Evaluation of the Impacts of Live Fire Training at CFB Shilo (Final report)

G. Ampleman, S. Thiboutot, J. Lewis, A. Marois, A.Gagnon and M. Bouchard
DRDC-Valcartier

R. Martel, R. Lefebvre, C. Gauthier and J.M. Ballard
Institut national de la recherche scientifique

T. A. Ranney
Science and Technology Corporation

T. F. Jenkins U.S. Army Engineer Research and Development Center
Cold Regions Research Engineering Laboratory

J. C. Pennington
U.S. Army Engineer Research and Development Center
Environmental Laboratory

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Author

Guy Ampleman

G. Ampleman

Approved by

Mr. Jocelyn Tremblay

Section Head/Emerging Energetic Materials

Abstract

This work describes the evaluation of the impacts of the training activities in CFB Shilo training area and is the continuation of the first phase done in Sept 2000. During the first phase, three battleruns were sampled for energetic materials, metals, VOCs and petroleum products to measure their impacts on soils and biomass, as well as on subsurface soils, surface water and ground water in the training areas. Such an assessment required an appropriate definition and understanding of the geological and hydrogeological context of the site. During the second phase, the two remaining battleruns, the rifle and the grenade ranges were sampled according to procedures described in this report. Since some trends were encountered in phase I around target areas, more specific sampling, including biomass samples was conducted. Explosives, ^{232}Thorium and heavy metals analyses revealed some localized problems related to environmental contamination and trends were observed that could be related to the firing activities. Some mitigation techniques are proposed for the identified problematic areas. Thorium analyses revealed a localized impact close to the targets both in surface soils and in ground water. The distribution of this chemical was not fully understood and more analyses were done at the end of the summer 2002 to establish if the concentrations in ground water are increasing or decreasing. Nevertheless, the concentrations of thorium in groundwater do not represent a threat being 10 times below the CCME criteria.

Résumé

Ce travail décrit l'évaluation de l'impact des activités d'entraînement faites au secteur d'entraînement de la BFC Shilo et est la suite de la phase I, effectuée en septembre 2000. Durant la première phase, trois champs de bataille avaient été échantillonnés pour évaluer la contamination par les explosifs, les métaux, les COVs et les produits pétroliers afin de mesurer l'impact de ceux-ci sur les sols, la biomasse, la sous-surface, les eaux de surface ainsi que sur l'eau souterraine dans les aires d'entraînement. Une telle évaluation avait requis une définition appropriée et une compréhension du contexte géologique et hydrogéologique du site. Durant la seconde phase, les deux derniers champs de bataille ainsi que les sites de tir à armes légères et de grenade ont été échantillonnés selon la procédure décrite dans ce rapport. Compte tenu que des tendances avaient été observées autour des cibles dans la biomasse durant la phase I, plus d'échantillons autour des cibles ont été prélevés durant la phase II. Les analyses pour les explosifs, les métaux lourds et le thorium 232 ont révélé des problèmes locaux de contamination et des tendances d'accumulation de certains contaminants qui sont reliées aux activités de tir ont été observées. Les analyses pour le thorium ont révélé des impacts localisés près des cibles et un patron de contamination a été observé et ce, tant pour les sols de surface que pour les eaux souterraines. La contamination par le thorium n'était pas complètement comprise et des analyses complémentaires ont été effectuées à la fin de l'été 2002 pour évaluer si les concentrations augmentaient ou diminuaient. Néanmoins, les concentrations en thorium dans l'eau souterraine ne représentent pas un problème, celles-ci étant dix fois inférieures au critère CCME.

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Executive summary

The international context of demilitarization, the closure of military bases and the more stringent aspects of environmental law, have led to the establishment of new areas for research and development. Many activities of the Canadian Forces such as the firing of ammunition, demolitions, and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment.

It is within this context that the Defence Research Development Canada-Valcartier (DRDC-Valcartier) initiated a research program to study the environmental impact of energetic materials that are found in the Department of National Defence (DND) ammunition stockpile. The Program on soil characterization positioned DND in a state of readiness and allowed the development of a unique expertise. The present study was done at Canadian Force Base Shilo, Manitoba, where German troops have trained intensively for the past 23 years. Prior to the German Army's withdrawal from Shilo, the Director General Environment (DGE) tasked DRDC-Valcartier to conduct an environmental assessment to determine the impact of training activities on soils, as well as subsurface soils, surface water and ground water in the training areas. The goal of the first phase was to assess the potential contamination by various residues and evaluate the total costs of future decontamination, if deemed necessary. Director Land Forces Services (DLFS) tasked DRDC-Valcartier to complete the evaluation of the entire area, understand the problem and propose mitigation techniques, if necessary, to sustain the activities. This generated the Phase II research activities. Worldwide, our study represents one of the first extensive efforts to characterize live firing ranges in an entire practice area.

To understand the potential environmental impacts caused by live firing activities, the characterization of battleruns, rifle and grenade ranges was conducted. Soils were sampled using a compositing technique. Biomass samples were also collected to ascertain their contamination. Subsurface soils were collected using a split-spoon sampler, and the boreholes were used to install observation wells. Ground water samples were collected using newly installed and existing wells. Surface water samples were also collected in nearby rivers, streams and lakes. Samples were analysed for explosive contamination using a gas chromatography-electron capture detector (GC-ECD) method. Heavy metals concentrations and thorium-232 were also assessed. Since MILAN missiles were fired at CFB Shilo, efforts were made to evaluate the concentrations of radioactive thorium at targeted sites. This report explains the specific approach and strategy taken on each site and presents the results obtained. The analyses for explosives, thorium 232 and heavy metals revealed localized problems in specific areas. Some mitigation techniques were proposed.

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Le contexte international de démilitarisation, de la fermeture de bases et de la sévérité croissante des lois environnementales a conduit à l'émergence de nouveaux champs de R&D. Plusieurs activités des Forces Armées Canadiennes telles que l'entraînement au tir de diverses munitions et la destruction de munitions, jugées désuètes ou en surplus, par brûlage ou détonation extérieure peuvent conduire à la dispersion de matériaux énergétiques et d'autres contaminants dans l'environnement.

C'est dans ce contexte que Recherches et Développement pour la Défense Canada - Valcartier (RDDC-Val) a initié un programme de recherche afin d'étudier les impacts environnementaux des composés énergétiques que l'on retrouve dans les munitions canadiennes. Le programme de caractérisation de sites a placé le Ministère de la Défense Nationale dans une position où il est prêt à répondre à des problèmes potentiels futurs de contamination et a conduit à l'établissement d'une expertise unique. La présente étude a été effectuée sur la base des Forces Canadiennes de Shilo, au Manitoba où les Allemands se sont entraînés intensivement au cours des 23 dernières années. Avant le retrait définitif des troupes allemandes de la base de Shilo, le Directeur Général Environnement avait mandaté le RDDC-Val pour effectuer la caractérisation environnementale des sites d'entraînement de la base afin de déterminer quels avaient été les impacts de l'entraînement allemand sur les sols, les sols de la sous-surface, les eaux de surface et souterraine. Le but de la première phase était d'évaluer la contamination résultante et d'évaluer les coûts de décontamination. Le Directeur du Service des Forces Terrestres (DSFT) a mandaté RDDC-Val pour compléter l'évaluation sur tout le site, de comprendre la problématique et de proposer des méthodes de mitigation pour soutenir les activités, ceci a généré la phase II. Au niveau mondial, notre étude représente les premiers efforts de caractérisation exhaustive de sites à tir réel sur un secteur d'entraînement complet des forces armées.

Pour comprendre les impacts environnementaux causés par les activités de tirs réels, la caractérisation des champs de bataille, des sites de tir à la mitrailleuse et de grenade a été poursuivie. Les sols ont été échantillonnés selon une approche composite. Des échantillons de biomasse ont également été prélevés afin d'évaluer leur contamination. Des sols de sous-surface ont été prélevés à l'aide d'un échantillonneur à cuillère fendue et des puits d'observation de l'eau souterraine ont été installés. De l'eau souterraine a été prélevée dans les nouveaux puits ainsi que dans les puits déjà existants. Des échantillons d'eaux de surface ont été prélevés dans les rivières, ruisseaux et lacs avoisinants. Tous les échantillons ont été analysés pour leur contenu en composés énergétiques à l'aide d'une méthode par chromatographie gazeuse et à détecteur de capture d'électrons. Les métaux lourds ainsi que le thorium-232 ont également été analysés. Compte tenu que des missiles MILAN ont été tirés à Shilo, les concentrations de thorium-232 ont été évaluées autour des cibles. Ce rapport présente l'approche et la stratégie spécifique à chaque site utilisées ainsi que les résultats obtenus. Les analyses pour les explosifs, les métaux lourds et le thorium 232 ont révélé des problèmes locaux de contamination. Des mesures correctrices ont été proposées.

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1 Introduction

Energetic materials are the main components of gunpowder, explosive warheads and solid rocket propellants and, therefore, can be found in war zones, training ranges or on industrial production sites. During this decade, many needs have already emerged related to the identification, quantification, delimitation and elimination of energetic contaminants dispersed by munitions, or present in explosives dumps, trials or destruction fields, firing areas and production sites [1-25]. The international context of the end of the Cold War resulted in the closing of many military bases and a growing awareness of environmental issues. Within this context, the Director Research and Development Branch, through DRDC-Valcartier, has directed some of its resources to assess and develop expertise related to the environmental risks associated with explosive compounds.

Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning/open detonation (OB/OD) ranges, which were used to destroy out-of-specification materials, were highly suspected of being contaminated with energetic substances as described in the literature [1-14]. To evaluate the contamination of DND sites, sampling and characterization of various ranges was performed over the last ten years. A protocol describing the different methods of sampling and the analytical chemistry was developed [15]. This protocol was recently updated in collaboration with CRREL and is presently being reviewed under the auspices of the Technical Cooperation Program (TTCP) by the member nations in a key technical area (KTA 4-28) [16]. Research results to date have demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In the United States, a lot of efforts have been made to develop analytical chemistry, to establish the best sampling procedure and understand the complex fate of explosives in the environment [3, 4, 6-12, 17-25].

The selection of CFB Shilo training area to conduct the first R&D efforts to assess the environmental aspects of live firing activities was based on the following factors. In the 1970s, Germany and Canada signed an agreement to allow German military troops to conduct training and perform manoeuvres at Canadian Force Base Shilo located in Manitoba. This exchange program was named GATES for German Army Training Exchange Shilo. For years German and Canadian soldiers trained in these battleruns using different German and Canadian weapons, tanks, and other armoured vehicles. In December 2000, Germany decided to stop training in Canada. The German and Canadian governments agreed to share UXO clean up and remediation costs on this site. Another area of concern was the use of MILAN missiles containing ^{232}Th, which leads to potential contamination by radioactive compounds. Accordingly, the Director General Environment (DGE) tasked DRDC-Valcartier in the summer of 2000 to conduct an environmental assessment in the Shilo training area to determine the level of contamination, if any, in surface soils, as well as subsurface soils surface water and ground water.

The ultimate goal of this sampling campaign was to assess global contamination related to explosives, heavy metals and to radioactive ^{232}Th. This information was used to determine Germany's share of any clean up and remediation costs, when required. This assessment required an appropriate definition and understanding of the hydrogeological context of the site, the Shilo base being located on a major aquifer that is heavily used for crop irrigation. Therefore, ensuring that no contamination migrated off site was critical.

This assessment addressed four areas of concern. The contamination patterns of surface soils around targets and in the battleruns were evaluated. The unconfined aquifer underlying the training area (hydrostratigraphy, hydraulic conductivity, ground water flow direction, etc.) and ground water quality were characterized. The extent of biomass contamination in the worst-case scenario locations was assessed, and, finally, the surface water quality was evaluated. In previous DRDC-Valcartier studies, both energetic materials and metals contaminated surface soils have been found in training ranges [1,2,13-14]. Characterizing the ground water quality, especially on such large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in ground water, presenting a threat to human health and the environment. Ground water flow had to be carefully assessed by determining its velocity and direction and its quality has also to be evaluated. Ground water is used as a drinking water source for the base, to sustain aquatic ecosystems and also serves for irrigation. Consequently, any contamination could impact human health, irrigated crops, and aquatic ecosystems. In fact, ground water flowing under CFB Shilo discharges as surface water in many springs southeast of the range, discharging into the Assiniboine River and into Marsh Creek to the north of the range. Both are highly sensitive areas for wildlife and humans receptors. Epinette Creek to the north is also used for irrigation. Biomass, such as prairie grass, has proven to bio-accumulate both metals and energetic materials [10, 20]. Therefore, prairie grass could represent a high potential intake source of these compounds for wildlife. Finally, since wildlife has access to the surface water and it can also be used for irrigation, surface water quality had to be verified.

The 2000 initial study will be referred to in the present document as Phase I, which was completed by the publication of a DRDC-Valcartier report [26]. The second phase of the study was initiated following a tasking from Directorate Land Forces Services (DLFS) to assess the impacts of live firing in major army training ranges in the general goal of sustaining the activities. CFB Shilo was selected as the first base to initiate this important program, since a lot of efforts had been devoted to Phase I. Moreover, at the same period, a joint venture between Canada and the United States was initiated to evaluate the fate of explosives in live firing ranges under the auspices of the Strategic Environmental Research and Development Program (SERDP), a major funding program in the U.S. Since the characterization of CFB Shilo had already begun with Phase I, Shilo was included as the first site for the collaborative work with the United States. Therefore, Canadian and U.S. scientists from both Cold Regions Research Engineering Laboratory (CRREL) and Environmental Laboratory (EL) with the support of both DLFS and SERDP accomplished Phase II.

This final report describes the work carried out during Phase II at CFB Shilo between September-October 2001, and the results obtained from this sampling campaign. This study is the follow-up of the first phase conducted in September 2000 and addressed the two remaining battleruns, and the rifle and grenade ranges. The anti-tank range was the only range not sampled, since no level-one clearance had been conducted at that site, and the site was judged unsafe for sampling. Since specific problems were identified during the first phase, localized sampling of biomass and soils around targets was conducted. More background samples were also collected to compare and assess the natural and anthropogenic contribution. During Phase II, it was not possible to field filter ground water samples. This resulted in a worst case scenario evaluation of the groundwater contamination by metals. Usually, ground water quality is evaluated using sediments-free samples to avoid contribution coming from adsorbed metals on particles. So, this situation was corrected by performing another ground water sampling in Sept-Oct 2002 and will be referred as Phase III within this document.

This study was performed under the work breakdown element 12ny01, "Characterization of DND Sites Contaminated with Energetic Materials," and was sponsored mainly by DLFS for the hydrogeological part, and SERDP for the surface soil sampling. All work was done in collaboration with the Institut national de la recherche scientifique (INRS) and Defence Construction Canada (DCC). DRDC-Valcartier and INRS have both developed expertise in the characterization and the environmental fate of energetic materials in Canadian Forces training ranges and open detonation ranges. DRDC-Valcartier exchanged information and collaborated with the U.S. Army Scientists from CRREL and EL under a the umbrella of Canada United States Test and Evaluation Programme (CANUSTEP) program and funds from SERDP.

2 Range History/Description

Military camp life in the Shilo area had its origin in 1910 with the acquisition of a training area sufficient in extent to provide for artillery practice and for manoeuvres of all arms in a central location in what was then Military District No. 10. This came about when the continued influx of population into the west first directed the attention of the Militia Department to the importance of securing areas of the prairie provinces as military reservations.

The first camp, which opened on June 21, 1910, was called Sewell Camp, a brigade camp attended by 154 officers and 1,315 other ranks located on Canadian Pacific Railway (CPR) property some 5 miles north of Shilo's present location. In July 1915, the CPR changed the name of their railway station at Sewell to Camp Hughes. During World War I, as many as 30,000 troops were on training and administration within its limits. After the war, Camp Hughes ceased to be a permanent camp and was used only for summer training of the Winnipeg Garrison of the Permanent Force and Western Canada militia units.

Late in 1931 the Engineers carried out the first survey in the area known today as CFB Shilo. This took place in what is now the Rifle Range Area. Further surveys were carried out in 1932, and these included most of what is the present Camp area. This survey not only covered the ground, but also included the discovery and placement of a Camp water supply, a supply that is in use today, emanating from its vast aquifer, a legacy of the post-glacial period.

Shilo had its first introduction to Army training in the summer of 1934 with mounted artillery and machine gun units taking part. In the following year, infantry units also trained here. From this day forward, Camp Shilo was in continuous use – first as a summer camp only, but after 1942, as a permanent year-round establishment. Not until 1940, and a new world war, did Shilo begin to assume the form we know today. With the reorganization of the Canadian Army after the war, Shilo became the permanent home of the Royal Canadian Artillery, except for the coast and anti-aircraft elements.

Artillery training has been carried out steadily since 1946, with increasing usage commencing in August 1950. In addition to this, Shilo has been the scene of the concentrated summer training of the artillery element and Militia units. During the period 1950-54, Shilo was also the scene of the Royal Canadian Armoured Corps and Directorate of Armament Development cold weather trials. In February 1954, the Canadian Provost Corps School moved here from Camp Borden, and was established in this centre. In 1960 the Royal Canadian School of Artillery was re-organized to include anti-aircraft, surface-to-surface missile, and apprentice soldier training. In 2000, an ammunition expenditure record was put together in order to evaluate the number of rounds that have been fired over the years. This document is presented in Appendix A and represents a good overview of what was fired on the site. In terms of the present study, this information gives an idea of the amplitude of the UXOs and contaminants that could have impacted the area over the years.

The Ranges, which today extend some thirty three km south and east of the main campsite with an average width of 10 to fifteen km, have an area of 96 000 acres or 38 000 hectares. CFB Shilo is located 25 km southeast of Brandon, Manitoba. The Government of Canada owns only 15 % of that land. The Manitoba government has leased the remaining part to the Government of Canada until 2013. Topographically, the Base lies on a relatively flat terrain with some dunes created after Glacial Lake Agassiz retreated from central Manitoba. Most of the area is treeless except for the forest in the northern parts (the Douglas Marsh and the Spruce Woods Provincial Park). Tree groves are also scattered throughout the area.

Boundaries of CFB Shilo consist mostly of rivers and parks. The southern part of the training area runs along the Assiniboine River. Spruce Woods Provincial Park defines the eastern limit of the training area. In addition, the Spruce Woods Provincial Park constitutes the northern border. Finally, the Cornwallis Rural Municipality serves as the western limit. A few cities and rural municipalities can be found around CFB Shilo. Shilo and Brandon are the most populated ones.

CFB Shilo is divided into 5 regions (A, B, C, D, E) from north to south. A general view of the entire area is presented in MAP No 1. The administrative buildings are located in the Northwest portion of the area. The anti-tank, grenade and rifle ranges are located in the northern part of the base. Five battleruns, Aachen, Berlin, Cologne, Deilinghofen and Essen, were used primarily by the German troops. These battleruns are found, respectively, in regions B, C, D and E. Each of the battleruns has its own area for petroleum refuelling, called "Parkplatz". Most of the targets found in the battleruns were pop-up targets instead of static targets. Consequently, different approaches than used on other ranges had to be taken to sample the battleruns. This will be explained in more details in the next section.

CFB Shilo's climate can be described as a continental climate, with harsh winters where the average temperature of the coldest month is below 3°C and the mean temperature of the warmest month exceeds 10°C. The mean daily temperature ranges from a high of 18.7°C in July to –18.4°C in January. The annual mean temperature in CFB Shilo is 1.8°C. CFB Shilo's weather is a land-controlled climate, which is influenced by tropical and polar air masses. Winter and summer temperatures are characterized as relatively severe. The annual mean precipitation is 453 mm (this number includes the equivalent amount of water due to snowfalls). Three quarters of all precipitation occurs between April and October. The remaining 25 % represents snowfall. Wind is a constant factor at CFB Shilo. During winter, the winds in the area are predominantly from the west. In the spring, they can alternate from the west, northwest, and northeast. Wind speeds generally increase during these spring months. In summer, the wind speeds tend to decrease and come from the east to northeast. In the fall, wind speeds increase and direction becomes gradually northwest to west again. A more detailed description of Shilo climatology can be found in section 5.1.2.

The bedrock essentially consists of Cretaceous shale with some traces of siltstone and sandstone. This could not be observed during drilling conducted under that study since the wells installed were not deep enough to reach the bedrock. Deltaic sand deposits dating from the Quaternary period (i.e. 12 000 years ago) were found over the bedrock. These deposits originated from the meetings of the Assiniboine River and Glacial Lake Agassiz. Once the glacial lake subsided, aerial erosion shaped these deposits into a series of dunes. The thickness of this layer varies from 6 m to 40 m. Two zones of different grain sizes occur. The Stockton sand covers almost all of the training area. Stocton is fine sand originating from the lacustrine deposits, which are highly susceptible to erosion. The Miniota sand found in the southern and western part of the training area is distinguished by a silty and clayey composition. This kind of sand is rarely affected by erosion. The surficial geology of the site is illustrated in MAP No 2.

The drainage system includes two watersheds, the Epinette Creek and the Assiniboine River. The Epinette Creek passes through the military base, while the Assiniboine River is located along the southern border. Both rivers flow towards the east (Figs. 1,2). CFB Shilo occupies part of the Assiniboine Delta Aquifer. This unconfined aquifer covers an area of 3900 km^2. The sand thickness is the smallest near the Assiniboine River (approximately 6 m). Between Aachen and Essen battleruns (northern part of the training area), the thickness is the highest, approximately 30 m. The major uses of ground water are for domestic purposes and for irrigation of farmlands that surround the base (Figs. 3,4).

3 Experimental

3.1 Contractors Involved

Mr. Rob Riesz from CFB Shilo was responsible for hiring all of the contractors, including Defence Construction Canada (DCC), the analytical laboratory, the drillers and the proofing firm. DCC was responsible for supplying all of the analytical tools, solvents, etc., and the manpower to assist DRDC-Valcartier and INRS for the sampling of soils, biomass, ground water and surface water. DCC partial report of activity can be found in Appendix B. Sub-contractors for UXO proofing (X-Tech), borehole drilling (Paddock Drilling Inc), and GPS survey (Lennon Surveys Brandon, MB) were hired for the hydrogeological needs of the study. The analytical work for metals and perchlorates was sub-contracted to Enviro-Test Laboratory (ETL) from Winnipeg, Manitoba. Dr. Conrad Gregoire from the Geological Survey of Canada (NRCan) was sub-contracted by INRS for the thorium-232 analytical work. Dr. Michel Parent from the Geological Survey of Canada (NRCan) was also subcontracted by INRS for geological work (field work and map production) and was helped by M. Marc Cloutier and M. Pierre Gagnon from Cogéo Consultants and Martin Ross from INRS-ETE.

3.2 Parameters Monitored and Analytical Methods

Soil and biomass samples were analysed for metals, energetic materials, and thorium-232. Ground water and surface water samples were analysed for metals, anions, thorium-232, energetic materials and perchlorates. Since no petroleum products including volatile organic compounds (VOCs) and benzene, toluene, ethyl xylene (BTEX) were found in Parkplatz during the first phase of this study, these parameters were analysed only in a few ground water and surface water samples during Phase II. Metals were analysed by Inductively Coupled Plasma Mass Spectrometry (ICP/MS) by the external laboratory (ETL) and all of the parameters available by this method were included in the study. The analytical results for all individual water samples as well as grain size analysis curves, hydraulic conductivity, and borehole logs can be retrieved in Appendix C that is a compilation of all these large files on a compact disk. For ground water samples, energetic materials were analysed at DRDC-Valcartier by Gas Chromatography/Electron Capture Detector, a method that can produce a 0.004 ppb detection limit. In our study, a quantification limit of 0.01 ppb for all analytes was obtained based on interferences peaks in the chromatograms. Analyses were performed with a GC HP6890 equipped with an ECD detector, an auto-injector HP7683 at an injection temperature of 250 °C. A capillary column based on phenylmethyl siloxane HP-5 (HP19095J-121) of 10.0 m x 0.53 mm was used under helium carrier gas. The temperature run used was as follows: 100 °C/ 2 minutes, ramp of 10°C/ minute until 200 °C, ramp of 15° C/minute until 280 °C, and a pause of 4 minutes at 280 °C. This method was based on recent work published in the U.S. [22-23].

Soil samples were dried in the dark, homogenized by adding acetone to form a slurry which was then evaporated. Soils were sieved through 25 mesh sieve and extracted at DRDC-Valcartier according to the following procedure: Four grams of soil were mixed in acetonitrile (10 mL) and a vortex was applied for one minute, followed by a sonication period of 18 hours and left to settle 30 minutes. The mixture was then filtered on a 45 microns filter and these extracts were shipped to CRREL. The extracts were then analysed by CRREL using the following procedure:

> Soil extracts were maintained at 4°C until analyzed by GC-ECD. The auto sampler vials containing the acetonitrile soil extracts were placed into GC auto sampler trays that were continuously refrigerated by circulating 0°C glycol/water through the trays. The samples were injected into a HP-6890 GC equipped with a Ni^{63} cell micro-electron capture detector (GC-µECD). Results were obtained according to the general procedure outlined in EPA SW846 Method 8095 (www.epa.gov). Direct injection of 1-µL of soil extract was made into a purged packed inlet port, maintained at 250°C, that was equipped with a deactivated Uniliner from Restek Corporation, Bellefonte, PA. Primary analysis was conducted on a 7-m x 0.53-mm ID fused-silica column, with a 0.5-µm film thickness of 5%-(phenyl)-methylsiloxane (Rtx-5MS from Restek). The GC oven was temperature programmed as follows: 100°C for 2 min, 10°C/min ramp to 270°C, 2 min hold. The carrier gas was hydrogen at a constant flow of 10 mL/min (linear velocity approximately 95 cm/sec). The detector temperature was 300°C. The ECD makeup gas was nitrogen flowing at 45 mL/min.
>
> If a peak was observed in the retention window for a specific signature compound, the extract was reanalyzed on a confirmation column, 6-m X 0.53-mm ID having a 1.0-µm film thickness of a proprietary phase (Rtx-TNT2 from Restek). The GC oven was temperature programmed as follows: 130°C for 1 min, 10°C/min ramp to 160°C, 30°C/min ramp to 270°C, 2 min hold. The carrier gas was hydrogen at a constant flow of 15 mL/min (linear velocity approximately 150 cm/sec). The detector temperature was 300°C. The ECD makeup gas was nitrogen flowing at 45 mL/min. Concentrations were estimated against commercial multianalyte standards (from Restek) from peak heights. Where analyte concentrations exceeded the highest standard, appropriate dilutions of the extract were made and the diluted extract re-analyzed. If analyte concentrations were within the linear range of the ECD, concentrations reported were taken from the determination on the primary column, unless co-elution with another compound was evident. In such cases, reported concentrations were taken from the determination of the confirmation column.

The quantification limits obtained for energetic materials in the present study varied between 0.5 and 12.5 ppb for soils depending of the analyte. No biomass samples were analysed for energetic materials, since no explosives were detected in Phase I. INRS conducted the following on site ground water and surface water measurements: pH, electrical conductivity, temperature, salinity, dissolved oxygen and Eh. Furthermore, water level measurements, *in situ* permeability tests, and ground water flow direction and velocity measurements were also conducted in monitoring wells. Thorium-232 was analysed by the Geological Survey of Canada using ICP/MS with a detection limit of 10 ppt for aqueous samples and 0.1 ppm for soils.

3.3 Sample Handling and Treatment

Explosives are not volatile compounds and, therefore, no specific precautions, such as the use of sealed containers, had to be taken during sampling of media containing explosives. Soil samples were composites based on a minimum of 20 random sub samples and stored in polyethylene bags. The bags were immediately stored in ice coolers in the dark to avoid photodegradation of light-sensitive compounds. The use of polyethylene bags decreased the space needed for storing samples and reduced shipping costs. The soil samples were shipped frozen to ETL, who split the samples into two sub samples after a thorough hand homogenization. One set of frozen samples was sent to DRDC-Valcartier for explosives analysis and the other was digested and analyzed for metals by ETL. Water samples were collected and kept cold in 1-L amber glass, stabilized with sodium bisulfate (1.5 g) and sent to DRDC-Valcartier for explosive analysis (see section 4.10 for method of collection). Water samples for metals analyses were collected in standard 500-ml polyethylene bottles, and acidified to a pH of 2. These water samples were not filtered on site due to the lack of the right filter units. This represents the worse case scenario, since the unfiltered particles present in water samples may contain adsorbed metals that are dissolved by the acidic conditions prior to the analyses. In September 2002 re-sampling of more ground water samples was achieved in wells showing metal concentrations higher than CCME threshold criteria. These samples were field-filtered prior to acidification and then shipped to ETL for metal analyses. Moreover, several samples from the same locations were sent both filtered and acidified and non-filtered and acidified in order to evaluate the contribution coming from dissolved metals or metals adsorbed on soil particles. During this last sampling (Phase III), 30 ground water samples (29 well locations and one QA/QC sample) were also collected and sent to ETL for perchlorate analysis (detection limit was 0.1 ppb, quantification limit 0.5 ppb) to evaluate the potential contamination by this compound that is used in many types of ammunition. These analyses were performed under contract using ion-pair extraction with electro-spray with ionization mass spectrometry.

Soil and water samples for thorium analysis were shipped in 500-ml polyethylene jars to the Geological Survey of Canada. Water sample collected for nutrients and anions analysis were also collected in 500 ml polyethylene bottles and shipped cold to ETL. Biomass samples were collected in polyethylene bags, kept frozen in the dark, and sent to ETL. The samples were then cut in small pieces, homogenized, digested and analyzed for metals by ETL.

3.4 Field Investigation

The field investigation included borehole drilling, monitoring well installation and development, monitoring wells testing for *in situ* hydraulic conductivity estimation, and *in situ* measurements of ground water velocity and direction. Safety proofing of all the drilling sites was done with the help of an electromagnetic device (EM-61) and a Dillon magnetometer (Figs. 5,6). Stratigraphic section and lithostratigraphy and water table elevation in the unconfined Assiniboine aquifer are illustrated in MAP No 3 and 4. All surface and water sampling locations, soil and biomass samples and were GPS surveyed and are illustrated in MAP No 5, 6 and 7 respectively.

3.5 Sample Nomenclature

All samples were named according to the following five-parts labelling system:
First part: sample type

S:	Soils
SW:	Surface Water
GW:	Ground water
B:	Biomass (Prairie Grass and other species)
SS:	Subsurface Soils collected during the drilling

Second part: Location by range

A:	Aachen
B:	Berlin
C:	Cologne
D:	Deilinghofen
E:	Essen
KE:	Klein Essen
GRE:	Hand Grenade Range
RIF:	Rifle Range
ATR:	Anti-tank Range
BG:	Background Sample

Third part: Identification of the sample source

Target number (1, 2 and 3) or
Well number (1 to 81) or
Range number ex: RIF 1 or
Background location (ex: Southwest of Berlin) or
Background location by GPS or
LS for linear sampling at XX% of the range
where XX%=% of the overall range length or
HS for hot spots followed by the GPS locations or
Xm where X is the distance perpendicular to the bunker

Fourth part: Identification of the sample

Linear sampling (A or B): A being the closest sample from the starting point near the road access
Systematic target sampling (0-1m, 1-3 m, 3-5 m, 5-10 m, 10-20 m)
In rifle ranges: X-Y where X is the left target and Y the right target
In grenade ranges: A or B, A being on the right half of the range, B on the left part of the range when looking at the bunker.

Fifth part: Date of Collection or GPS locations

3.6 QA/QC

Quality assurance and quality control programs were included in this study. Background soil and surface water samples were collected away from the ranges. Moreover, representative background samples were collected in each geological formation found in the area. Background wells were also installed up gradient and background ground water samples were collected. Background biomass samples were also collected. Analyses were done twice for energetic materials (lab replicates), but were done only once for the other parameters. Ten percent of field replicates were also sent for analysis. The contracted laboratory reported their QA-QC including surrogates and blanks, detection limits, and quantification limits. Trip blanks and field blanks were also included in the QA/QC plan.

3.7 Safety and Emergency Plan

The sampling of an UXO contaminated area represents an increased level of risk for personnel. The Range Control Officers gave a safety briefing to people involved in the sampling program. This briefing explained the precautions to be taken to avoid contact with UXO on the ranges and also described the various types of UXO that may be found on ranges. A safety and emergency plan was also put in place for any incident that could have occurred while sampling water, soils, and biomass. This plan was under the responsibility of the Shilo Range Control unit. When on site for sampling, personnel were always equipped with radios to contact range control in case of an emergency. Walkie-talkies were available to communicate between the teams.

3.8 Sampling Strategy

Soil and biomass sampling was conducted under DRDC-Valcartier supervision, while surface water and ground water sampling was conducted under the guidance of INRS. A total number of 156 soil samples were collected in Phase II. These included 21 backgrounds and 12 field duplicates (8%). All samples were analysed for metals (156), while a limited number were analysed for thorium (61) and energetic materials (108 soils- 8 field duplicates). Sixty-four biomass samples were collected including 3 field duplicates and 17 background samples. Ninety-two ground water and 22 surface water samples were collected in 2001 and were analysed for metals and energetic materials. In 2002, 72 water samples were collected for metals and perchlorate.

Background soil samples are critical for establishing the anthropogenic contribution versus the natural contribution for all parameters. One of the weaknesses of the Phase I was the limited number of representative soil and biomass background samples. This was the result of a limited timeframe for Phase I. This situation was corrected in Phase II during which 21 soil and 17 biomass background samples were collected in all directions around the training area. As an example, soils and biomass background samples were collected nearby road No. 5, east of the training area (fig. 7), and in a grazing area northeast of the base (Fig. 8). Moreover, background sampling locations were carefully chosen to represent the various geological formations that can be found in the area. Geological formations found at CFB Shilo vary from sand, swamp deposit to silt deposits. Therefore, background samples were collected for each of these formations. The background composite samples were collected in a random manner, in a circular pattern of approximately 20 meters in different locations inside and outside the base. A minimum of 30 sub samples was collected to form each background sample. A statistical analysis was done with the results. This statistical analysis allows the identification of a mean background concentration. Samples located at the extremity of the lognormal curve were identified, the limits were chosen for a probability of 97.72% (2 times the standard deviation). The probability of finding a result with a value higher than this limit is 2.28 %. The authors are aware that the limited number of background samples does not allow a very high degree of confidence on these mean BG values. However, it is still valid and interesting to compare training range samples with these mean background values to highlight trends.

Each of the five battleruns in Shilo is approximately 2 km wide. Three battleruns were sampled during Phase I (Berlin, Deilinghofen and Essen), and the two remaining (Aachen and Cologne) during Phase II. A small part of Essen (Klein Essen) was also sampled. Deilinghofen and Essen battleruns were again visited during Phase II to re-sample a few targets to verify that the patterns obtained for soils in Phase I would be obtained in biomass. The Parkplatzs in Cologne and Aachen were not sampled for VOCs or petroleum products during the second phase, since nothing was found in the first phase in the three other battleruns. The same strategy used in the previous study was adopted for the Aachen and Cologne ranges, using both linear transects and circular pattern at selected targets (Figs. 9-12). These strategies are described in more details on the next pages. However, a smaller number of samples were collected using a different strategy in Klein Essen. This later range was used mainly for small caliber and machine gun firing. Therefore, the strategy used in the other battleruns was not applicable there. Some samples were collected in the small caliber target areas and these samples were screening for metals only. Energetic materials were not screened in Klein Essen, since small arms bullets contain no explosive filling.

The initial strategy planned for soil sampling was based on systematic sampling around a representative number of targets in battleruns and also hot spots (broken UXOs or debris, etc.). This strategy was used in previous studies on antitank ranges, which showed very distinct patterns of contamination around targets [2]. However, the nature and type of firing exercises conducted in the battleruns were different from those conducted in antitank ranges. In this type of firing exercises, the ammunition makes the target flip, and pursues its flight until it reaches the end of the battlerun. The sampling strategy was modified to account for this difference. We used two sampling approaches, both based on the collection of composite samples, in order to decrease the high level of heterogeneity usually observed with explosives residues in such scenarios [2,6].

The first sampling approach consisted of sampling targets by compositing samples taken in a circular pattern. A minimum of 20 surface sub samples were collected at a depth of 0-2 cm within a radius of 1 meter, 1 to 3, 3 to 5 and 5 to 10 meters immediately surrounding the target areas, as shown in Figure 11. A rope marked at these prescribed distances was fixed to a stick as close as possible to the target. Circles were defined by turning the rope around the stick at the defined distance. All targets were sampled in a 360 degrees pattern around the targets. The GPS locations of all the sampled targets were recorded. These GPS locations are presented in Table I. Since a pattern of contamination was observed around targets in Phase II, more biomass and soil samples were collected according to this approach.

The second sampling approach consisted in using a linear sampling pattern. This approach was used to evaluate whether the level of contamination by metal, thorium, or energetic materials was following a pattern with distance in the battleruns. If firing activities lead to the accumulation of contaminants in soils, higher levels would have been found at the end of battleruns, since most of the ammunitions fired were supposedly found there and the number of UXO items would be greater in these locations. Therefore, composite samples were collected at distances of 20, 40, 60, 100 and 120 % of the length of each range, when accessible. For all battleruns, an access road was located along the range. Transects were fixed with the help of the Global Positioning System (GPS). The GPS locations are reported in Table I. The linear samples corresponded to the point of the access road where the sampling team started walking perpendicularly to the range using a GPS to keep on a straight line. As explained earlier, the ranges are generally 2-km wide. The sampling team walked for 1.5 km in a straight direction, and started sampling on their way back. The sample collected at the first 500-m distance was identified as Sample B, while the sample collected at the other 500-m distance was identified as Sample A, Sample A being the nearest to the access road (Fig. 9). A minimum of 20 surface sub samples taken at 0-2 cm depth were collected to build each composite sample A and B corresponding to the two portions of 500m along transects in the middle of battleruns at each 20 % intervals from the parkplatzs.

During the drilling of the boreholes, subsurface soil samples were also collected prior to the drilling of the last 2 m. Sampling was conducted with a 51-mm split spoon (60 cm long) at the depth of the middle of the screened interval of 1.52 m of the well. All of the soil samples were sent to INRS-ETE laboratory for grain size analysis and hydraulic conductivity estimation. Results are presented in section 5.2.1.

The sediments encountered in the subsurface during drilling were visually described. Among the 41 boreholes, a total of four boreholes, namely SS-A-6, SS-B-6, SS-D-1 and SS-E-5, were sampled continuously every 60 cm with a 51-mm split-spoon sampler for soil classification and identification. The samples were composite samples at depth of 0 to 1, 1 to 2, 3 to 4, 5 to 6, 7 to 8, 9 to 10, 11 to 12, 13 to 14, 15 to 16 and 17 to 18 feet. Some duplicates were also collected. A total of 15 of these soil samples were sent to ETL for metal analysis. Detailed descriptions of the soil profiles were made by DCC and were recorded in boreholes logs (appendix C). Additional soil samples were also obtained along the screened interval directly from the auger to make the calibration-curve in the laboratory for the ground water velocity measurements in the field with the Geoflo 40 flow meter.

Wherever biomass samples were collected, the method used consisted of building composite samples of indigenous living plants by cutting various types of plants randomly. A minimum of 20-30 sub samples of mixed biomass material was collected around targets. No biomass samples were collected along the transects in battleruns during Phase II because no trends in biomass had been observed in battleruns during Phase I. Only the upper part of the plants (without roots) was collected, since grazing animals rarely eat the roots of the prairie grass as verified by consulting an expert from Environment Canada (Lucie Olivier, Environment Cananda-Montréal). Moreover, explosives (particularly RDX and HMX) are known to bio-accumulate in the upper part of the plant [2, 20]. Metals could bio-accumulate either in the upper plant system or in the roots, depending of the solubility of the metals. Only one sample of roots was collected in the MILAN missile impact area to verify if the results obtained for thorium and other parameters would be higher in this sample. Background samples were collected mainly inside and outside the base at different locations corresponding to the different geological formations encountered in the studied area. A total of 64 biomass samples including 17 background samples were collected in, and around the training areas. Metals were evaluated by digesting the biomass samples using a standard procedure in nitric acid. In Phase II, plant leachates were not included, since results obtained in Phase I did not show any representative trends for the leachate results. So, only the total digestion of the plants was conducted. Moreover, the sampling was concentrated in a circular pattern around targets in the battleruns, since the results from Phase I did show some trends around targets for soils.

For thorium-232, the composite soil samples were also formed of a minimum of 20 sub samples. The target areas for the MILAN missiles were identified and the approach using the circular pattern was applied to collect soil samples (Fig. 12). The areas were swept for radioactivity during Phase I. No radioactivity was detected, which was not surprising since the half-life of ^{232}Th is very long and the radiation is emitted very slowly. In order to detect such low emission sources, a special detector should have been used and left in place for days. No radioactivity sweep was performed in Phase II. Nevertheless, soil samples were collected and sent for analysis in order to verify the results obtained in Phase I, and moreover, to assess whether the concentrations were decreasing with time. Biomass samples were also collected around MILAN targets using the circular approach specific for targets. This was done to verify that bioaccumulation in plant tissues could be measured. A sample of plant roots was also collected in one occasion, since low solubility metals are known to bio-accumulate in plant roots instead of plant tissues. When the Essen impact area was visited, some MILAN missile remains could still be found (Fig. 13). These areas were sampled in a circular pattern as in Phase I. In Essen target area, the sampling team wore protecting disposable masks, gloves and Tivex suits to avoid any contact with the soil dust.

Specific sampling strategies were used in grenade and rifle ranges. The grenade range is smaller and was composed of a detonation area and a concrete bunker for the grenade launcher. Composite linear samples were collected in transects perpendicular to the grenade launching direction at distances of 5, 10, 15, 20, 30 and 35 m (Figs. 14,15). Each transect measured 14 m long and was split into two portions of 7 m each, and named A and B samples. "A" was on the right-hand side of the grenade bunker when looking at the bunker from the detonation area. This sampling pattern was selected to verify whether a trend in the concentrations with the distance from the bunker could be observed. Moreover, a circular pattern would not have been helpful, since no targets were present on the range. Since there was only one crater in the detonation area, it was sampled as a potential hot spot (HS) by collecting 15 sub samples in the wall and at the bottom of the crater. The sampling pattern selected for the grenade range is illustrated in Figure 14. In this range, no biomass samples were collected since the range was sandy and not vegetated.

The four rifle ranges in Shilo consisted of a series of numbered targets having sand butts (berms) in front of them. These butts are supposed to be regularly sieved for metal debris. Surface soils, subsurface soils, and biomass samples were collected at three rifle ranges (1, 2 and 4). Rifle range Number 3 was not sampled based on its lower use by troops. Surface soils were collected from 0 to 10 cm deep, using stainless steel spoons. Subsurface soils were collected using a hand-operated auger. The soil was collected in the auger after drilling in the subsurface. All the auger content was collected. This represented a composite core sample of a depth between 5 and 50 cm. Eight composite surface soil samples were built of at least 20 sub samples and were collected in front of groups of three nearby targets (24 targets sampled) (Figs. 16,17). Four subsurface soil samples were collected in each rifle range in front of four equally distance targets. Biomass samples were collected since all the rifle ranges were highly vegetated around the sand butts and many deer droppings were seen on site. This means that many deer graze on this vegetation. The sampling pattern selected is illustrated in Figure 16. Four biomass composite samples were collected, each being built of at least 30 sub samples. Samples were collected in the area in front of a group of six close targets.

4 Hydrogeological Survey

4.1 Safety Proofing

In order to allow the safe drilling of boreholes for the well installations in UXO impacted training ranges, it is imperative to proof the drilling location. Safety proofing consisted of surveying the ground to detect surface laid and buried metallic objects, thus ensuring the absence of unexploded ordnance (UXO) at the location of the well. A level 2 clearance proofing (0-6m deep) was conducted by XTECH Explosive Decontamination Inc. prior to drilling at all well locations in order to ensure the safety of drilling and technical personnel. XTECH, along with Range Control and INRS personnel, first used GPS to locate and identify future drilling sites. An electronic ordnance avoidance search was then performed at each of the 71 drilling sites located within the danger area boundaries (37/42 in 2000, 34/36 in 2001). The procedure included the proofing of a 2 m x 2 m square grid on drilling sites with a Geonix EM61 device, followed by a final search with a magnetometer (Forester Search Instrument in 2000 and with a Dillon magnetometer F1A4 Minelab in 2001) (Figs. 5,6). The Geonix EM61 and the magnetometer can detect large ferrous objects at depth of 9 meters. As an example, 155-mm shells can be detected at a 3-5 meters depth, which was considered safe to drill when no signals were observed. Cleared locations were identified with red ribbon and a stake indicating the date and drilling site number. No live firing was allowed during the period between the proofing event and the actual drilling of the borehole, ensuring that the drilling location was still safe.

4.2 Borehole Drilling

Drilling and installation of ground water monitoring wells was conducted in October 2000 (42 wells) and September 2001 (36 wells). All wells were drilled by Paddock Drilling Ltd (Brandon, MB) and were installed under INRS guidance by Cochrane Engineering Ltd (Winnipeg, MB) in 2000 and by Defence Construction Canada in 2001. The majority of boreholes were drilled with a Caterra rig, while a Nodwell-Brat 22 caterpillar was required for a few boreholes located in difficult access areas. Both rigs were equipped with a hollow-stem auger. For each site location, a probe hole was drilled with a 125-mm stem auger to determine the depth of the water table and then backfilled with bentonite. This initial step was executed to ensure that all observation wells would be drilled to at least 2 meters below the water table. Then, a 200-mm diameter borehole was drilled with the hollow-stem auger at least one meter away from the probe hole. This borehole was drilled to a depth of 2 m below the depth of the water table.

Well locations were selected according to several criteria including site safety, ease of access, proximity to potential contamination sources, and adequate site coverage. Three wells were located outside of the base limits in order to obtain background values for all measured parameters. Further information on well localization and design can be found in Table II.

4.3 Equipment Decontamination

To avoid cross-contamination between drilling sites, the drilling bit, augers and soil sampling equipment (split-spoon) were decontaminated using the following procedure:

1 - Washing with high-pressure water, followed by brushing with tap water and a phosphate-free detergent (Fig. 18)
2 - Washing with a 10% hydrochloric acid solution.
3 - First rinse with distilled (purified) water
4 - Cleaning with acetone
5 - Final rinse with distilled water

4.4 Monitoring Wells Installation

Monitoring wells were installed according to ASTM-D5092-90 standards. Fifty-one - mm PVC tubing with a 1.5 meter well screen (0.010 inches slots) was used for most of the wells. However, a 3.05-meters well screen was used for a few wells such as GW-GRE and GW-RIF due to the absence of 1.5-m well screen. For 16 of the wells drilled in 2000, a silica sand pack was placed around the screened interval to block the entry of fine particles into the well. This sand pack extends from 0.6 to 1 meter above the screened interval. For the remaining wells, the sand formation collapsed under the water table level, thus impeding the installation of a complete sand pack. In such cases, the in situ sand formation is either directly or partially in contact with the well screen. In 2001, silica sand packs were placed in all of the thirty-six wells; however, sand blow-ups occurred in 23 wells, resulting in a partial collapse of the sand formation (0.3 –to 1.5-meter height) at the bottom of those wells prior to sand pack installation.

The annular space between the PVC tubing (51 mm) and the borehole wall (200 mm) was filled above the sand pack with bentonite grout up to 0.6 to 0.9 meters below the soil surface in order to prevent preferential infiltration of water from the surface. A cement seal filling the rest of the annular space up to the surface was installed. Most wells were cased with a flush-mount protective metal casing and a locking cap as requested by CFB Range personnel since they were located in training areas where they could be in the way of army vehicles (Fig. 19). A few wells located in areas prone to floods during springtime were equipped with a stick-up of 1-m protective casing in order to facilitate their localization at all times (GW-A-7, GW-Antenna, GW-AMA-1, GW-AMA-2, GW-ZONE-4-E). All well locations were GPS recorded for future re-sampling (Table II).

Thirteen-mm, high-density polyethylene (HDPE) tubing going from the bottom to the top of the well and equipped with a D-32 foot valve was placed inside the PVC tubing for use in the process of well development and ground water sampling with an electric Waterra pump (Hydrolift II) that uses an arm attached to the HDPE tubing that extends downward toward the screen interval of the well. (Fig. 20). Well development involves removing fine particles in natural soil or in the sand pack around the screened interval by the movement of a surge block and by pumping water from each well (see section 4.10). The purpose of well development is to obtain a representative ground water sample (one that contains no sediments). Furthermore, ground water samples are usually field filtered to remove the fine particles. Well development took longer than expected because the sand pack grain size was too large for the grain size of the sand formation and because the in situ sand formation was sometimes in direct contact with the screen of the well. Well development was done shortly after well installation. A one-way foot valve and a surge block were attached to the end of the tubing. This allowed water and sediments to flow into the tubing during the down stroke into the well, then close as the arm moved upward, lifting the water column and fine sediments 150 mm per stroke. When the water being pumped from the well became clear and free of sediments, the tubing was lowered by 150 mm to begin developing the next section of the screen. This process continued until the entire length of the screen (top to bottom) had been developed below the water table. In 2000, the process of well development typically took 12 to 16 hours per well with some wells taking considerably longer. Well development took place at three wells simultaneously, with each well using one of the three available pumps. In 2000, wells were not fully developed because of time constraints. Each well was pumped for 3 to 5 hours until water was clear enough for sampling.

Well development occurred shortly after the first wells were drilled, in Phase I from mid-October to early November in 2000, and for Phase II, during the first two weeks of September in 2001. In 2000 training exercises interrupted well development for approximately one week. However, over this time frame, 35 of 41 wells were developed in the five training ranges, the rifle, grenade and rocket ranges and the background well located off the base to the north. Seven wells remain undeveloped because of constraints of bad weather and equipment failure. Four of those were subsequently developed in 2001. The remaining three wells were dry (GW-D-1-A, GW-D-1-B) or could not be found (GW-B-2). In Phase II all of the 36 wells drilled in 2001 were developed at least for three to five hours.

4.5 Testing of the Monitoring Wells

Slug tests were made in all developed wells for an estimation of hydraulic conductivity of the sand formation. Slug tests were performed in one of two ways. The first way was by injecting compressed air into the well with a special device to drop the water table between 30 and 70 cm below its natural static level (Fig. 21). After an instantaneous pressure release, the rise in water table was recorded with a Level Logger pressure gauge (from Solinst). Data interpretation was done with the Bower and Rice method to evaluate hydraulic conductivity [27]. The second slug test method was conducted by removing water from the well with a bailer to drop the water table 60 cm below static level instead of using pressurized air. This method was used where the water table was located below the top of the screened interval. Sixty-four (64) slug tests were performed in 2000. Eighty-eight (88) more were performed in 2001 in order to obtain a more complete set of data and a more precise estimate of hydraulic conductivity. In total, 152 slug tests were performed in 71 wells in 2000 and 2001. One to three tests were performed in each well. Results from both years were similar and are presented in section 5.2.1. Slug tests results are presented in Table III.

4.6 Land Survey

Wardrop Engineering Inc. (Winnipeg, MB) provided GPS locations (northing and easting) of monitoring wells drilled in 2000 and elevations of the metal well cap (Fig.

22). Adjustments were made to calculate the elevation of the PVC tubing used as the point of reference for water level measurements. The error associated with GPS location is ± 2 m, whereas the precision on elevation was ± 0.01 m. The technique involved the use of 2 GPS.

Wells drilled in 2001 were surveyed by Lennon Surveys (Brandon, MB). GPS locations and elevations of the metal well caps were provided for each well. Adjustments were made to calculate the elevation of the PVC tubing used as the point of reference for water level measurements. Well locations and elevations can be found in Table II.

4.7 Water Level Measurements and Water Table Map

Water level measurements were made after well development was completed and enough time had elapsed to allow the water table to recover its original level. An electronic measuring tape with a precision of ±0.5 cm was used to record the water depth in every well in relation to the top of the PVC tubing. Water level measurements were made in October 2000 and September 2001. Elevation of the water table in wells was calculated using values obtained by the survey of the wells. These values, along with the elevation of surface water estimated from topographic maps, were used to calculate the elevation of the water table. The water table contours were calculated using a Kriging technique in Surfer V. 7.0 software. This map shows that ground water flows in a radial fashion in a general north to south direction. The aquifer underlying CFB Shilo is unconfined and is recharged directly by infiltration of precipitation. The unconfined aquifer discharges into the Assiniboine River. The horizontal hydraulic gradient is steeper near the Assiniboine River than in the rest of CFB Shilo. A more precise water table map using 2001 measurements including 2000 and 2001 wells is presented in MAP No 4.

4.8 Hydraulic Head Map and Ground water Direction and Velocity

The horizontal component of ground water velocity and direction was measured in situ with a flow meter (Geoflo 40L) within the developed wells. The Geoflo 40L is a probe with eight thermistors placed around a heat source. This probe was introduced into the well and a reading was taken at two elevations within the screened interval (30 cm from the bottom of the well and 30 cm below the top of the screen) to see if ground water velocity and direction varied with depth (Fig.23). Soil samples obtained along the screened interval during borehole drilling were used in the laboratory to make the calibration curve for the field measurement of ground water velocities with the Geoflo 40 L.

The instrument measures the propagation and the deformation of a heat pulse in ground water. In dynamic systems like an aquifer, the heat pulse propagates with an elliptic shape and the long-axis is oriented in the ground water flow direction. The length and the orientation of this axis can be calculated with usual trigonometric formulas. The resultant vector is fitted on a calibration curve made in the laboratory using sand from the aquifer to get the ground water velocity. Results are presented in section 5.2.2.

4.9 Recharge Evaluation

Ground water recharge is the product of effective porosity and the change in water level observed during recharge events (snow melt and rain episodes). The estimation of the ground water recharge was based on a water table hydrograph from a well (near GW-A-2) located in the centre of CFB Shilo. This well was selected because its water level was influenced by neither irrigation nor supply wells. Hydrologic data from this monitoring well are spread between January 1983 and January 2000; nineteen recharge events can be distinguished. Recharge was evaluated to vary between 0 and 142 mm/year. Mean recharge value is 50 mm/y over the 17-year period used for evaluation.

4.10 Ground water Sampling

Physicochemical parameters were measured in the field with YSI 63, YSI 95 and YSI 556 probes. These parameters included temperature, pH, conductivity, specific conductivity, salinity, dissolved oxygen and redox potential. Ground water was sampled for nutrients analysis, anions, metals, energetic material, thorium and perchlorate. The ground water sampling protocol of the Quebec Ministry of the Environment was followed. Prior to collection of the samples, at least three volumes of ground water standing in the well and in the pore volume of the sand pack were purged from each well. A Waterra Hydrolift II pump coupled to a dedicated 31-mm HDPE tubing connected to a foot valve was used for the purging of most wells, although a few were purged by hand-pumping. In 2001 none of the ground water samples could be filtered, since filters of proper dimensions were not supplied on time; however, samples for metal analysis were acidified in the field. Given the absence of filtration, the concentrations in metals may be overestimated since the metals associated to colloids or adsorbed on particles will be released into the water sample under acidic conditions prior to the analyses. This does not represent the ideal situation since the state of the art implies a filtration of the samples or a low-flow purging level and sampling procedure which avoid the introduction of particles in the groundwater sample. The results for metals analysis in 2001, therefore, represent a worst-case scenario. Groundwater samples that were collected in most of the wells at the end of summer 2002 were filtered on site prior to shipping to the lab. In a few locations, duplicate water samples, one filtered and the other unfiltered, were collected; the resulting analysis provided an insight into the potential contribution of particles larger than 0.45 μm to the metal load.

Descriptive statistics and box plot diagrams are presented in Figure 24 to illustrate the effect of filtration on metal concentrations in groundwater samples. These diagrams present the median value, the 25th and 75th percentile as well as the outlier and extreme values of selected metal concentrations and total ion concentration for filtered and unfiltered samples collected simultaneously in the same well in 2002 (Phase III). A total of eight wells were used to make this comparison. This figure shows that metal and ion concentrations in non-filtered samples are higher and much more variable than those measured in filtered samples. This is a clear indication that the acidification of the unfiltered samples resulted in the desorption of ions adsorbed to particles and/or in the dissolution of the latest, leading to an increase in metal concentration in solution. However, the ion concentration increase differs according the ion involved; the increase was generally higher for metals than for major ions.

In 2000, 35 out of 42 INRS-drilled wells were sampled, compared to 70 out of 78 in 2001 and 52 out of 78 in 2002. A few of those wells could not be sampled because of difficult access created by weather conditions, because they could not be developed, or because they could not be found. A number of observation wells that had been installed on the base several years ago for previous ground water studies were also sampled as follows: four (4) in 2000, fourteen (14) in 2001 and six (6) in 2002. Two of the three base supply wells were sampled in 2001 and all three were sampled in 2002. Wells located in Spruce Woods Provincial Parks and equipped with hand pumps were also sampled: two in 2001, one in 2002. Moreover, one private well were sampled in 2001 and five in 2002. Four duplicates were taken for quality control in 2000 compared to 13 in 2001 and 8 in 2002 . Finally, ground water flowing from three emerging springs located near the shores of the Assiniboine River was collected both in 2000 and 2001. The total is 42 sampling locations and 4 duplicates for 2000, 92 sampling locations and 13 duplicates for 2001 and 67 sampling locations and 8 duplicates in 2002. In 2002, 6 INRS-drilled wells not included in the total of 67 sampling locations were sampled for perchlorate only.

A number of wells located near potential sources of volatile organic compounds, namely Parkplatz zones (GW-A-1, GW-C-1, GW-E-1), or near inhabited or training areas (GW-OBS-SUP-5, GW-OBS-SUP-16, GW-OBS-SUP-27, GW-OW-1, GW-OW-2, MW-108) were sampled for VOCs. A special double needle device was used for collecting ground water samples for VOC analysis to minimize volatile losses (Fig. 25). Nine wells were sampled for VOCs, three in 2000, and six in 2001. Locations of the observation wells, supply wells, and springs used for ground water sampling are presented in Table II. A detailed schedule of surface water sampling is presented in appendix C.

4.11 Surface Water Sampling

Surface water samples were collected in Sewell Lake, Epinette Creek, Souris River, the Assiniboine River and neighbouring streams and lakes to assess the quality of surface water. Nine sites were sampled in 2000: Assiniboine River and nearby lakes (SW-HLAKE, SW-MLAKE, SW-SA-1, SW-SA2, SW-SA3, SW-ZONE6-LAKE), Sewell Lake and Epinette Creek (SW-SE1, SW-SE2, SW-SE3). These same sites were re-sampled in 2001 except for SW-SA-3; however, two samples were taken in two new nearby locations. Eight more sampling sites were added in 2001: Assiniboine River and surroundings (SW-ANTEN-SPRING, SW-ADAMS-SPRING, SW-SWAIS-SPRING, SW-SA-2A, SW-SA-2C, SW-SA3-AMONT, SW-SA3-AVAL) and Souris River (SW-SS-1) to provide a more complete coverage of surface water. A few samples were also taken from dugouts in the southern part of CFB Shilo (SW-DO-2, SW-DO-3, SW-DO4, SW-DO-5). In 2002, three new sampling sites were added on the Assiniboine river: two background locations to the west of the base (SW-BGR-1 and SW-BGR-2) and one location in Spruce Woods Provincial Park (SW-SA-4). The Souris River was resampled (SW-SS-1) as well as Sewell Lake and Epinette Creek (SW-SE-1, SW-SE-3 and SW-SE-4). SW-SE-4 is a new sampling location. One duplicate was taken for quality control each year: GW-SP-4 as duplicate of SW-ZONE6-LAKE in 2000, SW-Horsel as duplicate of SW-Hlake in

2001, and SW-SA-5 as duplicate of SW-SA-4 in 2002. YSI and ORP probes were also used to measure physicochemical parameters of surface water. No filtering of the surface water samples was made in the field prior to sending them to the lab for chemical analysis, except for a few samples in 2000. A detailed schedule of surface water sampling is presented in appendix C.

4.12 Water Supply at CFB Shilo and Aquifer Modeling

A conceptual model of the aquifer will be built to illustrate the hydrogeology and transport mechanisms and the observed behaviour of the potential contaminants in soil and ground water. Based on measured physical properties such as hydraulic heads, hydraulic conductivity, recharge, etc., and based on the information on pumping rate of the supply wells at CFB-Shilo, or irrigation wells, a numerical model of the ground water flow in the studied area will be built, including well head protection area defined for the water supply of the base. The model will be produced in the master's thesis of Ms Catherine Gauthier, who is also co-author of the present report.

5 Water Analyses, Results, and Discussion

5.1 Regional Context

5.1.1 Geology

The geologic map of CFB shilo in Appendix D was produced using information collected during fieldwork in September 2001 (MAP No 2). Two deep boreholes were drilled to evaluate the sequence of sediment formations and the depth of the aquifer. Georadar measurements were also made to obtain further information of sediment structures. Surficial geologic mapping surveys showed that CFB Shilo is entirely underlain by thick sandy sediments of the Assiniboine delta, a large meltwater-fed delta that was deposited at an elevation of about 375 m above sea level (ASL) in Lake Agassiz during the last deglaciation [28-31]. The deltaic sand is medium- to coarse-grained with an observed thickness ranging from 15 m in natural sections on the banks of the Assiniboine River to as much as 36 m in the built-up area of the base. Because of the shallow depth of most boreholes located within the training area, two deep boreholes were augered to determine the thickness of the deltaic sand and the depth of the aquifer. This stratigraphic information (MAP No 3) revealed that the deltaic sands are generally underlain by glaciolacustrine silts whose thickness ranges from a few centimeters to 25 m or more and, which are in turn underlain by dense, matrix-dominated gray till.

The Assiniboine delta grades distally into and interfingers with silty sands, which have been reported in at least one borehole northeast of the Douglas Marsh. Most of the surface of the deltaic sands has been reworked extensively by wind activity; these aeolian features range from reworked deltaic sand to composite parabolic dunes. These medium to fine-grained aeolian sands are hence commonly finer-grained than the underlying deltaic sands. Subsurface investigations (boreholes and GPR surveys) showed that the aeolian sands also contain several discontinuous organic layers, which form paleosols or buried peats of Holocene age. The surface of the Assiniboine delta is overlain by organic sediments in the vicinity of the Douglas Marsh and Epinette River.

5.1.2 Climatology

CFB Shilo's climate can be described as a continental climate, with harsh winters where the average temperature of the coldest month is below 3 °C and the mean temperature of the warmest month exceeds 10 °C. The mean daily temperature ranges from a high of 18.7 °C in July to -18.4 °C in January. The annual mean temperature of CFB Shilo is 1.8 °C. CFB Shilo's weather is a land-controlled climate, which is influenced by tropical and polar air masses. Winter and summer temperatures are characterized as relatively severe. At CFB Shilo, the annual mean precipitation is 453 mm. The bulk of this precipitation falls as rain during April and October. Wind is a constant factor at CFB Shilo. During winter, the winds in the area are predominately from the west. In the spring, they can alternate from west, northwest and northeast. Wind speeds generally increase during the spring months. In summer, the wind speeds tend to decrease and come from the east to northeast. In the fall, wind speeds increase and direction becomes gradually northwest to west again.

5.1.3 Hydrology and Hydrogeology

The drainage system includes two watersheds, Epinette Creek and Assiniboine River. The first one passes through the military base, while the second one is located along the southern border (Figs. 1-2). Both rivers flow towards the east. Dillon Consulting and Render estimated the value of aquifer recharge by precipitation at 5% of the precipitation (20 out of 400 mm and 24 out of 483 mm in 2000 and 2001, respectively). Ground water recharge was also estimated from a water table hydrograph in a well located in the center of CFB Shilo. Individual events were evaluated to vary between 0 and 142 mm/y with a mean annual recharge of 50 mm/y for a 17-year period.

CFB Shilo is located on part of the Assiniboine Delta aquifer. This unconfined aquifer covers an area of 3900 km^2. The sand thickness is smallest near the Assiniboine River (approximately 6 meters). Between Aachen and Essen battleruns (northern part of the training area), the thickness is at its maximum at approximately 30 meters. Major uses of ground water are for domestic purposes and irrigation of farmlands surrounding the base.

5.2 Hydraulic Properties of the Aquifer

5.2.1 Determination of the Hydraulic Conductivity

During the drilling of the boreholes, subsurface soil samples were collected with a 51-mm split spoon (60 cm long) at the depth of the middle of the screen interval and were sent to INRS laboratory for grain-size analysis. Grain-size analysis was performed by sieving for the coarse soil fraction and by laser analysis for the grains under 63 µm. Two types of soils were analyzed in 2000, the deltaic sand formation and the glacio-lacustrine silt formation. The sand had a grain size that varied from 0.5 µm to 1 mm with a mean of 350 µm. The estimated hydraulic conductivity established with the Hazen formula based on the d10 of the grain-size curves varied between 1.3 x 10^{-3} m/s to 4.0 x 10^{-6} m/s with a geometric mean of 1.8 x 10^{-4} m/s. Analysis made in 2001 on sand using the same methodology resulted in an estimated hydraulic conductivity varying between 1.05 x 10^{-3} m/s and 1.0 x 10^{-4} m/s, with a geometric mean of 2.1 x 10^{-4} m/s. These results are in agreement with the slug test results of 1 x 10^{-4} m/s. This value was calculated using the results of 152 slug tests performed in 2000 and 2001 in a total of 71 wells. One to three tests were performed in each well.

According to 2000 analysis, the glacio-lacustrine silt formation had a grain size that varied from 0.5 to 400 µm with a mean of 30 µm. The estimated hydraulic conductivity by the Hazen formula varied between 8.9 x 10^{-8} m/s to 3.2 x 10^{-9} m/s with a geometric mean of 8.7 x 10^{-9} m/s.

5.2.2 Determination of Ground water Flow Direction and Velocity

Ground water flow directions measured by the Geoflo 40L are consistent with the piezometric map except for four wells (GW-A-6, GW-B-6, GW-B-3 and GW-GRE). Local ground water flow may have been affected by the water table, or false readings of the instrument may be responsible for these differences. Ground water velocities estimated from the Geoflo 40L data were consistent with the velocities calculated from other field data (70 to 700 m/y with an average velocity of 350 m/y). The calculated ground water velocity is based on the average hydraulic conductivity estimated from slug tests (1 x 10^{-4} m/s), the horizontal hydraulic gradient measured on the water table map (0.002 to 0.02 with a mean gradient of 0.01) and an estimated porosity of 0.3.

5.3 Geochemical Results

5.3.1 Ground water

Ground water at CFB Shilo is characterized by a neutral pH (mean 7.58), a low alkalinity (mean 216 mg/L), a low conductivity (mean 433 µS/cm (µohms/cm)) for lab data and mean 403 µS for field data), a low total dissolved solids concentration (mean 256 mg/L), a low salinity (mean 0.2 ppt) and a very low concentration in anions (mostly below detection limits for carbonate, chloride and sulphate). The redox potential averages 181 mV indicating an oxidizing environment. The high level of dissolved oxygen in ground water (59%) confirms that aerobic environment exists. Table IV presents physicochemical parameters measured in the field.

An analysis of the proportion of major ions in ground water samples was performed in order to determine the water type of the Assiniboine aquifer under CFB Shilo. Major cations are Ca, Mg, Na and major anions are HCO3, SO4 and Cl. The following water types were establish when taking into account all ions whose concentration exceeds 10% of molar major ion concentration. A limit of 10% was chose instead of the typical 20% value in order to identify minor variations in water quality in this relatively homogenous aquifer.

Ca-HCO3	29 samples
Ca-Mg-HCO3	69 samples
Ca-Na-HCO3-Cl	1 sample

The Piper diagram presented in figure 26 indicates that the water type is predominantly Ca-HCO3, with a steady increase in Mg as groundwater flows towards the Assiniboine river. The only sample with the Ca-Na-HCO3-Cl type of water was collected at well MW-111, just down gradient of the active dump area at CFB Shilo. The high sodium and chloride concentrations are probably due to the leacheates from the dump.

Metals were analyzed in ground water samples collected at 42 locations in 2000, at 92 locations in 2001, and at 67 locations in 2002. Table V presents CCME guidelines for aquatic life, drinking water, livestock watering, and irrigation. The limit of detection of ETL analytical methods is also shown. Metal concentrations were compared to these criteria except those for aquatic life, since they only apply to surface water. Table VI shows metals in ground water that were higher than these criteria.

In 2000 the background sample (GW-BGR) was located north of CFB Shilo, upstream Epinette Creek, away from inhabited areas and human activity. No parameter was found exceeding CCME guidelines for this location. Aluminium concentrations measured in both field and trip blanks were, respectively, 60 and 20 ppb. These values are higher than those observed in several ground water samples, indicating either a lab contamination (lab water, bottles or analytical instrument) or a sample contamination during transportation or field manipulation. Therefore, 60 ppb should be considered the quantification limit for aluminium; results lower than these are not relevant.

Apart for INRS-drilled wells, two other wells installed by the base prior to this study (OW-1 and OW-2) and two wells installed by other engineering firms (MW-108 and MW-112) were sampled (Table VI). These wells were installed to ascertain that no contamination was coming from the northern part of the training area. In particular, the anti-tank, grenade and rifle ranges were suspected as possible contributors of contaminants. No problems of contamination were detected in any of those wells in regard of CCME threshold criteria except for high aluminium concentrations (9 times the background, 4.5 times the field blank) in one well (MW-108). However, these concentrations were still below CCME guidelines.

Metal analysis from 2001 generally showed concentrations much higher than those of 2000. However, this is due to the fact that samples were acidified in the field without filtration, thereby liberating metals adsorbed on fine sediments present in the groundwater samples. The error on the charge balance associated with the laboratory analysis of the unfiltered samples vary between 0,7% and 90%, with a mean of 17%. This is an indication that the solution had not reached equilibrium at the time of analysis and that sediments were still reacting with the acid. A 5% error on charge balance is generally considered acceptable. Therefore, these values cannot be compared to those of 2000/2002 and are not representative of real concentrations of metals transport or circulating in ground water. Comparing these values to drinking water guidelines can still be an interesting exercise; if metal concentrations for unfiltered and acidified samples do not exceed guidelines, therefore we have strong evidence that natural concentrations in ground water are well below established criteria. Parameters exceeding guidelines are the following: aluminium (Al, 83 well samples), arsenic (As, 7 well samples), antimony (Sb, 34 well samples), barium (Ba, 7 well samples), chromium (Cr, 1 well sample), iron (Fe, 93 well samples), lead (Pb, 22 well samples), manganese (Mn, 87 well samples) and selenium (Se, 3 well samples). Aluminium, manganese and iron are naturally occurring in the environment; high concentrations are probably the results of desorption or dissolution of particles following acidification. The same phenomenon is probably responsible for the high concentrations of other metals. However, since these metals are sometimes linked to military activities, locations showing concentrations above guidelines were re-sampled in September 2002 to verify that these concentrations would not occur in filtered water samples.

Results from the 2002 sampling campaign indicated no groundwater contamination problem in the training areas. Iron and manganese concentrations exceeding CCME drinking water guidelines were found in several wells; however, the measured concentrations are common in groundwater and are linked to the geological conditions of the Assiniboine aquifer. Aluminum was found exceeding CCME drinking water quality guidelines in three wells (D-8, E-11 and A-9) and arsenic in one well (GW-D-1-A); however, these are isolated cases. The result from well GW-D-1-A should be interpreted with caution as the well had not been developed nor purged properly and the sample was extremely dirty. During the 2002 sampling campaign, two sets of samples (one filtered and one unfiltered) were collected in each of eight different wells in order to evaluate the influence of water filtration on measured metal concentrations. In all cases, metals such as arsenic, barium, lead and selenium were detected or exceeded CCME guidelines only in unfiltered samples. Aluminum, manganese and iron concentrations were two or three orders of magnitude higher in unfiltered samples than in filtered samples. The graphs presented in figure 24 illustrate the influence of filtration on metal concentrations measured in these eight wells.

In 2000, energetic materials were not detected in the 39 ground water samples. However, traces of TNT were seen on gas chromatograms below the quantification limit of the analytical instrument. The samples showing traces of TNT were GW-Spring-2, GW-B-7, GW-D-6, GW-A-7, GW-A-2 and GW-MARSH 1. One hundred one ground water samples were analyzed in 2001 to confirm these results. Once again, no energetic materials were detected over the quantification limit of 0.01 ppb meaning that earlier results for TNT were due to background noise.

Volatile organic carbon and BTEX compounds were not detected in the three ground water samples taken from parkplatz of Aachen, Cologne and Essen in 2000. In 2001 in contrast, the following compounds were detected in very low concentrations: xylenes in one well (OBS-SUP-5), and toluene in a second (OBS-SUP-16); methylene chloride in these same wells, and in two other wells (OBS-SUP-27 and MW-108). OBS-SUP-5, 16 and 27 wells are located within the inhabited area of the base a few hundred meters away from supply wells, while MW-108 is located in dump area. Results for VOCs are presented in Table VII. These contaminants may be are related to spill of gasoline on the ground. The toluene concentration (28 ppb) slightly exceeded the CCME guideline of 24 ppb. A total of 6 wells were sampled in 2001; one of them was sampled twice. The four wells previously mentioned were located in building areas such as garages where conventional activities were numerous and opportunities for contamination of wells or sampling equipment by volatile compounds from solvents were numerous. Such sources could explain the very low concentrations observed. For example, well OBS-SUP-27 was installed just in front of a garage, slightly below ground level. During sampling, the space between the casing and the PVC tubing was found flooded with dirty water. Some infiltration of surface water could have occurred, and, considering the proximity of potential sources of contamination, may explain the low concentration of VOCs observed. Five of the six samples indicated very high concentrations of acetone (from 1,000 to 2,200,000 ppb). Contamination of the samples by a leaky acetone bottle used for decontamination purposes and carried previously in the same cooler was suspected; this was confirmed by the re-sampling of the well that had exhibited the highest acetone concentration. No traces of acetone were detected in the new samples.

The metal thorium (Th) was present in small quantities in certain types of MILAN missiles fired at CFB Shilo. According to information provided by Shilo personnel, MILAN missiles were fired in specific locations in Essen, Cologne and Deilinghofen battleruns. Based on this information, ground water samples from ten (10) wells and three (3) springs located near these locations were collected and analyzed for thorium in 2000. A year later, ground water sampling for thorium analysis was performed in 87 wells, 2 base supply wells and 3 springs. Finally, in 2002, thorium analysis was performed on samples from 13 wells and from 3 base-supply wells. Radioactivity threshold criteria for thorium obtained from CCME guidelines was transformed into a concentration criteria using calculations that can be retrieved in Appendix E. This criteria is 24.5 ppb or 0.1 Bq/L. Thorium results are presented in parts-per-billion (ppb). The limit of detection was 5 ppt in 2000 and 10 ppt in 2001 and 2002.

The Canadian Guidelines for Drinking Water Quality established by the Canadian Council of Ministers of the Environment (CCME) specifies Maximum Acceptable Concentrations (MAC) in drinking water for several radionucleides. Standards for Thorium-232 and Lead-210 are the most stringent and were established at 0.1 Bq/L, or 24.5 ppb. This standard was used to determine that no sample contained thorium concentrations above the CCME standard; in fact, the highest thorium concentration measured, 2.35 ppb found in GW-D-8 near the firing area, is one order of magnitude below the standard.

Thorium concentrations in ground water varied by three orders of magnitude. They ranged from <0.005 ppb (below detection limit) to 2.35 ppb. However, measured concentrations were below 0.50 ppb in almost all sampling locations. Several background samples were collected in 2001 and 2002 to assess the background concentration for thorium. Five of them had thorium values below detection limit (BGR, BGR-7, BGR-8, BGR-9, and BGR-10) and one reached 0.04 ppb in 2001 and 0.09 ppb in 2002. One sampling location initially considered as background (BGR-4) revealed high thorium concentration (0.25 and 0.84 ppb in 2001 and 2002 respectively). These values were surprisingly high, as this well is located out of CFB shilo borders, about 3.5 kilometres north of the base and upstream from target areas. The values observed indicate thorium concentrations much higher than those of other wells located closer to or downstream from MILAN impact areas. In fact, the value observed in 2001, 0.84 ppb is the fourth highest concentration observed during the 3-year sampling campaign. This may be an indication that thorium concentrations at BGR-4 were influenced by MILAN firing activities. Therefore, this location is not considered representative of background concentrations. Four out of the five background locations where no thorium was detected were located far from CFB Shilo (5 to 40 kilometres away), providing a strong indication that the real background thorium concentration in the Assiniboine aquifer is below 0.01 ppb.

The three highest thorium concentrations were observed in Deilinghofen battlerun (D-8: 2.35 ppb in 2001, 0.51 ppb in 2002, D3: 1.15 ppb in 2000, 0.31 ppb in 2001 and 0.02 ppb in 2002) and in Cologne battlerun (C-2: 0.91 ppb in 2000 and 0.10 ppb in 2001), right on or close to MILAN impact areas. The pattern observed for the rest of CFB Shilo is less clear. Very low thorium concentrations in groundwater are found close to MILAN impact areas and adjacent to sampling locations with much higher thorium values, and relatively high thorium values are found several kilometres away from these impact areas. Moreover, concentrations measured at the same sites vary from year to year and show no clear trend. Detailed thorium results for ground water are presented in Table VIII and are presented on MAP No 8. The following conclusions can be drawn from the analysis of the pattern of thorium concentrations at CFB Shilo.

Most thorium concentrations from sampling locations located far from CFB Shilo were below detection limit, while most values measured within the limits of the base around MILAN target areas varied between 0.01 and 0.50 ppb. These results suggest the contribution of an anthropogenic source located on the base. The threshold value obtained from the mean background (BG) was 0.03 ppb with a standard deviation of 0.03. (six background locations included in calculation; GW-BGR-4 excluded from calculation as the high Th concentration measured in that well indicate the influence of MILAN missile firing in that location). When compared to this background level (BGL) plus 2 times the standard deviation, several samples located in the battlerun presented concentrations over this limit (Aachen 80% of samples, Berlin 16%, Cologne 78%, Deilinghofen 73%, Essen 40%). These percentages remain the same when using a more stringent methodology based on tolerance limits (mean plus 3.7 times the standard deviation for a population of 6 background samples) [32].

Although thorium concentrations are heterogeneously distributed, the general pattern of thorium concentration in ground water at CFB Shilo is broadly one of decreasing concentrations with distance from targeted areas (see Map No 8). Very low concentrations, or values below the detection limit, were observed in Spruce Woods Provincial park, in the areas adjacent to agricultural zones to the east and southeast of the base, and on the other side of the marsh area to the west of the base. This is an indication of a measurable contribution of an anthropogenic source of Th in ground water at CFB Shilo.

However, this pattern is not consistent with the general direction of ground water flow; high thorium concentrations were found up gradient from MILAN target locations, while lower concentrations were recorded just down gradient from the same locations. This was especially obvious in Aachen and near the building areas, which were not located along the flow lines coming from the MILAN impact areas and still contain high thorium concentrations, including GW-OW-3 and GW-OW-2 at 0.82 and 0.54 ppb, respectively. These results indicated that ground water flow is not the only factor controlling thorium concentrations in ground water and that other phenomenon are prevailing before thorium reaches the water table and may exert a strong influence on thorium distribution.

A possible explanation for the high thorium concentrations observed in ground water outside the general flow path could be transport and deposition by wind prior to percolation to the water table. This transport could happen either during the firing exercises or by dust transport. The directions of prevailing winds in southern Manitoba (northwest and southeast) correlates relatively well with the observed pattern of thorium distribution around target areas. Thorium concentrations form ellipsoids around target areas, the elongated side of the ellipse being parallel to prevailing winds. However, since a high proportion of ground water sampling locations are in line with prevailing wind directions, further thorium analyses outside the axis of these winds would be necessary to verify this hypothesis.

On the other hand, the short distance between sampling locations with high thorium concentrations and others with values under detection limits suggests the possible presence of hotspots. These hotspots could be created by the deposition of missile debris following the explosion or wind transport. Such small hotspots would be difficult to locate and could provide a reasonable explanation for the great variations in thorium levels found in ground water.

In September 2002 during Phase III, 30 wells were sampled for perchlorates. This was decided following the inclusion of perchlorate as one of our contaminant of concern. In the USA, a perchlorate plume was found at the MMR training range and this was and still is a big issue. The possibility of finding other groundwater plumes in training ranges in USA is a raising issue and is of great concern. Years ago, the threshold criteria for perchlorate in drinking water was 300 ppb. US EPA lately lowered this threshold criterion to 14-18 ppb and the EPA is now examining the possibility of decreasing the acceptable threshold for perchlorate to 1 ppb in drinking water which would be very stringent. All this demonstrates the increasing importance of this contaminant in ground water. Out of the 30 wells sampled in Shilo, two perchlorate results were higher than the detection limit of 0.5 ppb. No perchlorate was detected in background wells located around the base.

The sampled wells were chosen according to groundwater flow and based on the knowledge of training activities using flares and smoke in specific ranges. These two types of munitions are known as sources of perchlorate, and cause frequently grasses fires when ignited. At CFB Shilo, there are two principal areas where smoke and flares are used, because these areas are completely encircled by large sandy firebreaks. The sampled wells were chosen south of these two training zones since ground water is flowing from North to South and since percolation of perchlorates through ground water would move these contaminants in that direction. The following wells were sampled for perchlorates: GW- A-10, A-2, A-3, A-4, A-5, AMA-1, B-5, B-6, BGR, BGR-3, BGR-8, BGR-9, C-10, C-2, C-3, C-4, C-5, D-2, D-4, D-5, D-6, D-9, E-11, E-12, GRE-1, GRE-2, Zone-4E, Zone-4W, Zone-5N and GW-Zone-5S. Prior to sampling, wells were purged of at least 10 pore-volumes of water prior to sampling. Pumping was performed with a Waterra brand inertial pumping system, composed of the pump, a length of tubing sufficient to reach groundwater, and a foot-valve. Depth to groundwater was generally around 10 m. Among these only GW-A-5 and GW-GRE-2 revealed perchlorate concentrations higher than the detection limits.

GW-A-5, is a well located several hundred meters south of the northernmost training area where flares and smoke pots are used. The well revealed a concentration of 0.0006 mg/L (0.6 ppb). However, it is interesting to note that GW-A-2, GW-A-3 and GW-A-4 all located along the southern boundary of this training area showed no contamination. GW-GRE-2 revealed a perchlorate concentration of 1.3 ppb. This can indicate that smoke grenades containing perchlorate might have been used on the grenade range. Again, another well, GW-GRE-1, located nearby showed a perchlorate concentration below the detection limit.

This perchlorate sampling campaign was an initial effort and only half of the wells at CFB Shilo were sampled. It is interesting to note that perchlorates were found in areas where it was expected but surprisingly, the nearby wells were found to be cleaned. Nevertheless, the levels encountered are still very low, being less than 1.5 ppb in both cases and does not represent an issue for the moment.

5.3.2 Surface Water

Several water quality parameters measured in the various rivers surrounding CFB Shilo showed values higher than in ground water; these parameters include alkalinity, conductivity and total dissolved solids concentration. For the Assiniboine River, no tendency along the river course could be observed, and mean values for years 2000, 2001 and 2002 were respectively: alkalinity as HCO3- (289mg/L, 298 mg/L, and 275 mg/L), lab conductivity (910 µohms/cm, 956 µohms/cm, 1016 µohms/cm), and total dissolved solids concentration (587 mg/L, 650 mg/L, 637 mg/L). The same parameters showed an increase along the course of Epinette Creek for all three years: alkalinity as HCO3- (195 to 410 mg/L, 211 to 395 mg/L, and 197 to 411 mg/L), lab conductivity (338 to 609 µohms/cm, 318 to 584 µohms/cm, and 329 to 603 µohms/cm) and total dissolved solids concentration (180 to 340 mg/L, 160 to 370 mg/L and 160 to 330 mg/L). A noteworthy increase for these and other parameters such as pH could be observed between Sewell Lake (source of Epinette Creek) and Epinette Creek. Physicochemical parameters measured in the field are presented in Table IV.

The presence of chloride was detected in every sampling year in the Assiniboine River (25 to 39 mg/L) and in the Souris River (29 to 35 mg/L). Sulphate was also detected every year of sampling in both rivers: Assiniboine (200 to 260 mg/L) and Souris (279 to 359 mg/L). However, chloride and sulphate were neither detected in Sewell Lake nor Epinette Creek, except for low sulphate concentrations at the southernmost sampling points on Epinette Creek in 2001 and 2002 (12 and 11 mg/L respectively). The presence of chloride and sulphate in the Assiniboine and Souris River can be linked to industrial and agricultural activities upstream. Sewell Lake and Epinette Creek, on the other hand, are taking their source in an extended marsh area north of the base which acts as a buffer zone.

An analysis of water types was also performed on surface water. Only ions exceeding 20% of the total major ions molar concentration were taken into account. Samples whose cations concentrations were below 20% and more or less equal were considered of mixed type. Water types are as follows:

Assiniboine River	Mixed-SO4/HCO3
Sewell Lake	Mg-HCO3
Epinette Creek	Ca-HCO3
Souris River	Na-SO4/HCO3

These different water types reflect the different geological environments and human activities affecting the water courses (Fig. 27).

Water samples from the Assiniboine River, Sewell Lake, Epinette Creek, Souris River, as well as neighbouring lakes, streams and dug outs were analyzed for metals and results were compared to CCME threshold criteria for aquatic life (Table IX). Samples collected in 2000 in the Assiniboine River, in Sewell Lake and in Epinette Creek were filtered, whereas all other samples collected in 2000, 2001 and 2002 were not filtered. Therefore, a separate analysis will be presented for each sample type (filtered and unfiltered).

Filtered samples results indicate that two parameters exceeded CCME guidelines in the Assiniboine River; arsenic (7 ppb) at all three sampling points along the river course (SA-1, SA-2 and SA-3) and copper (12 ppb) downgradient of CFB Shilo (SA-3). In the upstream part of Epinette Creek (SE-1 and SE-2), arsenic concentrations were found above CCME threshold guidelines (6 and 8 ppb) while one sampling location down gradient (SE-3) showed an exceeding copper concentration (14 ppb). CCME criteria are 5 ppb for arsenic and 4 ppb for copper. Since no problem associated with copper in soils or ground water was found down gradient of the range, copper contamination should not be related to the training activities. The same conclusion holds for arsenic.

A number of samples were collected in ponds and lakes (HLAKE, MLAKE and Zone 6 Lake) in 2000 and 2001, and none of these samples were filtered. Two sampling locations (HLAKE and Zone-6-Lake) indicated aluminium levels exceeding CCME aquatic life and drinking water criteria. Reported values were 290 ppb for Horseshoe Lake and 230 ppb for Zone 6 Lake. However, because Horseshoe Lake (H Lake) is intermittent, the aquatic life is not of concern. Zone 6 Lake is a ground water outcrop that was named for sampling purposes. This lake is not listed in the record of the province and, therefore, is not considered to be a lake. Therefore, excess aluminium concentrations are not of concern for aquatic life. These high levels cannot be linked to anthropogenic contribution from Shilo training areas. Moreover, measured aluminium concentrations for these two locations for year 2001 were below CCME drinking water and aquatic life threshold. However, it has to be noted that measured aluminium concentrations in both field and trip blanks from year 2000 were higher than aluminium concentrations exceeding aquatic life criteria, indicating either that water provided by the lab was naturally rich in aluminium, or that a certain level of contamination of the samples occurred during transportation and field manipulations. Therefore, measured levels in field (20 ppb) and trip (60 ppb) blanks should be considered as the quantification limit for aluminium

In 2001 and 2002, metals were analyzed in 21 and 7 surface water samples respectively. High concentrations of aluminium, iron and manganese exceeding both CCME drinking water and aquatic life guidelines were measured in almost all samples. These metals are naturally occurring in soils and sediments and are not linked to training activities. The same explanation is also valid for the numerous water samples exceeding aquatic life criteria for copper and arsenic as well as for the few samples exceeding aquatic life criteria for zinc and silver, and exceeding drinking water guidelines for arsenic, barium and antimony. Even if samples were acidified in the absence of filtration, few concentrations of the metals detected exceeded CCME guidelines. This is a strong indication that surface waters are not contaminated with metals coming from military training activities.

In 2000, energetic materials were not reported in the nine surface water samples collected at HLAKE and MLAKE. A total of 17 surface water samples, including HLAKE and MLAKE, were analyzed in 2001; no energetic materials were detected above the quantification limit of 0.01 ppb.

Thorium concentrations observed in surface water were in general lower than those observed in groundwater. They range from below detection limit to 0.08 ppb. For the Assiniboine River, the two background samples indicated values below detection limit in Brandon and 0.02 ppb north west of the base. Thorium concentrations then increased to 0.06 ppb along the course of the Assiniboine River as it flows to the south of the base and finally decreased to below detection limit as the river reaches Spruce Woods Provincial Park. The highest thorium concentration was observed in the Souris River: 0.08 ppb. Thorium concentrations in Sewell Lake and Epinette Creek were all below detection limit except for one value of 0.02 ppb at SE-3. The same pattern was observed in the various lakes sampled in 2000 (Zone-6, HLAKE and MLAKE), with values ranging from below detection limit to 0.02 ppb. The dug-out showed values ranging from 0.01 to 0.04 ppb. These results are an indication that MILAN missile firing did not contribute to significant thorium concentrations in nearby lakes and rivers. Thorium results for surface water are presented in Table X.

5.3.3 Quality Control of Water Samples

Field and trip blanks were analyzed for metals in 2000. Aluminium concentrations measured in both samples were, respectively, 60 and 20 ppb, indicating that the higher value should be considered as the quantification limit for this metal. Duplicates indicated values similar to those from samples taken at the same location. Field and trip blanks analysis for 2001 (GW-FIELD-1 and GW-ROAD) resulted in values below or slightly above detection limits for all parameters, indicating the absence of contamination during field operations and transport of samples. Results of analyses of the 13 duplicates indicated values more or less similar to their corresponding sample. The difference in measured values is probably due to a difference in water turbidity, leading to a greater or lesser leaching of metals during acidification of the unfiltered samples.

In 2002, two field blanks and two trip blanks (FIELDBL1, FIELDBL2, TRANSP1 and TRANSP2) were analyzed for metals and thorium. A sample of distilled water provided by the lab (DISTILL1) was also analyzed to verify that the water provided was free on contaminants in the first place. The analysis for these five samples resulted in values below detection limits for all parameters, providing an indication that no contaminants were introduced in the samples during sampling or transportation. Moreover, in order to ensure that the tip of the water-level probe introduced in the well to measure the water level prior to sampling (but before well purging) did not introduce contaminants in well water, final rinse water used to wash the probe was collected and analyzed for thorium. Measured concentrations were below detection limit, indicating that the samples collected were not affected by the measurement of the water level prior to sampling and purging the wells. Finally, the analysis of eight (8) duplicate samples indicated results very similar to those of the corresponding samples collected at the same location.

6 Soils and Biomass Analyses

6.1 Global Results from Phase I

For Phase I, the analytical results obtained for the parameters tested in all types of samples showed no major environmental impacts related to the training activities. In soils, the accumulation of some heavy metals associated with ammunition was observed around pop-up targets, but did not reach levels of concern. Neither surface nor subsurface soil samples showed levels of metals higher than agricultural CCME criteria. Phase I results clearly demonstrated no major problems associated with soil contamination. The fact that higher levels of contaminants were encountered around targets proved that the firing activity caused an accumulation of contaminants locally, but not to levels of concern. However, one exception to this was accumulation of radioactive thorium near targets in both soils and ground water. This represented a concern. Soil samples near targets presented statistically higher results for ^{232}Th, while results for ground water showed measurable levels of this radioactive compound close to identified MILAN missile impacted areas. This emphasized the fact that these missiles impacted the environment. Levels were still very low, both in soils and ground water, but considering the very long half-life of this particular contaminant, finding measurable traces of this element is of concern. ^{232}Th had accumulated around target impact areas, and in spite of a very low solubility, trace levels occurred in the ground water. The possibility of migration off range in a long-term scenario had to be investigated. None of the analyses for explosives revealed contamination in soils, ground water, or biomass.

Results for metals concentrations in plants (extracts) and on the plants (leachates) from battleruns showed no levels of concern when compared to the biomass background mean values. Only five detections were encountered in the Berlin battlerun where some metals showed concentrations higher than for the background samples. These concentrations were not considered critical. Higher levels of chromium and aluminium were found at the 80 and 120 % transects where the highest concentrations of UXOs were expected. No metals were detected in Essen or Deilinghofen battleruns.

Unfortunately, no biomass samples were collected around targets for which systematic soil sampling was carried out in order to keep the cost of the study as low as possible. However, trends in accumulation of metals were observed for soils around targets and biomass samples were collected during Phase II to evaluate this tendency.

6.2 General Approach for the Results Analysis

In our evaluation of the results for Phase II, the mean values for background samples were the mean of all collected backgrounds for each parameter measured. When results were higher than the mean background, they were also compared to the backgrounds specific to the same geological formation. When results lower than detection limits were encountered for specific background samples, the detection limit was chosen as the result for the calculation of the mean value. The results obtained in training areas were compared to the mean value of the background to which was added twice the standard deviation. This allowed the selection of results having values greater than the background means, while being statistically representative. When greater values (hits) were encountered, we compared these to the mean of background samples that were collected in the same geological setting close to the samples showing high hits. This was conducted in order to avoid a comparison that would be non-representative of the particular sample location since the geology of the Shilo area presented various types of formations including sand, silt and swamp deposits. As an example, copper can be found in high concentrations in the marsh northeast of the Shilo training area where it is naturally occurring, while not detected in other geological formations. Results are presented for each parameter instead of per sample to facilitate the analysis of the results, since trends can be easily seen for each parameter. Backgrounds were always tabulated first with mean and standard deviation values. Then, results for samples collected in the training area were tabulated. For soils, results over the CCME threshold values for agricultural soils were highlighted in blue bold fonts, while results over the mean value added to twice the standard deviation were highlighted in red bold fonts in Table XI. For biomass, results higher than the mean values added to twice the standard deviation were highlighted in red bold fonts in Table XII. Metals concentrations in ground water samples exceeding either the Background Level (BGL) or the Agricultural Water Quality Guideline (AWQG) in all ranges were presented in Table XIII. The following tables were then built by extracting all results exceeding either the CCME threshold values or the mean of the background values. Tables for ground water, soils, and biomass in each range were built for Aachen (Table XIV), Berlin (Table XV), Cologne (Table XVI), Deilinghofen (Table XVII), Essen (Table XVIII, Rifle (Table XIX) and Grenade Range (Table XX).

Surface soil samples were compared to the most stringent agricultural CCME threshold levels for metals that were included in the latest published CCME quality guideline (see www.ccme.ca). For metals that were not included in the CCME list, results were compared to the mean values of all soil backgrounds samples. The same approach used for the biomass was then selected and results exceeding the mean value added to twice the standard deviation were highlighted. Again here, results that exceeded the mean values were compared in a second run with the mean value of backgrounds found in the same geological formations.

6.3 Energetic Materials

All soils, ground water, and surface water samples were analysed for energetic materials except soils samples collected in the rifle ranges, in Klein Essen battlerun, and at the Antenna Service Area (ASA) area where only metal contamination was suspected. Thirteen parameters were screened for explosives including the most common explosives RDX, HMX and TNT. In ground water and surface water samples, no explosives were detected. Since no explosives were detected in biomass samples during Phase I, no biomass samples were analysed for explosives contamination during Phase II.

A total of 108 soil samples were analysed for energetic materials including 21 backgrounds. The samples collected for energetic material analysis in the training area were collected in the following areas: Aachen, Cologne, Essen, and Deilinghofen battleruns, and in the grenade range. No samples for energetic material analyses were collected in Klein Essen and rifle ranges, since only small arms were used in these ranges. Results for energetic materials are presented in Table XXI. In battleruns, both linear transect patterns (between 20 and 120% of the range length at each 20% interval) and circular patterns around targets (at 0 – 1m, 1 – 3m and 3 - 5 m away from the centre of the target) were done, as in Phase I (Figs. 9,11). Moreover, "hot spot" samples (HS) were collected in battleruns where craters, munitions, or munitions debris were encountered. These samples were named HS with the GPS locations where they were collected. All samples were composite samples built of at least 15 sub samples either in linear transects, circular around targets or circles around the hot spots. When munitions were found, the samples were collected as near as possible to the UXO with sub samples around it. Out of the 87 samples collected in the firing ranges, 36 presented measurable traces of at least one explosive analyte. These results will be discussed range by range in the following section.

Analysis by GC using the EPA-8095 method was done at CRREL. This method allows detection limits in fractions of ppb for explosive analytes. However, the quantification limits for our soil samples were slightly higher based on interference peaks present in the soils extracts. The quantification limits obtained for the following analytes were, respectively (in ppb): NG (5), 1,3-DNB (0.5), 2,6-DNT (0.4), 2,4-DNT (2), TNB (10), TNT (0.25), PETN (12.5), RDX (1.5), 4-am-DNT (0.8), 2-am-DNT (1.3), 3,5-DNA (5), Tetryl (10) and HMX (12.5).

One background sample (BG) presented traces of HMX (S-BG-52660E 22764N) and another one presented traces of both HMX and TNT (S-BG-62033E 01742N). The first one was collected far away from the training area (approximately 2 km). The presence of HMX is quite unusual at that remote location. This sample was re-sampled in Sept 2002 to verify this result that could be explained by laboratory cross-contamination. The second BG showing the presence of both TNT and HMX was collected southwest of the limit of the Cologne BR still within the limit of the training area. A field duplicate was also collected in Sept 2002 to confirm this result. Soil erosion and wind from Cologne BR could explain the presence of traces of both energetic analytes in this last sample. Results obtained from Phase III showed no traces of energetic residues indicating that laboratory cross-contamination did occur during the earlier sample treatment.

All samples were thoroughly homogenised and analysed in duplicates (lab-duplicates) to verify the sample homogenization efficiency. Means and standard deviations were calculated for all sets of replicate measurements. Suspect individual measurements were flagged on the basis of extreme values of the relative standard deviation (RSD) and inconsistencies in the overall pattern for that sample or analyte. More than 80 % of the laboratory replicates showed a relative standard deviation (RSD) < 30 %, which indicates that the approach taken for soil homogenization by adding acetone after the drying step was quite efficient. However, for some parameters RSD as high as 155% were still observed.

Twelve field duplicates of the 87 soil samples collected across the training area were collected to assess the field reproducibility achieved by the composite sampling approach. The results obtained for field replicates varied from sample to sample as well as from analyte to analyte within the same sample. For sample S-GR-25M-B and S-GR-25M-B-dup, respectively, results showed good agreement between field duplicates. All analytes for sample S-GR-25M-B were detected in the same order of magnitude as in sample S-GR-25M-B-dup. In general, the % RSD was higher for field replicates than for lab replicates in this study, and this has been often observed in past studies [5, 17, 18]. However, the levels measured in all field replicates did not vary more than one order of magnitude between replicates and the general trend was the same for both samples. The main goal for analyzing field and lab duplicates within this study was not to perform a detailed statistical analysis of the data set, but to increase the level of confidence. Since, in general, the % RSD for most lab replicates was relatively low, and the same trends were seen for field replicates, the acquired data were judged adequate and conclusions were drawn from them. This demonstrated again that explosives showed a pattern of high spatial heterogeneity as field contaminants, and that, even with careful compositing, the % RSD between field replicates is often still high.

6.4 Metals

For all soil samples, 29 parameters, including the most common metals, were analysed by ICP/MS (Al, As, Ba, Be, B, Bi, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Sr, Tl, Sn, Ti, U, Th, V, and Zn). Thorium was analysed only for a limited number of samples, most of them being located in areas where MILAN missiles had been fired. For biomass samples, 28 parameters, including the most common metals, were analysed (Al, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Sb, Se, Ag, Na, Sr, Tl, Sn, Ti, Th, V, and Zn). Again, Thorium was analysed only in a limited number of samples. For aqueous samples, the following 48 parameters were analysed: alkalinity as $CaCO_3$, alkalinity as bicarbonate, alkalinity as hydroxide, pH, electrical conductivity, total dissolved solids, turbidity, chloride, nitrite-nitrate, sulphate, hardness as $CaCO_3$, and metals (Al, As, Sb, Ba, Be, B, Bi, Cd, Ca, Cr, Co, Cu, Ce, Fe, Pb, Li, Mg, Mn, Mo, Ni, P, K, Ru, Se, Ag, Na, Sr, Tl, Sn, Te, Ti, U, Th, V, W, Zr, and Zn). Since the results for metals are presented in many tables, and since many parameters exceeded the criteria, global analysis of all metals would have been confusing and not relevant. We, therefore, analyzed them on a range by range basis that will be presented in section 7.

6.5 Thorium

In soils thorium concentrations varied from 1.19 to 6.35 ppm in Aachen battlerun (Table XXII). The calculated mean value for the background samples was 2.73 ppm and the average measured concentrations of thorium in soils were around 3 ppm. No trends in thorium concentrations were observed around targets nor in the battleruns. The highest concentration of 6.35 ppm was found around Target 1 in Aachen battlerun where no MILAN missiles were supposed to be have been fired. Since this result is twice the background value, it can be considered not statistically significant. According to this, only 25% of the samples collected in Aachen were screened for thorium.

For surface water samples, most concentrations of thorium were detected at very low levels or were below the detection limits (Table X). In ground water samples, thorium concentrations generally decreased with distance from targeted areas (Table VIII). The highest concentration measured in 2000 reaches 1.145 ppb and was located in Deilinghofen firing area (GW-D-3). At this same location, in 2001, the concentration decreased to 0.31 ppb. This could indicate that the concentration of thorium is decreasing as stated in the previous section (GW-D-3 location). The highest concentrations measured were 2.35 ppb again in Deilinghofen (GW-D-8, located down gradient of GW-D-3). Nevertheless, this concentration is lower than the CCME threshold criteria. No thorium was found in the three springs and in the two supply wells of the base.

In biomass samples, thorium exceeded the BGL for some Essen samples (Table XXIII). Only two background biomass samples were analysed for thorium concentration and this situation was corrected by collecting more biomass background samples during the Sept 2002 sampling campaign. The mean value calculated from the two background samples was 0.80 ppb. In Essen, seven biomass samples showed thorium concentrations higher than 0.80 ppb. The updated value of the mean background including the additional samples collected in Sept 2002 remained at 0.80 ppb with a standard deviation of 0.2. Nevertheless, most of the results were around 1 ppb, with the highest being at 1.38 ppb close to missile debris. This value is very low being less than twice the mean background value; therefore, thorium concentrations in biomass should not be considered a threat. One sample included only the roots of the plants. In this sample a concentration of 15.69 ppb was observed. Plants are known to be capable of concentrating metals in their root system. As discussed earlier, grazing animals do not eat the root system; therefore, no threat should be considered against grazing animals. Moreover, this sample represented a localized source, since it was taken directly under MILAN missile debris and did not represent the situation for the entire range. No action is required except removing and disposing the debris according to the existing radiological procedure. In Deilinghofen, no biomass samples showed thorium concentration higher than the background levels.

7 Results and Discussion

Since some particular contaminants were observed in specific areas, such as around targets in the battleruns, in grenade and rifle ranges, etc., the specific problem related to each type of ranges was evaluated. Concentrations of contaminants in soils, biomass and ground water were correlated. Attempts were made to correlate the firing activities with the resulting observed contamination patterns. Recommendations to propose solutions or mitigation techniques were made.

The results for metals in soils and biomass are presented at Tables XI and XII. The results in red are higher than the mean background levels (BGL) added to twice the standard deviation. The results in blue are higher than the CCME agricultural soil quality guidelines (ASQG). A total number of 46 biomass and 130 soil samples were collected during Phase II in 2001. The parameters analyzed in soils were as follows: Al, As, Ba, Be, B, Bi, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Sr, Tl, Sn, Ti, U, V, and Zn. The parameters analyzed in biomass were as follows: Al, As, Sb, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Ag, Na, Sr, Tl, Sn, Ti, V, Zn. Thus, a total number of 1,257 parameters were analyzed for biomass and 3,045 for soils. Out of these, 19 % exceeded the BGL for biomass and 12 % exceeded either the BGL or the ASQG for soils. The results for plants correspond to the total amount of metals both bio-accumulated and deposited on the plants, since the total digestion of the plants was accomplished. Analyzing leachates to discriminate between metals in and on plants was not judged necessary, since wildlife ingest the total amount of metals being deposited or bioaccumulated by eating the entire plants.

Since ground water results were obtained from unfiltered samples, these represent the worst-case scenario. Nevertheless, final conclusions were drawn from ground water results coming from Phase III since these samples were field filtered. However, comparing results with results from soils and biomass is still worthy and interesting. The results obtained are presented for rifle ranges, grenade range, for Aachen, Cologne, Deleighofen, Essen and Klein Essen battleruns, and for the Antenna Service Area (ASA).

7.1 Rifle Ranges

Three of the four Shilo rifle ranges were sampled as described in section 3.8 based on their extensive use by the troops. Both soil and biomass samples were collected in front of targets as shown in Figures 16 and 17. Thirty-four soil and 11 biomass samples were collected in these ranges. Subsurface soils were also collected using either stainless steel scoops or a manually operated core sampler. Subsurface soils were collected to verify whether contamination would be observed in the vertical soil profile. Many deer tracks and droppings were observed on these ranges.

Soils

One hundred twenty-six parameters exceeded either the BGL or the ASQG out of the 952 parameters analysed for in the 34 soil samples (Table XIX). These parameters were as follows:

-As: 6 surface soils samples that exceeded the ASQG (maximum level at 1.4 times higher or 16.3 ppm);
-Bi: 21 samples, including 6 subsurface samples that exceeded the BGL (maximum level at 21 times higher or 4.16 ppm);
-Cu: 32 samples that exceeded the BGL and ASQG (15 samples were lower than 100 ppm, while 17 samples presented results over 100 ppm). Both surface and subsurface soils were impacted with high levels of copper (maximum level at 84 times higher than the ASQG or 7620 ppm);
-Pb: All samples presented high levels of lead. Results varied from 32 ppm to 44,000 ppm. In range #2, the results exceeded the Industrial Soil Quality Guideline (ISQG) by 73 times or 44,000 ppm (this represents 4.4% lead in soils);
-Ni: 4 samples including surface and subsurface soils exceeded the ASQG (maximum level at 3.6 times higher or 183 ppm);
-Sr: 4 samples slightly exceeded the BGL in ranges 1 and 2;
-Tl: 5 samples slightly exceeded the BGL in ranges # 2 and 4;
-Sn: 7 samples exceeded the BGL in ranges # 2 and 4 (maximum level at 3 times higher or 14 ppm);
-Zn: Fourteen samples exceeded the ASQG including surface and subsurface (maximum level at 683 times higher or 683 ppm).

The results obtained for metal concentrations in soils demonstrated a clear impact of the firing activities with small arms. Both surface and subsurface soils showed the same trends. The samples were carefully sieved to avoid the inclusion of metallic fragments in the digest. By doing this, we evaluated the potential contribution of metals attached to soil particles that can be inhaled or transported via sedimentation or dissolution through the ground water. However, very fine metallic particles that were included contributed to the total amount of metals and may not represent necessarily the bio-available metals. Large fragments are understood to be non-bioavailable, but will eventually contribute to ground water contamination with time since they are slowly dissolved by atmospheric conditions. Therefore, removing metallic fragments from the ranges decreases the potential intake for ground water contamination and represents a good practice that should be continued. Running leachate experiments on these soils would give information on their potential to contaminate the ground water table and consequently should be done.

Biomass

Seventy-five of the 308 parameters exceeded the BGL in the 11 biomass samples. These were as follows:

-Al: 1 sample slightly exceeded the BGL for Al;
-As: 4 samples exceeded (maximum level at 2 times higher, or 466 ppm);
-Sb: All samples greatly exceeded the BGL (maximum level at 218 times higher, or 19.6 ppm);

-Ca, Mg, Na: 10 samples exceeded the BGL for either Ca, Mg or Na with a maximum for Ca at 7,870 ppm;
-Cu: 8 samples exceeded the BGL. (maximum level at 6.3 times higher on rifle range # 2, or 47 ppm);
-Fe: 1 sample slightly exceeded BGL.
-Pb: All samples greatly exceeded (vary from 38 to 789 times the BGL, or 631 ppm);
-Mo: 3 samples slightly exceeded BGL in rifle range # 1;
-Se: 4 samples in the three ranges slightly exceeded BGL;
-Sr: 10 samples exceeded BGL (maximum level at 2.4 times higher or 24.9 ppm);
-V: 1 sample slightly exceeded BGL;
-Zn: All samples exceeded (maximum level at 2 times higher, or 65.3 ppm);

Results obtained for soils in rifle ranges correlated well with results obtained for the biomass samples. In particular, high levels of arsenic, copper, lead, strontium and zinc were found both in soils and biomass (Table XIX). Lead was found at the highest concentration compared to backgrounds and was as high as 789 times the BGL in plants. Antimony was also found at high levels in the biomass extracts. Unfortunately, Sb was not included in the soil analysis series. A peculiar difference between soils and biomass was observed. The larger amount of alkaline metals (Na-Mg-K) in plants was not found in soils. These analytes are known to be readily extracted by plants. The mixed contamination of plants by heavy metals and Ca-K-Mg-Na create a preferential intake of these contaminated plants by the wildlife. This was observed on the ranges where many deer tracks and droppings were seen. The salty taste of the Na-Mg-K attracts the deer to this heavy metal contaminated vegetation. The presence of these elements might be explained by the fact that de-icing salts are used on the ranges to avoid freezing of the moving targets during winter. This problem should be addressed in the future to avoid grazing animals on these areas. A measure as simple as a tall fence around the rifle ranges should correct this situation, at least for large animals like deer.

Ground water

The following parameters that exceeded BGL or CCME SQGL criteria for soils and biomass were also found exceeding ground water BGL or WQGL criteria during Phase II: As, Pb, Cu, Fe, Ni and Sn. These metals were allowed to percolate through the ground water, even at neutral pH, by moving of particles containing metals or dissolved metals. However metals concentrations found in the ground water of the rifle ranges were not very high, indicating that the process of desorption is very slow, since the concentrations in soils were very high. During Phase III, no metals were detected above the CCME Drinking Water criteria in GW-RIF 1 and GW-RIF 3. This indicates that the results from Phase II with unfiltered samples can be attributed to metals adsorbed on fine particles forming colloidal suspension. This represents a potential charge of contaminants that can become available and move into ground water if pH changes. However, state of the art ground water sampling implies filtration of the samples that remove these fine particles containing metals. Consequently, the water quality based on results from Phase III is good and no corrective action is needed.

7.2 Hand Grenade Range

Soils

Seventeen soil samples were collected at the grenade range. Ninety of the 364 metals exceeded either the BGL or the ASQG. These parameters were as follows:

-Cd: All samples exceeded the ASQG except the crater sample (maximum level at 4 times higher, or 3.24 ppm);
-Cr: All samples exceeded the BGL (maximum level at 1.5 times higher, or 29.4 ppm);
-Cu: All samples exceeded the ASQG (maximum level at 5 times higher, or 40.5 ppm);
-Pb: 13 samples exceeded the ASQG (maximum level at 5.7 times higher than the ASQG, 20 times the BGL, or 72.8 ppm);
-Mg: 12 samples exceeded the BGL (maximum level at 1.5 times higher, or 7810 ppm);
-Ni: 9 samples exceeded the ASQG (maximum level at 1.2 times higher, or 46 ppm);
-Ti: 7 samples exceeded the BGL (maximum level at 1.3 times higher, or 210 ppm);
-Zn: All samples exceeded the ASQG (maximum level at 12 times higher, or 1770 ppm).

Many metal concentrations were higher than the BGL or ASQG in the grenade range. Metals for which hits were encountered were found on the entire surface of the range, even at the farthest distance from the grenade launching point (35m). No specific trends were seen in the linear sampling results, neither with length nor with width of the site (A and B samples at different distances, Figures. 14, 15). The metals found can be related to the Canadian grenade composition. Many parameters exceeded the ASQG. It can be noted that Cadmium parameters exceeded ASQG and Chromium concentrations are also quite high. Canadian hand grenades do not contain these two metals while German Grenades do. Consequently, the presence of these two metals at these concentrations can be attributed to the use of German grenades on the Shilo grenade range. It should be mentioned that German grenade ranges are contaminated by cadmium and efforts are presently being made in Germany to clean German sites from this contaminant.

Biomass

No biomass samples were collected at the first sampling event, since the range was not vegetated. However, vegetation was present around the perimeter of the range. If the biomass around the range shows problematic concentrations of some metals, a fence blocking the access of wildlife to the contaminated plants could be installed around the impacted area.

Ground water

Results for many parameters were greater than the BGL or the WQGL in the two wells located down gradient of the grenade range. The parameters exceeding both soils and ground water criteria were Cd, Cu, Cr, Ni, Pb, Ti and Zn. Moreover, many other parameters, including W, Ag, As and Bi, exceeded the BGL or the WQGL for ground water. This clearly indicates that an impact to the ground water may be caused by the grenade range, which can be considered a point source. However, according to CCME Drinking Water criteria, only Al, Fe and Mn were of concern but these metals were not detected in ground water samples from Phase III in GW-GRE 2 and GW-GRE wells.

Since the soils of the grenade range are impacted with various heavy metals, mitigation techniques should be put into place to reduce or eliminate the dissolution and transport of these to the vadose zone where they may reach the ground water and move outside of the area. Ground water results from Phase II demonstrated a potential threat for ground water even if results from Phase III showed no metal detection. The results for soils at the Shilo grenade range are probably representative of all Canadian grenade ranges. The results are not surprising, since grenades are designed to fragment their metallic casing and to project these fragments into the surrounding environment.

For future operations, a new design for grenade ranges should be put in place if sustained activities are desired. One can imagine that if the water percolating from the grenade range is controlled, the training activity can go on forever. To control the water, the equivalent of a house foundation with a central drain to collect and treat the water could be built. First, a concrete slab covering all the range could be constructed and filled with sand (5 feet thick). The slab should be surrounded by concrete walls and equipped with a central drain system to collect the water that would percolate through the sand. This contaminated water would have to be stored and treated, according to the state of the art, prior to disposal. This structure would prevent the metals from leaching to the ground water, ensuring sustained range activity. Another solution les expensive would consist in using a resistant liner that could be equipped with a central drain as well. These options are our first thoughts of solutions that could be put into place to control and prevent the contamination. These potential solutions should be discussed in more depth with the end users who would select the best and most practical solution.

Energetic Materials

The hand grenade range was sampled linearly as described earlier (see section 3.8, Fig. 14). Fifteen surface samples were collected across the grenade range. Subsurface samples were not collected since the EOD military officer did not allow digging. However, the frequent detonation of hand grenades allows the mixing of the soil profile and, therefore, surface samples represent a mix of both surface and shallow subsurface soils. All samples presented at least measurable amounts of 6 explosive residues. Detailed results for the hand grenade range can be found in Table XXI.

The explosive residues found in this range were 2,6-DNT, 2,4-DNT, TNT, RDX, 4-am-DNT, 2-am-DNT, 3,5-DNA, Tetryl and HMX. Concentrations of these analytes varied from non-detected to as much as 4,058 ppb for RDX, 5 meter away from the bunker wall. The highest hit for TNT was 725 ppb and was measured in a crater freshly formed by recent grenade detonation. In the same sample, RDX and HMX were also detected at 2,188 and 191 ppb, respectively. The hand grenade range clearly presented a very distinctive contamination pattern when compared to battlerun patterns. The contamination was relatively uniform and present on the entire surface of the range, even at the limit of the range, 35 meters away from the bunker. Sample S-GR-30m-A and B presented higher levels of 2,6- and 2,4-DNTs compared to TNT, which is somewhat unusual.

Currently, the Canadian hand grenades are C7 fragmentation grenades, which contain Composition B (186 g), a melt-cast explosive (RDX (60%), TNT (39%) and HMX (about 10% as an impurity in military grade RDX). Military grade TNT contains about 1% TNT isomers (other than the 2,4,6-isomer), 2,4-DNT, 2,6-DNT, 1,3-DNB and 1,3,5-TNB. The detonator of the grenade also includes 1.3 g of RDX. The grenade primer and fuse systems, and casings contain various heavy metals as well. The ratio of RDX/HMX should be around 8, based on the main composition of the grenade explosive charge. The field ratios obtained of RDX/HMX were between 11 (in the fresh crater sample) and 2.2 for sample 35m-A. This is not surprising since RDX leaches more rapidly in the soils since it is more water soluble than HMX, has a faster dissolution rate, and thereby results in a lower field RDX/HMX ratio for weathered residues.

In general, the pattern of contamination observed at the Shilo hand grenade range can be directly related to the C7 hand grenade used there. The ratio of various explosive analytes was not always the same as in the grenade composition, but differences can be easily explained by various biotic, abiotic transformation (degradation, photolysis, reaction with organic matter, etc.) and preferential dissolution. The levels of explosive analytes encountered in the hand grenade range are higher than in the battleruns. The contamination on the hand grenade range was present all across the range. However, the maximum level measured was still under 5 ppm, which is not considered a high level of contamination. No explosives were detected in ground water. Similar results for explosives in range soils were obtained in USA hand grenade ranges at Fort Lewis and Fort Richardson [7]. The levels of EM and metals in soils measured in these two ranges were somewhat higher than the one measured in the Shilo hand grenade range, potentially explained by a more intense use of their ranges.

Considering all of the results obtained at the grenade range, activity clearly impacts the range soils. The idea of building a slab and controlling the infiltration of metals and also the dissolution of explosives residues should be considered to definitely solve this problem.

7.3 Anti-Tank Range

No soil and biomass samples were taken in the anti-tank range due to safety reasons. Since level-one clearance had not been done for some times, the probability of walking on UXOs was too high (Fig. 28).

Ground water

Two wells were installed down gradient of the anti-tank range. Results showed that the following parameters exceeded the BGL or the WQGL: nitrate-nitrite, Al, As, Sn, Cr, Co, Cu, Fe, Pb, Mn, Ni, P, Ru, Tl, Ti, V, and Zr. The anti-tank range may represent a point source for many metals, but, unfortunately, these results cannot be compared with neither soils nor biomass analyses. Surprisingly, no explosives were detected in the two wells as seen in another study [2]. No metals were detected in filtered samples in GW-ATR 1 during Phase III. Again here, metals concentrations observed during Phase II can be attributed to the presence of colloid particles but not to dissolved metals.

7.4 Battleruns

Aachen Battlerun

Soils

Twenty-one soils samples were collected in Aachen battlerun. Linear sampling was conducted at 20, 40, 60, 80 100 and 120 % of the range length. Sample 100% B was not collected due to the presence of large bushes and trees on that portion of the range. Two field duplicates were collected at 40 and 80 % transects. At the 20% linear transect, a large quantity of debris from ammunition was observed. Two targets were sampled using the circular pattern both for soils and biomass. Two hot spots were found on the range. They were S-A-HS 60021E 12160N and S-A-HS-60042E 12060N. One looked like a hole where ammunition was dumped, and the other was a spot where a flare had burned.

Out of the 588 parameters analyzed in the 21 soil samples, eight parameters exceeded either the BGL or the ASQG in Aachen. (Table XIV). These were as follows:

-Cu: 2 samples exceeded ASQG;
-Ni: 3 samples exceeded ASQG and 16 times BGL, or 394 ppm;
-Mo: 1 sample slightly exceeded BGL;
-Cd: 1 sample exceeded ASQG;
-Co: 1 sample exceeded BGL.

The results demonstrated that the firing activity conducted in the Aachen battlerun did not lead to the accumulation of high levels of metals in soils. This confirms the results obtained in the other battleruns sampled during Phase I in 2000. However, five samples showed values higher than ASQG levels for Cu, Ni, Cd and Co (ASQG is the most sever and conservative criteria).

Biomass

Four biomass samples were collected around targets # 1 and 2. They were collected in a circular pattern between 0 and 3 m and 3 and 5 m from the center of the target. Nine of the 108 parameters exceeded the BGL in the four biomass samples. These were as follows:

-Pb: 2 samples exceeded (highest hit at 5.5 times BGL, or 4.43 ppm);
-Cd: 2 samples slightly higher than BGL;
-Sr: 2 samples slightly higher than BGL;
-Zn: 1 sample slightly higher than BGL.

The results obtained for biomass in Aachen presented mainly higher hits for lead at target # 1. By comparing the soils and biomass results, a parallel can be established for cadmium at target # 2 where both soils and biomass showed higher levels than both the BGL and ASQG. The levels of lead in soils at target # 1 did not present values higher than those found in the biomass.

Ground water

Many parameters exceeded the BGL and the WQGL in Aachen wells presented in Table XIV. More particularly, Co, Cu, Mo, Ni and Zn were found in soils, biomass, and ground water. Moreover, 14 metal analytes in ground water exceeded either BGL or WQGL, while not exceeding the BGL or SQGL in soils, or the BGL in biomass. Among these, Al, Fe, Mn and Pb concentrations were higher than the CCME Drinking Water criteria but no metals were detected in Aachen ground water samples collected during Phase III. Our surface soil sampling did not include the coverage of the entire surface of the battlerun and represented only a limited portion of the area. Therefore, results from ground water analyses were more representative of the impact by the activity.

Energetic Materials

For the energetic materials, the linear transect sampling was done, two targets were sampled with the help of the circular pattern, and two hot spots were sampled. One hot spot was near the remains of a flare (S-A-HS 62033E 10742N) and the other was in a crater where munition debris was seen (S-A-HS-60021E 12160N). Out of the 14 samples collected in Aachen, 5 presented measurable traces of explosives. They were respectively as follows:

S-A-LS 20 % A: NG and 2,4-DNT (15 and 6 ppb)
S-A-LS 20 % B: TNT and RDX (27 and 6 ppb)
S-A-LS 60 % B: TNT (1,2 ppb)
S-A-LS 80 % A: TNT (5 ppb)
S-A-LS 120 % B: TNT (52 ppb)

No explosive residues were neither detected in the two locations where debris of munition were present (HS samples) nor in the two circular samples near targets. Explosive residues were detected along the battlerun at 20, 60, 80 and 120 % of the range length. At 20% sample A, traces of NG and 2,4-DNT were found that can be related to the compositions of gun propellants deposited at the firing position or to the burning of excess gun propellants at the end of the activity. Solutions are presently suggested to avoid the burning of excess gun propellants at the end of firing activities. TNT and RDX present in other transects were found in low concentrations with the highest result being around 1ppm of TNT.

Berlin Battlerun

Neither soils nor biomass were collected in Phase II. However, ground water samples were collected and metals analytes that exceeded the BGL or WQGL are presented in Table XV. Many parameters exceeded the threshold levels including Uranium probably coming from metals adsorbed on colloidal particles. Once again, no metals were detected in ground water samples collected during Phase III indicating that these metals were not dissolved but adsorbed on particles.

Cologne battlerun

Soils

Thirty soil samples were collected in 20, 40, 60, 80, 100 and 120 % linear transects. Three targets were sampled using the circular pattern and 7 hot spots nearby various UXOs or UXO debris were collected as well (Figs. 29-31). Six biomass samples were collected around the three targets.

The seven hot spots sampled were 63025E 02811N (small caliber shells), 65011E 02663N (melted flare), 68010E 02205N (120 mm mortar), 65235E 02905N (155 mm), 65266E 02930N (155 mm), 66040E 02939N (155 mm live), and 66017E 02566N (155 mm, shell broken open).

Forty-two parameters exceeded either the BGL or the ASQG out of the 840 parameters analysed for these 30 soils samples (Table XVI). These were the following:

Al, As, Be, Bi, Cd (over ASQG (4X), or 5.86 ppm);
Cr, Co, Pb (over ASQG (5 X) or 181 ppm);
Mg, K, Tl, Ti, U (over BGL, highest at 4 times BGL or 17,100 ppm;
Zn (over ASQG (25X), or 4970.

For the melted flare sample, lead concentration was higher than the ASQG and was five times the BGL. The same sample presented higher levels of Al, Bi, Cd and Zn. Target # 1 concentrations were higher for uranium and arsenic, which were also found at two hot spots. This could indicate that ammunition-containing uranium might have been used in the past in the battlerun. The uranium and arsenic concentrations were 33% higher than the BGL, and the arsenic concentration was 40% higher than ASQG.

Nine samples presented concentrations higher than ASQG in Cologne battleruns, mainly at targets and hot spots. The results obtained for linear transects correlated well with what was observed during Phase I in the 2000 study in the sense that only a few hits were observed in the battleruns, but never exceeded the ASQG. This demonstrated that localized impacts around targets and hot spots can be observed and may exceed the ASQG in some localized spots in battleruns.

Biomass

Eight parameters of the 162 parameters exceeded the BGL in the 6 biomass samples. These were As, Sb, Pb, and Sr. Out of these, only the results for lead showed values more than twice the BGL. The highest result was found at target #2 where lead was measured at 3 times the BGL, or 3.31 ppm. This result was not correlated to the surface soil results where no higher trend for this analyte was observed. At target # 1, both soils and biomass presented higher levels of arsenic.

Ground water

Results for the ground water collected in 9 wells located in the Cologne battlerun are presented in Table XVI. Twenty-seven metal analytes were detected at levels higher than the BGL or the WQGL. Of these, 16 were also detected over the threshold values in soils or biomass. Uranium was again detected at levels higher than the ASQG in soils and over the BGL in ground water. Arsenic and cadmium were also detected at levels higher than the ASQG in soils and over the BGL in ground water. These results demonstrated that these compounds are coming from an anthropogenic source, and can be related to the firing conducted in this battlerun. Since uranium is not found in background samples, its presence can only be related to the use of weapons containing this element. To our knowledge, depleted uranium ammunition was not fired on this site according to the range control. Therefore, the presence of uranium may indicate that some of these weapons were sporadically fired in the past and that the firings were not recorded. According to table XI, many metals were higher than the drinking Water criteria but Phase III results showed no metals detection over the detection level of the method.

Energetic Materials

For the energetic materials, the linear transect sampling was used in this battlerun. Moreover, three targets were sampled in the circular pattern, and six hot spots were sampled close to various munition debris and near a broken 155 mm UXO (S-C-HS-66017E 02566N). Out of the 30 samples collected, 6 presented measurable traces of explosives. They were the following, respectively:

S-C-LS 20 % B: RDX (21 ppb)
S-C-LS 80 % B: NG and 2,4-DNT (12 and 25 ppb)
S-C-LS 120 % A: TNT (10 ppb)
S-C-LS 120 % B: RDX (5 ppb)
S-C-2-1-3: RDX (20 ppb)
S-C-HS- 66017E 02566N: 2,6-DNT (2 ppb)

In this battlerun, six hot spot locations were identified within the range. Out of these six potential sources, only one showed traces of 2,6-DNT near a broken 155 mm UXO. At that location, neither TNT nor RDX were present. At target number 2, only one sample showed traces of RDX. In the linear transects, we observed the same trends as in the Aachen battlerun, where traces of TNT, RDX, NG or 2,4-DNT were detected at 20, 80 and 120 % of the BR length. In general, traces of some of the explosive analytes were found in six samples, but always at concentrations lower than 0.05 ppm.

Deilinghofen battlerun

The Deilinghofen range was characterized in the 2000 study (Phase I). In Phase II, soils and biomass samples were collected at two additional targets and in hot spots. This range was searched to identify some localized potential problems and also to collect biomass samples around targets. Only three hot spots were found on the range and were live large caliber ammunitions (155 mm) lying on the surface. They were all complete unbroken shells.

Soils

Twenty-two parameters exceeded either the ASQG or the BGL out of the 252 parameters analysed for in these 9 soil samples (Table XVII). These were as follows:

-Co: 5 out 6 target samples largely exceeded the BGL (highest hit 12.5 times BGL, or 140 ppm);
-Cu: All the target samples largely exceeded the ASQG (highest hit 3.4 times ASQG, or 137 ppm);
-Pb: All target samples exceeded the ASQG (highest hit 3.4 times ASQG, or 241 ppm);
-Mo: 2 samples slightly exceeded the BGL at target # 2;
-Sr: Three samples exceeded the BGL at target # 1 and 2.

Results obtained for the six soils samples around targets exceeded the ASQG both for copper and lead. These metals are usually found in small arms range and are characteristic of them. So, this indicated that these targets were used for small arms targets as well as larger caliber rounds as confirmed by range control. Tank maneuvers often include the firing of small caliber ammunition with mounted machine guns.

Biomass

Twenty-nine parameters exceeded the BGL out of the 112 parameters analyzed for the 4 biomass samples. These were as follows:

-Sb, Ba, Cd, Ca: All samples exceeded, highest 2.1 times the BGL, or 15,500 ppm;
-Cr: 1 sample exceeded at target #1, highest 1.46 times the BGL, or 25.3 ppm;
-Co: 3 samples exceeded, samples at 0-3 m from targets, 3.2 and 2.4 times the BGL or 4.63 ppm maximum;
-Pb: 1 sample exceeded at target #1, 2.1 times the BGL, or 1.72 ppm;
-Mg: 3 samples exceeded, highest hit 1.5 times the BGL, or 2,930 ppm;
-P and K: 4 samples exceeded, highest at 1.5 times the BGL, or 18,600 ppm;
-Na: all samples exceeded the BGL;
-Sr: all samples exceeded, two samples nearby targets greatly exceeded (19 times, or 197 ppm);
-Zn: 1 sample exceeded at 40.9 ppm.

The results obtained for the biomass samples in Deilinghofen demonstrated that higher levels of various metals were found in the vicinity of targets. The results correlated well with those of the soil samples where, in both cases, higher levels of cobalt, lead and strontium were found. However, copper was not found in biomass samples, while it was found in high levels in soils. This might indicate that this metal was not phytoaccumulated in the biomass, while cobalt, lead and strontium were. Some higher results were obtained in plants for calcium, magnesium and sodium while not observed in soils. This can be explained by the solubility of these particular alkaline and earth-alkaline metals. They are rapidly dissolved by rain or snow melt, can be taken up by plants or leached through the ground water leaving the concentrations in soils very low. The presence of these analytes at higher levels might attract wildlife to the range since they are known as attractants because of their salty taste. Therefore, the wildlife present on the Shilo range might ingest preferentially these plants that contain not only the alkaline and earth-alkaline metals, but also the other metals phytoaccumulated in the biomass.

Ground water

Twenty-five metal analytes were detected in exceedance of the BGL or the WQGL in samples collected in the 10 wells located in this battlerun. Out of these 25 metals, 9 were found over the threshold values (BGL or SQGL) in either soils or biomass. Chromium, Pb, Co and U were of particular concern, since they were found in the majority of wells over at least twice the BGL or over the AWQG. Uranium was found in all of the wells at values greater than the BGL, which can indicate that uranium is naturally occurring in this part of the range or that depleted uranium and thorium weapons or targets were used in Deilinghofen. Thorium 232 is not a decomposition product of neither natural uranium nor depleted uranium meaning that these co-contaminants are not directly related. Results from Phase III (2002) sampling campaign indicate no groundwater contamination problems. Iron and manganese concentrations exceeding CCME Drinking Water guidelines were found in several wells; however, the measured concentrations are common in groundwater and are linked to the geological conditions of the Assiniboine aquifer. Aluminum was found exceeding CCME drinking water quality guidelines in one well (D-8) and arsenic in one well (GW-D-1-A); however, these are isolated cases. The result from well GW-D-1-A should be interpreted with caution as the well had not been developed nor purged properly and the sample was extremely dirty. During the 2002 sampling campaign, two sets of samples (one filtered and one unfiltered) were collected in each of eight different wells in order to evaluate the influence of water filtration on measured metal concentrations. In all cases, metals such as arsenic, barium, lead and selenium were detected or exceeded CCME guidelines only in unfiltered samples. Aluminum, manganese and iron concentrations were two or three orders of magnitude higher in unfiltered samples than in filtered samples. This is typical of the area.

Energetic Materials

Since they were conducted in Phase I, no linear transects were done in this battlerun. A total of nine samples were collected at two targets and three HS locations. Only 2 showed traces of explosive residues. They were as follows:

S-D-HS-74215E 01278N: TNT, 4-am-DNT and 2-am-DNT (46, 26 and 28 ppb, respectively)
S-D-1-3-5: NG (6 ppb)

In this particular battlerun, one sample collected near a UXO presented detectable traces of TNT and its two amino metabolites. Another sample presented low levels of NG at target number 1. Here again, the levels encountered were low with a maximum of 0.05 ppm for TNT.

<u>Essen Battlerun</u>

The Essen range was characterized in Phase I (2000). As for the Deilinghofen range, it was revisited in 2001 for the same reasons. A total 6 soils and 13 biomass samples were collected, soils near two UXOs and biomass near four MILAN missile debris sites. One plant root sample was collected in a spot where most of the MILAN debris was observed. This was done to verify the hypothesis that roots bioaccumulate more contaminants than the stem and leaves of the plants. Moreover, analyses for thorium were repeated to verify if the thorium concentrations (MILAN missile impact area in Essen range, Fig. 32) changed with time in both soils and ground water.

Soils

Ten samples exceeded the ASQG for copper and lead out of the 224 parameters analysed for the 8 soil samples (Table XVIII). These were the following:

-Cu, Pb: 6 samples exceeded the ASQG for lead (highest hit, 6.7 times the ASQG, or 476 ppm),

Biomass

Seventy-three parameters exceeded the BGL out of the 351 parameters analysed in the 13 biomass samples. These were as follows:

-Sb: 6 samples exceeded (highest hit 4.3 times the BGL, or 0.6 ppm);
-Ba: 9 samples exceeded (highest hit was 2 times the BGL, or 108 ppm);
-Cd, Ca, Mg and Na: 10 samples exceeded either one of these analytes nearby MILAN debris up to 12,000 ppm;
-Cr, Co, Cu, Pb, Mo, and Sr: all samples exceeded, (highest hit 3 times the BGL, or 45.6 ppm).

The root sample exceeded by far the BGL found for Al, Ba, Be, Cd, Cr, Co, Fe, Pb, Mn, Ni, Se, Na, Sr, Tl, Ti, V and Zn. These results showed a very strong trend proving that roots bioaccumulate metals to a higher extent than the leaves and stems. These results could not be directly compared to the backgrounds, since no roots were collected in a background area. The impact would depend on whether the roots are eaten by various species of wildlife likely to graze on the site. For species that eat the roots, the conclusions about risk to wild life in the 2000 and 2001 study are highly underestimated. An expert (Dr Lucie Olivier, project manager from Environment Canada) stated that normally the deer and other grazing animals eat preferentially the upper plant tissues and not the roots (Tel. Conf. March 2002).

The results obtained for the plant tissues in Essen clearly showed an accumulation of various analytes of concern, including heavy metals, especially lead, molybdenum and strontium. The presence of other analytes such as sodium, calcium and potassium may act as an attractant for the wildlife and enhance the grazing of these contaminated biomass samples relative to less contaminated areas of the base.

The results obtained in soils for copper and lead were correlated with those obtained for the biomass where these two analytes were found at higher levels in both media.This may indicate that target areas were also used for small arms firing using tank mounted machine guns.

Ground water

Seventeen metal analytes exceeded either the BGL or the WQGL in the 7 wells located in this battlerun. Out of these, 5 analytes (Co, Cu, Cd, Cr, and Pb) were also found at levels higher than the BGL or SQGL in soils and biomass. In particular, Cu and Pb levels were found at high levels in all types of samples. During Phase III, Al, Fe and Mn were detected above the Drinking Water criteria but as already explained, this is typical of the area and is related to the geological formations.

Energetic Materials

The linear transect sampling was not conducted in this battlerun, since it was accomplished in Phase I. Fourteen samples were collected around 4 targets and at two HS locations. Six of these presented measurable concentrations of propellant residues. They were the following, respectively:

S-E-1-0-1: NG (21 ppb)
S-E-1-1-3: NG (41 ppb)
S-E-1-3-5: NG (360 ppb)
S-E- 2-0-1: NG (3 ppb)
S-E-2-1-3: NG (10 ppb)
S-E-2-3-5: NG and 2,4-DNT (56 and 2 ppb)

In Essen targets, only NG and 2,4-DNT were found with no detectable traces of RDX and TNT. These two analytes are related to gunpowder and could be the result of the MILAN missile firing that was conducted there. MILAN missile propellant might have not completely burned when the missiles hit the targets. Again, the level of NG and 2,4-DNT were negligible, the highest concentration being less than 0.4 ppm. The two hot spots where ammunition debris was found were free of detectable explosive residues.

Klein Essen

A limited number of samples were collected in Klein Essen. The activity conducted there consisted mainly of machine gun firing. Only five soil and four biomass samples were collected near targets and the bunker. No energetic materials analyses were done at this range since energetic materials are not associated with small arms. Samples were collected near the bunker since a lot of small arms shells were seen on the ground. No wells were installed in this range.

Soils

Fifteen parameters exceeded either the BGL or the ASQG out of the 140 parameters analysed for in the 5 soil samples. These were as follows:

-Cu: 6 samples higher than ISQG (highest at 46 times the ISGQ, or 4200 ppm);
-Pb: 4 samples higher than ISQG (highest at 10 times the ISQG, or 6840 ppm);
-Ni: 4 samples exceeded BGL (highest at 2.7 times the BGL or 50.6 ppm, equal to ISQG;
-Zn: all samples exceeded BGL (highest at 8 times the BGL or 425 ppm, highest at 1.2 times ISQG.

All samples presented high levels of both copper and lead, higher than the ASQG, even higher than the industrial soil quality guidelines (ISQG), the most permissive criteria. The highest hit for copper was at 46 times the ISQG. The results obtained for soils clearly showed the accumulation of high levels of copper and lead from the firing activity conducted in Klein Essen. Results higher than ISQG were encountered and are similar to the ones encountered in rifle ranges where small arms are also used.

Biomass

Three biomass samples were collected in Klein Essen, one at a target and two near the bunker (in front and behind).

Sixteen parameters exceeded the BGL out of the 81 parameters analysed in the 3 biomass samples. These were as follows:

-Sb, Cd, Ca, Cr, Cu, Pb: 3 samples exceeded (highest result 15.7 times the BGL, or 12.0 ppm);
-P, K, Sr: 3 samples exceeded (highest at 3 times the BGL, or 22.1 ppm);
-Zn: 1 sample exceeded (91.5 times the BGL, or 38.4 ppm).

In general, many analytes of concern were accumulated in both the surface soils and the plants, with results obtained in both media correlating well. It was found that both firing positions and the target areas were impacted by various metals. On should keep in mind that often, militaries are lying on the ground to practice shooting and thereby, they are lying in a contaminated area and could be in close contact with metals. This particular point will be addressed and potential solutions will be proposed later.

Antenna Service Area (ASA)

The ASA area was sampled even though this was not a firing range. The ASA was sampled to complete all areas potentially impacted by metals. The ASA area was suspected of being contaminated by metals, since two activities were conducted there over the last few years. The first activity consisted of burning obsolete small arms in an incinerator without a gas scrubber, and the second consisted of accumulating metallic debris coming from the clearances of the ranges. A previous study conducted at CFAD Dundurn demonstrated that the burning of small arms in this type of incinerator led to the contamination of surrounding soils, buildings and biomass [33]. Soils at three hot spots were sampled around the pile of metallic debris, and 6 composite samples were collected linearly at distances of 5 to 30 m from the furnace at 5-meters intervals. A total of 9 composite soil samples were collected and 5 biomass samples. Three biomass samples were collected around the pile of metallic debris and 2 biomass samples were collected at distances of 0-15 and 15-30 meters from the furnace in a downwind direction.

Soils

Sixty-five parameters exceeded either the BGL or the ASQG out of the 252 parameters analysed for the 9 soil samples. These were as follows:

-Al, As, Be, Cd: all samples around metal debris pile exceeded the ASQG (highest was at 1.2 times, or 27 ppm);
-Cr and Co: all samples exceeded the BGL;
-Fe, Mo, Sr, Tl, Ti: most of the samples exceeded (2 times the BGL);
-Pb: 1 sample exceeded ASQG (close to incinerator at 75.1 ppm);
-Zn: 3 samples exceeded ASQG (hotspots, highest at 495 ppm).

Many metals concentrations were higher than the BGL and the ASQG near these two sources at ASA. No trends related to the distance of the incinerator were observed. The identified problematic analytes were similar to the ones observed in the CFAD Dundurn study [33]. Since this incinerator was probably less used than the one in Dundurn, the contamination did not reach the same levels in the ASA when compared to Dundurn.

Biomass

Thirty-two parameters exceeded the BGL out of the 125 parameters analysed for the 5 biomass samples. These following analytes showed higher values than the related BG:

-Al: 2 samples exceeded (highest hit 868 ppm or 5 times BGL);
-As: 3 samples exceede(highest hit 0.58 ppm or 4 times BGL);
-Cd: 3 samples exceeded (highest hit 1.74 ppm or 17 times BGL);
-Cr: 1 sample exceeded (41.7 ppm or 4.6 times BGL);
-Co: 2 samples exceeded (highest hit 0.79 ppm or 4 times BGL);
-Fe: 2 samples exceeded (highest hit 1510 ppm or 47 times BGL);
-Pb: 4 samples exceeded (highest hit 2.77 ppm or 6.9 times BGL);
-Mo: 2 samples exceeded (6.14 ppm or 4.4 times BGL);
-Ni: 1 sample exceeded (19.5 ppm or 3 times BGL);
-Se: 1 sample exceeded (0,3 ppm or 3 times BGL);
-Sr: 4 samples exceeded (highest hit 14.3 ppm or 2 times BGL);
-Ti: 2 samples exceeded (highest hit 33 ppm or 825 times BGL);
-V: 2 samples exceeded (highest hit 1.42 ppm or 3.5 times BGL);
-Zn: 3 samples exceeded (highest hit 43.8 ppm or 2 times BGL);

In general these parameters exceeded between 2 times and 825 times for Titanium, which reveal a high impact for this later element. The biomass collected near the ASA clearly showed the accumulation of various metals that were also observed in the soils. Some results in the biomass samples exceeded the BGL for Cd by as much as 5 times.

Many parallels can be established between the soil and biomass results. Both media were impacted by various analytes and trends were comparable. The results indicated that both activities led to the spreading of metals in the surrounding environment. This type of furnace was banned following the Dundurn study [33]. Therefore, the adverse impacts of this activity were stopped. As for the piling of metal debris, a mitigation measure could be put in place such as a concrete slab, equipped with a central drain, on which the debris would be piled instead of sitting directly on the surface soils. The management of the drainage system would be critical to hinder the metals from reaching the ground water. Moreover, no wildlife can have access to the biomass presenting higher levels of metals since the area is fenced. The main potential threat at this site is the leaching of the contamination through the soil to reach the underlying ground water.

Ground water

Two wells were located southwest of the ASA area (AMA1, AMA2). In these wells, only copper and tin were found at levels slightly higher than the BGL. No correlation can be established between the soil-biomass and ground water results in this case. This might be explained by the remote position of the two wells compared to the two sources sampled at the ASA. No metals were detected during Phase III.

8 Conclusions

According to the hydrogeological evaluation, ground water characteristics at CFB Shilo are as follows: a neutral pH (mean 7.58), a low alkalinity (mean 216 mg/L), a low conductivity (mean 433 µS/cm (µohms/cm) for lab data and mean 403 µS (µohms/cm) for field data), a low total dissolved solids concentration (mean 256 mg/L), a low salinity (mean 0.2 ppt) and a very low concentration in anions (mostly below detection limits for carbonate, chloride and sulphate). The redox potential averages 181 mV indicating an oxidizing environment. The high level of dissolved oxygen in ground water (59%) confirms that aerobic environment exists. Ground water velocity was estimated from the Geoflo 40L data and was consistent with the velocities calculated from other field data at 70 to 700 m/y with an average velocity of 350 m/y. The calculated ground water velocity is based on the average hydraulic conductivity estimated from slug tests (1 x 10-4 m/s), the horizontal hydraulic gradient measured on the water table map (0.002 to 0.02 with a mean gradient of 0.01) and an estimated porosity of 0.3. Ground water flow was generally from north to south.

Metal analysis in ground water from 2001 sampling campaign generally showed concentrations much higher than those from samples collected in 2000. However, this is due to the fact that the 2001 samples were acidified in the field without filtration, thereby liberating metals adsorbed on particles. The two wells showing the highest metal concentrations are also those with the highest concentrations of dissolved solids (GW-C-8 TDS 1,700 mg/L, and MW-111, TDS 1,100 mg/L). This can be seen as the potential maximum charge of metal that can be brought to the GW level over the years both in solution and in suspension. These values do not, however, represent the concentrations of dissolved metals that would be present in ground water at any time. Parameters exceeding guidelines were the following: aluminium (Al 83 wells), arsenic (As 7 wells), antimony (Sb 34 wells), barium (Ba 7 wells), chromium (Cr 1 well), iron (Fe 93 wells), lead (Pb 22 wells), manganese (Mn 87 wells), and selenium (Se 3 wells). Aluminium, manganese and iron are naturally occurring in the environment; high concentrations are probably the results of desorption following acidification. The same phenomenon is probably responsible for the high concentrations of other metals. However, since these metals are sometimes linked to military activities, locations showing concentrations above guidelines were re-sampled in September 2002 and demonstrated that these concentrations did not occur in filtered water samples. Generally, metals that exceeded criteria in ground water during Phase II also exceeded criteria in soils and biomass. However, metals exceeded the BGL or the AQGL more often in ground water than in soils. This is not surprising since all contaminants, at a certain moment, reach the ground water and this situation corresponds to a bigger surface source compared to surface sampling, which is localized source. In other words, ground water concentrations represent a composite from the whole surface source, while the soil concentrations represent small localized sources.

According to the state of the art in ground water sampling, water samples should be filtered prior to acidification, but the fact that we did not do so, allowed us to evaluate the total contaminant present in both the dissolved and suspended state (colloid) . This represents the worst-case scenario as a potential threat to ground water quality. Since the pH of Shilo's ground water is constant and neutral, the release of metals from the soils particles is very slow and does not present a threat for the time being. Our study demonstrated that metals are adsorbed onto particles that can be spread out by irrigation when unfiltered water is used. Nevertheless, dissolved metals are the parameters of concern in water quality evaluation and results from Phase III demonstrated that no impacts were done by military activities.

Thorium-232 concentrations in ground water varied by three orders of magnitude. Concentrations ranged from <0.005 ppb (below detection limit) to 2.35 ppb. While even the highest result was one order of magnitude below the CCME guideline (24.5 ppb), several considerations should be kept in mind. Measured concentrations generally decreased with distance from MILAN firing ranges, several being below the detection limit. This is an indication of a measurable contribution of an anthropogenic source of Th in ground water at CFB Shilo. When compared to the thorium BGL, 12 ground water samples located in the target areas presented concentrations over this limit. The highest thorium concentration was found in GW-D-8 near the firing area (2.35 ppb), and was one order of magnitude below the CCME standard of 24.5 ppb.

The second and third highest concentrations were 0.907 ppb and 0.217 ppb, measured respectively in Cologne (GW-C-2) and Essen battleruns (GW-E-6). Analytical results for location GW-D-3, where the highest concentration was measured during Phase I in 2000 (1.15 ppb), revealed a lower concentration of 0.31 ppb in 2001. This may suggest that the contamination of thorium-232 is presently decreasing. No thorium was found neither in the three springs nor in the two supply wells of the base. The general pattern of thorium concentration in ground water at CFB Shilo is one of decreasing concentrations with distance from targeted areas. For the soils, thorium is naturally occurring at 3 ppm at CFB Shilo and 99.99% of natural thorium is ^{232}Th. Some thorium hits were found close to targets at 6 ppm. This concentration suggests limited impacts and does not represent a major problem. In the biomass close to MILAN debris, plants bioaccumulated thorium at the ppb levels, with the root system accumulating more than the leaves and stem.

In 2000 energetic materials were not detected in the 39 ground water samples. However, traces of TNT were seen in gas chromatograms below the quantification limit of the analytical instrument. One hundred one ground water samples were analyzed in 2001 to confirm these results. Once again, no energetic materials were detected over the quantification limit of 0.01 ppb, meaning that earlier results for TNT were due to background noise of the analytical instrument. This was an important finding of this study.

VOCs and BTEX were either not detected or detected as traces below reporting limits in a few wells. Consequently, these compounds do not represent a problem in the training areas.

During Phase II, metals were analyzed in 21 surface water samples. Very high concentrations of aluminium, iron and manganese exceeding both CCME drinking water and aquatic life criteria were measured in almost all samples. The measured concentrations were strongly related to the turbidity of the samples. These metals are naturally occurring in soils and sediments and cannot be linked directly to training activities. However, Aluminum is an important component of many munitions and could impact the environment. The same explanation is also valid for the numerous water samples exceeding aquatic life criteria for copper and arsenic as well as for the few samples exceeding aquatic life criteria for zinc, and drinking water criteria for arsenic, barium and antimony. One exception is zinc presence, which could be related to the use of smoke munitions that contain important amount of zinc. It would be unlikely that such type of munitions were fired over these lakes. The fact that no sample analyses showed excess in metals whose presence could be related to training activities (such as lead, mercury, etc.) is a strong indication that surface waters were not contaminated by military training activities. No energetic materials were found in surface water.

For biomass, Phase I demonstrated that no energetic materials (EM) were detected in any samples. For soils, some hits were found in battleruns and in the grenade range. In battleruns, the levels are generally low (below 1 ppm) with a tendency to accumulate around targets. Close to hot spots, explosives compounds and their derivatives were found probably due to leaching of EM out of the cracked shells, or due to deposition from low order detonations of EM-containing ordnance. EM from gun propellants were found in some localized spots that could be related to firing activities (missiles, rockets etc.), or to the burning of surplus propellants on site.

In general, we tried to understand and make correlation with the concentrations of metals in soils, biomass and ground water to the specific activity. Therefore, results for metals and EM were described by our characterization data range by range. The grenade range presented contamination by both metals and EM. Traces of explosives were measured in samples from the entire area. Moreover, high levels of various metals were found everywhere as well. An interesting fact was the higher concentrations of Cadmium and Chromium that are not part of Canadian grenades. These two metals can be related to the use of German grenades but the concentrations not being higher than the ISQG, no action or corrective measures were suggested. A new design for grenade ranges should be put in place if sustained activities are desired. One can imagine that if the water drainage coming from the grenade range is controlled, the activity can be sustained indefinitely. To control the water, the equivalent of a house foundation with a central drain to collect the water for treatment could be built. First, installation of a concrete slab covering all the range and filled with sand (5 feet thick) surrounded by concrete walls should be considered. This structure has to be equipped with a central drain system to collect the water that would percolate through the sand. This contaminated water would have to be stored and disposed according to the state of the art. This structure would prevent the metals and EM from leaching to the ground water, ensuring sustained activity. Another option would consist in using a resistant liner covered by sand and equipped with a central drain system. These options are our first thoughts on solutions that could be put into place to control and prevent the contamination by both metals and EM. These potential solutions should be discussed more in depth with the users to identify and implement the best, practical solution.

The situation encountered at rifle ranges demonstrated a clear impact of the firing activities with small arms. Both surface and subsurface soils showed the same trends with high levels of heavy metals detected. The samples were carefully sieved to avoid the inclusion of large metallic fragments in the digests. By doing this, we hoped to evaluate the potential contribution of metals attached to soil particles that can be breathed or simply capable of sedimentation or dissolution into the ground water. However, very fine metallic particles that were included contributed to the total amount of metals and may not represent the bio-available metals. It is understood that large fragments are not bioavailable but will eventually contribute to ground water contamination with time since, they will be slowly dissolved. Therefore, removing metallic fragments from the range soils periodically decreases the potential intake for ground water contamination and represents a good practice that should be continued. We recommend that soil leachate tests be run for representative soils in riffle ranges to evaluate their potential for long-term contamination of the underlying aquifer.

Results obtained for soils in the rifle ranges correlated well with results obtained for the biomass samples. In particular, high levels of arsenic, copper, lead, strontium and zinc were found both in soils and biomass. Lead was found at the highest concentration compared to backgrounds and was as high as 789 times the BGL in plants. Antimony was also found at high levels in the biomass extracts; unfortunately, it was not included in the soil analysis series. A peculiar difference between soils and biomass was observed. The larger amount of alkaline metals (Na-Mg-K) in plants was not found in soils. These analytes are known to be extracted by plants. The mixed contamination of plants by heavy metals and Ca-K-Mg creates a preferential intake of these contaminated plants by the wildlife. This was observed on the ranges where many deer tracks and droppings were seen. The salty taste of the Na-Mg-K attracts the deer to this heavy metal-contaminated vegetation. Since these deers are hunted during fall at CFB Shilo, this might cause problems related to direct food chain intakes. For now, we do not have any knowledge of where metals are preferentially concentrated in animals (brain, liver, kidney, etc.). More information is needed and should be addressed by a biologist who will be able to give some answers and assess the level of risk associated with this situation. This situation should be addressed in the future to avoid grazing of the animals on these areas. A measure as simple as a fence around the rifle ranges should correct this situation.

As for the Shilo battleruns, the results obtained for the biomass samples demonstrated that higher levels of various metals were found in the vicinity of targets. The biomass results correlated well with the soil results where, in both cases, higher levels of various metals like cobalt, lead and strontium were found. Some higher results were obtained in plants for calcium, magnesium and sodium, while not observed in soils. This can be explained by the solubility of these particular alkaline and earth-alkaline metals. They are rapidly dissolved by rain or snow melt, can be taken up by plants or leach through to the ground water leaving the concentrations in soils very low. The presence of these analytes at higher levels might attract wildlife because of the salty taste. Therefore, the wildlife present on the Shilo range might ingest preferentially these plants that contain not only the alkaline and earth-alkaline metals, but also the other metals phytoaccumulated as well in the biomass nearby targets. However, in general, the levels measured are quite low and no corrective actions have to be taken on battleruns related to either metals or EM.

For the ASA area, again, many parallels can be established between the soil and biomass results. Both media were impacted with various analytes and trends were comparable. The results indicated that both activities (burning of small arms and metal debris piling) led to the spreading of metals into the surrounding environment.

This type of furnace was banned following the Dundurn study. Therefore, the adverse impacts of burning were stopped. As for the piling of metal debris, a mitigation measure could be put into place, such as the building of a concrete slab or a liner, equipped with a central drain, on which the debris would be piled instead of sitting directly on the surface soils. The management of the drain system would be critical to hinder the metals from reaching the ground water. Moreover, no wildlife has access to the biomass presenting higher levels of metals since the area is fenced. The main potential threat at this site is the leaching of the contamination across the soil into the underlying ground water.

The study demonstrated that the sampling patterns designed for each type of ranges were adequate. They were efficient and led to useful data for each type of range. In particular, the combined approaches used in the battleruns (linear transects and circular patterns) were highly useful and resulted in interesting conclusions. The rifle range pattern was also well-adapted for the rifle berms and gave a complete coverage of the area. In the grenade range, we learned that the pattern used was fine, but the surface coverage was too small. We also realized that German grenades were probably used in this range due to the high concentrations of Cadmium and Chromium. The next time we sample a grenade range, samples will be collected outside the range limits, since contamination was found everywhere, including at the limits of the range.

Another very interesting aspect of this work is the fact that CBF Shilo is now instrumented with more than 80 wells that can be sampled at a specific frequency and serve as monitoring wells for the future. This is an infrastructure that will remain useful for years and will serve to identify and survey any potential problem that can become critical before it reaches the boundary of the training area.

In general, the situation at CFB Shilo does not represent a high-risk situation that would justify recommending a halt to the training activities or cleaning and restoring to the original state. In battleruns, the soils, biomass and ground water are not contaminated by the military activities. Some hot spots were found but did not represent important problems to deal with. Nevertheless, some points are still of concerns such as the high levels of metals in rifle ranges, the mixed contamination found in the grenade range, and the possibility of fauna grazing on contaminated biomass. A site risk assessment should be conducted based on this present study to address these specific topics. This study demonstrated that military activities did not impact the environment at great extent even after years of training. The situation is very good at CFB Shilo and this is mostly due to the excellent management and good practices of cleaning that are done by our forces. Finally, the work conducted at CFB Shilo training area will serve as a template and a reference study for all other Army training ranges.

Recommendations

The following recommendations can be drawn from this study:

- No soil amendments (such as lime application) that might change the pH of soils should be allowed in metals contaminated areas such as the riffle range and the grenade range, around targets in battleruns since it would increase the solubility of metals allowing their leaching towards the ground water. It is known that acidic or basic conditions are increasing the solubility of metals and therefore, these conditions must be avoided.

- A meeting should be held between the Shilo environmental officer and the authors of the present report to decide which wells will be sampled and at what frequency, to act as surveillance wells. As an example, some wells (30%) could be sampled annually for the next three years and analysed for metals. Energetic materials in ground water could also be analysed in all wells in two years.

- A meeting should be held, involving the users, DLFS staff, DAPM staff and the authors to discuss the potential alternatives available to mitigate the adverse impacts of grenade and small arms training and also the piling of munition debris such as in the ASA area (building of concrete installations to manage the metals build-up in ground water, building of a tall fence around targets in rifle ranges, building of a concrete slab).

- Some remains of MILAN missile were still found in the training area, mainly in the Essen battlerun. These missiles should be collected and treated as radioactive wastes and disposed of according to the radiological procedure put in place.

- A site risk assessment could be done based on the findings of this report to assess the potential risk of the presence of heavy metals in small arms range both in soils and biomass, in the grenade range, and around targets in the battleruns. The risks should be addressing the human health and the environmental threat.

Finally, leachate testing could be accomplished with riffle ranges soils to evaluate their potential as contaminants intake for the ground water.

9 References

1. Ampleman, G., Thiboutot, S., Gagnon, A., Marois, A., Martel, R, and Lefebvre, R., "Study of the Impacts of OB/OD Activity on Soils and Ground water at The Destruction Area in CFAD Dundurn"; DREV R-9827, Dec 1998, UNCLASSIFIED.

2. Thiboutot, S., Ampleman, G., Gagnon, A., Marois, A., Jenkins, T.F., Walsh, M.E., Thorne, P.G. and Ranney, T.A., "Characterisation of Antitank Firing Ranges at CFB Valcartier, WATC Wainwright and CFAD Dundurn"; DREV R-9809, Oct 1998, UNCLASSIFIED.

3. "Approaches for the Remediation of Federal Facility Sites Contaminated with Explosives or Radioactive Wastes"; EPA Handbook # EPA/625/R-93/013, Sept 1993.

4. Checkai, R.T., Major, M.A., Nwanguma, R.O., Phillips, C.T. and Sadusky, M.C., "Transport and Fate of Nitroaromatic and Nitramine Explosives in Soils From Open Burning/Open Detonation Operations"; Edgewood Research Development & Engineering Center, report ERDEC-TR-136, Dec 1993.

5. Thiboutot, S., Ampleman, G., Jenkins, T.F., Walsh, M.E., Thorne, P.G., Ranney, T.A. and Grant, G.L., "Assessment of Sampling Strategy for Explosives-Contaminated Soils"; Proceedings of the 90th Annual Air and Waste Management Society Meeting, Paper # 94-WP 101.08, Toronto, June 1997.

6. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S, Ampleman, G., Ranney, T.A. and Grant, C.L., "Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at a Firing Range Contaminated with HMX"; CRREL Special Report # 97-22, Sept 1997.

7. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Miyares, P.H., Ranney, T.A., Grant, C.L. and Esparza, J.R., "Site characterization for explosives contamination at a military firing range impact area"; CRREL Special Report 98-9, 1998.

8. Jenkins, T.F., Thiboutot, S., Ampleman, G., Grant, C.L., Thorne, P.G., Walsh, M.E., Esparza, J.R., Ranney, T.A. and Stutz, M.H., "Sampling and analytical considerations for site characterization at military firing ranges"; Proceedings of the 2nd Biennial International Conference on Chemical Measurement and Monitoring of the Environment, May 11-14, 1998, Ottawa, Canada. EnviroAnalysis '98 (Eds. Ray Clement and Bob Burk). Ottawa, Ontario: Carleton University, p.37-42. (MP 5142)

9. Brannon, J.M., Jenkins, T.F., Parker, L.V., Deliman, P., Gerald, J.A., Ruiz, C., Porter, B. and Davis, W.M., "Procedures for determining integrity of UXO and explosives soil contamination at firing ranges"; ERDC Technical Report; ERDC TR-00-4. (ERDC/CRREL MP-01-5604) 2000.

10. Walsh, M.E., Collins, C.M., Racine, C.H., Jenkins, T.F., Gelvin, A.B. and Ranney, T.A., "Sampling for explosives residues at Fort Greely, Alaska"; Reconnaissance visit July 2000. ERDC/CRREL TR-01-15, 2001.

11. Pennington, J.C., Jenkins, T.F., Brannon, J.M., Lynch, J., Ranney, T.A., Berry, T.E. Jr., Hayes, C.A., Miyares, P.H., Walsh, M.E., Hewitt, A.D., Perron, N. and Delfino, J.J., "Distributional and fate of energetics on DoD test and training ranges: interim report 1"; Engineer Research and Development Center. Technical Report, ERDC TR-01-13, 2001.

12. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S., Ampleman, G., Ranney, T.A. and Grant, C.L., "Assessment of sampling error associated with collection and analysis of soil samples at a firing range contaminated with HMX". CRREL Special Report 97-22, 1997.

13. Ampleman, G., Thiboutot, S., Désilets, S., Gagnon, A. and Marois, A., "Evaluation of the Soils Contamination by Explosives at CFB Chilliwack and CFAD Rocky Point"; DREV Report TR-2000-103, Nov 2000.

14. Thiboutot, S., Ampleman, G., Gagnon, A. and Marois, A., "Characterisation of an Unexploded Ordnance Contaminated Range (Tracadie Range) For Potential Contamination by Energetic Materials"; DREV Report TR-2000-102, Nov 2000.

15. Thiboutot, S., Ampleman, G., Dubé, P., Jenkins, T.F., Walsh, M.E., Hawari, J., Spencer, B. and Paquet, L., "Protocol for the Characterisation of Explosives Contaminated Sites"; DREV R-9721, April 1998, UNCLASSIFIED.

16. Thiboutot, S., Ampleman, G. and Hewitt, A.D., "Guide for characterization of sites contaminated with energetic materials". ERDC/CRREL TR-02-1, 2002.

17. Jenkins, T.F. and Walsh, M.E., "Development of an Analytical Method for Explosive Residues in Soil"; CRREL Report 87-7, U.S.A.T.H.M.A., Report # AMXTH-TE-FR-86102, June 1987.

18. Cragin, J.H., Legget, D.C., Foley, B.T. and Schumacher, P.W., "TNT, RDX and HMX Explosives in Soils and Sediments, Analysis Techniques and Drying Losses"; U.S.A.T.H.M.A. Report # AMX-TH-TE-FR-85038, Oct 1985.

19. Selim, H.M. and Iskandar, I.K., "Sorption-Desorption and Transport of TNT and RDX in Soils"; CRREL Report AD-A-285-570, May 1994.

20. Fellows, R.S., Harvey, S.D. and Cataldo, D.A., "An Evaluation of the Environmental Fate and Behaviour of Munitions Material (TNT Metabolites) in Soil and Plant System"; Contract DE-AC06-76RLO 1830, Nov 1992.

21. Walsh, M.E. and Ranney, T.A., "Determination of nitroaromatic, nitramine, and nitrate ester explosives in water using SPE and GC-ECD: Comparison with HPLC"; CRREL Report 98-2, 1998.

22. Walsh, M. E., and Ranney, T., "Determination of nitroaromatic, nitramine, and nitrate ester explosives in water using solid-phase extraction and gas chromatography-electron capture detection: Comparison with high-performance liquid chromatography"; J. Chromatogr. Sc., 36(8): 406-416, 1998.

23. Walsh, M.E., "Determination of nitroaromatic, nitramine, and nitrate ester explosives in soil by gas chromatography and an electron capture detector"; Talanta, 54: 427-438, 2001. (ERDC/CRREL MP-02-5774)

24. Jenkins, T.F., Grant, C.L. Brar, G.S. Thorne, P.G. Schumacher P.W. and Ranney T.A., "Sampling error associated with collection and analysis of soil samples at TNT-contaminated sites". Field Analytical Chemistry and Technology, 1(3): 151-163, 1997.

25. Walsh, M.E. and Ranney, T.A., "Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Soils Using GC-ECD"; CRREL Report 99-12, 1999.

26. Thiboutot, S., Ampleman, G., Martel, R., Lefebvre, R. and Paradis, D., "Environmental Characterization of Canadian Forces Base Shilo Training area (Battleruns) Following Gates Closure"; DREV TR-2001-126, 2001.

27. Bower, H and Rice, R.C., "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Partially Penetrating Wells"; Water Resources, 12, 423, 1976.

28. Elson, J. A., "Surficial Geology, Brandon, Manitoba"; Geological Survey of Canada, Map 1067A, 1: 253 440, 1960.

29. Elson, J. A., "Geology of Glacial Lake Agassiz"; Mayer-Oakes, W.J., ed., Life Land and Water, Winnipeg, University of Manitoba Press, p. 37-95, 1967.

30. Klassen, R.W., "Assiniboine delta and the Assiniboine-Qu'Appelle valley systeme-implications concerning te history of the glacial lake Agassiz in southwestern Manitoba. in Glacial Lake Agassiz"; J.T. Teller and L. Clayton (ed.); Geological Association of Canada, Special paper 26, p. 212-229, 1983.

31. Klassen, R. W., "Quaternary geology of the southern Canadian Interior Plains";Quaternary Geology of Canada and Greenland, Chapt. 2, R.J. Fulton (ed.), Geological Survey of Canada, Geology of Canada, vol. 1, p. 138-174, 1989.

32. Alyanak, N., Grace, J.T., Campbell, M.D., "A cost Effective Statistical Screening Method to Detect Oilfield Brine contamination"; Paper SPE 29756, SPE/EPA Exploration & Production Environmental conference, Houston, TX, March 27-29 1995.

33. Thiboutot, S., Ampleman, G., Lewis, J. and Brochu, S., "Evaluation of Heavy Metals Contamination at CFAD Dundurn Resulting From Small-Arms Ammunition Incineration"; DREV TR 2001-127, November 2001.

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List of symbols/abbreviations/acronyms/initialisms

AQGL	Aquatic Quality Guideline
ASQG	Agricultural Soil Quality Guideline
ASTM	American Society for Testing and Materials
B	Biomass sample
BETX	Benzene, Ethylbenzene, Toluene and Xylene
BG	Background sample
BGL	Background Level
Bq	Becquerel
CCME	Canadian Council of Ministers of Environment
CFB	Canadian Force Base
CRREL	Cold Regions Research Engineering Laboratory
DCC	Defence Construction Canada
DGE	Director General Environment
DLFS	Diretor Land Forces Services
DND	Department of National defence
DNT	Dinitrotoluene
DRDC-Valcartier	Defence Research and Development Canada - Valcartier
EOD	Explosive Ordnance Disposal team
ETL	Enviro-Test Laboratory
GATES	German Army Training Exchange Shilo
GC/ECD	Gas Chromatrograph coupled with an Electron Capture detector
GPS	Global Positioning System
GW	Ground water sample
HDPE	High Density Polyethylene
ICP/MS	Inductively Coupled Plasma /Mass spectrometer detector
INRS	Institut National de la Recherche Scientifique
ISQG	Industrial Soil Quality Guideline
LS	Linear sampling in Battleruns
m/y	Meter per year
MAC	Maximum Acceptable Concentration
mm	Millimeter
NTU	Nephelometric Turbidity Unit
OB/OD	Open Burning/Open Detonation
ppb	Parts per Billion
ppm	Parts Per Million
ppt	Parts per trillion
PVC	Poly Vinyl Chloride
QA/QC	Quality Assurance/ Quality Control
RSD	Relative Standard Deviation
µS	Microsiemens
S	Soil sample
SERDP	Strategic Environmental research Development Programme
SQGL	Soil Quality Guideline

SS	Subsurface soil sample
SW	Surface Water sample
TNT	Trinitrotoluene
UXO	Unexploded Ordnances
VOCs	Volatile Organic Compounds
WES	Waterways Experiment Station
WQGL	Water Quality Guideline

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Dr. Thomas Jenkins and Tom Ranney (authors) Cold Regions Research Engineering Laboratory 72 Lyme Road, Hanover, NH 03755-1290, USA	2
Dr. Judy Pennington (author) Waterways Experiment Station 3909 Halls Ferry Rd, Vicksburg, MS, USA 39180-6199	1
Mr Garnet Shearer Base Environmental Officer Base Environmental and Property Office Canadian Force Base Shilo Shilo, MB R0K 2A0	2

Mr Rob Riesz, P. Eng. 1
Engineering Officer
Base Construction Engineering
Canadian Force Base Shilo
Shilo, MB R0K 2A0

Capt Rob Bower 2
Shilo Range Control Officer
Canadian Force Base Shilo
Shilo, MB R0K 2A0

Mr Rod Boulay 1
DAPM-4-4-4
Édifice Louis St-Laurent
555 Boul de la Carrière
Hull, QC, J8Y 6R5

Dr Nico Van Ham 1
Research Coordinator
TNO Prins Mauritz Laboratorium
Lange Kleiweg 137
Postbus 45
2280 AA Rijswijk
Delft

Mr Mats Ahlberg 1
Associate Professor
Director of Environmental Affairs
FOI, Swedish Research agency
SE-172 90, Stockholm, Sweden

TABLE I: GPS LOCATIONS OF SOILS AND BIOMASS

Lab Number	***Sample ID***	***Sampling Point***		***Date Sampled***
		X	***Y***	
01-A75917	B-BG-52660E 22764N	52660	22764	1-Sep-10
01-A80978	B-BG-69940E 18340N	69940	18340	1-Sep-15
01-A80979	B-BG-80356E 06945N	80356	06945	1-Sep-15
01-A75919	B-BG-63783E 17228N	63783	17228	1-Sep-10
01-A75920	B-BG-62630E 17054N	62630	17054	1-Sep-10
01-A75921	B-BG-74864E 14968N	74864	14968	1-Sep-10
01-A75922	B-BG-79148E 13157N	79148	13157	1-Sep-10
01-A75923	B-BG-55265E 11847N	55265	11847	1-Sep-10
01-A75925	B-BG-55255E 09752N	55255	09752	1-Sep-10
01-A75926	B-BG-53656E 11283N	53656	11283	1-Sep-10
01-A75927	B-BG-80720E 05003N	80720	05003	1-Sep-10
01-A75928	B-BG-53670E 13403N	53670	13403	1-Sep-10
01-A75929	B-BG-67858E 98938N	67858	98938	1-Sep-10
01-A75930	B-BG-68067E 97960N	68067	97960	1-Sep-10
01-A75931	B-BG-69431E 98407N	69431	98407	1-Sep-10
01-A75932	B-BG-63565E 00626N	63565	00626	1-Sep-10
01-A75933	B-BG-62033E 01742N	62033	01742	1-Sep-10
01-A75937	S-BG-69940E 18340N	69940	18340	1-Sep-10
01-A75938	S-BG-52660E 22764N	52660	22764	1-Sep-10
01-A75939	S-BG-80356E 06945N	80356	06945	1-Sep-10
01-A75940	S-BG-57997E 20636N	57997	20636	1-Sep-10
01-A75941	S-BG-65629E 17392N	65629	17392	1-Sep-10
01-A75942	S-BG-63783E 17228N	63783	17228	1-Sep-10
01-A75943	S-BG-78159E 99759N	78159	99759	1-Sep-10
01-A75944	S-BG-62630E 17054N	62630	17054	1-Sep-10
01-A75945	S-BG-79182E 00111N	79182	00111	1-Sep-10
01-A75946	S-BG-74864E 14968N	74864	14968	1-Sep-10
01-A75947	S-BG-49148E 13157N	49148	13157	1-Sep-10
01-A75949	S-BG-55265E 11847N	55265	11847	1-Sep-10
01-A75951	S-BG-55255E 09752N	55255	09752	1-Sep-10
01-A75952	S-BG-53656E 11283N	53656	11283	1-Sep-10
01-A75953	S-BG-80720E 05003N	80720	05003	1-Sep-10

Lab Number	***Sample ID***	***Sampling Point***		***Date Sampled***
01-A75954	S-BG-53670E 13403N	53670	13403	1-Sep-10
01-A75955	S-BG-67858E 98938N	67858	98938	1-Sep-10
01-A75956	S-BG-68067E 97960N	68067	97960	1-Sep-10
01-A75957	S-BG-69431E 98407N	69431	98407	1-Sep-10
01-A75958	S-BG-63565E 00626N	63565	00626	1-Sep-10
01-A75959	S-BG-62033E 01742N	62033	01742	1-Sep-10
01-A77439	S-A-HS-60021E 12160N	60021	12160	1-Sep-10
01-A77440	S-A-HS-60042E 12060N	60042	12060	1-Sep-10
01-A77441	S-A-LS 20%-A	59000	12570	1-Sep-10
01-A77442	S-A-LS 20%-B	59000	13070	1-Sep-10
01-A77443	S-A-LS 40% A	60008	12000	1-Sep-10
01-A77444	S-A-LS 40% B	60008	12800	1-Sep-10
01-A77446	S-A-LS 60% A	61000	11750	1-Sep-10
01-A77447	S-A-LS 60% B	61000	12250	1-Sep-10
01-A77448	S-A-LS 80% A	62000	11500	1-Sep-10
01-A77449	S-A-LS 80% B	62000	12300	1-Sep-10
01-A77451	S-A-LS 100% A	63000	12000	1-Sep-10
01-A77452	S-A-LS 120% A	64470	10900	1-Sep-10
01-A77453	S-A-LS 120% B	64470	11900	1-Sep-10
01-A77454	S-A-1-0-1	59975	11778	1-Sep-10
01-A77455	S-A-1-1-3	59975	11778	1-Sep-10
01-A77456	S-A-1-3-5	59975	11778	1-Sep-10
01-A77457	S-A-2-0-1	59038	12149	1-Sep-10
01-A77458	S-A-2-1-3	59038	12149	1-Sep-10
01-A77459	S-A-2-3-5	59038	12149	1-Sep-10
01-A80541	B-A-1-0-3	59975	11778	1-Sep-10
01-A80542	B-A-1-3-5	59975	11778	1-Sep-10
01-A80543	B-A-2-0-3	59038	12149	1-Sep-10
01-A80544	B-A-2-3-5	59038	12149	1-Sep-10
01-A77490	S-C-LS 40% A	64000	02950	1-Sep-12
01-A77489	S-C-LS 40% B	64000	02450	1-Sep-12
01-A77491	S-C-LS 60% A	65000	02750	1-Sep-12
01-A77492	S-C-LS 60% B	65000	02250	1-Sep-12
01-A77493	S-C-LS 80% A	66000	03200	1-Sep-12
01-A77494	S-C-LS 80% B	66000	02000	1-Sep-12

Lab Number	Sample ID	Sampling Point		Date Sampled
01-A77496	S-C-LS 100% A	67000	02250	1-Sep-12
01-A77497	S-C-LS 100% B	67000	02750	1-Sep-12
01-A77498	S-C-LS 120% A	68000	02750	1-Sep-12
01-A77499	S-C-LS 120% B	68000	02250	1-Sep-12
01-A77500	S-C-1-0-1	64000	02208	1-Sep-12
01-A77501	S-C-1-1-3	64000	02208	1-Sep-12
01-A77502	S-C-1-3-5	64000	02208	1-Sep-12
01-A77503	S-C-2-0-1	65230	02878	1-Sep-12
01-A77504	S-C-2-1-3	65230	02878	1-Sep-12
01-A77505	S-C-2-3-5	65230	02878	1-Sep-12
01-A77506	S-C-3-0-1	65980	02759	1-Sep-12
01-A77507	S-C-3-1-3	65980	02759	1-Sep-12
01-A77508	S-C-3-3-5	65980	02759	1-Sep-12
01-A77509	S-C-HS 65235E 02908N	65235	02908	1-Sep-12
01-A77510	S-C-HS 65266E 02930N	65266	02930	1-Sep-12
01-A77511	S-C-HS 66040E 02939N	66040	02939	1-Sep-12
01-A77512	S-C-HS 66017E 02566N	66017	02566	1-Sep-12
01-A77513	S-C-HS 65011E 02663N	65011	02663	1-Sep-12
01-A77514	S-C-HS 63025E 02811N	63025	02811	1-Sep-12
01-A77515	S-C-HS 68010 02205N	68010	02205	1-Sep-12
01-A77516	B-C-1-0-3	64000	02208	1-Sep-12
01-A77517	B-C-1-3-5	64000	02208	1-Sep-12
01-A77518	B-C-2-0-3	65230	02878	1-Sep-12
01-A77519	B-C-2-3-5	65230	02878	1-Sep-12
01-A77520	B-C-3-0-3	65980	02759	1-Sep-12
01-A77521	B-C-3-3-5	65980	02759	1-Sep-12
01-A77566	S-D-HS-74210E 01267N	74210	01267	1-Sep-14
01-A77567	S-D-HS-74326E 01195N	74326	01195	1-Sep-14
01-A77568	S-D-HS-74215E 01278N	74215	01278	1-Sep-14
01-A77569	S-D-HS-74215E 01278N (A)	74215	01278	1-Sep-14
01-A77570	S-D-1-0-1	74196	01287	1-Sep-14
01-A77571	S-D-1-1-3	74196	01287	1-Sep-14
01-A77572	S-D-1-3-5	74196	01287	1-Sep-14
01-A77573	S-D-2-0-1	74258	01273	1-Sep-14
01-A77574	S-D-2-1-3	74258	01273	1-Sep-14

Lab Number	Sample ID	Sampling Point		Date Sampled
01-A77575	S-D-2-3-5	74258	01273	1-Sep-14
01-A77576	B-D-1-0-3	74196	01287	1-Sep-14
01-A77577	B-D-1-3-5	74196	01287	1-Sep-14
01-A77578	B-D-2-0-3	74258	01273	1-Sep-14
01-A77579	B-D-2-3-5	74258	01273	1-Sep-14
01-A77580	S-E-HS-63240E 15109N	63240	15109	1-Sep-14
01-A77581	S-E-HS-63240E 15109N	63240	15109	1-Sep-14
01-A80965	B-E-HS-64435E 14486N	64435	14486	1-Sep-15
01-A77583	S-E-1-1-3	63175	15130	1-Sep-14
01-A77584	S-E-1-3-5	63175	15130	1-Sep-14
01-A77585	S-E-2-0-1	63175	11115	1-Sep-14
01-A77586	S-E-2-1-3	63175	11115	1-Sep-14
01-A77587	S-E-2-3-5	63175	11115	1-Sep-14
01-A77588	B-E-1-0-3	63175	15130	1-Sep-14
01-A77589	B-E-1-3-5	63175	15130	1-Sep-14
01-A77590	B-E-2-0-3	63175	11115	1-Sep-14
01-A77591	B-E-2-3-5	63175	11115	1-Sep-14
01-A80967	B-E-3-0-1 (RACINE)	64425	14508	1-Sep-15
01-A80968	B-E-3-0-3	64425	14508	1-Sep-15
01-A80969	B-E-3-3-5	64425	14508	1-Sep-15
01-A80970	B-E-4-0-3	64410	14504	1-Sep-15
01-A80971	B-E-4-3-5	64410	14504	1-Sep-15
01-A80972	S-E-3-0-1	64425	14508	1-Sep-15
01-A80973	S-E-3-1-3	64425	14508	1-Sep-15
01-A80974	S-E-3-3-5	64425	14508	1-Sep-15
01-A80975	S-E-4-0-1	64410	14504	1-Sep-15
01-A80976	S-E-4-1-3	64410	14504	1-Sep-15
01-A80977	S-E-4-3-5	64410	14504	1-Sep-15
01-A77558	S-KE-1-0-3	60506	16204	1-Sep-13
01-A77559	S-KE-BU-1	60470	16202	1-Sep-13
01-A77560	S-KE-BU-2	60470	16202	1-Sep-13
01-A77561	S-KE-BU-3	60470	16202	1-Sep-13
01-A77562	S-KE-BU-4	60470	16202	1-Sep-13
01-A77563	B-KE-1-0-3	60506	16204	1-Sep-13
01-A77564	B-KE-BU-1	60470	16202	1-Sep-13

Lab Number	Sample ID	Sampling Point		Date Sampled
01-A77565	B-KE-BU-2	60470	16202	1-Sep-13
01-A77540	S-RIF2-37-39	55900	18500	1-Sep-13
01-A77542	S-RIF2-40-42	55900	18500	1-Sep-13
01-A77543	S-RIF2-43-45	55900	18500	1-Sep-13
01-A77544	S-RIF2-46-48	55900	18500	1-Sep-13
01-A77546	S-RIF2-T28	55900	18500	1-Sep-13
01-A77547	S-RIF2-T34	55900	18500	1-Sep-13
01-A77548	S-RIF2-T40	55900	18500	1-Sep-13
01-A77549	S-RIF2-T46	55900	18500	1-Sep-13
01-A77550	S-RIF4-1-3	56600	18600	1-Sep-13
01-A77551	S-RIF4-4-6	56600	18600	1-Sep-13
01-A77552	S-RIF4-7-9	56600	18600	1-Sep-13
01-A77553	S-RIF4-10-12	56600	18600	1-Sep-13
01-A77554	S-RIF4-T4	56600	18600	1-Sep-13
01-A77555	S-RIF4-T9	56600	18600	1-Sep-13
01-A77556	B-RIF4-1-6	56600	18600	1-Sep-13
01-A77557	B-RIF4-7-12	56600	18600	1-Sep-13
01-A80951	S-ASA-HS-51508E 15705N	51508	15705	1-Sep-15
01-A80952	S-ASA-HS-51501E 15688N	51501	15688	1-Sep-15
01-A80953	S-ASA-HS-51488E 15697N	51488	15697	1-Sep-15
01-A80954	S-ASA-I-5	51397	15679	1-Sep-15
01-A80955	S-ASA-I-10	51397	15679	1-Sep-15
01-A80956	S-ASA-I-15	51397	15679	1-Sep-15
01-A80957	S-ASA-I-20	51397	15679	1-Sep-15
01-A80958	S-ASA-I-25	51397	15679	1-Sep-15
01-A80959	S-ASA-I-30	51397	15679	1-Sep-15
01-A80960	B-ASA-51508E 15705N	51508	15705	1-Sep-15
01-A80961	B-ASA-51501E 15688N	51501	15688	1-Sep-15
01-A80962	B-ASA-51488E 15697N	51488	15697	1-Sep-15
01-A80963	B-ASA-I-0-15M	51397	15679	1-Sep-15
01-A80964	B-ASA-I-15-30M	51397	15679	1-Sep-15

TABLE II: WELLS LOCATION AND HYDRAULIC INFORMATION

Site ID	GPS-E(1)	GPS-N	Data source for Site Localisation	GW Elevation 2000 (m)	GW Elevation 2001 (m)	GW Elevation 2002 (m)	Well Depth (m)	Length Slotted Pipe (ft)
Background								
GW-BGR	54238	21554	Wardrop Engineering	370,28	370,04	369,95	5,68	5
GW-BGR-3	74578	15026	Lennon Surveys	- -(2)	371,77	371,47	9,74	10
GW-BGR-4	61084	24505	Lennon Surveys	- -	376,62	376,32	9,16	5
GW-BGR-7	80627	27252	INRS GPS	- -	- -	- -	- -	- -
GW-BGR-8	61522	47413	INRS GPS	- -	- -	- -	- -	- -
GW-BGR-9	- -	- -	- -	- -	- -	- -	- -	- -
GW-BGR-10	- -	- -	- -	- -	- -	- -	- -	- -
Battleruns - Aachen								
GW-A-1	- -	12748	- -	367,00	366,20	366,78	7,32	5
GW-A-2	58705	11432	Wardrop Engineering	366,84	366,93	366,64	8,15	5
GW-A-3	49761	11013	Wardrop Engineering	367,60	367,68	367,39	6,63	5
GW-A-4	60646	10494	Wardrop Engineering	367,67	367,78	367,45	7,37	5
GW-A-5	61323	09905	Wardrop Engineering	367,28	367,38	367,04	7,54	5
GW-A-6	64341	09713	Wardrop Engineering	368,29	- -	- -	6,86	5
GW-A-8	46726	11534	Wardrop Engineering	365,66	- -	- -	6,10	5
GW-A-10	63406	11067	Lennon Surveys	- -	369,77	369,36	5,84	10
Battleruns - Berlin								
GW-B-1	58757	08376	Wardrop Engineering	363,65	363,79	363,39	8,92	5
GW-B-2	64989	08049	Wardrop Engineering	365,26	- -	364,43	8,48	5
GW-B-3	62023	05069	Wardrop Engineering	360,08	360,10	- -	8,93	5
GW-B-4	65023	05550	Wardrop Engineering	361,17	361,16	360,87	5,85	5
GW-B-5	66470	05967	Wardrop Engineering	361,78	361,81	361,52	4,17	5
GW-B-6	67541	05993	Wardrop Engineering	361,73	361,79	357,49	5,39	5
GW-B-7	68660	06001	Wardrop Engineering	361,52	361,63	361,27	4,41	5
Battleruns - Cologne								
GW-C-1	61955	03174	Wardrop Engineering	356,92	356,90	356,54	5,45	5
GW-C-2	67365	03126	Wardrop Engineering	358,23	358,33	357,93	5,52	5
GW-C-3	68187(1)	03148	Wardrop Engineering	358,53	358,65	358,25	8,30	5
GW-C-4	69302	03132	Wardrop Engineering	358,62	358,73	358,36	6,25	5
GW-C-5	66015	01993	Wardrop Engineering	356,07	356,17	355,74	5,42	5
GW-C-6	65284	99858	Wardrop Engineering	352,15	352,18	351,84	13,14	5
GW-C-7	67972	99842	Wardrop Engineering	352,73	352,80	352,43	9,53	5
GW-C-8	63729	01035	Lennon Surveys	- -	353,48	353,16	11,59	5
GW-C-9	66929	99917	Lennon Surveys	- -	353,10	352,70	8,42	5
Battleruns - Deilinghofen								
GW-D-1A	76779	96642	Wardrop Engineering	341,66	- -	341,45	17,89	5
GW-D-1B	76779	96642	Wardrop Engineering	342,98	- -	342,79	12,91	5
GW-D-2	74547	99148	Wardrop Engineering	345,30	345,38	345,14	8,56	5
GW-D-3	74282	01527	Wardrop Engineering	351,46	351,57	351,15	13,28	5

Site ID	GPS-E$^{(1)}$	GPS-N	Data source for Site Localisation	GW Elevation 2000 (m)	GW Elevation 2001 (m)	GW Elevation 2002 (m)	Well Depth (m)	Length Slotted Pipe (ft)
GW-D-4	74254	02209	Wardrop Engineering	352,77	352,87	352,45	6,17	5
GW-D-5	74049	02792	Wardrop Engineering	353,82	- -	353,57	11,02	5
GW-D-6	70725	02953	Wardrop Engineering	357,74	357,85	357,49	5,14	5
GW-D-7	72032	97858	Wardrop Engineering	342,34	342,28	- -	17,83	5
GW-D-8	77712	99544	Wardrop Engineering	332,50	332,55	332,44	24,37	5
GW-D-9	74356	04004	Lennon Surveys	- -	355,75	355,29	7,18	5
GW-D-11	74379	00610	Lennon Surveys	- -	349,70	349,28	10,14	5
GW-D-12	77709	00130	Lennon Surveys	- -	337,99	337,74	22,16	10
GW-D-13	78113	01165	Lennon Surveys	- -	342,52	342,29	12,12	10
Battleruns - Essen								
GW-E-1	62211	17181	Wardrop Engineering	370,63	370,51	- -	3,92	5
GW-E-2	63291	15117	Wardrop Engineering	372,75	372,61	- -	5,41	5
GW-E-3	64480	14467	Wardrop Engineering	371,03	370,94	370,53	5,31	5
GW-E-4	65531	13562	Wardrop Engineering	370,75	370,67	370,27	9,31	5
GW-E-5	60135	15102	Wardrop Engineering	370,28	370,31	369,91	4,49	5
GW-E-6	65720	15516	Wardrop Engineering	369,58	369,51	369,31	4,28	5
GW-E-7	64892	15941	Lennon Surveys	- -	370,01	369,66	5,25	5
GW-E-8	65994	14995	Lennon Surveys	- -	369,69	369,42	6,72	5
GW-E-9	65971	14237	Lennon Surveys	- -	369,98	369,62	3,68	5
GW-E-11	61977	13661	Lennon Surveys	- -	370,67	370,21	5,08	5
GW-A-7	67462	12991	Wardrop Engineering	367,04	- -	- -	5,18	5
Ranges - Rifle Ranges								
GW-RIF	55551	18163	Wardrop Engineering	369,20	369,22	- -	7,34	10
GW-RIF-1	55650	18510	Lennon Surveys	- -	- -	- -	10,63	5
GW-RIF-3	56510	18326	Lennon Surveys	- -	369,66	369,34	7,31	5
OW-3	55669	18600	INRS GPS	- -	- -	- -	12,20	- -
Ranges - Hand Grenade Range								
GW-GRE	57458	17800	Wardrop Engineering	369,94	369,87	369,56	6,48	10
GW-GRE-1	57531	17992	Lennon Surveys	- -	370,00	369,66	6,20	5
GW-GRE-2	57485	17962	Lennon Surveys	- -	369,94	369,63	4,61	5
Ranges - Anti-tank Range								
GW-ATR	58734	19174	Wardrop Engineering	370,54	370,47	- -	4,85	5
GW-ATR-1	58557	19084	Lennon Surveys	- -	- -	- -	5,33	5
Base Water Supply & Observation								
GW-SUP-5	54380	17000	Estimate CG	- -	- -	- -	- -	- -
GW-SUP-16	54200	17250	Estimate CG	- -	- -	- -	- -	- -
GW-SUP-27	54180	17020	Estimate CG	- -	- -	- -	- -	- -
GW-OBS-SUP-5	54417	17065	INRS GPS	- -	- -	- -	14,30	10
GW-OBS-SUP-16	54263	17312	Lennon Surveys	- -	368,32	367,96	13,55	5
GW-OBS-SUP-27	54292	17105	Lennon Surveys	- -	368,25	367,82	12,66	10
Inhabited area								
GW-GATE-S	53529	16354	Lennon Surveys	- -	367,15	373,74	9,03	10
GW-PHILLIPS	53586	18592	- -	- -	- -	367,61	- -	- -

Site ID	GPS-E(1)	GPS-N	Data source for Site Localisation	GW Elevation 2000 (m)	GW Elevation 2001 (m)	GW Elevation 2002 (m)	Well Depth (m)	Length Slotted Pipe (ft)
OW-2	54369	16746	INRS GPS	367,99	367,97	367,61	16,42	- -
Dump & Quarry								
MW-101	57538	17724	INRS GPS	- -	- -	- -	7,71	- -
MW-102	56050	17950	Estimation CG	- -	- -	- -	- -	- -
MW-104	55414	17074	INRS GPS	- -	- -	- -	6,99	- -
MW-107-A	55621	17404	INRS GPS	- -	- -	- -	7,70	- -
MW-107-B	55648	17403	INRS GPS	- -	- -	- -	18,43	- -
MW-108	55127	17261	INRS GPS	369,27	368,35	- -	- -	- -
MW-109	55896	17305	INRS GPS	- -	- -	- -	- -	- -
MW-110	57294	17434	INRS GPS	- -	- -	- -	10,73	- -
MW-111	57143	17434	INRS GPS	- -	- -	- -	9,24	- -
MW-112	56734	17376	INRS GPS	369,39	369,34	369,03	9,20	- -
MW-113	55222	17330	INRS GPS	- -	- -	- -	7,72	- -
Ammunition Dump								
GW-AMA-1	51371	15945	Lennon Surveys	- -	365,42	365,01	6,08	5
GW-AMA-2	51359	15701	Lennon Surveys	- -	365,21	364,82	8,38	5
OW-1	51819	15634	INRS GPS	365,60	365,49	- -	11,77	- -
Agricultural Area West of the Base								
GW-ANTENNE	50107	13767	Lennon Surveys	- -	361,89	361,54	14,63	10
GW-ZONE-4E	55282	13887	Lennon Surveys	- -	366,37	365,97	8,60	10
GW-ZONE-4W	53722	14810	Lennon Surveys	- -	366,02	365,61	9,17	5
GW-ZONE-5N	55251	11039	Lennon Surveys	- -	364,03	363,66	8,87	10
GW-ZONE-5S	55235	08363	Lennon Surveys	- -	361,21	360,84	9,20	10
South of the Base								
GW-ZONE-7	68312	97496	Lennon Surveys	- -	347,70	347,43	9,13	10(3)
GW-ZONE-7W	466672	97613	Lennon Surveys	- -	347,56	347,25	10,28	10
GW-SPRING-3	470678	98362	INRS GPS	- -	- -	- -	- -	- -
North of the Base								
GW-TR	57112	18359	Lennon Surveys	- -	369,87	369,57	5,13	5
GW-ZONE-9N	59767	19509	Lennon Surveys	- -	370,75	370,48	9,10	5
GW-ZONE-9S	58562	17394	Lennon Surveys	- -	370,16	369,85	3,23	5
GW-ZONE-9W	59053	18441	Lennon Surveys	- -	370,52	370,18	8,60	5
East of the Base								
GW-A-9	69904	09655	Lennon Surveys	- -	365,70	365,71	3,06	5
GW-MARSH-1	74053	07164	Wardrop Engineering	362,00	362,04	361,68	7,48	5
Spruce Woods Provincial Park								
GW-PARC-1	78334	00022	INRS GPS	- -	- -	- -	- -	- -
GW-PARC-2	80450	01075	INRS GPS	- -	- -	- -	- -	- -

(1) GPS Locations: Universal Transverse Mercator NAD 83, Zone 14

(2) - -: Non-available or non-applicable

(3) Contradictory data regarding the length of the slotted pipe, (5 or 10 feet?)

TABLE III: SUMMARY OF SLUG TEST ANALYSIS AT CFB SHILO

Observation Well	Hydraulic Conductivity (m/sec)			Average (m/sec)	Test Date
	Test 1	Test 2	Test 3		
Background					
GW-BGR	2,54E-04	2,34E-04	- - (1)	**2,44E-04**	2000
GW-BGR-3	2,09E-04	1,85E-04	- -	**1,97E-04**	2001
GW-BGR-4	2,97E-04	2,29E-04	- -	**2,63E-04**	2001
GW-BGR-7	- -	- -	- -	- -	- -
GW-BGR-8	- -	- -	- -	- -	- -
GW-BGR-9	- -	- -	- -	- -	- -
GW-BGR-10	- -	- -	- -	- -	- -
Battleruns - Aachen					
GW-A-1	2,69E-04	2,73E-04	- -	**2,71E-04**	2000
GW-A-2	1,20E-04	1,22E-04	1,29E-04	**1,24E-04**	2000
GW-A-3	1,84E-04	2,14E-04	- -	**1,98E-04**	2000
GW-A-4	5,27E-05	4,95E-05	- -	**5,11E-05**	2000
GW-A-5	8,41E-05	- -	- -	**8,41E-05**	2000
GW-A-6	2,57E-05	2,80E-05	- -	**2,68E-05**	2000
GW-A-8	2,79E-05	1,96E-04	- -	**7,39E-05**	2000
GW-A-10	3,03E-04	2,54E-04	- -	**2,79E-04**	2001
Battleruns - Berlin					
GW-B-1	3,67E-04	4,10E-04	3,61E-04	**3,79E-04**	2001
GW-B-2	- -	- -	- -	- -	- -
GW-B-3	1,34E-04	1,45E-04	- -	**1,39E-04**	2000
GW-B-4	9,97E-05	1,27E-04	- -	**1,13E-04**	2000
GW-B-5	7,20E-05	6,78E-05	- -	**6,99E-05**	2000
GW-B-6	1,09E-04	1,34E-04	- -	**1,21E-04**	2000
GW-B-7	1,18E-04	1,17E-04	- -	**1,17E-04**	2000
Battleruns - Cologne					
GW-C-1	2,35E-04	- -	- -	**2,35E-04**	2000
GW-C-2	2,73E-04	2,41E-04	- -	**2,57E-04**	2000
GW-C-3	1,41E-04	1,06E-04	- -	**1,22E-04**	2000
GW-C-4	1,46E-04	1,26E-04	- -	**1,36E-04**	2000
GW-C-5	2,73E-04	2,64E-04	- -	**2,68E-04**	2000
GW-C-6	2,72E-04	2,31E-04	- -	**2,51E-04**	2000
GW-C-7	- -	- -	- -	- -	- -
GW-C-8	2,27E-04	2,05E-04	- -	**2,16E-04**	2001
GW-C-9	2,13E-04	2,34E-04	2,28E-04	**2,25E-04**	2001
Battleruns - Deilinghofen					
GW-D-1A	- -	- -	- -	- -	- -
GW-D-1B	- -	- -	- -	- -	- -
GW-D-2	1,04E-05	2,54E-04	- -	**5,14E-05**	2000
GW-D-3	8,39E-05	1,06E-04	- -	**9,43E-05**	2000
GW-D-4	1,18E-04	1,51E-04	- -	**1,33E-04**	2000
GW-D-4 (2)	2,04E-04	2,32E-04	- -	**2,18E-04**	2001
GW-D-5	9,33E-05	- -	- -	**9,33E-05**	2000
GW-D-6	1,16E-04	9,62E-05	- -	**1,06E-04**	2000

Observation Well	**Hydraulic Conductivity (m/sec)**			**Average (m/sec)**	**Test Date**
	Test 1	**Test 2**	**Test 3**		
GW-D-7	- -	- -	- -	- -	- -
GW-D-8	- -	- -	- -	- -	- -
GW-D-9	1,53E-04	1,57E-04	1,83E-04	**1,64E-04**	2001
GW-D-11	4,75E-05	5,87E-05	5,90E-05	**5,51E-05**	2001
GW-D-12	5,73E-05	5,68E-05	5,73E-05	**5,71E-05**	2001
GW-D-13	1,89E-05	1,10E-05	2,08E-05	**1,69E-05**	2001
Battleruns - Essen					
GW-E-1	2,53E-05	2,60E-05	- -	**2,56E-05**	2000
GW-E-2	5,46E-05	5,38E-05	5,84E-05	**5,56E-05**	2000
GW-E-3	7,41E-05	7,72E-05	- -	**7,56E-05**	2000
GW-E-4	4,10E-05	- -	- -	**4,10E-05**	2000
GW-E-5	1,97E-04	1,90E-04	2,06E-04	**1,97E-04**	2001
GW-E-6	4,39E-05	3,23E-05	- -	**3,77E-05**	2000
GW-E-7	1,30E-04	1,15E-04	- -	**1,23E-04**	2001
GW-E-8	1,70E-04	1,15E-04	- -	**1,42E-04**	2001
GW-E-9	1,14E-04	1,23E-04	- -	**1,18E-04**	2001
GW-E-11	3,54E-05	4,19E-05	5,43E-05	**4,39E-05**	2001
GW-A-7	6,71E-05	6,37E-05	- -	**6,54E-05**	2000
Ranges - Rifle Ranges					
GW-RIF	2,73E-04	- -	- -	**2,73E-04**	2000
GW-RIF-1	3,10E-04	2,69E-04	- -	**2,90E-04**	2001
GW-RIF-3	1,23E-04	1,33E-04	1,38E-04	**1,31E-04**	2001
0W-3	- -	- -	- -	- -	- -
Ranges - Hand Grenade Range					
GW-GRE	8,49E-05	1,02E-04	- -	**9,31E-05**	2000
GW-GRE-1	1,93E-04	- -	- -	**1,93E-04**	2001
GW-GRE-2	1,44E-04	- -	- -	**1,44E-04**	2001
Ranges - Anti-tank Range					
GW-ATR	1,36E-04	- -	- -	**1,36E-04**	2000
GW-ATR-1	2,58E-04	2,81E-04	- -	**2,70E-04**	2001
Base Water Supply & Observation					
GW-SUP-5	- -	- -	- -	- -	- -
GW-SUP-16	- -	- -	- -	- -	- -
GW-SUP-27	- -	- -	- -	- -	- -
GW-OBS-SUP-5	1,40E-04	1,35E-04	- -	**1,37E-04**	2001
GW-OBS-SUP-16	3,20E-04	2,77E-04	3,88E-04	**3,28E-04**	2001
GW-OBS-SUP-27	1,50E-04	1,49E-04	- -	**1,50E-04**	2001
Inhabited area					
GW-GATE-S	3,17E-04	3,39E-04	- -	**3,28E-04**	2001
GW-PHILLIPS	- -	- -	- -	- -	- -
OW-2	- -	- -	- -	- -	- -
Dump & Quarry					
MW-101	- -	- -	- -	- -	- -
MW-102	- -	- -	- -	- -	- -
MW-104	- -	- -	- -	- -	- -
MW-107-A	- -	- -	- -	- -	- -
MW-107-B	- -	- -	- -	- -	- -

Observation Well	**Hydraulic Conductivity (m/sec)**			**Average (m/sec)**	**Test Date**
	Test 1	**Test 2**	**Test 3**		
MW-108	- -	- -	- -	- -	- -
MW-109	7,82E-05	8,31E-05	- -	**8,06E-05**	2000
MW-110	- -	- -	- -	- -	- -
MW-111	- -	- -	- -	- -	- -
MW-112	- -	- -	- -	- -	- -
MW-113	- -	- -	- -	- -	- -
Ammunition Dump					
GW-AMA-1	2,90E-04	3,48E-04	- -	**3,19E-04**	2001
GW-AMA-2	7,35E-04	7,42E-04	- -	**7,38E-04**	2001
OW-1	- -	- -	- -	- -	- -
Agricultural Area West of the Base					
GW-ANTENNE	- -	- -	- -	- -	- -
GW-ZONE-4E	1,02E-04	1,10E-04	9,85E-05	**1,03E-04**	2001
GW-ZONE-4W	4,00E-04	3,95E-04	3,97E-04	**3,97E-04**	2001
GW-ZONE-5N	2,69E-04	2,57E-04	3,31E-04	**2,86E-04**	2001
GW-ZONE-5S	4,35E-04	4,49E-04	4,18E-04	**4,34E-04**	2001
South of the Base					
GW-ZONE-7	2,96E-04	- -	- -	**2,96E-04**	2001
GW-ZONE-7W	3,91E-04	- -	- -	**3,91E-04**	2001
GW-SPRING-3	- -	- -	- -	- -	- -
North of the Base					
GW-TR	2,33E-04	1,95E-04	- -	**2,14E-04**	2001
GW-ZONE-9N	9,59E-05	1,12E-04	1,53E-04	**1,20E-04**	2001
GW-ZONE-9S	1,21E-04	9,49E-05	- -	**1,08E-04**	2001
GW-ZONE-9W	4,06E-05	3,73E-04	- -	**2,07E-04**	2001
East of the Base					
GW-A-9	6,28E-05	5,69E-05	4,89E-05	**5,62E-05**	2001
GW-MARSH-1	7,82E-05	8,31E-05	- -	**8,06E-05**	2000
Spruce Woods Provincial Park					
GW-PARC-1	- -	- -	- -	- -	- -
GW-PARC-2	- -	- -	- -	- -	- -
GEOMETRIC MEAN				**1,36E-04**	

(1) - - Not available

(2) Slug tests performed in the same well two years in a row.

TABLE IV: PHYSICO-CHEMICAL PARAMETERS MEASURED IN GROUND WATER AND SURFACE WATER WITH YSI AND ORP PROBES

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
Background									
GW-BGR	00	6,1	7,40	536	839	0,4	266	22,4	2,81
	01	7,2	7,32	538	770	0,4	26	1,2	0,22
	02	8,4	7,16	423	619	0,30	-8	23,9	2,79
GW-BGR-3	00	- - (2)	- -	- -	- -	- -	- -	- -	- -
	01	9,7	7,55	311	438	0,2	151	62,9	7,17
	02	8,8	7,52	283	410	0,20	151	21,6	2,51
GW-BGR-4	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,5	7,70	233	347	0,2	229	89,4	10,73
	02	7,7	7,75	199	297	0,14	96	29,0	3,45
GW-BGR-7	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	8,4	7,42	332	486	0,24	-94	12,9	1,50
GW-BGR-8	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,7	6,90	327	488	0,24	180	28,3	3,37
GW-BGR-9	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	13,6	7,34	313	399	0,19	163	68,4	7,04
GW-BGR-10	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	23,00	7,20	384	511	0,25	-119	20,8	2,24
Battleruns - Aachen									
GW-A-1	00	7,4	7,79	281	422	0,2	270	47,9	5,83
	01	8,9	7,70	267	- -	0,2	262	74,4	8,38
	02	7,6	7,84	234	351	0,17	184	59,3	6,95
GW-A-2	00	7,3	7,93	265	401	0,2	279	- -	- -
	01	7,5	7,80	262	392	0,2	289	117,7	14,25
	02	7,1	- -	211	321	0,15	167	67,1	7,87
GW-A-3	00	9,2	7,89	267	381	0,2	265	64,2	7,47
	01	10,3	7,95	271	- -	0,2	239	71,0	8,05
	02	8,5	8,14	234	341	0,16	184	37,0	4,28
GW-A-4	00	11,3	7,78	272	367	0,2	246	100,5	10,58
	01	8,7	7,70	202	- -	0,1	247	98,9	11,48
	02	7,8	- -	182	271	0,13	192	68,2	8,09
GW-A-5	00	11,2	7,91	288	392	0,2	267	100,6	10,91
	01	7,7	7,75	247	370	0,2	187	122,2	14,60
	02	7,2	7,42	243	368	0,18	151	35,9	4,33
GW-A-6	00	10,8	7,92	270	371	0,2	267	96,5	10,43
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-A-8	00	8,1	7,99	260	385	0,2	206	126,3	15,07

Site ID		**Sampling**							
	Year	**T (°C)**	**pH**	**Conductivity (μS/cm)**	**Specific Conductivity (μS/cm)**	**Salinity (ppt) (1)**	**Redox Potential (mV)**	**Dissolved Oxygen (%)**	**Dissolved Oxygen (mg/L)**
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-A-10	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	12,2	7,39	215	- -	0,1	213	91,4	9,81
	02	8,1	8,03	221	326	0,16	176	61,6	7,23
Battleruns - Berlin									
GW-B-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,5	6,30	249	364	0,2	114	77,8	9,09
	02	7,5	7,54	242	364	0,17	55	45,0	5,38
GW-B-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-B-3	00	9,6	7,92	275	389	0,2	291	103,1	11,70
	01	7,9	7,79	275	406	0,2	202	104,1	12,35
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-B-4	00	9,6	7,72	307	435	0,2	290	75,9	8,65
	01	14	7,62	173	- -	0,1	240 (3)	65,1	6,72
	02	9,5	- -	245	340	0,16	178	72,1	8,32
GW-B-5	00	9,9	7,74	304	427	0,2	279	29,0	3,31
	01	14,9	7,48	323	- -	0,2	242 (3)	44,5	4,65
	02	10,7	7,24	239	329	0,16	144	12,2	1,35
GW-B-6	00	11,0	7,88	326	445	0,2	265	82,7	9,08
	01	13,8	7,40	484	- -	0,2	243 (3)	28,6	3,10
	02	9,4	7,18	233	332	0,16	172	3,6	0,41
GW-B-7	00	12,0	7,84	295	400	0,2	238	89,6	9,69
	01	13,7	7,40	402	- -	0,2	241 (3)	41,8	4,36
	02	10,1	- -	233	325	0,16	182	14,1	1,64
Battleruns - Cologne									
GW-C-1	00	12,2	7,62	331	437	0,2	235	44,9	4,76
	01	13,6	7,55	444	- -	0,2	236 (3)	26,6	2,80
	02	8,6	7,27	228	332	0,16	-14	1,2	0,14
GW-C-2	00	10,5	7,98	302	418	0,2	249	85,3	9,48
	01	11,6	5,90	266	- -	0,2	194 (3)	33,7	3,67
	02	9,5	7,36	264	374	0,18	73	7,1	0,81
GW-C-3	00	12,3	8,09	262	347	0,2	268	96,1	10,40
	01	13,0	6,14	237	- -	0,2	222 (3)	91,8	9,79
	02	7,4	7,38	235	354	0,17	37	32,6	3,86
GW-C-4	00	9,7	7,75	291	410	0,2	271	59,0	6,66
	01	11,8	6,16	284	- -	0,2	165 (3)	60,9	6,65
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-C-5	00	9,9	7,88	288	411	0,2	245	83,9	9,54
	01	10,7	4,49	243	- -	0,2	231 (3)	60,0	6,67
	02	10,1	7,62	271	376	0,2	172	88,6	9,92
GW-C-6	00	8,2	7,90	235	346	0,2	246	91,2	10,70
	01	12,3	7,70	276	- -	0,2	234 (3)	121,5	12,69

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
	02	7,9	7,11	245	362	0,2	150	166,3	19,73
GW-C-7	00	6,8	8,00	249	384	0,2	256	82,8	10,40
	01	12,4	7,62	277	- -	0,0	291	88,8	9,52
	02	8,7	8,02	248	353	0,2	215	98,2	11,50
GW-C-8	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,5	7,96	204	306	0,1	284	116,5	14,02
	02	7,4	7,68	173	261	0,12	128	47,6	5,73
GW-C-9	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	11,8	8,02	181	- -	0,1	278 (3)	126,0	13,68
	02	8,0	7,98	213	303	0,1	170	188,1	22,17
Battleruns - Deilinghofen									
GW-D-1A	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,7	7,17	271	404	0,20	-68	2,3	0,28
GW-D-1B	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-D-2	00	9,7	7,78	277	392	0,2	292	73,9	8,36
	01	8,2	7,00	219	315	0,2	320	12,3	1,32
	02	7,9	7,36	226	336	0,16	-68	1,2	0,14
GW-D-3	00	9,8	7,79	308	434	0,2	285	47,8	5,35
	01	8,0	7,53	299	444	0,2	244	104,8	12,11
	02	7,9	7,41	287	427	0,21	88	4,6	0,54
GW-D-4	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	224 (3)	- -	- -
	02	8,8	7,54	227	328	0,16	133	4,6	0,53
GW-D-5	00	12,6	7,71	298	391	0,2	181	83,3	8,75
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	8,2	7,48	239	352	0,17	157	18,0	2,11
GW-D-6	00	9,4	7,84	305	434	0,2	296	76,3	8,86
	01	11,7	6,00	300	- -	0,2	250 (3)	52,0	5,69
	02	9,5	7,32	314	447	0,22	93	14,7	1,68
GW-D-7	00	7,1	8,09	0	0	0,2	258	52,1	6,52
	01	7,6	7,00	227	336	0,2	- -	19,9	2,65
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-D-8	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,1	8,42	271	399	0,2	214	4,7	0,51
	02	10,6	7,02	236	326	0,16	-23	35,6	3,98
GW-D-9	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,0	8,05	428	- -	0,2	279 (3)	85,1	9,74
	02	8,2	7,56	217	319	0,15	133	14,3	1,68
GW-D-11	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,6	8,33	407	- -	0,2	276 (3)	114,3	12,70
	02	8,00	7,53	193	287	0,14	116	82,0	9,71
GW-D-12	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	11,8	7,86	220	- -	0,2	282 (3)	101,7	9,86

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
	02	8,3	7,16	338	497	0,24	-56	6,5	0,78
GW-D-13	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,5	7,93	115	- -	2,8	279 (3)	107,0	10,50
	02	8,4	7,54	179	261	0,13	86	52,2	6,11
Battleruns - Essen									
GW-E-1	00	9,6	7,73	315	445	0,2	253	52,6	6,12
	01	- -	- -	- -	- -	- -	288 (3)	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-E-2	00	10,0	7,76	295	412	0,2	252	33,1	3,84
	01	- -	- -	- -	- -	- -	285 (3)	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-E-3	00	10,9	8,16	245	339	0,2	175	88,6	10,18
	01	10,1	7,70	255	352	0,2	294	61,8	7,03
	02	9,9	7,46	258	363	0,17	191	28,1	3,16
GW-E-4	00	7,7	7,42	256	383	0,2	228	58,9	7,29
	01	14,5	7,41	242	- -	0,1	243 (3)	83,5	8,50
	02	8,7	7,38	265	385	0,19	173	8,6	0,99
GW-E-5	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	281 (3)	- -	- -
	02	10,2	8,18	296	413	0,2	112	50,7	5,64
GW-E-6	00	8,6	7,44	349	510	0,2	251	51,5	6,25
	01	15,4	7,50	322	- -	0,2	249 (3)	23,8	2,48
	02	11,5	7,28	323	434	0,2	66	2,9	33,00
GW-E-7	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	13,5	7,59	120	- -	0,1	283	117,3	12,13
	02	10,1	7,04	343	478	0,2	25	3,1	0,35
GW-E-8	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	13,8	7,23	439	551	0,3	270	32,8	3,44
	02	10,1	7,05	364	509	0,2	-53	15,5	1,76
GW-E-9	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	12,7	7,66	300	- -	0,2	296	2,9	0,30
	02	13,1	7,40	267	345	0,2	92	61,4	6,46
GW-E-11	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	0,0 (4)	8,10	280	- -	0,2	278 (3)	105,0	10,92
	02	11,2	8,48	251	342	0,2	108	103,8	103,10
GW-A-7	00	9,3	7,57	339	485	0,2	190	41,5	4,81
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
Ranges - Rifle Ranges									
GW-RIF	00	9,3	7,85	237	337	0,2	238	93,8	10,71
	01	11,1	8,13	102	- -	0,1	263	48,1	4,64
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-RIF-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	12,0	7,95	273	- -	0,1	230	108,2	11,52
	02	7,3	- -	193	292	0,14	207	80,8	8,65
GW-RIF-3	00	- -	- -	- -	- -	- -	- -	- -	- -

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (μS/cm)	Specific Conductivity (μS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
	01	8,3	6,60	213	314	0,2	140	69,5	8,50
	02	- -	- -	- -	- -	- -	- -	- -	- -
OW-3	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,0	7,54	295	450	0,2	231	96,3	11,70
	02	- -	- -	- -	- -	- -	- -	- -	- -
Ranges - Hand Grenade Range									
GW-GRE	00	11,9	7,81	232	310	0,1	200	71,1	7,60
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	9,5	7,68	236	336	0,16	102	39,0	4,42
GW-GRE-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,7	8,40	160	- -	0,1	232	41,2	4,51
	02	9,0	8,42	276	400	0,2	- -	22,6	2,62
GW-GRE-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	14,0	7,57	156	- -	0,1	295	67,0	6,86
	02	11,6	7,19	293	395	0,2	- -	44,8	5,07
Ranges - Anti-tank Range									
GW-ATR	00	9,6	8,37	279	395	0,2	206	73,8	8,70
	01	11,1	8,14	19	- -	0,1	263	99,5	9,64
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-ATR-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	11,9	8,03	240	313	0,2	271	127,4	13,83
	02	10,7	8,51	242	335	0,2	139	85,6	9,71
Base Water Supply & Observation									
GW-SUP-5	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	8,8	7,35	345	500	0,24	71	17,3	1,99
GW-SUP-16	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	8,2	7,29	375	553	0,27	-69	24,9	2,89
GW-SUP-27	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	8,7	7,26	326	474	0,23	-28	25,3	2,93
GW-OBS-SUP-5	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,9	5,56	334	480	0,2	110	98,4	11,48
	02	8,9	7,34	277	400	0,19	145	44,5	5,14
GW-OBS-SUP-16	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,6	6,20	261	390	0,2	111	78,3	9,46
	02	7,6	7,17	251	375	0,18	175	38,4	4,57
GW-OBS-SUP-27	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,0	6,10	312	440	0,2	111	91,5	10,37
	02	10,1	7,32	365	511	0,2	117	130,3	14,70
Inhabited area									
GW-GATE-S	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	242	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-PHILLIPS	00	- -	- -	- -	- -	- -	- -	- -	- -

Site ID		**Sampling**							
	Year	**T (°C)**	**pH**	**Conductivity (μS/cm)**	**Specific Conductivity (μS/cm)**	**Salinity (ppt) (1)**	**Redox Potential (mV)**	**Dissolved Oxygen (%)**	**Dissolved Oxygen (mg/L)**
	01	12,1	7,53	307	407	0,2	- -	71,9	48,20
	02	10,0	7,47	267	375	0,18	162	56,8	6,36
OW-2	00	5,2	8,08	361	564	0,3	244	72,9	9,06
	01	8,2	7,95	363	535	0,3	228	68,8	8,10
	02	8,2	7,59	352	518	0,25	176	21,9	2,57
Dump & Quarry									
MW-101	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	9,1	7,70	436	- -	0,2	288	27,9	3,21
	02	8,2	7,33	311	458	0,22	213	18,4	2,18
MW-102	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,6	7,95	267	- -	0,1	283	57,6	6,53
	02	- -	- -	- -	- -	- -	- -	- -	- -
MW-104	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	12,2	7,70	201	163	0,1	268	86,6	9,24
	02	- -	- -	- -	- -	- -	- -	- -	- -
MW-107-A	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,2	7,36	377	556	0,3	200	32,1	3,74
	02	8,4	7,08	356	521	0,25	95	13,2	1,54
MW-107-B	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,6	7,33	295	439	0,2	-41	1,4	0,17
	02	7,4	7,42	262	394	0,19	-130	1,0	0,12
MW-108	00	6,3	8,04	237	360	0,2	255	113,0	13,93
	01	7,9	7,86	253	381	0,2	250	99,3	11,78
	02	- -	- -	- -	- -	- -	- -	- -	- -
MW-109	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,1	7,30	320	473	0,2	-5	2,5	0,29
	02	- -	- -	- -	- -	- -	- -	- -	- -
MW-110	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,0	7,18	389	576	0,3	200	7,7	0,75
	02	8,4	7,30	324	475	0,23	48	5,6	0,65
MW-111	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,3	7,34	652	958	0,5	229	4,1	0,45
	02	9,2	7,34	540	772	0,38	107	16,8	1,92
MW-112	00	5,7	8,10	253	390	0,2	263	69,0	8,62
	01	7,3	7,68	256	387	0,2	188	90,4	10,80
	02	7,4	7,56	242	364	0,17	141	36,8	4,43
MW-113	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	7,4	7,49	324	486	0,2	132	3,0	0,33
	02	- -	- -	- -	- -	- -	- -	- -	- -
Ammunition Dump									
GW-AMA-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	13,7	7,70	250	- -	0,2	259	64,8	7,20
	02	9,7	7,74	289	409	0,2	187	6,1	0,67
GW-AMA-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,7	7,60	271	- -	0,2	272	67,0	7,45
	02	8,3	7,78	210	308	0,15	175	62,1	7,29

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
OW-1	00	4,9	7,98	260	422	0,2	261	83,9	10,91
	01	9,4	7,94	186	- -	0,0	282	61,7	6,96
	02	- -	- -	- -	- -	- -	- -	- -	- -
Agricultural Area West of the Base									
GW-ANTENNE	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	11,9	7,60	280	- -	0,2	278	21,0	2,50
	02	7,1	7,79	225	342	0,16	196	15,3	1,84
GW-ZONE-4E	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,7	7,68	187	- -	0,1	134	48,3	5,48
	02	9,7	8,00	340	481	0,2	109	116,6	13,30
GW-ZONE-4W	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,8	7,59	219	326	0,16	196	47,8	5,63
GW-ZONE-5N	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,9	8,14	224	333	0,16	179	72,1	8,30
GW-ZONE-5S	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,9	8,48	257	380	0,2	155	158,8	18,82
South of the Base									
GW-ZONE-7	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	11,2	7,60	210	- -	0,1	269	48,4	4,82
	02	8,4	7,94	226	334	0,2	175	139,1	16,12
GW-ZONE-7W	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	10,7	7,51	103	- -	0,1	275 (3)	42,3	4,58
	02	7,3	7,61	186	281	0,13	101	12,8	1,54
GW-SPRING-3	00	10,8	7,56	290	400	0,2	216	75,2	8,53
	01	9,3	8,06	286	- -	0,2	55	96,3	11,04
	02	- -	- -	- -	- -	- -	- -	- -	- -
North of the Base									
GW-TR	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	208	- -	- -
	02	11,0	8,05	281	371	0,2	- -	8,7	0,95
GW-ZONE-9N	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,4	7,73	128	- -	0,1	216	66,0	7,60
	02	9,1	8,38	238	341	0,2	0	65,7	7,71
GW-ZONE-9S	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	13,8	7,76	397	- -	0,2	284 (3)	117,7	12,17
	02	12,3	8,17	360	478	0,2	- -	59,2	6,37
GW-ZONE-9W	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	7,2	7,15	243	368	0,18	157	35,0	4,18
East of the Base									
GW-A-9	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	13,4	6,50	258	332	0,2	296	9,5	1,10

Site ID		**Sampling**							
	Year	**T (°C)**	**pH**	**Conductivity (μS/cm)**	**Specific Conductivity (μS/cm)**	**Salinity (ppt)** $^{(1)}$	**Redox Potential (mV)**	**Dissolved Oxygen (%)**	**Dissolved Oxygen (mg/L)**
	02	11,7	7,85	270	362	0,17	165	1,5	0,15
GW-MARSH-1	00	10,5	7,91	227	322	0,2	274	95,8	10,56
	01	8,3	8,08	229	318	0,2	278	120,5	13,98
	02	8,6	8,05	166	241	0,12	175	65,5	7,62
Spruce Woods Provincial Park									
GW-PARC-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,4	7,51	333	- -	0,2	-68	41,1	4,80
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-PARC-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	8,6	7,42	340	496	0,2	220	86,2	49,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-SPRING-1	00	12,4	7,56	298	388	0,2	188	73,5	7,82
	01	10,1	7,78	320	- -	0,2	30	101,8	11,45
	02	- -	- -	- -	- -	- -	- -	- -	- -
GW-SPRING-2	00	12,1	7,39	346	458	0,2	-35	70,8	7,64
	01	7,8	7,68	315	- -	0,2	-38	52,1	6,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
Surface Water									
Assiniboine River									
SW-BGR-1	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	9,06	8,34	664	955	0,47	192	40,1	4,64
SW-BGR-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	11,8	8,27	724	970	0,48	77	48,8	4,56
SW-SA-1	00	4,9	- -	- -	- -	- -	258	- -	- -
	01	18,4	8,76	394	-	0,5	122	125,0	12,00
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-2	00	4,4	- -	- -	- -	- -	243	- -	- -
	01	18,8	8,83	837	- -	0,5	166	151,0	13,98
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-2A	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	18,3	8,83	696	- -	0,4	222	102,8	9,69
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-2C	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	17,1	8,10	747	882	0,4	186	99,2	50,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-3	00	6,4	- -	- -	- -	- -	211	112,6	13,66
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-3-AMONT	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	17,3	7,78	363	425	0,2	195	99,3	51,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SA-3-AVAL	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	17,1	8,12	740	872	0,4	194	100,3	51,20
	02	- -	- -	- -	- -	- -	- -	- -	- -

Site ID		Sampling							
	Year	T (°C)	pH	Conductivity (μS/cm)	Specific Conductivity (μS/cm)	Salinity (ppt) [1]	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
SW-SA-4	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	17,6	8,79	716	833	0,41	82	128,9	12,29
Souris River									
SW-SS-1	00	19,3	8,78	1143	- -	0,6	183	103,5	9,55
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	22,0	8,80	11	1190	0,59	121	87,9	7,67
Epinette Creek									
SW-SE-1	00	4,6	- -	- -	- -	- -	166	90,0	11,48
	01	- -	- -	- -	- -	- -	47	- -	- -
	02	18,7	8,50	257	292	0,14	123	66,6	6,22
SW-SE-2	00	4,9	- -	- -	- -	- -	215	57,2	7,30
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SE-3	00	5,1	- -	- -	- -	- -	125	84,5	10,64
	01	14,9	7,10	425	527	0,3	224	70,5	49,20
	02	15,4	7,44	450	552	0,27	13	22,1	2,22
SW-SE-4	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	- -	- -	- -	- -	- -	- -	- -	- -
	02	9,5	7,10	494	700	0,34	-174	15,7	1,78
Lakes , Streams, Dug holes									
SW-ADAMS SPRING	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	12,0	7,29	316	421	0,2	201	56,7	47,10
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-ANTEN-SPRING	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	15,7	7,30	348	- -	0,0	42	34,4	3,39
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-HLAKE	00	11,9	8,01	337	450	0,2	225	86,6	9,32
	01	19,0	7,42	237	- -	0,1	216	106,5	9,72
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-MLAKE	00	8,7	- -	- -	- -	- -	207	104,6	11,99
	01	19,3	7,62	206	231	0,1	172	88,8	50,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-SWAIS-SPRING	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	16,0	7,72	530	- -	0,0	178	73,6	7,29
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-ZONE6	00	8,9	8,08	248	358	0,2	242	75,6	8,80
	01	15,5	7,67	333	- -	0,0	232	84,4	8,45
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-DO-2	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	20,7	7,94	239	261	0,1	216	56,4	48,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-DO-3	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	20,1	7,89	653	770	0,4	218	93,9	51,90
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-DO-4	00	- -	- -	- -	- -	- -	- -	- -	- -

Site ID		Sampling						Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
	Year	T (°C)	pH	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	Salinity (ppt) (1)	Redox Potential (mV)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)
	01	16,2	8,16	214	258	0,1	225	88,7	50,20
	02	- -	- -	- -	- -	- -	- -	- -	- -
SW-DO-5	00	- -	- -	- -	- -	- -	- -	- -	- -
	01	19,9	8,78	262	289	0,1	190	151,5	56,30
	02	- -	- -	- -	- -	- -	- -	- -	- -

(1) The precision of salinity measurements differ according to the model of YSI probe used at each location.

(2) - - Not available

(3) Value measured in the lab a few hours after water collection in the well as the probe was not available while in the field,

(4) Values measured in november 2001

TABLE V: WATER QUALITY THRESHOLD CRITERIA

Parameter	***Unit***	***CCME Guidelines for Canadian Drinking Water Quality***	***EPA Maximum Contaminant Level (for drinking water)***	***WHO guidelines for drinking water***	***CCME Guidelines: Aquatic life, Freshwater***	***CCME Guidelines: Agriculture, Irrigation***	***CCME Guidelines: Agriculture, Livestock***	***ETL Detection limit***
Alkalinity as $CaCO_3$	mg/L							30
Alkalinity as Bicarbonate	mg/L							40
Alkalinity as Hydroxide	mg/L							10
pH	No Unit	6,5 - 8,5	6,5 - 8,5	Around neutrality	6,5-9,0			-
Conductivity	µohms /cm							20
Solids - Dissolved	mg/L	<ou égal 500	500	1000		500 - 3 500	3 000	5
Turbidity	NTU	1 et <ou égal 5	5	5				-
Chloride - Soluble	mg/L	<ou égal 250				100 - 700		10
Nitrate-Nitrite-N Soluble	mg/L N	10 (nitrate - nitrogen), 45 nitrate	10 (nitrate nitrite)	nitrate (as NO_3^-) 50 acute, nitrite (as NO_2^-) 3 acute, 0,2 chronic			nitrate-nitrite: 100	1
Sulphate - Soluble	mg/L SO4	<ou égal 500	250 b (sulfate)	250			1 000	10
Aluminium - Total	mg/L	0,1	0,05-0,2	0,2	0,005 - 0,1	5	5	0,02

Parameter	***Unit***	***CCME Guidelines for Canadian Drinking Water Quality***	***EPA Maximum Contaminant Level (for drinking water)***	***WHO guidelines for drinking water***	***CCME Guidelines: Aquatic life, Freshwater***	***CCME Guidelines: Agriculture, Irrigation***	***CCME Guidelines: Agriculture, Livestock***	***ETL Detection limit***
Arsenic - Total	mg/L	0,025	0.01	0,01	0,005	0,1	0,025	0,0005
Antimony - Total	mg/L	0,006	0,006	0,005				0,001
Barium - Total	mg/L	1	2	0,7				0,0003
Beryllium - Total	mg/L		0,004	NAD		0,1	0,1	0,001
Boron - Total	mg/L	5	Under review	0,5		0,5 -6	5	0,03
Bismuth - Total	mg/L							0,0001
Cadmium - Total	mg/L	0,005	0,005	0,003	0,000017	0,0051	0,08	0,0002
Calcium - Total	mg/L	No criteria					1 000	0,1
Chromium - Total	mg/L	0,05	0,1	0,05				0,002
Cobalt - Total	mg/L					0.05	1	0,0002
Copper - Total	mg/L	<ou égal 1.0	1,3 et 1	2 et 1	0,002-0,004	0,2 - 1	0,5 - 5	0,001
Cesium - Total	mg/L	Cs 134 and						0,0001
Hardness as $CaCO_3$	mg/L	No criteria		No criteria				0,07
Iron - Total	mg/L	<ou égal 0,3	0,3	0,3	0,3	5		0,05

Parameter	***Unit***	***CCME Guidelines for Canadian Drinking Water Quality***	***EPA Maximum Contaminant Level (for drinking water)***	***WHO guidelines for drinking water***	***CCME Guidelines: Aquatic life, Freshwater***	***CCME Guidelines: Agriculture, Irrigation***	***CCME Guidelines: Agriculture, Livestock***	***ETL Detection limit***
Lead - Total	mg/L	0,010	0,015	0,01	0,001-0,007	0,2	0,1	0,0005
Lithium - Total	mg/L					2,5		0,002
Magnesium	mg/L	No criteria						0,01

NAD*:* No adequate data to permit recommendation on a health-based guideline value

TABLE VI: METALS CONCENTRATIONS DETECTED OVER CCME GUIDELINES FOR DRINKING WATER QUALITY IN GROUND WATER SAMPLES

ETL ID Number (2000)	*ETL ID Number (2001)*	*Sample ID*	*> CCME Drinking Water Concentration detected in 2001 (ppb)*	*> CCME Drinking Water Concentration detected in 2000 (ppb)*
2001 INRS wells				
N/A	01-A77028	GW-ANTENNE	Al (270), Fe (1660), Mn (1020)	
N/A	01-A77030	GW-AMA-1	Al (290), Fe (2510), Mn (114)	
N/A	01-A77032	GW-AMA-2	Al (300), Fe (1160), Mn (111)	
N/A	01-A78052	GW-ATR-1	Al (2380), Sb (33), Fe (10500), Mn (827)	
N/A	01-A78572	GW-A-9	Al (300), Fe (880), Mn (268)	
N/A	01-A77814	GW-A10	Al (510), Fe (1570), Mn (137)	
N/A	01-A78555	GW-BGR-3	Al (1000), Sb (26), Fe (1600), Mn (730)	
N/A	01-A78542	GW-BGR-4	Al (2040), Fe (6390), Mn (257)	
N/A	01-A78579	GW-C-8	Al (71100), As (302), Sb (36), Ba (3720), Cr (117), Fe (310000), Pb (158), Mn (19000)	
N/A	01-A77027	GW-C-9	Al (2380), Fe (6350), Mn (351)	
N/A	01-A77017	GW-D-9	Al (1560), Fe (4630), Mn (394)	
N/A	01-A77019	GW-D-11	Al (2560), Sb (11), Fe (6770), Mn (461)	
N/A	01-A77043	GW-D-12	Al (6850), Sb (14), Fe (9890), Mn (823)	

ETL ID Number (2000)	ETL ID Number (2001)	Sample ID	> CCME Drinking Water Concentration detected in 2001 (ppb)	> CCME Drinking Water Concentration detected in 2000 (ppb)
N/A	01-A77020	GW-D-13	Al (15500), Fe (23500), Pb (13.1), Mn (415), Se (15)	
N/A	01-A76577	GW-E-7	Al (1160), Cd (40.5), Fe (1980), Mn (87,2)	
N/A	01-A76578	GW-E-8	Al (960), Fe (6230), Mn (345)	
N/A	01-A76579	GW-E-9	Al (820), Fe (1280)	
N/A	01-A77817	GW-E-11	Al (3150), Sb (20), Fe (4660), Mn (164)	
N/A	01-A76604	GW-Gate-S	Al (460), Fe (1720), Mn (195)	
N/A	01-A77800	GW-GRE1	Al (1850), Fe(11900), Mn (127)	
N/A	01-A77801	GW-GRE2	Al (2050), Fe (3020)	
N/A	01-A77773	GW-RIF-1	Al (150), Fe (710)	
N/A	01-A78054	GW-RIF-3	Al (1000), Sb (22), Fe (2600), Mn (64)	
N/A	01-A77803	GW-TR	Al (2760), Fe (11000), Mn (717)	
N/A	01-A78619	OBS-SUP-5	Al (720), Sb (28), Fe (2350), Mn (237)	
N/A	01-A78625	OBS-SUP-16	Al (830), Sb (29), Fe (2670), Mn (169)	
N/A	01-A78620	OBS-SUP-27	Al (310), Sb (24), Fe (1390), Mn (76,6)	
N/A	01-A76603	GW-Zone-4-E	Al (2490), Fe (3190), Mn (238)	
N/A	01-A76602	GW-Zone-4-W	Al (500), Fe (2760), Mn (182)	
N/A	01-A76580	GW-Zone-5-N	Al (5690), Fe (12800), Pb (10.8), Mn (1770)	

ETL ID Number (2000)	***ETL ID Number (2001)***	***Sample ID***	***> CCME Drinking Water Concentration detected in 2001 (ppb)***	***> CCME Drinking Water Concentration detected in 2000 (ppb)***
N/A	01-A76581	GW-Zone-5-S	Al (1160), Fe (8150), Mn (184)	
N/A	01-A77818	GW-ZONE-7	Al (1030), Fe (8600), Mn (1080)	
N/A	01-A77771	GW-ZONE-7W	Fe (360), Mn (171)	
N/A	01-A76605	GW-Zone-9-N	Al (6320), Fe (11600), Mn (188)	
N/A	01-A77029	GW-Zone-9S	Al (800), Fe (7630), Mn (2830)	
N/A	01-A78056	GW-ZONE-9W	Al (1680), Sb (23), Fe (3130), Mn (254)	
2000 Wells				
00-A87898	01-A77823	GW-ATR	Al (1540), Fe (8590), Mn (368)	
00-A80083	01-A77822	GW-GRE	Al (5790), Fe (11100), Mn (455)	
N/A	01-A78629	GW-MARSH-1	Al (13000), Fe (17400), Pb (13.7), Mn (775)	
00-A87899	01-A78544	GW-BGR	Fe (1280), Mn (1760)	
00-A80082	01-A77774	GW-RIF	Al (2570), Sb (17), Fe (8020), Mn (699)	
00-A85950	01-A77040	GW-A-1	Al (4160), Fe (7230), Mn (641)	
00-A85948	01-A78581	GW-A2	Al (11900), Fe (36600), Pb (24.4), Mn (1480)	
00-A85949	01-A77042	GW-A-3	Al (1040), Fe (6700), Mn (457)	
00-A85951	01-A77041	GW-A-4	Al (15700), Fe (17300), Mn (422)	
N/A	01-A78571	GW-B-1	Al (270), Sb (14), Fe (1730), Mn (364)	

ETL ID Number (2000)	ETL ID Number (2001)	Sample ID	> CCME Drinking Water Concentration detected in 2001 (ppb)	> CCME Drinking Water Concentration detected in 2000 (ppb)
00-A83316	01-A78614	GW-B-3	Al (1420), Sb (37), Fe (8620), Mn (612)	
00-A83317	01-A78051	GW-B-4	Al (15500), Sb (26), Fe (22400), Pb (13.6), Mn (762)	
00-A83318	01-A78050	GW-B-5	Al (2960), Sb (37), Fe (6410), Mn (1160)	
00-A83319	01-A78073	GW-B-6	Al (333), Sb (29), Fe (2210), Mn (260)	
00-A83310	01-A78049	GW-B-7	Al (3290), Sb (36), Fe (7940), Mn (521)	
00-A83315	01-A78070	GW-C-1	Al (4770), Sb (30), Fe (24400), Pb (14.8), Mn (1360)	Mn (52)
00-A83312	01-A78545	GW-C-2	Al (3260), As (28.8), Fe (27500), Pb (14.5), Mn (4320)	
00-A83313	01-A78546	GW-C-3	Al (1880), Fe (26000), Pb (11.8), Mn (4530)	
00-A83314	01-A78617	GW-C-4	Al (1490), Fe (7860), Mn (603)	
00-A83311	01-A78547	GW-C-5	Al (2220), Fe (10400), Mn (1040)	
00-A80081	01-A78071	GW-C-6	Al (4750), Sb (30), Fe (10700), Pb (11.1), Mn (1800)	
00-A88118	01-A78072	GW-C-7	Al (4030), As (38.2), Sb (33), Fe (40300), Pb (32,7), Mn (3600), Se (15)	
00-A83322	01-A78630	GW-D-2	Al (120), Fe (1820), Mn (270)	Mn (279)
00-A83320	01-A78570	GW-D-3	Al (11400), As (47.1), Ba (1060), Fe (41600), Pb (25.7), Mn (5050)	
N/A	01-A78556	GW-D-4	Al (6850), As (40.7), Fe (37200), Pb (18.7), Mn (3790)	
00-A83323	01-A78618	GW-D-6	Al (1860), Fe (5700), Mn (380)	

ETL ID Number (2000)	***ETL ID Number (2001)***	***Sample ID***	***> CCME Drinking Water Concentration detected in 2001 (ppb)***	***> CCME Drinking Water Concentration detected in 2000 (ppb)***
00-A88120	01-A78053	GW-D-7	Al (2160), Fe (5000), Mn (512)	
N/A	01-A78615	GW-D-8	Al (46100), As (129), Sb (44), Ba (2270), Cr (93), Fe (169000), Pb (175), Mn (13100)	
00-A87900	01-A77819	GW-E-1	Al (2110), Fe (2840), Mn (197)	
N/A	01-A77802	GW-E-2	Al (7620), Fe (9590), Mn (456)	
00-A87904	01-A78543	GW-E-3	Al (160), Fe (500)	
00-A87903	01-A77816	GW-E-4	Al (10500), Sb (47), Fe (10400), Mn (424)	Al (180), Fe (320)
N/A	01-A77820	GW-E-5	Al (16200), Sb (7), Fe (36800), Pb (14.2), Mn (4560)	
00-A87902	01-A77815	GW-E-6	Al (22800), Sb (40), Fe (43700), Pb (16.8), Mn (1090)	Mn (948)
Private Wells				
N/A	01-A74111	GW-Philips	Fe (360)	
N/A	01-A74112	GW-PARC-1	Fe (13300), Mn (282)	
N/A	01-A75363	GW-PARC-2	Fe (670)	
Base Wells				
N/A	01-A75781	GW-SUP-5	Fe (1290), Mn (400)	
N/A	01-A75782	GW-SUP-16	Fe (1680), Mn (390)	
00-A88122	01-A78541	OW-1	Al (4450), Fe (7380), Mn (456)	
00-A88117	01-A78608	OW-2	Al (16200), Sb (28), Ba (1030), Fe (53600), Pb (26.3), Mn	

ETL ID Number (2000)	ETL ID Number (2001)	Sample ID	> CCME Drinking Water Concentration detected in 2001 (ppb)	> CCME Drinking Water Concentration detected in 2000 (ppb)
			(3890)	
N/A	01-A78609	OW-3	Al (12400), Sb (31), Ba (1600), Fe (79000), Pb (115), Mn (7080)	
N/A	01-A78597	MW-101	Al (7310), Fe (15300), Pb (12.6), Mn (2400)	
N/A	01-A78596	MW-102	Al (2060), Fe (5900), Mn (399)	
N/A	01-A78554	MW-104	Al (2940), Sb (17), Fe (14200), Mn (772)	
N/A	01-A78604	MW-107-A	Al (11500), Sb (42), Ba (1540), Fe (32600), Pb (20.5), Mn (3180)	
N/A	01-A78605	MW-107-B	Al (770), Sb (22), Fe (4830), Mn (309)	
00-A88116	01-A78621	MW-108	Al (5050), Sb (20), Fe (12900), Mn (1190)	
N/A	01-A78628	MW-109	Al (420), Sb (18), Fe (2030), Mn (682)	
N/A	01-A78606	MW-110	Al (12000), Sb (20), Fe (27300), Pb (15.4), Mn (1330)	
N/A	01-A78607	MW-111	Al (20400), As (50.2), Sb (24), Ba (2600), Fe (163000), Pb (67.3), Mn (9870), Se (11)	
00-A88115	01-A78627	MW-112	Al (2270), Fe (10000), Mn (743)	
N/A	01-A78626	MW-113	Al (980), Fe (12600), Mn (1160)	
Springs				
00-A79822	01-A74113	GW-Spring-1	Fe (1900), Mn (249)	
00-A79823	01-A74114	GW-Spring-2	Fe (4310), Mn (295)	

ETL ID Number (2000)	ETL ID Number (2001)	Sample ID	> CCME Drinking Water Concentration detected in 2001 (ppb)	> CCME Drinking Water Concentration detected in 2000 (ppb)
00-A79824	01-A74115	GW-Spring-3	Fe (800), Mn (139)	
Duplicates/Quality Control				
00-A87905	N/A	GW-A-9		
00-A88119	N/A	GW-C-8		
00-A88121	N/A	GW-D-9		
00-A87906	N/A	GW-E-7		
00-A79829	N/A	GW-SP-5		
00-A79830	N/A	GW-SP-6		
00-A79831	N/A	RESERVOIR		Fe(5800), Pb (12), Mn (86)
N/A	01-A78599	GW-BLANK-1 (GW-BGR-3)	Al (720), Sb(29), Fe (1670), Mn (755)	
N/A	01-A78582	GW-BLANK-2 (GW-BGR-4)	Al (2310), Fe (6740), Mn (260)	
N/A	01-A78553	GW-BLANK-3 (GW-A-9)	Al (290), Fe (730), Mn (260)	
N/A	01-A78610	GW-BLANK-4 (GW-BGR-3)	Al (145000), As (31.6), Sb (20), Ba (4810), Cr (216), Fe (204000), Pb (113), Mn (11300)	
N/A	01-A78573	GW-BLANK-5 (GW-B-1)	Al (130), Fe (1290), Mn (307)	
N/A	01-A78580	GW-BLANK-6 (GW-	Al (11800), Fe (36300), Pb (23.3), Mn (1340)	

ETL ID Number (2000)	***ETL ID Number (2001)***	***Sample ID***	***> CCME Drinking Water Concentration detected in 2001 (ppb)***	***> CCME Drinking Water Concentration detected in 2000 (ppb)***
		A-2)		
N/A	01-A78578	GW-BLANK-7 (GW-D-3)	Al (7500), As (33.4), Sb (18), Fe (30300) Pb (14.5), Mn (3130)	
N/A	01-A78611	GW-BLANK-8 (GW-B-3)	Al (1370), Sb (33), Fe (8070), Mn (555)	
N/A	01-A78612	GW-BLANK-9 (OW-2)	Al (11900), Ba (1040), Fe (53400), Pb (115), Mn (4210)	
N/A	01-A78598	GW-BLANK-10 (OW-1)	Al (3800), Sb (19), Fe (8620), Mn (557)	
N/A	01-A78613	GW-BLANK-11		
N/A	01-A77018	GW-D-9 (Dup)	Al (1320), Sb (9), Fe (4360), Mn (359)	
N/A	01-A77772	GW-ZONE-7W (Dup)	Fe (400), Mn (174)	
N/A	01-A78055	GW-RIF-3 (Dup)	Al (280), Sb (29), Fe (1020)	
N/A	01-A77821	GW-RIN-1	Al (270), Sb (21), Fe (19200), Mn (726)	
N/A	01-A75780	GW-DRILLER-1		
N/A	01-A78539	GW-FIELD-1		
N/A	01-A78540	GW-ROAD-1		

dup : duplicate

TABLE VII: VOLATILE ORGANIC COMPOUNDS (VOCS) DETECTED IN GROUND WATER SAMPLES

ETL ID number	***Sample ID***	***Elements and Concentrations (ppb) October 2000***	***Elements and Concentrations (ppb) September 2001***	***Elements and Concentrations (ppb) November 2001***
2000 INRS Wells				
00-A88114	GW-A-1		N/A (2)	N/A
00-A83315	GW-C-1		N/A	N/A
00-A88113	GW-E-1		N/A	N/A
2001 INRS Wells				
01-A78619	OBS-SUP-5	N/A	M + P XYLENES (7), METHYLENE CHLORIDE (7)	N/A
01-A78625	OBS-SUP-16	N/A	ACETONE (1) (2 200 000), TOLUENE (28)	METHYLENE CHLORIDE (1)
01-A78620	OBS-SUP-27	N/A	ACETONE (85000), METHYLENE CHLORIDE (12)	N/A
Base Wells				
01-A78541	OW-1	N/A	ACETONE (25000)	N/A
01-A78608	OW-2	N/A	ACETONE (1000)	N/A
01-A78621	MW-108	N/A	ACETONE (1000), METHYLENE CHLORIDE (8)	N/A
Duplicates				
01-A78613	GW-BLANK-11 (3)	N/A	ACETONE (100), METHYLENE CHLORIDE (2)	N/A

(1) There is no CCME criterion for acetone in drinking water. Criteria for the other chemicals are methylene chloride (50 ppb), m + p xylenes (300 ppb) and toluene (24ppb). Only one sample was found slightly exceeding one of CCME *Guidelines for Drinking Water Quality*, toluene in OBS-SUP-27

(2) Not Applicable

(3) Duplicate of OW-2

TABLE VIII: THORIUM CONCENTRATIONS MEASURED IN GROUND WATER

Well ID	***Thorium (ppb)*** **2000**	***Thorium (ppb)*** **2001**	***Thorium (Bq/L E-4)*** **2000**	***Thorium (Bq/L E-4)*** **2001**	***Comments***
2001 INRS Wells					
GW-ANTENNE	N/A	0,03	N/A	1,22	
GW-AMA-1	N/A	0,03	N/A		
GW-AMA-2	N/A	0,03	N/A	1,22	
GW-ATR-1	N/A	0,11	N/A	4,49	
GW-A-9	N/A	0,01	N/A	0,41	
GW-A-10	N/A	0,03	N/A	1,22	
GW-BGR-3	N/A	0,04	N/A	1,63	
GW-BGR-4	N/A	0,25	N/A	10,20	
GW-C-8	N/A	< 0,01	N/A	< 0,41	
GW-C-9	N/A	0,18	N/A	7,35	
GW-D-9	N/A	0,20	N/A	8,16	
GW-D-11	N/A	0,30	N/A	12,25	
GW-D-12	N/A	0,24	N/A	9,80	
GW-D-13	N/A	0,26	N/A	10,61	
GW-E-7	N/A	0,07	N/A	2,86	
GW-E-8	N/A	0,10	N/A	4,08	
GW-E-9	N/A	0,03	N/A	1,22	
GW-E-11	N/A	0,04	N/A	1,63	
GW-GATE-S	N/A	0,03	N/A	1,22	
GW-GRE-1	N/A	0,10	N/A	4,08	
GW-GRE-2	N/A	0,07	N/A	2,86	
GW-RIF-1	N/A	0,03	N/A	1,22	
GW-RIF-3	N/A	0,03	N/A	1,22	
GW-TR	N/A	0,14	N/A	5,71	

Well ID	Thorium (ppb) 2000	Thorium (ppb) 2001	Thorium (Bq/L E-4) 2000	Thorium (Bq/L E-4) 2001	Comments
GW-OBS-SUP-5	N/A	0,06	N/A	2,45	
GW-OBS-SUP-16	N/A	0,05	N/A	2,04	
GW-OBS-SUP-27	N/A	0,03	N/A	1,22	
GW-ZONE-4E	N/A	0,11	N/A	4,49	
GW-ZONE-4W	N/A	0,07	N/A	2,86	
GW-ZONE-5N	N/A	0,49	N/A	20,00	
GW-ZONE-5S	N/A	0,15	N/A	6,12	
GW-ZONE-7	N/A	0,27	N/A	11,02	
GW-ZONE-7W	N/A	0,01	N/A	0,41	
GW-ZONE-9N	N/A	0,09	N/A	3,67	
GW-ZONE-9S	N/A	0,08	N/A	3,27	
GW-ZONE-9W	N/A	< 0,01	N/A	< 0,41	
2000 INRS Well					
GW-ATR	N/A	0,31	N/A	12,65	
GW-GRE	N/A	0,03	N/A	1,22	
GW-MARSH-1	N/A	0,15	N/A	6,12	
GW-BGR	N/A	< 0,01	N/A	< 0,41	
GW-RIF	N/A	0,16	N/A	6,53	
GW-A-1	N/A	0,33	N/A	13,47	
GW-A-2	N/A	0,40	N/A	16,33	
GW-A-3	N/A	0,46	N/A	18,78	
GW-A-4	N/A	0,43	N/A	17,55	
GW-A-5	N/A	N/A	N/A	N/A	
GW-A-6	N/A	N/A	N/A	N/A	
GW-A-8	N/A	N/A	N/A	N/A	
GW-B-1	N/A	< 0,01	N/A	< 0,41	
GW-B-2	N/A	0,01	N/A	0,41	

Well ID	***Thorium (ppb)*** **2000**	***Thorium (ppb)*** **2001**	***Thorium (Bq/L E-4)*** **2000**	***Thorium (Bq/L E-4)*** **2001**	***Comments***
GW-B-3	N/A	0,08	N/A	3,27	
GW-B-4	N/A	0,16	N/A	6,53	
GW-B-5	N/A	0,08	N/A	3,27	
2000 INRS Wells					
GW-B-7	N/A	0,07	N/A	2,86	
GW-C-1	N/A	0,15	N/A	6,12	
GW-C-2	0,907	0,10	37,02	4,08	
GW-C-3	N/A	0,18	N/A	7,35	
GW-C-4	N/A	0,10	N/A	4,08	
GW-C-5	0,062	0,07	2,53	2,86	
GW-C-6	0,093	0,11	3,80	4,49	
GW-C-7	N/A	0,38	N/A	15,51	
GW-D1-A	N/A	N/A	N/A	N/A	
GW-D1-B	N/A	N/A	N/A	N/A	
GW-D-2	0,010	N/A	0,41		
GW-D-3	1,145	0,31	46,74	12,65	
GW-D-4	N/A	0,01	N/A	0,41	
GW-D-5	0,041	N/A	1,67	0,00	
GW-D-6	N/A	0,10	N/A	4,08	
GW-D-7	N/A	0,10	N/A	4,08	
GW-D-8	N/A	2,35	N/A	95,93	
GW-E-1	N/A	0,08	N/A	3,27	
GW-E-2	0,021	0,13	0,86	5,31	
GW-E-3	0,033	0,02	1,35	0,82	
GW-E-4	0,082	0,04	3,35	1,63	
GW-E-5	N/A	0,27	N/A	11,02	
GW-E-6	0,217	0,23	8,86	9,39	

Well ID	**Thorium (ppb)**	**Thorium (ppb)**	**Thorium (Bq/L E-4)**	**Thorium (Bq/L E-4)**	**Comments**
	2000	**2001**	**2000**	**2001**	
GW-E-7	0,054	N/A	2,20	N/A	
Private Wells					
GW-PHILIPS		< 0,01		< 0,41	
GW-PARC-1	N/A	< 0,01	N/A	< 0,41	
GW-PARC-2	N/A	< 0,01	N/A	< 0,41	
Base Wells					
GW-SUP-5		< 0,01		< 0,41	
GW-SUP-16	N/A	< 0,01	N/A	< 0,41	
GW-SUP-27	N/A	N/A	N/A	N/A	
OW-1	N/A	0,37	N/A	15,10	
OW-2	N/A	0,54	N/A	22,04	
OW-3	N/A	0,82	N/A	33,47	
MW-101	N/A	0,28	N/A	11,43	
MW-102	N/A	0,03	N/A	1,22	
MW-104	N/A	0,25	N/A	10,20	
MW-107-A	N/A	0,07	N/A	2,86	
MW-107-B	N/A	0,05	N/A	2,04	
MW-108	N/A	0,12	N/A	4,90	
MW-109	N/A	0,04	N/A	1,63	
MW-110	N/A	< 0,01	N/A	< 0,41	
MW-111	N/A	< 0,01	N/A	< 0,41	
MW-112	N/A	0,10	N/A	4,08	
MW-113	N/A	0,17	N/A	6,94	
Springs					
GW-SPRING-1	< 0,005	< 0,01	< 0,20	< 0,41	
GW-SPRING-2	< 0,005	< 0,01	< 0,20	< 0,41	
GW-SPRING-3	< 0,005	< 0,01	< 0,20	< 0,41	

Well ID	***Thorium (ppb)*** **2000**	***Thorium (ppb)*** **2001**	***Thorium (Bq/L E-4)*** **2000**	***Thorium (Bq/L E-4)*** **2001**	***Comments***
Duplicates					
GW-BLANK-1	N/A	0,04	N/A	1,63	Duplicate of GW-BGR-3 (2001)
GW-BLANK-2	N/A	0,28	N/A	11,43	Duplicate of GW-BGR-4 (2001)
GW-BLANK-3	N/A	0,01	N/A	0,41	Duplicate of GW-A-9 (2001)
GW-BLANK-4	N/A	0,22	N/A	8,98	Duplicate of GW-BGR-3 (2001)
GW-BLANK-5	N/A	< 0,01	N/A	< 0,41	Duplicate of GW-B-1 (2001)
GW-BLANK-6	N/A	0,37	N/A	15,10	Duplicate of GW-A-2 (2001)
GW-BLANK-7	N/A	0,12	N/A	4,90	Duplicate of GW-D-3 (2001)
GW-BLANK-8	N/A	0,06	N/A	2,45	Duplicate of GW-B-3 (2001)
GW-BLANK-9	N/A	0,36	N/A	14,70	Duplicate of OW-2 (2001)
GW-BLANK-10	N/A	0,33	N/A	13,47	Duplicate of OW-1 (2001)
GW-D-9 (Dup)	N/A	0,25	N/A	10,20	Duplicate of GW-D-9 (2001)
GW-ZONE-7W (Dup)	N/A	0,01	N/A	0,41	Duplicate of GW-ZONE-7W (2001)
GW-RIF-3 (Dup)	N/A	< 0,01	N/A	< 0,41	Duplicate of GW-RIF-3 (2001)
GW-RIN-1	N/A	0,06	N/A	2,45	Driller's final rinse water (2001)
GW-DRILLER-1	N/A	< 0,01	N/A	< 0,41	Brandon municipal water (2001)
GW-FIELD-1	N/A	< 0,01	N/A	< 0,41	Distilled water; bottle opened during field sampling (2001)
GW-ROAD-1	N/A	< 0,01	N/A	< 0,41	Distilled water; bottle opened during transportation (2001)

TABLE IX: METALS CONCENTRATIONS DETECTED OVER CCME GUIDELINES IN SURFACE WATER

Sample ID	***Concentration detected > Drinking Water guidelines in 2001 (ppb)***	***Concentration detected > Aquatic Life Guidelines in 2001 (ppb)***	***Concentration detected > Drinking Water guidelines in 2000 (ppb)***	***Concentration detected > Aquatic Life Guidelines in 2000 (ppb)***
SW-Adams-Spring	Fe (700) Mn (377)	Cu (7) Fe (700)		
SW-DO-2	Fe (1220) Mn (224)	As (5.7), Cu (8) Fe (1220)		
SW-DO-3	Al (340), Fe (6660) Mn (1340)	Al (340), As (13.3) Cu (25), Fe (6660)		
SW-DO-4	Al (1450), Fe (4450) Mn (253)	Al (1450), Cu (8) Fe (4450),		
SW-DO-5	Al (130), As (32) Fe (6100), Mn (1290)	Al (130), As (32), Cu (8), Fe (6100)		
SW-HLake	Mn (53,8)	Cu (11)	Al(290), Fe(690), Mn(143)	Al (290), Fe (690)
SW-MLake		Cu (8)	Al (230), Fe (690), Mn(90)	Al (230), Fe (690)
SW-SA-1	Al (190), Fe (580) Mn (52,1)	Al (190), As (7.2) Cu (10), Fe (580)		
SW-SA-2	Al (310), Sb (13) Fe (770), Mn (56,2)	Al (310), As (6.8) Cu (7), Fe (770)		
SW-SA-2A	Al (1110), Fe (1460), Mn (169)	Al (1110), As (7.5) Cu (12), Fe (1460)		
SW-SA-2C	Al (1340), Fe (1630), Mn (153)	Al (1340), As (6.6) Cu (16), Fe (1630)		
S-A-3				Cu (12)
SW-SA3-AMONT	Al (650), Fe (970) Mn (99,2)	Al (650), As (7.1) Cu (8), Fe (970)		
SW-SA-3-AVAL	Al (780), Fe (1090), Mn (152)	Al (780), As (6.4) Cu (14), Fe (1090)		
SW-SE-1	Fe (330)	As (7.3), Cu (13) Fe (330)		
SW-SE-2	Fe (4040), Mn (1700)	As (24.6), Cu (11) Fe (4040),		
SW-SE-3	Ba (1010), Fe (2490), Mn (241)	As (12.5), Cu (16) Fe (2490)	Mn (64.8)	Cu (13.6), Mn (64.8)
SW-SS-1	Al (1810), Fe (2050), Mn (258)	Al (1810), As (7.5) Cu (9), Fe (2050) Zn (40)		
SW-SWA1S-SPRING	Fe (580), Mn (95)	As (6.6), Cu (14) Fe (580), Zn (60)		
SW-Zone6	Fe (770), Mn (99,2)	Cu (11), Fe (770)	Al (230), Fe (690), Mn(90.2)	Al (230), Fe (690)
SW-SP-4 (1)			Al (240), Fe(720), Mn(91)	Al (24), Fe(720)
SW-Horsel (2)				Se (2)

(1) Duplicate of SW-ZONE6-LAKE

(2) Duplicate of Hlake

TABLE X: THORIUM CONCENTRATIONS MEASURED IN SURFACE WATER

Sample ID	*Thorium (ppb)* 2000	*Thorium (ppb)* 2001	*Thorium (Bq/L E^{4})* 2000	*Thorium (Bq/L E^{4})* 2001
SW-ANTEN-SPRING	N/A	< 0,01	N/A	< 0,41
SW-ADAMS-SPRING	N/A	< 0,01	N/A	< 0,41
SW-DO-2	N/A	0,01	N/A	0,41
SW-DO-3	N/A	0,03	N/A	1,22
SW-DO-4	N/A	0,04	N/A	1,63
SW-DO-5	N/A	0,01	N/A	0,41
SW-HLAKE	0,018	< 0,01	0,73	< 0,41
SW-HORSEL	N/A	< 0,01	N/A	< 0,41
SW-MLAKE	0,014	< 0,01	0,57	< 0,41
SW-SA-1	N/A	0,02	N/A	0,82
SW-SA-2	N/A	0,02	N/A	0,82
SW-SA-2A	N/A	0,05	N/A	2,04
SW-SA-2C	N/A	0,06	N/A	2,45
SW-SA-3	N/A		N/A	
SW-SA3-AMONT	N/A	0,04	N/A	1,63
SW-SA-3-AVAL	N/A	0,04	N/A	1,63
SW-SE-1	N/A	< 0,01	N/A	< 0,41
SW-SE-2	N/A	< 0,01	N/A	< 0,41
SW-SE-3	N/A	< 0,01	N/A	< 0,41
SPRING-1	N/A		N/A	
SW-SS-1	N/A	0,08	N/A	3,27
SW-SWAIS-SPRING	N/A	< 0,01	N/A	< 0,41
SW-ZONE6	0,006	< 0,01	0,24	< 0,41
SW-HORSEL	N/A	< 0,01	N/A	< 0,41

TABLE XIa : METALS CONCENTRATIONS IN SOILS (Al to Co)

Sample	**Al**	**As**	**Ba**	**Be**	**B**	**Bi**	**Cd**	**Ca**	**Cr**	**Co**
	ppm (mg/Kg)									
S-BG-69940E 18340N	4680	3.07	203	0.34	6.4	0.11	0.29	9990	8.1	7.7
S-BG-52660E 22764N	4620	4.01	273	0.31	23.6	0.11	0.54	30500	10.3	6.57
S-BG-80356E 06945N	6290	6.69	272	0.41	6	0.12	0.76	11200	9.2	8.46
S-BG-57997E 20636N	3630	6.17	102	0.24	3.6	0.05	0.21	34900	23.8	6.52
S-BG-65629E 17392N	4130	7.93	404	0.23	16.1	0.11	0.61	41800	11.1	5.41
S-BG-63783E 17228N	2400	3.17	54.3	0.18	1.1	0.04	0.09	2080	4.8	3.38
S-BG-78159E 99759N	1800	4.91	65.1	0.17	1.6	0.02	0.13	17200	7.4	2.92
S-BG-62630E 18054N	3550	3.81	92	0.24	1.9	0.05	0.18	3210	6.1	4.03
S-BG-79182E 00111N	2300	6.37	65.2	0.19	2.8	0.04	0.16	23100	5.9	3.47
S-BG-74864E 14968N	2430	2.76	62.1	0.19	1.1	0.04	0.14	2160	5.1	3.67
S-BG-49148E 13157N	6330	9.24	234	0.46	7.9	0.11	0.46	33500	21.5	9.25
S-BG-49148E 13157N (Dup)	6950	11.4	212	0.56	6.4	0.12	0.51	12700	20.4	12
S-BG-55265E 11847N	4020	4.4	133	0.26	4	0.05	0.26	8760	11.2	5.02
S-BG-74864E 14968N (Dup)	2130	2.51	54.8	0.18	0.9	0.03	0.1	1890	5.2	3.35
S-BG-55255E 09752N	4620	5.49	131	0.29	5.7	0.07	0.26	14600	12.9	6.19
S-BG-53656E 11283N	6560	7.13	170	0.42	6.6	0.1	0.33	20100	18.3	8.82
S-BG-80720E 05003N	2090	4.85	72.4	0.16	3	0.03	0.14	35800	6.2	3.33
S-BG-53670E 13403N	5250	6.64	146	0.34	4.5	0.15	0.31	12000	27.3	8.04
S-BG-67858E 90938N	4520	5.85	126	0.3	5.1	0.09	0.39	6320	8.3	6.05
S-BG-68067E 97960N	7660	8.79	207	0.48	9.1	0.17	0.7	11600	13.7	9.84
S-BG-69431E 98407N	6820	9.82	207	0.54	7.8	0.16	0.66	9330	11.1	9.36
S-BG-63565E 00626N	6750	9.39	209	0.45	6.5	0.19	0.75	8700	11.7	8.61
S-BG-62033E 01742N	8370	10.1	238	0.54	7.4	0.21	0.76	9520	14.4	10.5
Mean Value for background	4691	6.28	162.3	0.33	6.0	0.09	0.38	15694	11.9	6.63
Standard Deviation	1631	2.12	73.4	0.11	3.2	0.05	0.20	9682	5.0	2.29

Sample	Al	As	Ba	Be	B	Bi	Cd	Ca	Cr	Co
	ppm (mg/Kg)									
S-A-HS-60021E 12160N	3590	4.17	166	0.22	2.9	0.06	1.29	6440	20.3	5.58
S-A-HS-60042E 12060N	4820	4.34	118	0.27	4.3	0.07	0.66	19000	19.6	5.77
S-A-LS 20%-A	4060	4.5	132	0.24	3.6	0.09	0.54	7080	16.9	5.88
S-A-LS 20%-B	3440	4.46	86.2	0.22	2	0.05	0.38	4410	14.3	5.43
S-A-LS 40% A	4430	5.26	121	0.29	3.1	0.08	0.83	5860	17.3	6.65
S-A-LS 40% B	4370	4.96	116	0.26	2.5	0.07	0.56	5190	16	7.01
S-A-LS 40% B (Dup)	4290	4.97	130	0.29	2.6	0.07	0.44	9080	18.8	7.13
S-A-LS 60% A	4810	5.27	176	0.33	3.4	0.1	0.69	8570	16.5	6.76
S-A-LS 60% B	4440	4.49	161	0.25	3.1	0.1	0.56	6420	16.9	5.86
S-A-LS 80% A	3910	5.09	127	0.25	2.7	0.08	0.41	6890	15.4	6.55
S-A-LS 80% B	3590	4.87	139	0.26	3.1	0.09	0.91	6940	18.4	8.29
S-A-LS 80% A (Dup)	4580	4.71	141	0.26	2.8	0.09	0.45	5950	14.4	6.3
S-A-LS 100% A	3590	3.42	128	0.21	3.1	0.05	0.13	12300	16.6	4.34
S-A-LS 120% A	3190	3.68	89.4	0.17	1.6	0.05	0.27	5400	16.4	4.76
S-A-LS 120% B	3650	4.24	109	0.21	2.1	0.08	0.31	5190	18.6	5.05
S-A-1-0-1	2810	4.49	75.4	0.17	1.8	0.05	0.39	19700	18.5	5.62
S-A-1-1-3	3330	4.71	72.5	0.17	1.9	0.04	0.48	15900	18.6	6.64
S-A-1-3-5	4290	5.03	117	0.23	2.7	0.07	1.98	8020	18.8	12.1
S-A-2-0-1	2650	3.82	87.8	0.15	1.3	0.04	0.33	3750	15.7	4.94
S-A-2-1-3	2920	4.1	83.6	0.17	1.6	0.04	0.25	3520	17.4	4.89
S-A-2-3-5	3490	4.48	145	0.2	3.5	0.06	0.71	5790	20.1	6.05
S-GR-5M-A	4700	5.11	267	0.32	4.3	0.11	4.21	21900	28.2	7.17
S-GR-5M-B	5050	5.89	280	0.42	5.8	0.12	4.75	18600	29	8.1
S-GR-10M-A	4720	5.65	211	0.37	8.6	0.11	3	24200	33.6	7.68
S-GR-10M-B	5410	5.13	199	0.39	5.4	0.1	2.45	28600	29.1	6.81
S-GR-15M-A	5060	5.22	198	0.33	6	0.08	3.12	31900	30	6.67
S-GR-15M-B	5030	4.96	194	0.34	5.2	0.08	2.86	23900	28.4	6.18

Sample	**Al**	**As**	**Ba**	**Be**	**B**	**Bi**	**Cd**	**Ca**	**Cr**	**Co**
	ppm (mg/Kg)									
S-GR-15M-B (Dup)	5180	5.37	201	0.29	5.9	0.08	2.81	30600	29.9	6.5
S-GR-20M-A	4230	4.5	158	0.29	4.5	0.07	1.84	24000	26.8	5.68
S-GR-20M-B	5060	5.44	193	0.32	5.5	0.08	2.26	28900	34.1	6.79
S-GR-25M-A	5720	5.04	194	0.38	6.1	0.1	2.21	26100	33.2	7.11
S-GR-25M-B	5380	4.77	166	0.35	5.1	0.09	1.94	22300	28.5	6.68
S-GR-25M-B (Dup)	4640	4.46	153	0.33	4.5	0.08	1.76	18400	28.2	5.91
S-GR-30M-A	5220	5.25	193	0.41	5.8	0.09	2.32	18900	32.3	7.37
S-GR-30M-B	5050	5.05	223	0.39	5.1	0.08	2.89	18200	28	6.78
S-GR-35M-A	5330	5.65	217	0.38	5.7	0.1	2.6	17900	29.4	7.18
S-GR-35M-B	3940	4.98	225	0.28	4	0.08	3.24	13700	22.5	6.12
S-GR-HS-57538E 18001N	3840	4.85	122	0.27	2.7	0.05	1.08	6830	15.2	5.49
S-C-LS 20% A	4800	6.81	131	0.27	2.2	0.09	0.51	9130	13.9	6.78
S-C-LS 20% B	7450	8.24	186	0.4	5.2	0.15	0.66	14600	12.4	8.53
S-C-LS 40% A	7820	9.63	208	0.4	4.7	0.16	0.72	11000	13.4	10.1
S-C-LS 40% B	8120	9.31	216	0.44	5.9	0.18	0.76	13300	13.7	10.2
S-C-LS 40% A (Dup)	7610	9.19	210	0.42	4.8	0.18	0.75	12000	14.1	10.3
S-C-LS 60% A	6940	8.47	186	0.4	3.2	0.15	0.87	8980	11.1	9.2
S-C-LS 60% B	8290	9.61	230	0.44	6.3	0.21	0.83	13600	13.3	10.9
S-C-LS 80% A	5520	7.59	151	0.32	2.5	0.12	0.69	7340	13.5	7.68
S-C-LS 80% B	5830	8.53	175	0.36	4.2	0.14	0.85	13200	11.4	9.21
S-C-LS 80% B (Dup)	6440	9.16	193	0.4	4.7	0.16	0.92	14500	12.7	9.85
S-C-LS 100% A	3860	5.09	102	0.21	0.6	0.08	0.45	5910	6.6	4.65
S-C-LS 100% B	7500	9.51	222	0.45	5	0.17	0.79	12300	13.9	12.2
S-C-LS 120% A	4640	4.63	129	0.26	1.4	0.11	0.41	6890	8.2	6.16
S-C-LS 120% B	5200	5.31	178	0.32	2.5	0.14	1.33	8140	9.2	6.67
S-C-1-0-1	5550	12.3	160	0.36	4.1	0.11	1.01	35900	17.2	11.8
S-C-1-1-3	5400	14.8	158	0.39	5.4	0.12	0.5	38900	16.1	12.5

Sample	**Al**	**As**	**Ba**	**Be**	**B**	**Bi**	**Cd**	**Ca**	**Cr**	**Co**
	ppm (mg/Kg)									
S-C-1-3-5	6560	13.3	203	0.57	8.4	0.16	0.64	23000	14.6	13.3
S-C-2-0-1	3100	4.65	71.1	0.23	0.6	0.05	0.29	3250	7.2	4.08
S-C-2-1-3	4820	5.3	139	0.32	1.8	0.08	0.45	5630	8.5	5.66
S-C-2-3-5	5960	5.59	168	0.34	2.5	0.13	1.07	6000	10.4	6.34
S-C-3-0-1	5400	9.97	203	0.39	3.7	0.1	0.89	13600	18.6	8.94
S-C-3-1-3	5140	8.62	176	0.37	2.7	0.08	0.55	8800	13.2	7.36
S-C-3-3-5	5670	9.3	183	0.43	3.9	0.12	0.73	8010	12	8.65
S-C-HS 65235E 02908N	4590	6.37	179	0.41	3.3	0.14	0.97	6570	11.3	7.3
S-C-HS 65266E 02930N	6660	6.13	229	0.42	4.5	0.2	1.45	9240	12.7	7.84
S-C-HS 66040E 02939N	4320	6.77	171	0.37	3	0.16	5.86	6940	12.9	7.27
S-C-HS 66017E 02566N	5100	14.5	251	0.57	11.9	0.2	1.29	29500	18.2	15.9
S-C-HS 65011E 02663N	13100	9.83	197	0.52	3.8	0.31	0.86	3360	16.8	9.45
S-C-HS 63025E 02811N	3260	6.58	82.4	0.2	0.6	0.05	0.24	11200	21.9	4.75
S-C-HS 68010 02265N	5470	4.94	175	0.38	4.1	0.17	0.95	9000	9.4	6.87
S-RIF1-1-3	1870	3.46	56.2	0.13	1.6	0.02	0.08	7960	12.6	3.92
S-RIF1-4-6	2040	3.97	61	0.15	1.7	0.23	0.09	9840	13.5	4.35
S-RIF1-7-9	2110	4.11	67.5	0.15	1.8	0.06	0.11	12300	14.8	4.9
S-RIF1-10-12	1860	3.87	58.6	0.14	1.6	0.16	0.1	9730	12.2	4.14
S-RIF1-10-12 (Dup)	1800	3.74	59.3	0.15	1.5	0.08	0.1	11700	12.7	4.22
S-RIF1-13-15	1920	3.82	63.5	0.15	1.5	0.13	0.11	9180	12.8	4.37
S-RIF1-16-18	1900	3.9	59.9	0.16	1.4	0.16	0.1	9120	12.2	4.26
S-RIF1-19-21	2000	3.78	60.8	0.13	3.1	0.11	0.1	7540	11	4.13
S-RIF1-19-21 (Dup)	1890	3.66	59.3	0.15	1.6	0.16	0.09	14200	11.9	4.09
S-RIF1-22-24	2090	4.04	67.9	0.16	1.5	0.22	0.1	9910	12.7	4.56
S-RIF1-T24	2010	3.93	67	0.15	1.4	0.06	0.09	11900	12.6	4.37
S-RIF1-T16	2530	4.4	80.2	0.2	1.8	0.08	0.14	7960	12.7	5.36
S-RIF1-T12	3700	6.47	92.3	0.31	2.6	0.43	0.17	16700	11.5	6.14

Sample	**Al**	**As**	**Ba**	**Be**	**B**	**Bi**	**Cd**	**Ca**	**Cr**	**Co**
	ppm (mg/Kg)									
S-RIF1-T6	2110	4.37	77	0.17	1.6	0.13	0.12	12400	13.3	4.7
S-RIF2-25-27	2370	13.9	67.2	0.23	2.3	3.27	0.26	7340	13.3	5.3
S-RIF2-28-30	2300	15.3	63.3	0.19	1.8	3.66	0.22	5000	10.2	5.18
S-RIF2-31-33	2700	14.5	74.2	0.24	2.2	2.95	0.23	6380	10.1	5.82
S-RIF2-34-36	3610	17.1	94.3	0.26	2.2	4.16	0.3	6780	13.9	6.44
S-RIF2-37-39	3580	13.9	98.7	0.29	2.6	2.89	0.28	7080	11.9	6.71
S-RIF2-37-39 (Dup)	3590	12.9	95.5	0.28	2.4	2.54	0.27	6990	11.8	6.47
S-RIF2-40-42	5230	8.29	129	0.36	3.1	0.85	0.34	6340	14.3	7.85
S-RIF2-43-45	5300	7.28	144	0.4	2.8	0.38	0.35	6280	14.4	8.48
S-RIF2-46-48	4260	6.62	96.3	0.31	2.4	0.67	0.2	9610	17.4	7.01
S-RIF2-46-48 (Dup)	4850	6.02	129	0.32	2.4	0.19	0.32	5690	11.7	7.64
S-RIF2-T28	2850	5.98	93.9	0.28	1	0.48	0.18	15300	9.2	6.33
S-RIF2-T34	2130	5.65	70.5	0.21	0.6	0.17	0.15	5900	10.1	6.63
S-RIF2-T40	2980	5.89	81.3	0.25	0.6	0.07	0.16	7060	8.6	6.61
S-RIF2-T46	7740	7.67	141	0.6	7.2	0.32	0.49	12900	15.8	9.2
S-RIF4-1-3	2460	10.7	73.1	0.17	0.8	2.74	0.23	5240	8.5	5.09
S-RIF4-4-6	2670	11.4	87	0.22	1.1	2.71	0.48	5520	8.8	5.44
S-RIF4-7-9	2450	11.4	80.5	0.22	0.8	2.92	0.29	5900	8.2	5.24
S-RIF4-10-12	2600	9.43	81.8	0.26	1	2.18	0.23	5680	8.8	5.28
S-RIF4-T4	2620	6.24	83.1	0.22	0.6	0.82	0.19	8980	9.8	6.87
S-RIF4-T9	2770	7.43	91.5	0.27	0.7	0.97	0.2	8300	14.1	7.67
S-KE-0-3	5080	5.63	101	0.35	2.8	0.51	0.24	8780	15.7	6.37
S-KE-BU-1	2440	4.16	71.7	0.19	1.2	0.11	0.16	8620	11.8	4.3
S-KE-BU-2	2260	3.81	92.5	0.15	0.6	0.04	0.13	5630	12.3	3.92
S-KE-BU-3	2130	3.8	68.9	0.17	0.6	0.04	0.11	8640	12.4	3.85
S-KE-BU-4	2080	3.44	65.7	0.16	0.6	0.05	0.13	6650	10.2	3.54
S-D-HS-74210E 01267N	5770	5.85	188	0.36	4.7	0.17	0.75	14000	13	9.76

Sample	Al	As	Ba	Be	B	Bi	Cd	Ca	Cr	Co
	ppm (mg/Kg)									
S-D-HS-74326E 01195N	3620	5.19	113	0.23	3.4	0.07	0.36	11300	10.1	8.2
S-D-HS-74215E 01278N	4530	6.33	135	0.31	3.3	0.12	0.5	11100	15.2	**11.6**
S-D-1-0-1	2630	5.98	274	0.17	0.7	0.1	0.19	11500	15.2	**140**
S-D-1-1-3	2220	5.84	117	0.15	0.6	0.08	0.18	10600	12.3	**72.8**
S-D-1-3-5	2400	5.84	92.1	0.19	1.1	0.08	0.27	13100	16.3	**62.5**
S-D-2-0-1	2370	7.06	102	0.17	0.6	0.07	0.19	14500	18.3	**112**
S-D-2-1-3	3060	7.1	104	0.2	1.7	0.09	0.28	14900	18.9	**47.8**
S-D-2-3-5	2730	5.56	101	0.19	1.5	0.06	0.22	15900	11.9	23.3
S-E-HS-63240E 15109N	2640	4	123	0.14	0.8	0.08	0.13	5560	10.7	6.34
S-E-HS-63240E 15109N	4020	3.85	125	0.28	2	0.08	0.31	5220	7.2	8.37
S-E-1-0-1	2960	4.25	91.5	0.2	0.6	0.11	0.14	3880	7.8	6.14
S-E-1-1-3	2540	3.21	56.6	0.17	0.8	0.04	0.11	2690	8.7	4.39
S-E-1-3-5	2850	4.4	114	0.19	0.8	0.1	0.19	4060	8.2	9.73
S-E-2-0-1	2790	4.38	69.7	0.15	0.6	0.1	0.14	6800	8.7	8.19
S-E-2-1-3	2630	4.56	61.4	0.19	0.6	0.1	0.14	6380	8.4	7.31
S-E-2-3-5	2760	4.04	63.6	0.16	0.6	0.05	0.12	3220	7.9	**12.8**
S-ASA-HS-51508E 15705N	6770	**14**	250	0.44	4.9	0.13	**27**	12800	**26.6**	**10.7**
S-ASA-HS-51501E 15688N	6470	9.43	190	0.38	4.4	0.1	8.72	18000	**24.7**	**11.3**
S-ASA-HS-51488E 15697N	5960	12	213	0.44	6	0.11	4.49	18300	**26.2**	**12.4**
S-ASA-I-5	6930	10.1	215	0.45	6.5	0.13	1.01	24600	**26.8**	**12.5**
S-ASA-I-10	9140	**12.4**	253	0.6	7.5	0.16	0.9	14000	**28.2**	**14.9**
S-ASA-I-15	7280	10.2	190	0.48	5.2	0.12	0.73	18000	**26.4**	**12.6**
S-ASA-I-20	10100	**13.1**	271	0.69	7.1	0.17	0.81	15600	**32.1**	**17.1**
S-ASA-I-25	8470	11.2	232	0.54	5.9	0.14	0.68	19400	**29.3**	**14.6**
S-ASA-I-30	7640	9.71	235	0.54	6	0.15	0.74	15900	**23.4**	**13.1**

Values in red: Results over the mean value added to twice the standard deviation are highlighted in red bold fonts
Values in blue: Results over the CCME threshold value for agricultural soils are highlighted in blue bold fonts

TABLE XIb: METALS CONCENTRATIONS IN SOILS (Cu to Ag)

Sample	*Cu*	*Fe*	*Pb*	*Mg*	*Mn*	*Mo*	*Ni*	*K*	*Se*	*Ag*
	ppm (mg/Kg)									
S-BG-69940E 18340N	11,1	10200	12,2	2490	1070	0,58	13,2	1110	0,7	1
S-BG-52660E 22764N	25,2	13000	18,4	5450	2090	1,16	17,6	1740	1,1	1
S-BG-80356E 06945N	16,8	13800	10,5	2750	1450	0,92	15,3	980	0,9	1
S-BG-57997E 20636N	44,7	25500	48,4	9990	1230	3,53	34	665	0,2	1
S-BG-65629E 17392N	146	13100	132	4320	3180	1,85	18,2	1230	0,6	1
S-BG-63783E 17228N	4,1	7680	4,38	1150	312	0,34	7,3	527	0,1	1
S-BG-78159E 99759N	10,5	10700	3,68	1540	352	0,97	9,9	295	0,1	1
S-BG-62630E 18054N	5,3	8870	6,28	1340	384	0,39	8	643	0,2	1
S-BG-79182E 00111N	5,9	9910	3,75	5810	435	0,53	8,2	428	0,2	1
S-BG-74864E 14968N	4,6	7700	6,67	1090	360	0,42	6,1	609	0,2	1
S-BG-49148E 13157N	131	21800	44,5	10100	1070	2,43	30,4	1510	0,5	1
S-BG-49148E 13157N (Dup)	37,3	24800	13	4380	1590	2,23	35,7	1710	0,7	1
S-BG-55265E 11847N	17,9	13800	7,62	2870	780	1,33	14,5	889	0,3	1
S-BG-74864E 14968N (Dup)	5,3	7400	5,06	947	305	0,4	6,3	488	0,1	1
S-BG-55255E 09752N	22,7	17000	9,81	5680	1050	1,52	20	824	0,4	1
S-BG-53656E 11283N	32,2	24100	11,7	8380	1570	2,09	28,1	1210	0,4	1
S-BG-80720E 05003N	7,1	10500	3,93	6830	368	0,65	9,1	307	0,2	1
S-BG-53670E 13403N	55	30000	12,2	4880	1210	3,92	38,8	941	0,4	1
S-BG-67858E 90938N	12	12000	10,3	2380	943	0,85	13,7	1140	0,4	1
S-BG-68067E 97960N	22,6	19200	21,1	4200	1720	1,35	24,1	1830	0,8	1
S-BG-69431E 98407N	16	17500	15,4	3450	1430	0,98	22,8	1640	0,7	1
S-BG-63565E 00626N	19,1	17000	15,8	2850	1500	1,27	20,7	1490	0,7	1
S-BG-62033E 01742N	23	19700	18,4	3350	1600	1,47	24,7	1660	0,8	1
Mean Value	29,4	15446	18,9	4184	1130	1,36	18,6	1038	0,5	1

Sample	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**K**	**Se**	**Ag**
	ppm (mg/Kg)									
Standard Deviation	23,5	5403	14,8	2087	534	0,71	8,2	422	0,2	0
S-A-HS-60021E 12160N	52,4	18500	49,3	1720	503	2,72	26,2	641	0,2	1
S-A-HS-60042E 12060N	55,5	19200	34,3	6880	644	2,39	54,4	987	0,3	1
S-A-LS 20%-A	48,4	16500	27,1	1660	661	2,2	24,8	834	0,4	1
S-A-LS 20%-B	32,7	15800	7,92	1420	527	1,89	20,9	546	0,2	1
S-A-LS 40% A	41	17200	11,9	1680	664	2,03	23,6	824	0,4	1
S-A-LS 40% B	41,1	17500	8,84	1700	678	1,91	22,3	719	0,4	1
S-A-LS 40% B (Dup)	48,2	19000	12,9	2120	636	2,43	26,1	704	0,3	1
S-A-LS 60% A	87,7	16300	13,6	2510	738	1,96	394	1120	0,4	1
S-A-LS 60% B	40,5	17200	12,3	1770	754	2,14	25,4	1050	0,3	1
S-A-LS 80% A	33,3	15300	10,3	2010	590	1,89	22,2	925	0,3	1
S-A-LS 80% B	41,2	14700	10,9	1780	493	2,26	26,2	933	0,4	1
S-A-LS 80% A (Dup)	37,3	15700	10,3	1700	699	1,61	20,5	948	0,3	1
S-A-LS 100% A	38,6	15100	17,5	2080	368	2,19	22,3	578	0,5	1
S-A-LS 120% A	42,9	16700	8,68	1580	498	2,2	57,2	656	0,2	1
S-A-LS 120% B	44,7	18200	9,42	1500	546	2,58	31,5	668	0,3	1
S-A-1-0-1	46,6	20100	9,49	2640	481	2,57	26,5	484	0,1	1
S-A-1-1-3	45,6	19400	6,85	2490	472	2,51	25,6	462	0,2	1
S-A-1-3-5	47,3	19200	9,55	1910	647	2,32	29,9	689	0,3	1
S-A-2-0-1	80,8	15500	10,7	1240	444	2,16	23,1	511	0,2	1
S-A-2-1-3	55,7	18400	9,66	1230	459	2,41	24,4	545	0,2	1
S-A-2-3-5	51,5	17400	15,7	1480	570	2,8	28,8	932	0,3	1
S-GR-5M-A	779	18700	404	10700	850	1,46	50,4	1270	0,3	1
S-GR-5M-B	318	17300	261	10800	741	1,37	48,1	1820	0,3	1
S-GR-10M-A	295	20400	191	11900	911	1,98	58,6	1650	0,3	1
S-GR-10M-B	182	20100	133	11700	937	1,17	52,6	1500	0,2	1
S-GR-15M-A	161	21300	114	11800	1140	1,2	53,1	1280	0,2	1

Sample	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**K**	**Se**	**Ag**
	ppm (mg/Kg)									
S-GR-15M-B	199	20200	84	9100	978	0,98	50,5	1220	0,2	1
S-GR-15M-B (Dup)	154	22100	83,3	11100	1060	1,12	51,9	1250	0,1	1
S-GR-20M-A	120	17000	68,3	9310	907	1	48,2	1060	0,1	1
S-GR-20M-B	167	20900	80,5	11600	917	1,25	59,4	1260	0,2	1
S-GR-25M-A	174	20900	78,3	10800	907	1,14	59,3	1580	0,2	1
S-GR-25M-B	194	18900	75,6	9280	750	0,99	49,2	1410	0,2	1
S-GR-25M-B (Dup)	176	18500	60,5	7740	701	1,15	48,1	1210	0,2	1
S-GR-30M-A	156	18300	106	8780	769	1,1	54,9	1600	0,2	1
S-GR-30M-B	153	17500	71,8	7810	778	0,86	49,9	1340	0,3	1
S-GR-35M-A	93,6	19300	72,8	7640	756	1,19	49,2	1670	0,2	1
S-GR-35M-B	93,3	19100	58,3	5590	602	1,34	39,1	932	0,1	1
S-GR-HS-57538E 18001N	105	15200	24,6	3160	604	1,02	24,5	729	0,1	1
S-C-LS 20% A	21,2	17500	9,65	2510	922	1,71	20,7	869	0,3	1
S-C-LS 20% B	16,5	17500	15,5	4630	1280	1,2	19,1	1510	0,6	1
S-C-LS 40% A	27	19700	18,1	3890	1470	1,35	21,8	1530	0,6	1
S-C-LS 40% B	19,3	18600	18,7	4280	1450	1,23	21,3	1760	0,7	1
S-C-LS 40% A (Dup)	22,6	18900	18,9	4120	1430	1,39	23,2	1620	0,7	1
S-C-LS 60% A	14,5	16100	15,1	3010	1260	1,07	18,9	1300	0,6	1
S-C-LS 60% B	20,7	19400	19,1	4250	1650	1,28	22,7	1970	0,8	1
S-C-LS 80% A	20,5	18400	11,9	2430	1080	1,53	20,7	1080	0,5	1
S-C-LS 80% B	16,6	17400	13,8	4440	1340	1,15	19,6	1440	0,5	1
S-C-LS 80% B (Dup)	22,9	18500	16,6	4690	1430	1,29	21,1	1490	0,6	1
S-C-LS 100% A	5,1	10300	8,2	1540	709	0,62	9,5	716	0,3	1
S-C-LS 100% B	17,8	19500	15,5	4060	1780	1,26	23,9	1360	0,7	1
S-C-LS 120% A	8	11500	9,72	1860	968	0,63	12,3	866	0,4	1
S-C-LS 120% B	11,1	12500	14,2	1940	1060	0,75	13,2	1190	0,4	1
S-C-1-0-1	28,8	23600	13,2	12000	1240	2,22	34,1	1180	0,5	1

Sample	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Ag
	ppm (mg/Kg)									
S-C-1-1-3	26,4	22400	12,4	15100	1090	2,03	33,7	1100	0,5	1
S-C-1-3-5	41,1	20600	15,2	8540	1370	1,56	28,8	1550	0,7	1
S-C-2-0-1	5,4	10700	4,27	1380	479	0,69	9	451	0,2	1
S-C-2-1-3	7,3	12100	7,85	1680	827	0,81	10,6	880	0,4	1
S-C-2-3-5	10,9	13200	15,2	2030	897	0,87	12,1	1350	0,4	1
S-C-3-0-1	29,7	19500	13,3	4880	940	2,23	27,9	1050	0,5	1
S-C-3-1-3	19,7	16500	8,8	3250	817	1,44	19,5	888	0,5	1
S-C-3-3-5	13,5	14900	11,4	2780	1040	1,19	18,6	1170	0,6	1
S-C-HS 65235E 02908N	10,8	14500	16,8	2260	698	0,97	13,4	1540	0,5	1
S-C-HS 65266E 02930N	18,8	14200	22,8	2610	1090	1,25	15,8	1780	0,6	1
S-C-HS 66040E 02939N	21,3	11700	24	2420	747	1,33	17,4	1450	0,4	1
S-C-HS 66017E 02566N	31,2	17100	20,1	17100	1160	2,14	36,4	2320	0,8	1
S-C-HS 65011E 02663N	26,5	17500	181	3030	974	1,37	19,3	1740	0,7	1
S-C-HS 63025E 02811N	16,6	14700	16,5	2130	518	1,71	16,8	433	0,2	1
S-C-HS 68010 02265N	12,2	11800	17,8	2360	1050	0,74	13	1710	0,6	1
S-RIF1-1-3	30,2	13400	32,4	1340	286	1,67	19,2	366	0,1	1
S-RIF1-4-6	99	14500	1830	1840	322	1,86	23,8	393	0,1	1
S-RIF1-7-9	116	16800	288	2250	382	2,05	23,7	403	0,1	1
S-RIF1-10-12	184	13500	1920	1860	321	1,65	20,6	357	0,1	1
S-RIF1-10-12 (Dup)	94,2	13500	738	2090	349	1,74	19,8	344	0,1	1
S-RIF1-13-15	123	13700	1250	1720	333	1,75	20,3	360	0,1	1
S-RIF1-16-18	192	13400	1740	1670	323	1,66	18,7	352	0,1	1
S-RIF1-19-21	626	12400	954	1510	310	1,48	16,6	380	0,2	1
S-RIF1-19-21 (Dup)	256	13000	1700	5200	323	1,63	17,6	364	0,1	1
S-RIF1-22-24	127	14100	2940	2130	353	1,74	19,3	405	0,2	1
S-RIF1-T24	48,4	14000	1130	2010	377	1,77	19,5	377	0,1	1
S-RIF1-T16	69	14500	533	1870	407	1,68	24,9	542	0,1	1

Sample	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**K**	**Se**	**Ag**
	ppm (mg/Kg)									
S-RIF1-T12	472	13500	4610	4240	396	1,49	23,9	632	0,2	1
S-RIF1-T6	225	15900	1270	2420	417	1,84	21,8	402	0,1	1
S-RIF2-25-27	2730	14500	37500	2250	378	2,2	38,7	515	0,2	1
S-RIF2-28-30	4330	11800	44000	1710	380	2,06	28,5	462	0,3	1
S-RIF2-31-33	3190	12100	32300	2110	443	1,76	24,3	521	0,3	1
S-RIF2-34-36	4190	14800	45000	2540	502	2,27	32,7	834	0,4	1
S-RIF2-37-39	3110	14500	31300	2740	489	1,58	46	894	0,3	1
S-RIF2-37-39 (Dup)	3120	13900	30900	2530	508	1,51	43,4	801	0,4	1
S-RIF2-40-42	1320	15700	10400	2650	714	1,43	38,4	1110	0,4	1
S-RIF2-43-45	2530	15200	4050	2690	730	1,31	49,9	1190	0,5	1
S-RIF2-46-48	7260	16600	7380	3410	467	1,74	107	865	0,4	1
S-RIF2-46-48 (Dup)	2780	13900	2220	2480	665	0,98	55,4	1180	0,3	1
S-RIF2-T28	1550	12000	12400	3810	442	0,87	40,4	488	0,1	1
S-RIF2-T34	673	12700	2990	1980	440	1,2	32,2	357	0,2	1
S-RIF2-T40	232	12600	512	2330	449	0,86	21,4	376	0,2	1
S-RIF2-T46	213	16500	1430	4970	786	1,12	30,7	1710	0,7	1
S-RIF4-1-3	1860	11400	28300	1710	402	1,19	30,9	504	0,3	1
S-RIF4-4-6	2570	11800	28400	1800	425	1,4	22,8	573	0,3	1
S-RIF4-7-9	3820	11100	31000	1770	387	1,47	28	530	0,2	1
S-RIF4-10-12	3510	11600	25600	1830	405	1,3	21,1	565	0,2	1
S-RIF4-T4	3740	15100	25700	2310	407	1,28	159	470	0,3	1
S-RIF4-T9	7620	16700	13500	2350	470	1,98	183	445	0,4	1
S-KE-0-3	4200	16400	6840	3700	520	1,36	50,6	1000	0,3	1
S-KE-BU-1	1360	12800	1240	2190	361	1,24	24,4	416	0,1	1
S-KE-BU-2	747	13300	372	1120	349	1,52	20,2	354	0,1	1
S-KE-BU-3	1230	13600	283	1100	314	1,64	19,8	316	0,1	1
S-KE-BU-4	2660	11700	449	1370	322	1,27	17,1	348	0,1	1

Sample	Cu	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Ag
	ppm (mg/Kg)									
S-D-HS-74210E 01267N	32	15400	27,7	3650	930	1,07	18,2	1260	0,4	1
S-D-HS-74326E 01195N	27,2	13300	19,4	1780	689	1,16	14,8	803	0,3	1
S-D-HS-74215E 01278N	39,3	16400	56,6	3380	771	1,7	22	820	0,4	1
S-D-1-0-1	**137**	15200	**241**	1510	531	2,25	19,3	395	0,2	1
S-D-1-1-3	**101**	11700	**167**	1240	468	1,29	13,5	314	0,2	1
S-D-1-3-5	**99,1**	17200	**219**	1300	542	2,38	22,8	436	0,2	1
S-D-2-0-1	**95,4**	19600	**95,6**	1250	516	**2,81**	24,3	302	0,2	1
S-D-2-1-3	**95,2**	17800	**114**	1620	559	**2,9**	25,6	446	0,2	1
S-D-2-3-5	**63,9**	14100	**240**	1420	535	1,51	16,4	426	0,1	1
S-E-HS-63240E 15109N	56,7	11100	**268**	1310	246	1,04	12,4	387	0,1	1
S-E-HS-63240E 15109N	13	9450	42,2	1470	477	0,5	9,3	806	0,1	1
S-E-1-0-1	61,5	10200	**308**	1280	231	0,71	10,8	428	0,1	1
S-E-1-1-3	16,5	10800	24,4	1060	251	0,97	12,4	431	0,1	1
S-E-1-3-5	**103**	10400	**302**	1360	261	0,71	10,9	538	0,1	1
S-E-2-0-1	**79,6**	11500	**476**	1200	263	0,9	12,8	366	0,1	1
S-E-2-1-3	**106**	11000	**471**	1140	233	0,97	12,8	334	0,1	1
S-E-2-3-5	**82,3**	10500	**103**	1120	236	0,82	11,9	377	0,1	1
S-ASA-HS-51508E 15705N	55,9	21300	61	5260	1260	1,71	25,7	1420	0,4	1
S-ASA-HS-51501E 15688N	46,5	**28200**	24,2	8010	1550	2,51	35,1	1130	0,2	1
S-ASA-HS-51488E 15697N	45,8	24000	23	**9230**	1270	**2,83**	37,6	1420	0,4	1
S-ASA-I-5	59,7	**28700**	**75,1**	**12100**	1730	**3,02**	41,1	1770	0,3	1
S-ASA-I-10	55,7	**29700**	47,9	7200	1820	2,38	41,9	1760	0,5	1
S-ASA-I-15	49,7	**28500**	32,8	7900	1480	2,61	38,1	1360	0,4	1
S-ASA-I-20	57,4	**34500**	45,8	**8810**	1980	**2,84**	48	**1960**	0,5	1
S-ASA-I-25	49,7	**30800**	26,6	**10300**	1760	**2,79**	43,2	1660	0,5	1
S-ASA-I-30	39,9	25900	25	8080	1650	2,76	34,8	1640	0,5	1

Values in red: Results over the mean value added to twice the standard deviation are highlighted in red bold fonts
Values in blue: Results over the CCME threshold value for agricultural soils are highlighted in blue bold fonts

TABLE XIc: METALS CONCENTRATIONS IN SOILS (Na to Zn)

Sample	***Na***	***Sr***	***Tl***	***Sn***	***Ti***	***U***	***V***	***Zn***
	ppm (mg/Kg)							
S-BG-69940E 18340N	36	22,9	0,2	4	151	0,543	10,6	31
S-BG-52660E 22764N	198	60,4	0,2	4	115	0,521	10,7	59
S-BG-80356E 06945N	42	21	0,2	4	159	0,965	15,3	113
S-BG-57997E 20636N	151	36,2	0,2	4	169	0,611	15,4	27
S-BG-65629E 17392N	109	64,1	0,3	4	117	0,492	10,8	134
S-BG-63783E 17228N	22	6,65	0,2	4	108	0,418	9,38	15
S-BG-78159E 99759N	56	22	0,2	4	110	0,662	9,55	10
S-BG-62630E 18054N	33	9,98	0,2	4	130	0,457	11	29
S-BG-79182E 00111N	51	23,8	0,2	4	126	0,811	11,9	16
S-BG-74864E 14968N	33	6,02	0,2	4	132	0,422	9,39	22
S-BG-49148E 13157N	451	61,9	0,2	4	206	0,988	18,9	83
S-BG-49148E 13157N (Dup)	55	20,8	0,2	4	196	0,908	19,7	69
S-BG-55265E 11847N	106	16,5	0,2	4	155	0,571	12,3	41
S-BG-74864E 14968N (Dup)	27	5,82	0,2	4	119	0,361	8,73	15
S-BG-55255E 09752N	70	19,8	0,2	4	165	0,704	12,8	38
S-BG-53656E 11283N	102	26,6	0,2	4	221	0,811	17,2	44
S-BG-80720E 05003N	67	34,7	0,2	4	114	0,804	10,7	14
S-BG-53670E 13403N	78	18,2	0,2	4	181	0,689	15,5	48
S-BG-67858E 90938N	42	12,3	0,2	4	147	0,884	12,3	56
S-BG-68067E 97960N	52	19,5	0,2	4	182	0,903	17,8	87
S-BG-69431E 98407N	41	17,3	0,2	4	173	1,21	18,3	78
S-BG-63565E 00626N	38	19,5	0,2	4	167	1,2	17,5	102
S-BG-62033E 01742N	44	21,2	0,2	4	180	1,02	18,7	82
Mean Value	83	24,7	0,2	4	153	0,737	13,67	53
Standard Deviation	54	11,8	0,0	0	27	0,208	3,27	29

Sample	***Na***	***Sr***	***Tl***	***Sn***	***Ti***	***U***	***V***	***Zn***
	ppm (mg/Kg)							
S-A-HS-60021E 12160N	54	14,3	0,2	4	149	0,489	11,5	55
S-A-HS-60042E 12060N	735	47,7	0,2	4	183	1,03	13,8	104
S-A-LS 20%-A	26	16,1	0,2	4	142	0,589	12	67
S-A-LS 20%-B	20	10,1	0,2	4	130	0,473	10,7	36
S-A-LS 40% A	48	14,6	0,2	4	163	0,583	13,4	143
S-A-LS 40% B	53	12	0,2	4	160	0,516	12,8	66
S-A-LS 40% B (Dup)	66	16,6	0,2	4	164	0,576	13,6	54
S-A-LS 60% A	148	20,6	0,2	4	144	0,642	13,3	63
S-A-LS 60% B	56	17,3	0,2	4	145	0,529	12,5	66
S-A-LS 80% A	58	14,2	0,2	4	155	0,515	13,3	47
S-A-LS 80% B	60	15,5	0,2	4	170	0,57	13,5	48
S-A-LS 80% A (Dup)	50	13,9	0,2	4	151	0,528	12,6	55
S-A-LS 100% A	67	21,4	0,2	4	133	0,569	10,3	39
S-A-LS 120% A	68	13,9	0,2	4	119	0,464	10,4	36
S-A-LS 120% B	54	14,1	0,2	4	133	0,565	11,6	40
S-A-1-0-1	65	19,6	0,2	4	137	0,39	11,2	29
S-A-1-1-3	61	17,2	0,2	4	147	0,473	11,5	23
S-A-1-3-5	55	15,1	0,2	4	154	0,599	12,4	37
S-A-2-0-1	53	8,93	0,2	4	120	0,433	9,94	50
S-A-2-1-3	76	8,15	0,2	4	136	0,371	11,3	55
S-A-2-3-5	57	14,3	0,2	4	158	0,484	13,1	53
S-GR-5M-A	81	28,2	0,2	4	216	0,732	17,4	**1590**
S-GR-5M-B	96	38,6	0,2	4	233	0,867	21,6	**1380**
S-GR-10M-A	105	40,9	0,2	4	227	0,78	19,3	**1840**
S-GR-10M-B	84	44,8	0,2	4	209	0,738	18,1	**2100**
S-GR-15M-A	109	36,5	0,2	4	204	0,743	17,5	**2190**
S-GR-15M-B	97	33,7	0,2	4	188	0,638	16,7	**2020**

Sample	Na	Sr	Tl	Sn	Ti	U	V	Zn
	ppm (mg/Kg)							
S-GR-15M-B (Dup)	96	39	0,2	4	227	0,786	17,1	2120
S-GR-20M-A	89	27,6	0,2	4	165	0,599	14,5	2050
S-GR-20M-B	111	35,1	0,2	4	212	0,734	17,2	2400
S-GR-25M-A	95	32,2	0,2	4	203	0,763	18,8	2220
S-GR-25M-B	86	26,9	0,2	4	183	0,679	17,1	1750
S-GR-25M-B (Dup)	87	24,3	0,2	4	161	0,618	15,5	1560
S-GR-30M-A	92	27,8	0,2	4	192	0,699	18,7	1890
S-GR-30M-B	89	24,4	0,2	4	204	0,659	17,3	1730
S-GR-35M-A	79	27	0,2	4	203	0,666	18,1	1770
S-GR-35M-B	69	17	0,2	4	210	0,585	14,4	1180
S-GR-HS-57538E 18001N	64	12,7	0,2	4	149	0,538	13,4	622
S-C-LS 20% A	48	16,5	0,2	4	153	0,82	14,8	47
S-C-LS 20% B	50	22,1	0,2	4	155	0,876	16,6	73
S-C-LS 40% A	37	18,9	0,2	4	174	1,03	18,4	82
S-C-LS 40% B	57	22,4	0,2	4	175	1,1	18,8	88
S-C-LS 40% A (Dup)	44	20,2	0,2	4	174	1,01	17,8	84
S-C-LS 60% A	32	19,1	0,2	4	164	1,01	16,1	70
S-C-LS 60% B	36	22,4	0,3	4	161	1,12	19,2	104
S-C-LS 80% A	29	15,1	0,2	4	150	0,88	14,7	55
S-C-LS 80% B	40	18,7	0,2	4	161	0,949	16	74
S-C-LS 80% B (Dup)	50	21,6	0,2	4	173	1,05	17,5	88
S-C-LS 100% A	22	13,3	0,2	4	123	0,787	11,2	43
S-C-LS 100% B	49	21,8	0,2	4	178	0,98	17,7	90
S-C-LS 120% A	30	13,3	0,2	4	142	0,749	12,1	49
S-C-LS 120% B	33	18,9	0,2	4	162	0,869	14,2	81
S-C-1-0-1	48	29,1	0,3	4	173	1,31	18,7	54
S-C-1-1-3	60	31,8	0,3	4	177	1,39	20,2	49

Sample	Na	Sr	Tl	Sn	Ti	U	V	Zn
	ppm (mg/Kg)							
S-C-1-3-5	44	25,2	0,3	4	191	1,29	21,5	75
S-C-2-0-1	14	6,77	0,2	4	125	0,612	10,8	24
S-C-2-1-3	28	13,4	0,2	4	156	0,821	13,3	58
S-C-2-3-5	40	16,7	0,2	4	179	0,844	15,5	72
S-C-3-0-1	46	17,9	0,2	4	188	0,976	18,2	64
S-C-3-1-3	34	14,1	0,2	4	168	0,887	16	49
S-C-3-3-5	45	16,2	0,2	4	196	1,06	18	68
S-C-HS 65235E 02908N	45	19,4	0,2	4	200	0,998	17,1	88
S-C-HS 65266E 02930N	45	23,6	0,2	4	189	0,948	17,5	111
S-C-HS 66040E 02939N	43	20,8	0,2	4	186	0,858	16,6	132
S-C-HS 66017E 02566N	77	36,2	0,3	4	236	1,29	23,9	104
S-C-HS 65011E 02663N	35	7,98	0,3	4	204	1,18	21,7	4970
S-C-HS 63025E 02811N	33	15,5	0,2	4	137	0,737	12,1	467
S-C-HS 68010 02265N	27	18,4	0,2	4	169	0,79	13,9	139
S-RIF1-1-3	79	10,3	0,2	4	96,8	0,281	8,77	18
S-RIF1-4-6	84	12,1	0,2	4	101	0,318	9,46	27
S-RIF1-7-9	93	13,7	0,2	4	106	0,306	9,89	29
S-RIF1-10-12	75	11,9	0,2	4	89,7	0,281	8,36	35
S-RIF1-10-12 (Dup)	78	12,7	0,2	4	94,3	0,282	8,47	25
S-RIF1-13-15	77	11,5	0,2	4	101	0,309	8,95	30
S-RIF1-16-18	75	10,9	0,2	4	97,2	0,298	8,79	35
S-RIF1-19-21	78	10,2	0,2	4	93,4	0,358	8,58	82
S-RIF1-19-21 (Dup)	76	11,8	0,2	4	90,5	0,309	8,42	41
S-RIF1-22-24	78	11,7	0,2	4	98,1	0,314	8,97	33
S-RIF1-T24	82	13,1	0,2	4	103	0,324	8,95	22
S-RIF1-T16	76	11,7	0,2	4	117	0,409	10,4	31
S-RIF1-T12	75	57,6	0,2	4	121	0,515	12,4	80

Sample	**Na**	**Sr**	**Tl**	**Sn**	**Ti**	**U**	**V**	**Zn**
	ppm (mg/Kg)							
S-RIF1-T6	75	18,2	0,2	4	102	0,362	9,6	41
S-RIF2-25-27	74	38,5	0,2	10	79,8	0,368	9,83	281
S-RIF2-28-30	72	88,2	0,2	11	76,4	0,352	9,28	477
S-RIF2-31-33	67	54,1	0,2	7	101	0,423	10,8	343
S-RIF2-34-36	47	53,6	0,3	5	120	0,567	13,6	436
S-RIF2-37-39	50	35,6	0,3	4	129	0,609	14,6	319
S-RIF2-37-39 (Dup)	54	31,4	0,3	4	121	0,552	13,4	324
S-RIF2-40-42	39	17	0,2	4	153	0,732	16,9	171
S-RIF2-43-45	41	16,7	0,2	4	167	0,743	17,8	262
S-RIF2-46-48	77	22,1	0,2	4	147	0,588	14,7	659
S-RIF2-46-48 (Dup)	19	13,7	0,2	4	149	0,653	16,4	285
S-RIF2-T28	54	20,2	0,2	4	134	0,551	11,2	195
S-RIF2-T34	47	10	0,2	4	134	0,407	9,96	84
S-RIF2-T40	35	10,3	0,2	4	130	0,462	10,9	49
S-RIF2-T46	42	23,9	0,3	4	168	0,952	26,6	83
S-RIF4-1-3	45	26,3	0,2	11	112	0,425	9,74	198
S-RIF4-4-6	47	32,1	0,2	11	119	0,456	10,3	283
S-RIF4-7-9	49	33,3	0,2	14	99,3	0,406	9,54	400
S-RIF4-10-12	44	20,4	0,2	8	110	0,457	10,1	365
S-RIF4-T4	58	16,7	0,4	4	116	0,531	10,5	310
S-RIF4-T9	55	17,8	0,2	4	120	0,518	11,5	683
S-KE-0-3	103	21,5	0,2	4	158	0,654	15,4	425
S-KE-BU-1	42	11,9	0,2	4	116	0,424	10,2	164
S-KE-BU-2	36	9,89	0,2	4	110	0,391	9,4	93
S-KE-BU-3	33	11,6	0,2	4	110	0,426	9,39	137
S-KE-BU-4	37	10,6	0,2	4	107	0,36	8,6	281
S-D-HS-74210E 01267N	51	25,3	0,2	4	180	0,829	15,8	76

Sample	***Na***	***Sr***	***Tl***	***Sn***	***Ti***	***U***	***V***	***Zn***
	ppm (mg/Kg)							
S-D-HS-74326E 01195N	54	19,5	0,2	4	136	0,665	11,5	46
S-D-HS-74215E 01278N	48	22,4	0,2	4	151	0,771	13,6	51
S-D-1-0-1	62	**139**	0,2	4	105	0,514	8,81	45
S-D-1-1-3	56	**53,4**	0,2	4	99,2	0,481	8,5	40
S-D-1-3-5	57	33,6	0,2	4	112	0,519	10,6	46
S-D-2-0-1	52	**50,4**	0,2	4	104	0,562	10,4	32
S-D-2-1-3	58	41,7	0,2	4	105	0,647	12,9	38
S-D-2-3-5	48	37,9	0,2	4	104	0,657	11,5	33
S-E-HS-63240E 15109N	56	28,2	0,2	4	96,7	0,431	10,5	44
S-E-HS-63240E 15109N	28	15,8	0,2	4	114	0,534	12,3	48
S-E-1-0-1	37	21,1	0,2	4	102	0,424	11,8	33
S-E-1-1-3	20	7,02	0,2	4	96,9	0,38	10,2	21
S-E-1-3-5	35	27,4	0,2	4	104	0,542	12,1	39
S-E-2-0-1	38	19,3	0,2	4	101	0,457	11,7	33
S-E-2-1-3	32	16,3	0,2	4	91,2	0,519	11,1	28
S-E-2-3-5	23	13,3	0,2	4	98,8	0,409	11,3	26
S-ASA-HS-51508E 15705N	95	31	0,2	4	188	0,87	21	**495**
S-ASA-HS-51501E 15688N	103	26,7	0,2	4	**212**	0,802	21,7	**368**
S-ASA-HS-51488E 15697N	92	27	0,2	4	**210**	0,877	23,4	**243**
S-ASA-I-5	89	**56,8**	0,2	4	**235**	0,956	23,7	118
S-ASA-I-10	89	36,2	**0,3**	4	**215**	1,06	28,9	152
S-ASA-I-15	85	31,6	0,2	4	191	0,875	23,4	115
S-ASA-I-20	95	32,4	**0,3**	4	**236**	**1,16**	32,4	179
S-ASA-I-25	81	27,9	0,2	4	**230**	1,02	28,3	160
S-ASA-I-30	80	27,8	0,2	4	207	1	25,2	164

Values in red: Results over the mean value added to twice the standard deviation are highlighted in red bold fonts
Values in blue: Results over the CCME threshold value for agricultural soils are highlighted in blue bold fonts

TABLE XId: SOILS CHARACTERISTICS

Sample	*pH*	*Cation Exchange Capacity (meq/100g)*	*Carbon Organic (%)*	*Sand SSK*	*Total Inorganic Nitrogen*	*Silt SSK*	*Clay SSK*
S-A-LS 20%-B	7	4,6	0,7	91	1,4	2	7
S-A-LS 40% A	7,2	7,1	1,7	88	2,2	6	7
S-A-LS 80% B	7,2	4,3	0,8	90	4,4	6	5
S-A-LS 100% A	7,3	7,1	1	90	3,2	4	6
S-A-1-0-1	8,1	2,9	0,4	92	2,8	3	5
S-A-2-1-3	7,4	6	1	88	2,8	5	7
S-C-LS 20% B	7,6	9,1	2	85	2	8	7
S-C-LS 40% A	7,6	11,4	1,6	80	1,6	12	9
S-C-LS 40% A (Dup)	7,5	10,5	1,1	54	1,6	35	11
S-C-LS 80% B	7,7	8	1,6	84	1,8	9	7
S-C-LS 80% B (Dup)	7,7	8,3	1,3	84	1,8	10	6
S-C-LS 100% A	7,3	4,6	0,7	92	1,2	3	5
S-C-1-0-1	8,1	5,4	0,8	90	1,6	3	8
S-C-2-1-3	6,8	6,6	1,3	88	1,8	6	6
S-C-3-3-5	7,4	8,6	1,3	86	1,6	8	6

TABLE XIIa : METALS CONCENTRATIONS IN BIOMASS SAMPLES (Al to Co)

Sample	***Al***	***As***	***Sb***	***Ba***	***Be***	***Cd***	***Ca***	***Cr***	***Co***
	ppm (mg/Kg)								
B-BG-69940E 18340N	637	0,35	0,06	53,7	0,05	0,18	6090	16,7	0,66
B-BG-52660E 22764N	252	0,17	0,06	47,4	0,05	0,05	4520	15,2	0,31
B-BG-80356E 06945N	78	0,05	0,06	69,1	0,05	0,04	7460	9,6	0,12
B-BG-63783E 17228N	164	0,12	0,06	42,3	0,05	0,04	4870	11	0,19
B-BG-62630E 18054N	320	0,19	0,06	51,2	0,05	0,04	4550	12,7	0,3
B-BG-74864E 14968N	160	0,11	0,14	65,6	0,05	0,12	5080	6,9	0,17
B-BG-74864E 14968N (Dup)	46	0,05	0,06	33,4	0,05	0,13	4310	3	0,08
B-BG-79148E 13157N	152	0,11	0,06	39,9	0,05	0,07	6200	10,2	0,37
B-BG-55265E 11847N	162	0,11	0,06	18,1	0,05	0,16	5910	12	0,21
B-BG-55255E 09752N	519	0,27	0,06	33,9	0,05	0,05	5840	17	0,47
B-BG-53656E 11283N	131	0,05	0,06	29,1	0,05	0,03	5350	8,3	0,19
B-BG-80720E 05003N	5	0,11	0,06	29,1	0,05	0,02	3890	11,7	0,17
B-BG-53670E 13403N	13	0,32	0,06	34,5	0,05	0,06	4220	1,5	0,34
B-BG-67858E 98938N	86	0,05	0,06	25	0,05	0,09	6290	10,6	0,13
B-BG-68067E 97960N	104	0,13	0,06	24,4	0,05	0,05	6830	4,6	0,1
B-BG-69431E 98407N	251	0,17	0,06	27,3	0,05	0,40	5910	12,7	0,19
B-BG-63565E 00626N	3	0,07	0,06	20,2	0,05	0,03	3500	2,4	0,04
B-BG-62033E 01742N	3	0,07	0,12	26,1	0,05	0,03	7770	3	0,07
Mean Value	171	0,14	0,07	37,2	0,05	0,09	5477	9,4	0,23
Standard Deviation	125	0,07	0,01	12,1	0,00	0,06	1001	4,0	0,12
B-RIF1-1-6	309	0,34	7,26	36,5	0,05	0,08	7950	17	0,36
B-RIF1-7-12	466	0,57	17,3	37,9	0,05	0,05	7480	10,2	0,38
B-RIF1-13-18	174	0,22	7,95	43,4	0,05	0,08	8220	5,2	0,16
B-RIF1-19-24	162	0,18	7,38	43,5	0,05	0,05	7200	5,8	0,18
B-RIF2-25-30	124	0,21	10,8	29,9	0,05	0,02	7630	3,7	0,18

Sample	**Al**	**As**	**Sb**	**Ba**	**Be**	**Cd**	**Ca**	**Cr**	**Co**
	ppm (mg/Kg)								
B-RIF2-31-36	246	0,38	17,9	31,7	0,05	0,04	5910	9,8	0,31
B-RIF2-37-42	252	0,4	19,6	34,7	0,05	0,04	5550	9	0,23
B-RIF2-43-48	166	0,15	0,95	29	0,05	0,03	5540	5,7	0,14
B-RIF2-37-42 (Dup)	222	0,28	9,82	37,2	0,05	0,05	7000	5,3	0,21
B-RIF4-1-6	73	0,11	2,56	36,7	0,05	0,05	7870	4,6	0,16
B-RIF4-7-12	56	0,06	1,23	31,6	0,05	0,02	4450	2,6	0,08
B-C-1-0-3	276	0,32	0,06	35,3	0,05	0,04	5440	12,9	0,33
B-C-1-3-5	256	0,2	0,06	32,7	0,05	0,07	5010	10,1	0,28
B-C-2-0-3	151	0,11	0,11	53,1	0,05	0,2	5630	10	0,25
B-C-2-3-5	108	0,07	0,06	51,2	0,05	0,15	5120	7,8	0,15
B-C-3-0-3	95	0,08	0,06	17,4	0,05	0,08	5590	5,4	0,1
B-C-3-3-5	245	0,13	0,06	32,7	0,05	0,09	5250	8,1	0,22
B-KE-1-0-3	144	0,08	0,06	43	0,05	0,27	8100	2,2	0,06
B-KE-BU-1	192	0,09	0,06	50,2	0,05	0,13	8570	18	0,25
B-KE-BU-2	123	0,14	0,26	48,5	0,05	0,08	6710	2	0,11
B-D-1-0-3	54	0,07	0,15	67,3	0,05	0,05	15500	9	4,63
B-D-1-3-5	132	0,07	0,1	19,3	0,05	0,1	9880	25,3	0,62
B-D-2-0-3	64	0,11	0,06	61,2	0,05	0,23	14600	7,1	3,56
B-D-2-3-5	71	0,05	0,06	18,5	0,05	0,08	13600	0,1	0,25
B-E-1-0-3	139	0,14	0,38	55,8	0,05	0,21	11700	6,8	0,38
B-E-1-3-5	152	0,12	0,23	83,9	0,05	0,23	9840	3,8	0,33
B-E-2-0-3	134	0,11	0,24	29,8	0,05	0,17	10500	6,1	0,45
B-E-2-3-5	164	0,17	0,39	39,6	0,05	0,09	6790	8,3	0,77
B-E-3-0-1 (RACINE)	2430	2,1	0,08	108	0,14	0,25	4860	46,8	2,55
B-E-3-0-3	126	0,05	0,27	112	0,05	0,09	9610	5,6	0,16
B-E-3-3-5	180	0,08	0,06	101	0,05	0,05	6440	10,2	0,36
B-E-4-0-3	172	0,08	0,06	66,9	0,05	0,06	7710	12,8	0,46

Sample	Al	As	Sb	Ba	Be	Cd	Ca	Cr	Co
	ppm (mg/Kg)								
B-E-4-3-5	172	0,09	0,06	**90,6**	0,05	0,06	**8020**	**20,1**	**0,57**
B-E-HS-63240E 15109N	83	0,09	0,06	52,8	0,05	**0,23**	**7740**	3,2	0,19
B-E-HS-63240E 15109N	90	0,05	0,06	**77,9**	0,05	0,09	6670	5,3	0,26
B-E-HS-64435E 14486N	222	0,13	**0,6**	**83,2**	0,05	0,16	6780	12,8	0,31
B-E-HS-64435E 14486N (Dup)	125	0,09	0,06	**124**	0,05	0,05	**8070**	7,3	0,31
B-A-1-0-3	156	0,08	**0,25**	26,8	0,05	0,2	4760	5	0,25
B-A-1-3-5	145	0,05	0,06	23,7	0,05	**0,26**	5080	6,2	0,31
B-A-2-0-3	122	0,05	0,06	38,6	0,05	**0,22**	6350	1,9	0,28
B-A-2-3-5	67	0,05	**0,1**	44,9	0,05	0,21	7390	6,9	0,23
B-ASA-51508E 15705N	164	0,18	0,06	45,8	0,05	**1,74**	6030	16,3	0,27
B-ASA-51501E 15688N	**868**	**0,58**	0,06	49,2	0,05	**1,07**	6970	**41,7**	**0,79**
B-ASA-51488E 15697N	337	**0,47**	0,06	33,8	0,05	**0,78**	5630	11,1	**0,52**
B-ASA-I-0-15M	330	0,26	0,06	39	0,05	0,08	5450	4,2	0,21
B-ASA-I-15-30M	**670**	**0,5**	0,06	43,3	0,05	0,09	6580	13	0,28

Values in red: Results higher than the mean values added to twice the standard deviation are highlighted in red bold fonts.

TABLE XIIb : METALS CONCENTRATIONS IN BIOMASS SAMPLES (Cu to K)

Sample	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	K
	ppm (mg/Kg)								
B-BG-6994DE 18340N	2,4	1220	0,61	1920	110	3,06	8,6	2210	10900
B-BG-52660E 22764N	1,4	463	0,54	1910	46,8	0,44	7,4	1390	12300
B-BG-80356E 06945N	1,9	135	0,26	1530	59,8	0,66	3,8	1250	6380
B-BG-63783E 17228N	1,8	349	0,33	1070	57,9	3,05	4,3	1390	7370
B-BG-62630E 18054N	1,6	650	0,72	724	67,7	1,03	6,2	857	3180
B-BG-74864E 14968N	8,8	366	0,66	1500	116	1,28	12,4	1610	11500
B-BG-79148E 13157N	15,8	270	0,23	1400	70,9	1,78	29,7	2040	7690
B-BG-55265E 11847N	2,7	351	0,36	1940	121	3,96	6,1	1340	10100
B-BG-74864E 14968N (Dup)	1,3	49	0,17	1330	93,5	0,66	1,2	956	9550
B-BG-55255E 09752N	1,7	1180	0,64	1380	180	2,72	7,9	828	2680
B-BG-53656E 11283N	4,7	176	0,21	1030	44	2,16	4,8	1270	4520
B-BG-80720E 05003N	0,1	5	0,23	611	3,9	0,15	6,1	190	3590
B-BG-53670E 13403N	1,4	5	0,79	950	22	0,02	3,5	5	1540
B-BG-67858E 98938N	2	137	0,2	1110	44,8	1,31	4,5	1100	5820
B-BG-68067E 97960N	1,8	156	0,46	1010	53,3	0,67	1,6	751	5580
B-BG-69431E 98407N	2,9	255	0,74	1020	58,8	1,11	5,2	1100	7910
B-BG-63565E 00626N	0,1	5	0,47	652	9,9	0,07	0,8	109	5360
B-BG-62033E 01742N	0,1	5	0,24	1440	15,3	0,12	1,9	942	6620
Mean Value	2,9	321	0,44	1252	65,3	1,35	6,4	1074	6811
Standard Deviation	2,3	259	0,19	343	33,5	0,96	3,8	440	2537
B-RIF1-1-6	22,1	488	363	2270	83,2	4,38	8,6	1340	4820
B-RIF1-7-12	28,8	864	631	2160	74,6	3,46	5,9	1350	7570
B-RIF1-13-18	15,1	257	324	2110	58,2	3,57	3,4	1050	5580
B-RIF1-19-24	13,9	276	299	1690	68,5	3,14	3,4	861	3820
B-RIF2-25-30	18,2	221	325	2220	66,2	3,06	2,5	1540	4440

Sample	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**P**	**K**
	ppm (mg/Kg)								
B-RIF2-31-36	**33,2**	443	**595**	1800	81,4	2,92	5,3	1020	3790
B-RIF2-37-42	**47,6**	437	**611**	1650	59,5	0,97	5	914	3190
B-RIF2-43-48	4,3	243	**30,2**	1390	60,2	1,75	3	1300	3310
B-RIF2-37-42 (Dup)	**22,5**	343	**304**	1850	66,3	1,18	3,2	1250	4200
B-RIF4-1-6	5,6	121	**102**	1540	47,7	0,99	2	1310	5480
B-RIF4-7-12	6,1	101	**65**	931	45,1	0,83	1,4	926	2930
B-C-1-0-3	1,7	573	**1,18**	998	54,4	0,69	6,6	770	4360
B-C-1-3-5	1,7	476	**0,94**	763	51,8	1,18	5,1	743	3500
B-C-2-0-3	1,5	285	0,71	1150	66,2	0,7	4,9	1380	5630
B-C-2-3-5	1,7	85	**3,31**	1090	31,6	0,81	6,8	1340	6070
B-C-3-0-3	4,9	163	0,73	1220	35,5	0,72	2,9	1170	4840
B-C-3-3-5	1,9	439	**2,07**	872	55	1,15	4,1	1020	2960
B-KE-1-0-3	**8,9**	212	**1,05**	1510	55,9	0,54	1,4	**2120**	**15300**
B-KE-BU-1	6,4	364	**2,71**	1530	62,5	1,59	8	**2050**	11000
B-KE-BU-2	4	174	**12,9**	1400	44,9	0,87	1,4	1760	8710
B-D-1-0-3	5,5	113	**1,72**	**2930**	43,1	2,77	1,1	**2270**	**14400**
B-D-1-3-5	3,4	324	0,53	1700	54,3	1,02	10,5	1540	6540
B-D-2-0-3	7,2	130	0,51	**2290**	44,1	1,12	1,2	**3090**	**18600**
B-D-2-3-5	4,1	144	0,24	**2150**	48,2	0,74	1,4	1950	9270
B-E-1-0-3	**9,2**	364	**2,68**	1300	69,4	1,49	5,3	**1990**	9870
B-E-1-3-5	5,6	339	**1,85**	1650	45,5	0,81	3,5	1790	10100
B-E-2-0-3	7,4	317	**4,95**	**2080**	104	**4,88**	5,4	**1990**	5820
B-E-2-3-5	7	379	**3,11**	1100	69,1	1,61	6,1	1460	5860
B-E-3-0-1 (RACINE)	6	**4460**	**6,89**	1110	**259**	0,59	**28,3**	702	2250
B-E-3-0-3	3	212	0,4	1220	38,2	1,1	4,2	1280	8270
B-E-3-3-5	2,5	324	0,64	878	65,4	1,29	6,8	1180	4000
B-E-4-0-3	2,6	354	0,42	799	59,5	**3,32**	8,6	1470	6450

Sample	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**P**	**K**
	ppm (mg/Kg)								
B-E-4-3-5	3,3	368	0,47	958	92,1	1,99	12,7	1540	6970
B-E-HS-63240E 15109N	5,1	183	0,23	1330	52,2	1,4	3,2	1820	10900
B-E-HS-63240E 15109N	3,3	233	0,37	1110	54,1	1,78	5	1530	7930
B-E-HS-64435E 14486N	2,3	439	0,76	966	52,7	**39,9**	7,7	1360	5060
B-E-HS-64435E 14486N (Dup)	2,4	216	0,46	891	53,8	**4,6**	5,3	1080	5460
B-A-1-0-3	2,7	267	**4,43**	635	38,7	1,25	4,2	785	2670
B-A-1-3-5	4,8	224	**1,08**	687	40,8	2,02	4,6	956	3400
B-A-2-0-3	4,9	194	0,47	1110	60,3	0,7	2,9	1740	8550
B-A-2-3-5	5,9	131	0,34	1210	45,5	1,24	2,9	1740	8300
B-ASA-51508E 15705N	1,8	303	0,44	1600	52,8	**6,14**	8,3	1630	7770
B-ASA-51501E 15688N	2,7	**1510**	**2,77**	1710	105	2,51	**19,5**	1490	4930
B-ASA-51488E 15697N	2,4	802	**1,77**	1220	124	2,63	7,2	829	2490
B-ASA-I-0-15M	2,7	616	**1,26**	1280	41,9	**4,03**	3,6	1200	4710
B-ASA-I-15-30M	3,3	**1440**	**1,82**	1840	92,3	2,36	7,5	1130	5540

Values in red: Results higher than the mean values added to twice the standard deviation are highlighted in red bold fonts.

TABLE XIIc : METALS CONCENTRATIONS IN BIOMASS SAMPLES (Se to Zn)

Sample	**Se**	**Na**	**Sr**	**Tl**	**Sn**	**Ti**	**V**	**Ag**	**Zn**
	ppm (mg/Kg)								
B-BG-6994DE 18340N	0,4	16	10,8	0,04	1	18,5	1,64	1	25,4
B-BG-52660E 22764N	0,1	31	9,85	0,04	1	5,61	0,23	1	23
B-BG-80356E 06945N	0,1	7	9,3	0,04	1	1,82	0,08	1	23,4
B-BG-63783E 17228N	0,1	7	7,49	0,04	1	5,98	0,24	1	25,6
B-BG-62630E 18054N	0,1	12	7,84	0,04	1	11,4	0,78	1	19,8
B-BG-79148E 13157N	0,2	17	8,28	0,04	1	3,48	0,36	1	31,7
B-BG-55265E 11847N	0,2	9	7,62	0,04	1	4,82	0,41	1	17,8
B-BG-74864E 14968N	0,1	13	8,33	0,04	1	3,77	0,35	1	30,9
B-BG-74864E 14968N (Dup)	0,1	6	7,02	0,04	1	2,71	0,14	1	24,8
B-BG-55255E 09752N	0,1	12	7,51	0,04	1	17,8	1,53	1	20,1
B-BG-53656E 11283N	0,1	12	8,99	0,04	1	2,58	0,18	1	32,2
B-BG-80720E 05003N	0,1	15	3,2	0,04	1	5,1	0,06	1	4,5
B-BG-53670E 13403N	0,2	13	6,36	0,04	1	16,9	0,06	1	29
B-BG-67858E 98938N	0,1	10	9,19	0,04	1	1,64	0,12	1	18,4
B-BG-68067E 97960N	0,2	10	7,83	0,04	1	2,57	0,23	1	21,5
B-BG-69431E 98407N	0,1	12	7,12	0,04	1	3,5	0,34	1	30,9
B-BG-63565E 00626N	0,1	14	3,88	0,04	1	1,9	0,06	1	2,5
B-BG-62033E 01742N	0,1	12	7,81	0,04	1	2,15	0,06	1	23,8
Mean Value	0,1	13	7,69	0,04	1	6,24	0,38	1	22,5
Standard Deviation	0,1	3	1,26	0,00	0	4,41	0,31	0	5,9
B-RIF1-1-6	0,3	13	18,9	0,04	1	8,4	0,64	1	46,2
B-RIF1-7-12	0,4	11	18,2	0,04	1	11	1,15	1	39,3
B-RIF1-13-18	0,2	8	24,9	0,04	1	4,03	0,36	1	65,3
B-RIF1-19-24	0,1	8	19,9	0,04	1	6,01	0,33	1	65,8
B-RIF2-25-30	0,2	17	22,6	0,04	1	3,1	0,27	1	37

Sample	**Se**	**Na**	**Sr**	**Tl**	**Sn**	**Ti**	**V**	**Ag**	**Zn**
	ppm (mg/Kg)								
B-RIF2-31-36	0,3	10	17,9	0,04	1	6,05	0,44	1	47,4
B-RIF2-37-42	0,2	10	13,8	0,04	1	6,83	0,56	1	57,8
B-RIF2-43-48	0,2	7	9,76	0,04	1	5,02	0,33	1	45,9
B-RIF2-37-42 (Dup)	0,2	18	14,6	0,04	1	5,79	0,52	1	55
B-RIF4-1-6	0,3	22	17,1	0,04	1	2,14	0,11	1	60,5
B-RIF4-7-12	0,2	7	10,8	0,04	1	1,46	0,11	1	46,5
B-C-1-0-3	0,1	13	6,51	0,04	1	9,1	0,59	1	21,8
B-C-1-3-5	0,1	12	5,96	0,04	1	8,95	0,53	1	17,3
B-C-2-0-3	0,1	12	10,9	0,04	1	4,52	0,21	1	28,2
B-C-2-3-5	0,1	13	10,4	0,04	1	3,47	0,14	1	31,3
B-C-3-0-3	0,1	13	6,31	0,04	1	2,81	0,11	1	16,3
B-C-3-3-5	0,2	13	7,32	0,04	1	8,03	0,52	1	21,1
B-KE-1-0-3	0,1	19	20,7	0,04	1	3,16	0,34	1	38,4
B-KE-BU-1	0,1	18	22,1	0,04	1	2,68	0,3	1	30,7
B-KE-BU-2	0,1	11	13,2	0,04	1	4,48	0,28	1	26
B-D-1-0-3	0,1	23	197	0,04	1	1,43	0,06	1	27,6
B-D-1-3-5	0,1	25	13	0,04	1	4,97	0,06	1	29,7
B-D-2-0-3	0,1	33	184	0,04	1	2	0,06	1	40,9
B-D-2-3-5	0,1	22	17	0,04	1	2,33	0,16	1	25,3
B-E-1-0-3	0,1	19	45,6	0,04	1	5,16	0,25	1	29,8
B-E-1-3-5	0,1	20	28,6	0,04	1	5,99	0,29	1	34
B-E-2-0-3	0,1	27	26,4	0,04	1	4,91	0,34	1	42,9
B-E-2-3-5	0,2	24	16	0,04	1	7,66	0,31	1	27
B-E-3-0-1 (RACINE)	0,4	22	12,6	0,07	1	90,2	5,09	1	54,3
B-E-3-0-3	0,1	17	18,1	0,04	1	3,76	0,18	1	30,2
B-E-3-3-5	0,1	13	12,2	0,04	1	5,58	0,27	1	30,1
B-E-4-0-3	0,1	17	14,2	0,04	1	5	0,2	1	27,1

Sample	***Se***	***Na***	***Sr***	***Tl***	***Sn***	***Ti***	***V***	***Ag***	***Zn***
	ppm (mg/Kg)								
B-E-4-3-5	0,1	19	**15,6**	0,04	1	5,24	0,11	1	33,3
B-E-HS-63240E 15109N	0,1	16	**16,5**	0,04	1	2,28	0,16	1	30,4
B-E-HS-63240E 15109N	0,1	16	**14,3**	0,04	1	3,74	0,06	1	30,9
B-E-HS-64435E 14486N	0,1	17	**12,4**	0,04	1	8,53	0,34	1	28,4
B-E-HS-64435E 14486N (Dup)	0,1	17	**17**	0,04	1	3,85	0,14	1	28,9
B-A-1-0-3	0,1	15	7	0,04	1	5,59	0,25	1	17,7
B-A-1-3-5	0,1	12	7,84	0,04	1	3,36	0,24	1	20,5
B-A-2-0-3	0,1	18	**10,7**	0,04	1	4,41	0,27	1	32,9
B-A-2-3-5	0,1	16	**14,2**	0,04	1	2,49	0,06	1	**34,5**
B-ASA-51508E 15705N	0,2	13	**14,3**	0,04	1	3,6	0,17	1	**43,8**
B-ASA-51501E 15688N	0,2	**24**	**12,3**	0,04	1	**33**	**1,42**	1	**274**
B-ASA-51488E 15697N	0,2	19	7,88	0,04	1	14	0,66	1	**124**
B-ASA-I-0-15M	0,2	16	**14,2**	0,04	1	10,2	0,72	1	24,9
B-ASA-I-15-30M	**0,3**	18	**12**	0,04	1	**22,6**	**1,36**	1	31,8

Values in red: Results higher than the mean values added to twice the standard deviation are highlighted in red bold fonts.

TABLE XIII: PARAMETERS EXCEEDING EITHER THE BGL OR THE AWQG FOR SHILO GW - PER RANGE OR AREA

Range or area	*# well*	*Parameters*
Aachen	6	Al (2), As (3), Ba (2), Cr (3), Ce (3), Co (1), **Cu (5)**, **Fe (4),** Pb (4), Mg (1), Li (1), Mo (4), Ni (3) Ru (3), Sn (4), Ti (3), Tl (2), U (3), Va (1), Zn (2), Zr (3)
Berlin	6	Al (1), As (4), Sb (4), Al (1), Bi (1), Cd (2), Co (4), Cu (4), Cr (5), Ce (3), Fe (4), Ni (4), Pb (1), Ru (3), Sn (4), Ti (4), Tl (3), Zn (2), Zr (3), U (3),Va (3)
Cologne	9	Ag (1), Al (1), As (9), Al (1), Sb (2), Ba (3), Bi (4), Ca (1), Cr (8), Co (7), Ce (5), Cd (5), Cu (8), Fe (9), Li (1), Pb (9), Mo (1), Ni (7), Se (3), Ru (7), Sn (4), Sr (2), Ti (9), Tl (6), U (6), Va (4), Zn (3), Zr (8)
Deileignhofen	10	Al (6), As (7), Sb (3), Ba (3), Bi (4), Cd (4), Cu (10), Cr (7), Co (4), Ce (5), Fe (7), Li (1), Pb (6), Mo (2), Ni (7), Ru (8), Se (3), Sn (4), Ti (6), Tl (5),Va (6),U (10), W (1), Zn (4), Zr(5)
Essen	9	Al (3), As (2), Ba (1), Bi (2), Co (3), Cu (5), Cd (1), Cr (5), Ce (5), Fe (5), Li (2), Ni (7), Pb (4), Ru (5), Sn (3), Ti (5), Zr (5)
Rifle range	2	As (1), Cr (1), Co 91), Cu (2), Pb (1), Fe (1), Mn (1), Ni (1), Ru (1), Sn (1), Ti (1), Zr (1)
Grenade range	3	Al (2), Ag (1), As (2), Bi (1), Cd (1), Co (1), Cu (1), Cr (2), Ce (1), Fe (2), Mn (1), Ni (1), Pb (1), Se (2), Ru (1), Se (1), Sn (2), Ti (2), Tl (2), Va (1), W (2), Zn (1), Zr (2)
OW	2	Ag (1), Al (2), Ba (3), Bi (2), Cr (2), Co (2), Ce (2), Fe (2), Pb (2), Mn (2), Na (1), Ni (2), Ru (2), Se (1), Sn (3), Ti (2), Tl (2), U (2), Va (2), W(2), Zn (2), Zr (2)
DW	1	As (1), Cr (1), Ce (1), Fe (1), Mo (1), Ni (1), U (1), V (1)
Marsh	1	Bi (1), Cr (1), Ce (1), Fe (1)
Phillips	1	Bi (1)
MW	10	Ag (2), Al (4), As (5), Ba (4), Ce (1), Bi (4), Cd (5), Ce (4), Co (6), Cu (9), Cr (10), Fe (9), Li (1), Mn (8), Mo (2), Na (1), Ni (8), Pb (8), Ru (7),Tl (4), Se (2), Sn (5), Ti (5), W (2), Zr (5) Sb (1), Va (6), U (3), Zn (4)
TR	1	Bi (1), Cr (1), Ce (1), Fe (1), Ni (1), Pb (1), Ru (1), Ti (1), Tl (1), U (1), Va (1)
ATR	2	As (2), Co (1), Cu (2), Ni (2), Pb (2), Sb (1), Fe (2), Ru (1), Ti (1), Tl (1), Va (1), Zr (1)
Zone	10	As (5), Co (1), Cu (4), Cr (4), Ce (2), Fe (4), Mn (6), Ni (4), Pb (2), Ru (3), Ti (2), Tl (2), Va (2), W (1), Zr (3)

Bold fonts: Results either higher than the AWQG or higher than twice the BGL

TABLE XIV - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, THE BGL OR THE SQGL FOR SOILS, AND THE BGL FOR BIOMASS AT AACHEN BATTLERUN

Matrix	***Parameters exceeding either BGL or QGL***		
GW	Al (2), As (3), Ba (2), Cr (3), Ce (3), Co (1), **Cu (5)**, **Fe (4)**, Pb (4), Mg (1), Li (1), Mo (4), Ni (3), Ru (3), Sn (4), Ti (3), Tl (2), U (3), Va (1), Zn (2), Zr (3)		
Soil	**Cu**	S-A-LS 60 % A and S-A-2-0-1	Over ASQG
	Ni	S-A-HS 60042E 12060 N	Over ASQG
		S-A-LS 60 % A	Over ASQG and 16 times BGL
		S-A-LS 120 % A	Over ASQG
	Mo	S-A-2-3-5	Slightly over BGL
	Cd	S-A-1-3-5	Over ASQG
	Co	S-A-1-3-5	Over BGL
Biomass	**Pb**	B-A-1-0-3 and 1-3-5	Highest hit at 5.5 times BGL
	Cd	B-A-1-3-5 and 2-0-3	Slightly higher
	Sr	B-A-2-0-3 and 2-3-5	Slightly higher
	Zn	B-A-2-3-5	Slightly higher

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: parameters fond both in the GW and in the surface soils or in the ground water and the biomass

In red highlight: parameters found only in the ground water

TABLE XV - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, THE BGL OR THE SQGL FOR SOILS, AND THE BGL FOR BIOMASS AT BERLIN BATTLERUN

Matrix	***Parameters exceeding either the QGL or the BGL***
GW	**Al (1), As (4)**, Sb (4), Al (1), Bi (1), **Cd (2), Co (4), Cu (4), Cr (5)**, Ce (3), **Fe (4), Ni (4)**, Pb (1), **Ru (3), Sn (4), Ti (4)**, Tl (3), Zn (2), **Zr (3), U (3),** Va (3)
Soils	No soils were collected in 2001
Biomass	No biomass was collected in 2001

GW: ground water

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

TABLE XVI: PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, THE BGL OR THE SQGL FOR SOILS, AND THE BGL FOR BIOMASS AT COLOGNE BATTLERUN

Matrix	***Parameters exceeding either the QGL or the BGL***		
GW	Ag (1), Al (1), As (9), Sb (2), **Ba (3)**, Bi (4), Ca (1), **Cr (8), Co (7),** Ce (5), Cd (5), Cu (8), **Fe (9)**, Li (1), **Pb (9), Mo (1), Ni (7), Se (3)**, Ru (7), Sn (4), Sr (2), **Ti (9),** Tl (6), **U (6), Va (4),** Zn (3), Zr (8)		
Soils	**Al**	S-C-LS 40%B, 60%B, HS 65011E02663N	Over BGL
	As	S-C-1-0-1, 1-1-3, 1-3-5, HS 66017E02566N	Over ASQG
	Be	S-C-1-3-5, S-C-HS 66017E02566N	Over BGL
	Bi	S-C-LS-60%A, HS 65266E02930N S-C-HS65011E02663N, 66017E02566N	Over BGL
	Cd	S-C-HS 65266E02930N, 66040E 02939N	Over ASQG (4 times higher)
	Cr	S-C-HS 63025E 02811N	Over BGL
	Co	S-C-LS-100% A, S-C-1-0-1, 1-1-3, 1-3-5	Over BGL
	Pb	S-C-HS-65011E02663N	Over BGL
	Mg	S-C-1-0-1,1-1-3,1-3-5, HS66017E02566N	Over BGL
	K	S-C-LS 60%B, HS66017E02566N	Over BGL
	Tl	S-C-LS-60%B, S-C-1-0-1,1-1-3,1-3-5, S-C-HS 65266E02930N, 66040E 02939N	Over BGL
	Ti	S-C-HS 66017E02566N	Over BGL
	U	S-C-1-0-1, 1-1-3,1-3-5, HS66017E02566N	Over ASQG
	Zn	S-C-HS-65011E02663N, 63025E 02811N	Over BGL
Biomass	**As**	B-C-1-0-3	
	Sb	B-C-2-0-3	
	Pb	B-C-1-0-3, 1-3-5, 2-3-5, 3-3-5	
	Sr	B-C-2-0-3, 2-3-5	

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: parameters fond both in the GW and in the surface soils or in the ground water and the biomass

In red: parameters found only in the ground water

TABLE XVII - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, THE BGL OR THE SQGL FOR SOILS, AND THE BGL FOR BIOMASS AT DEILINGHOFEN BATTLERUN

Matrix	***Parameters exceeding either the BGL or the QGL***		
GW	Al (6), As (7), Sb (3), Ba (3), Bi (4), Cd (4), Cu (10), **Cr (7), Co (4), Ce (5), Fe (7), Li (1), Pb (6), Mo (2),** Ni (7), Ru (8), Se (3), Sn (4), Ti (6), Tl (5), **Va (6)**, U (10), W (1), Zn (4), Zr (5)		
Soils	Co	5 out of 6	Over BGL, highest 12.5 times
	Cu	All	Over ASQG, highest hit 3.4 times
	Pb	All	Over ASQG (highest hit 3.4 times
	Mo	Two samples	Over BGL at target # 2
	Sr	Three samples	Over BGL at target # 1 and 2 (highest hit 2.9 times)
Biomass	Sb	Two samples	Slightly exceed at target # 1
	Ba	One sample	Slightly exceed at target #2
	Cd	One sample	Slightly exceed at target #2
	Ca	All samples	Highest 2.1 times the BGL
	Cr	One sample target #1	1.46 time the BGL
	Co	Three samples	2.4 times the BGL
	Pb	One sample targer #1	2.1 times the BGL
	Mg	Three samples	Highest 1.5 times the BGL
	P, K	Four samples	Highest 1.5 times the BGL
	Na	Four samples	Highest 4 times the BGL
	Sr	Four samples	Highest 19 times
	Zn	One sample target #2	Slightly exceed

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: fond both in the GW and in the surface soils or in the ground water and the biomass

In red: parameters found only in the ground water

TABLE XVIII - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, THE BGL OR THE SQGL FOR SOILS, AND THE BGL FOR BIOMASS AT ESSEN BATTLERUN

Matrix	***Parameters exceeding either the BGL or the QGL***		
GW	Al (3), As (2), Ba (1), Bi (2), Co (3), Cu (5), **Cd (1), Cr (5), Ce (5),** Fe (5), Li (2), Ni (7), Pb (4), Ru (5), Sn (3), Ti (5), Zr (5)		
Soils	Cu	4 samples	Over ASQG by approximately twice the ASQG
	Pb	6 samples	Over ASQG, highest hit 6.7 times
Biomass	Sb	6 samples	Highest hit 4.3 times the BGL
	Ba	9 samples	Highest hit 2 times the BGL
	Cd	1 samples	Slightly exceed
	Ca, Mg, Na	10 samples	Over for these samples near MILAN debris
	C, Co	1 sample	Over for both samples at target #4
	Cu	1 sample	Slightly over at target #1
	Pb	4 samples	Slightly over at target # 1 and 2
	Mo	4 samples	Over t target # 2 and 4
	Sr	All samples	Over (highest hit 3 times the BGL

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: parameters fond both in the GW and in the surface soils or in the ground water and the biomass

In red: parameters found only in the ground water

TABLE XIX - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, AND THE BGL OR THE SQGL FOR SOILS FOR THE RIFLE RANGE

Matrix	***Parameters exceeding either the BGL or the QGL***		
GW	As (1), Cr (1), Co (1), Cu (2), Pb (1), Fe (1), **Mn (1)**, Ni (1), Ru (1), **Sn (1)**, **Ti (1)**, Zr (1)		
Soils	**As**	6 samples	Over ASQG, highest at 1,4 times higher
	Bi	21 samples including 6 sub-surface	Over BGL highest 21 times higher
		32 samples	Over the BGL and ASQG
	Cu	17 samples	Results over 100 ppm. Both surface and subsurface soils were impacted with high levels of Cu. Maximum level at 84 times higher than the ASQG
	Pb	All samples	Presented high levels of lead. Results varied from 32 ppm to 44,000 ppm. In range #2, the results exceeded the ISQG by 73 times
	Ni	4 samples including surface and subsurface soils	Exceeded the ASQG. Maximum level at 3.6 times higher
	Sr	4 samples	Slightly exceeded the BGL in ranges 1 and 2
	Tl	5 samples	Slightly exceeded the BGL in ranges #2 and 4
	Sn	7 samples	Over BGL in ranges #2 and 4. Maximum level at 3 times higher
	Zn	14 samples	Exceeded the ASQG including surface and subsurface. Maximum level at 683 times higher
Biomass	Al	1 sample	Slightly exceeded the BGL for Al
	As	4 samples	Exceeded (maximum level at 2 times higher
	Sb	All samples	Maximum level at 218 times higher
	Ca, Mg, Na	10 samples	Over for either Ca, Mg or Na
	Cu	8 samples	Maximum level at 6.3 times
	Fe	1 sample	Slightly over
	Pb	All samples	Vary from 38 to 789 times the BGL
	Mo	3 samples	Slightly over
	Se	4 samples	Slightly over
	Sr	10 samples	Maximum level at 2.4 times higher

Matrix	***Parameters exceeding either the BGL or the QGL***		
	V	1 sample	Slightly over
	Zn	All samples	Maximum level at 2 times higher

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: parameters fond both in the GW and in the surface soils or in the ground water and the biomass

In red: parameters found only in the ground water

TABLE XX - PARAMETERS EXCEEDING EITHER THE BGL OR THE WQGL FOR GROUND WATER, AND THE BGL OR THE SQGL FOR SOILS FOR THE GRENADE RANGE

Matrix	***Parameters exceeding either the BGL or the QGL***		
GW	Al (2), Ag (1), As (2), Bi (1), Cd (1), Co (1), Cu (1), **Cr (2),** Ce (1), Fe (2), Mn (1), Ni (1), Pb (1), Se (2), Ru (1), Sn (2), **Ti (2),** Tl (2), Va (1), W (2), Zn (1), Zr (2)		
Soils	**Cd**	All samples	Over ASQG, highest at 4 times
	Cr	All samples	Over BGL, highest at 1.5 times
	Cu	All samples	Over ASQG, highest at 5 times
	Pb	13 samples	Over ASQG, highest at 5.7 times the ASQG, 20 times the BGL
	Mg	12 samples	Over BGL, highest at 1.5 times
	Ni	9 samples	Over ASQG, highest at 1.2 times
	Ti	7 samples	Over BGL, highest at 1.3 times
	Zn	All samples	Over ASQG, highest at 12 times
Biomass	No biomass samples were collected during sampling in 2001		

In bold fonts: Results either higher than the AWQG or higher than twice the BGL

In blue fonts: parameters fond both in the GW and in the surface soils or in the ground water and the biomass

In red: parameters found only in the ground water

TABLE XXI: ENERGETIC MATERIAL CONCENTRATIONS IN SOILS

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-BG-69940E 18340N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-52660E 22764N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	30,5
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	21,8
	Average													26
S-BG-80356E 06945N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-57997E 20636N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-65629E 17392N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		Energetic material concentrations in soils ppb (µg/Kg)												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-63783E 17228N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-78159E 99759N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-62630E 18054N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-79182E 00111N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-74864E 14968N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		**Energetic material concentrations in soils ppb (µg/Kg)**												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-49148E 13157N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-49148E 13157N (dup)	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-55265E 11847N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-74864E 18968N (dup)	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.
	Average													
S-BG-55255E 09752N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-53656E 11283N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-80720E 05003N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.
	Average													
S-BG-53670E 13403N	a	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-67858E 98938N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-68067E 97960N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		**Energetic material concentrations in soils ppb (µg/Kg)**												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-69431E 98407N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-63565E 60626N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-BG-62033E 01742N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	11,3	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	14,6
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	17,5	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	20,0
	Average						14							17
S-A-HS-60021E 12160N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-HS-60042E 12060N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 20%-A	a	11,3	N.D.	N.D.	5,8	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	18,1	N.D.	N.D.	5,9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	15			6									
S-A-LS20%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	29,5	N.D.	5,0	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	25,5	N.D.	6,4	N.D.	N.D.	N.D.	N.D.	N.D.
	Average						28		6					
S-A-LS 40%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 40%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 40%-B(DUP)	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-GR-30M-A	a	N.D.	N.D.	113,2	2875,0	N.Q.	6,6	N.D.	16,1	18,5	N.D.	20,0	N.D.	N.D.
	b	N.D.	N.D.	128,0	3875,0	N.Q.	18,9	N.D.	12,7	18,1	N.D.	33,5	N.D.	N.D.
	Average			121	3375		13		14	18		27		
S-GR-30M-B	a	N.D.	N.D.	5,1	85,0	N.D.	N.Q.	N.D.	7,0	14,3	N.D.	10,8	N.D.	N.D.
	b	N.D.	N.D.	2,6	71,5	N.D.	N.Q.	N.D.	4,0	5,2	N.D.	6,0	N.D.	N.D.
	Average			4	78				6	10		8		
S-GR-35M-A	a	N.D.	N.D.	5,8	79,5	N.D.	16,8	N.D.	20,5	43,8	N.D.	31,2	34,2	19,7
	b	N.D.	N.D.	3,3	60,8	N.D.	9,6	N.D.	14,9	36,5	N.D.	27,0	18,1	12,6
	Average			5	70		13		18	40		29	26	16
S-GR-35M-B	a	N.D.	N.D.	3,2	7,2	N.D.	8,2	N.D.	N.Q.	26,2	N.D.	16,4	N.D.	N.D.
	b	N.D.	N.D.	1,4	6,7	N.D.	6,50	N.D.	N.Q.	20,0	N.D.	14,6	N.D.	N.D.
	Average			2	7		7			23		16		
S-GR-HS-57538E 18001N	a	N.D.	N.D.	N.Q.	5,8	N.Q.	695,0	N.D.	1775,0	47,0	N.D.	30,8	N.D.	219,2

SAMPLE		***Energetic material concentrations in soils ppb (μg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	N.D.	17,1	N.D.	755,0	N.D.	2600,0	18,0	N.D.	22,1	N.D.	163,0
	Average				11		725		2188	33		26		191
S-GR-5M-A	a	N.D.	N.D.	4,4	6,5	N.D.	N.Q.	N.D.	3390,0	12,9	N.D.	37,8	N.D.	154,8
	b	N.D.	N.D.	0,5	2,5	N.D.	N.D.	N.D.	4725,0	N.D.	N.D.	30,8	N.D.	152,8
	Average			2	5				4058			34		154
S-GR-5M-B	a	9,1	N.D.	2,7	5,4	N.D.	8,5	N.D.	42,2	35,5	N.D.	36,5	65,0	N.D.
	b	16,5	N.D.	1,8	3,9	N.D.	6,1	N.D.	21,4	22,0	N.D.	16,2	37,5	N.D.
	Average	13		2	5		7		32	29		26	51	
S-GR-10M-A	a	N.D.	N.D.	3,9	17,4	N.D.	5,2	N.D.	1257,5	28,2	N.D.	36,5	N.D.	43,0
	b	N.D.	N.D.	1,9	22,1	N.D.	7,7	N.D.	2312,5	8,2	N.D.	50,0	N.D.	79,5
	Average			3	20		6		1785	18		43		61
S-GR-10M-B	a	N.D.	N.D.	2,2	4,1	N.D.	N.Q.	N.D.	117,0	18,0	N.D.	21,0	N.D.	N.D.
	b	N.D.	N.D.	0,9	2,7	N.D.	N.Q.	N.D.	60,2	4,7	N.D.	9,6	N.D.	N.D.
	Average			2	3				89	11		15		
S-GR-15M-A	a	N.D.	N.D.	2,4	6,2	N.D.	6,2	N.D.	71,0	13,5	10,2	28,0	N.D.	12,7

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	1,2	8,9	N.D.	8,2	N.D.	71,0	7,5	6,5	18,8	N.D.	17,6
	Average			2	8		7		71	11	8	23		15
S-GR-15M-B	a	N.D.	N.D.	2,4	3,6	N.D.	N.Q.	N.D.	775,0	17,2	14,6	9,0	N.D.	29,5
	b	N.D.	N.D.	2,7	2,4	N.D.	N.Q.	N.D.	900,0	36,0	15,0	8,0	N.D.	47,5
	Average			3	3				838	27	15			39
S-GR-15M-B(DUP)	a	N.D.	N.D.	2,8	13,4	N.D.	5,4	N.D.	41,5	20,1	N.D.	15,0	N.D.	N.D.
	b	N.D.	N.D.	2,1	6,6	N.D.	5,4	N.D.	21,4	6,6	N.D.	8,6	N.D.	N.D.
	Average			2	10		5		31	13		12		
S-GR-20M-A	a	N.D.	N.D.	3,4	8,4	N.Q.	N.Q.	N.D.	63,2	11,7	N.D.	9,8	N.D.	14,8
	b	N.D.	N.D.	2,5	7,5	N.D.	N.Q.	N.D.	69,2	7,0	N.D.	7,5	N.D.	14,5
	Average			3	8				66	9		9		15
S-GR-20M-B	a	N.D.	N.D.	15,3	10,9	N.D.	N.Q.	N.D.	1537,5	21,3	N.D.	11,3	N.D.	83,5
	b	N.D.	N.D.	1,8	10,5	N.D.	N.Q.	N.D.	1322,5	5,7	N.D.	12,2	N.D.	98,2
	Average			9	11				1430	14		12		91
S-GR-25M-A	a	N.D.	N.D.	3,8	26,5	N.D.	N.Q.	N.D.	33,0	16,2	N.D.	12,0	N.D.	19,8

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	b	N.D.	N.D.	2,1	23,1	N.D.	N.Q.	N.D.	19,2	5,4	N.D.	19,2	N.D.	18,6
	Average			3	25				26	11		16		19
S-GR-25M-B	a	N.D.	N.D.	2,9	14,8	N.D.	52,5	N.D.	36,0	21,7	N.D.	23,4	N.D.	16,0
	b	N.D.	N.D.	1,6	11,1	N.D.	26,0	N.D.	18,9	11,0	N.D.	10,2	N.D.	N.D.
	Average			2	13		39		27	16		17		
S-GR-25M-B(DUP)	a	N.D.	N.D.	11,0	40,2	N.D.	9,1	N.D.	147,0	27,2	N.D.	20,0	N.D.	25,8
	b	N.D.	N.D.	2,2	27,8	N.D.	7,9	N.D.	128,0	15,0	N.D.	11,8	N.D.	16,8
	Average			7	34		9		138	21		16		21
S-C-HS--65266E 02930N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-HS-66040E 02939N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-C-HS-66017E 02566N	a	N.D.	N.D.	2,6	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	1,4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average			2										
S-C-HS-65011E 02663N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-HS-63025E 02811N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-HS-68010 02205N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 120%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	14,2	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	6,5	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average						10							

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-C-LS 120%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	5,0	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	5,3	N.D.	N.D.	N.D.	N.D.	N.D.
	Average								5					
S-C-1-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-1-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-1-3-5	a	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-2-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		Energetic material concentrations in soils ppb ($\mu g/Kg$)												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
S-C-2-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	23,2	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	16,8	N.D.	N.D.	N.D.	N.D.	N.D.
	Average								20					
S-C-2-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-3-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-3-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-3-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		**Energetic material concentrations in soils ppb (µg/Kg)**												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
S-C-HS-65235E 02908N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 20%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 20%-B	a	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	20,9	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	22,8	N.D.	N.D.	N.D.	N.D.	N.D.
	Average								22					
S-C-LS 40%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 40%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		Energetic material concentrations in soils ppb (µg/Kg)												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
S-C-LS 40%-A(DUP)	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 60%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 60%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 80%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 80%-B	a	11,5	N.D.	N.D.	8,3	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	12,5	N.D.	N.D.	4,9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	12			6,6									

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-C-LS 80%-B(DUP)	a	N.D.	N.D.	4,9	51,2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	2,2	41,7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average			4	46									
S-C-LS 100%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-C-LS 100%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-HS-63240E 15109N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-HS-63240E 15109N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		***Energetic material concentrations in soils ppb (μg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-E-1-0-1	a	18,5	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	24,8	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	22												
S-E-1-1-3	a	45,2	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	36,2	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	41												
S-E-1-3-5	a	408	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	313	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	360												
S-E-2-0-1	a	5,7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	4,9	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	5												
S-E-2-1-3	a	11,4	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	10,1	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	11												

SAMPLE		**Energetic material concentrations in soils ppb (µg/Kg)**												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
S-E-2-3-5	a	65,8	N.D.	N.D.	2,3	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	46,0	N.D.	N.D.	2,0	N.Q.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	56			2									
S-D-HS-74210E 01267N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-D-HS-74326E 01195N	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-D-HS-74215E 01278N	a	N.D.	N.D.	N.D.	N.D.	N.Q.	55,2	N.D.	N.D.	39,2	N.D.	40,8	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.Q.	37,0	N.D.	N.D.	12,4	N.D.	15,1	N.D.	N.D.
	Average						46			26		28		
S-D-1-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-D-1-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-D-1-3-5	a	6,1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	6,0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	6												
S-D-2-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-D-2-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-D-2-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		**Energetic material concentrations in soils ppb (µg/Kg)**												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
	Average													
S-A-2-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-2-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-2-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 60%-A	a	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-A-LS 60%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	2068	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	1034	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average						1551							
S-A-LS 80%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	5,4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	4,1	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average						5							
S-A-LS 80%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 80%-B(DUP)	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 100%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		Energetic material concentrations in soils ppb (µg/Kg)												
Name	**Number**	**NG**	**1,3-DNB**	**2,6-DNT**	**2,4-DNT**	**TNB**	**TNT**	**PETN**	**RDX**	**4-Am-DNT**	**3,5-DNA**	**2-Am-DNT**	**Tetryl**	**HMX**
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 120%-A	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-LS 120%-B	a	N.D.	N.D.	N.D.	N.D.	N.D.	55,2	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	52,5	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average						54							
S-A-1-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-A-1-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
	Average													
S-A-1-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-3-0-1	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-3-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-3-3-5	a	8,6	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	16,1	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average	12												

SAMPLE		***Energetic material concentrations in soils ppb (µg/Kg)***												
Name	***Number***	***NG***	***1,3-DNB***	***2,6-DNT***	***2,4-DNT***	***TNB***	***TNT***	***PETN***	***RDX***	***4-Am-DNT***	***3,5-DNA***	***2-Am-DNT***	***Tetryl***	***HMX***
S-E-4-0-1	a	N.D.	N.D.	N.D.	2,3	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-4-1-3	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	Average													
S-E-4-3-5	a	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
	b	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.Q.	N.D.	N.D.	N.D.	N.D.	N.D.
Estimated DL in extract		2,0	0,20	0,16	0,18	0,60	0,10	5,0	0,60	0,32	0,40	0,50	4,0	5,0
		Sample had numerous interference peaks												
a and b: lab duplicates		Sample analyzed only in diluted solution												
Quantification limits in soils (ppb)		5	0,5	0,4	2	10	0.25	12,5	1.5	0,8	5	1,3	10	12,5

Note = the quantification limits take into account the interference peak and background results.

N.D. : not detected

N.Q. : detected, but not quantified

TABLE XXII: THORIUM CONCENTRATIONS IN SOIL SAMPLES

Sample	***Concentration (ppm)***	***Sample***	***Concentration (ppm)***
S-BG-69940	3.89	S-E-HS-63450	2.46
S-BG-52660	3.26	S-E-1-0-1	2.94
S-BG-80356	2.59	S-E-1-1-3	3.26
S-BG-57997	3.04	S-E-1-3-5	3.46
S-BG-65629	1.19	S-E-2-0-1	2.10
S-BG-63783	2.74	S-E-2-1-3	2.98
S-BG-78159	1.41	S-E-2-3-5	3.17
S-BG-62630	2.70	S-D-HS-74210	3.68
S-BG-79182	3.52	S-D-HS-74215	5.55
S-BG-74864	3.64	S-D-HS-74215	1.79
S-BG-49148	1.76	S-D-1-0-1	2.37
S-BG-49148	2.97	S-D-1-1-3	4.14
S-BG-55265	3.90	S-D-1-3-5	2.31
S-BG-74864	2.41	S-D-2-0-1	1.31.
S-BG-55255	2.19	S-D-2-1-3	1.40
S-BG-53656	3.54	S-D-2-3-5	2.33
S-BG-80720	1.54	S-D-2-1-3	1.95
S-BG-53670	2.83	S-A-LS-80%B	3.44
S-BG-67858	3.21	S-A-LS-100%A	2.85
S-BG-68067	2.17	S-A-1-0-1	6.35
S-BG 69431	2.86	S-A-3-0-1	3.14
S-BG-63565	2.19	S-A-3-1-3	4.50
S-BG-62033	3.19	S-E-3-3-5	2.24

Sample	***Concentration (ppm)***	***Sample***	***Concentration (ppm)***
S-BG-MEAN	**3 ± 1**	S-E-4-0-1	3.41
S-A-LS-20%B	2.81	S-E-4-1-3	3.52
S-A-LS-40%A	2.38	S-E-4-3-5	2.92
S-C-1-0-1	2.05	Internal standard 6.5	6.5
S-C-2-1-3	4.46	Internal standard 1.2	1.22
S-C-3-3-5	2.43	Blank-1	<0.1
S-C-LS-20%B	2.50	Blank-2	<0.1
S-C-LS-40%A	3.66		
S-C-LS-40%A DUP	2.17		
S-C-LS-80%B	3.03		
S-C-LS-80%B-DUP	3.27		
S-C-LS-100%A	2.39		
S-E-HS-63240	4.67		

In red: value higher than mean background level + twice standard deviation

TABLE XXIII THORIUM CONCENTRATIONS IN BIOMASS SAMPLES

Sample	***Concentration (ppb)***
B-D-1-0-3	0.16
B-D-1-0-3	0.18
B-D1-3-5	0.54
B-D-12-0-3	0.25
B-D-2-3-5	0.43
B-E-1-0-3	0.97
B-E-1-3-5	0.85
B-E-2-0-3	0.77
B-E-2-3-5	0.99
B-E-HS-63240 15109	0.47
B-E-H-S-63240 15109 DUP	0.57
B-E-HS-64435 14486	1.38
B-E-HS-64435 14486	0.58
B-E-3-0-1 RACINE	15.69
B-E-3-0-3	0.68
B-E-3-3-5	1.03
B-E-4-0-3	0.93
B-E-4-3-5	0.83
BG-1	0.66
BG-2	0.75

Figures

Figure 1: Epinette Creek River

Figure 2. Assiniboine River

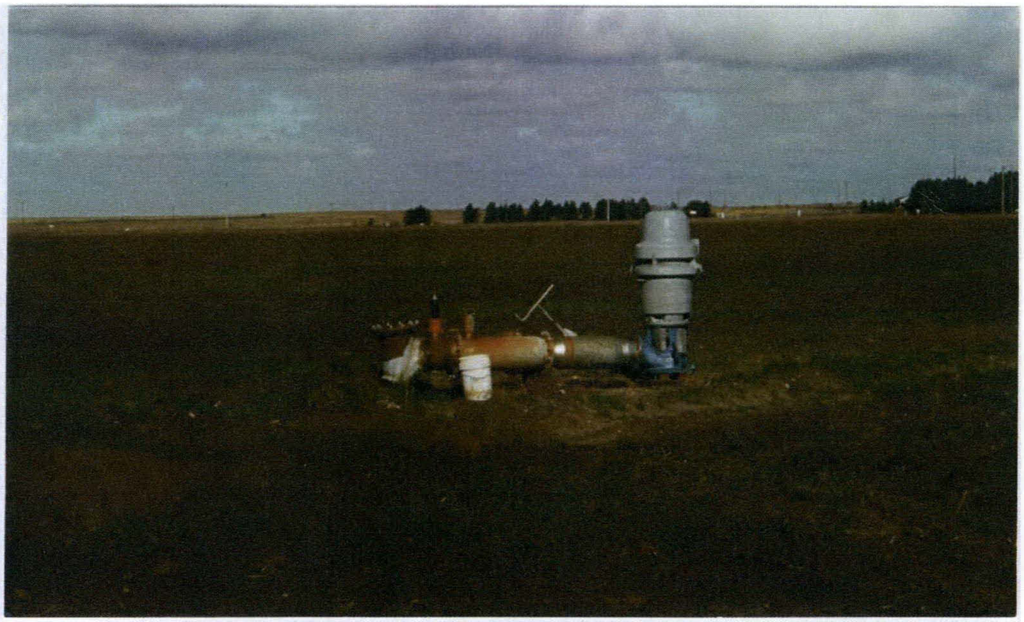


Figure 3. Irrigation Well in a Farmland Nearby CFB Shilo

Figure 4. Irrigation Well in a Farmland Nearby CFB Shilo

Figure 5. Preparation for Proofing of Well Location

Figure 6. Well Location Proofing Using EM-61

Figure 7. Background Soil Samples on Road 5

Figure 8. Background Soil Sample in Grazing Area NE of Base

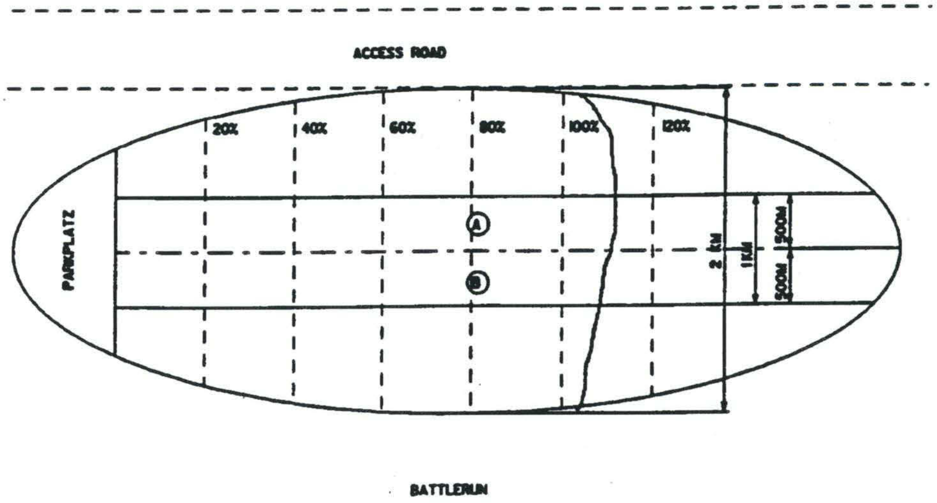


Figure 9. Schematic View of the Linear Soil Sampling Pattern

Figure 10. Typical CFB Shilo Topography Where Linear Sampling Was Applied

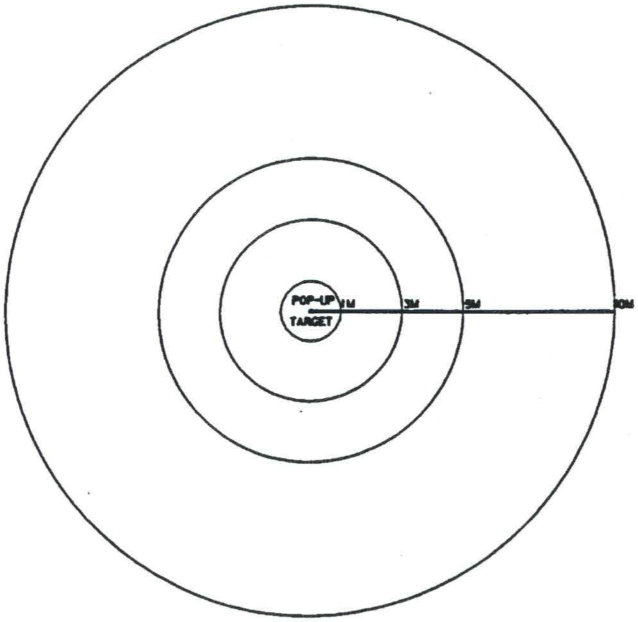


Figure 11. Circular Sampling Around Targets

Figure 12. Sampling of Soils in Essen Target Area Using Circular Approach

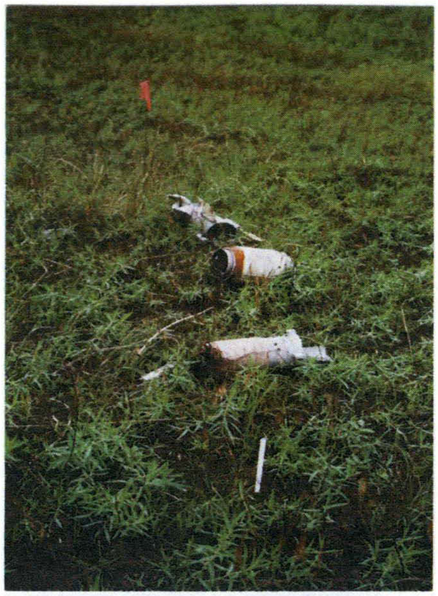


Figure 13. MILAN Missile Debris in Essen

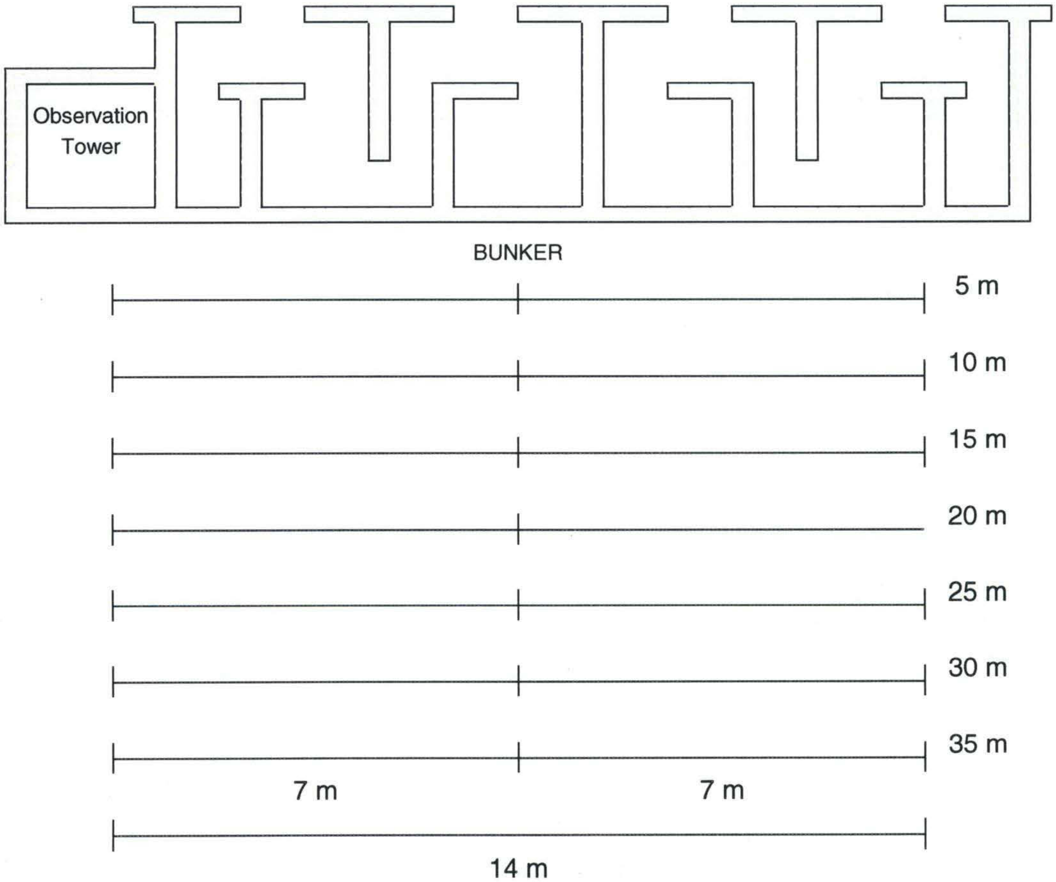


Figure 14. Grenade Range Sampling Illustration

Figure 15. Grenade Range Shilo

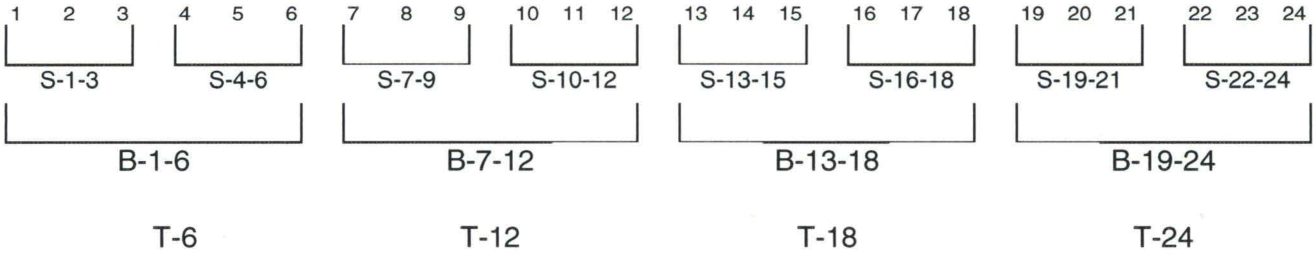


Figure 16. Rifle Range Sampling Illustration

Figure 17. Rifle Range Shilo

Figure 18. Decontamination of Drilling Equipment

Figure 19. Pumping of Well Equipped with Flush Mount Protective Casing

Figure 20. Development of Wells Using Mechanical Waterra Pump

Figure 21. Device for Injecting Compressed Air Into Well (Slug Tests)

Figure 22. GPS Location System for Well Land Surveying

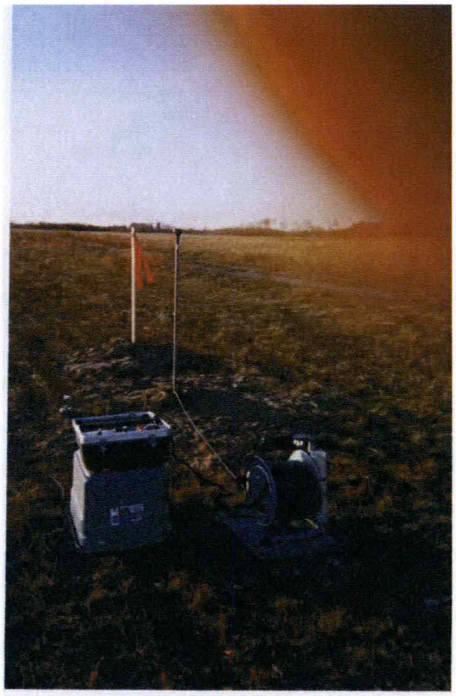
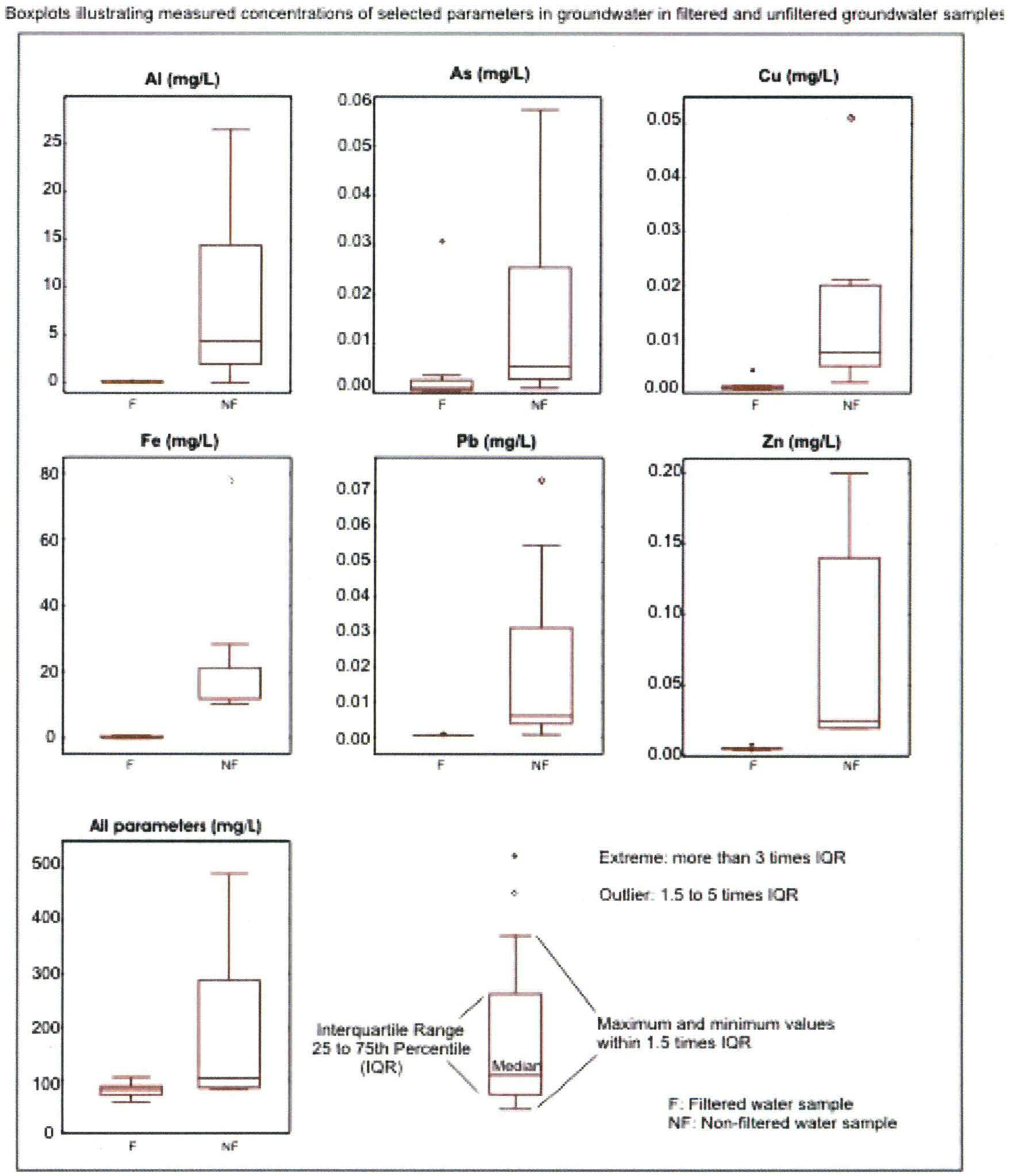


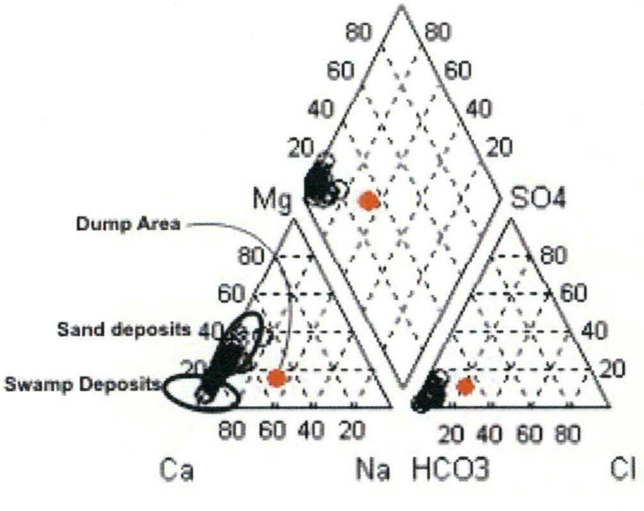
Figure 23. Hydraulic Head Measurements Using GEOFLO 40



Boxplots illustrating measured concentrations of selected parameters in groundwater in filtered and unfiltered groundwater samples

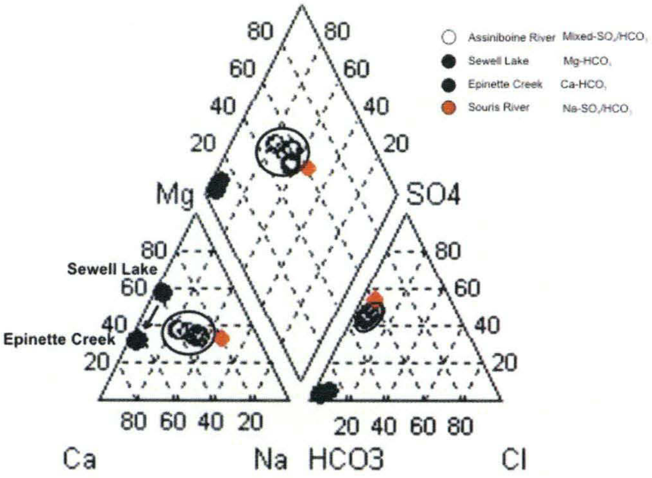
Figure 24. Comparison of Measured Concentrations of Selected Parameters in Filtered and Unfiltered Groundwater Samples

Figure 25. Double Needle Device for Sampling VOC's



Piper diagram illustrating an increase in magnesium as groundwater flows from the swamp deposits north of CFB Shilo to the deltaic sand deposits covering most of CFB Shilo

Figure 26. Piper Diagram of Groundwater at CFB Shilo.



Piper diagram illustrating the water types of rivers and streams surrounding CFB Shilo

Figure 27: Piper Diagram for Surface Water

Figure 28. Anti-Tank Range Shilo

Figure 29. Unexploded Ordnance (UXO) CFB Shilo

Figure 30 UXO, CFB Shilo

Figure 31. UXO, CFB Shilo

Figure 32. MILAN Missile Target in Essen, Shilo

Appendix A

CFB/ASU SHILO AMMO EXPENDITURE RECORD

CANADA **YEAR**	**AMMO TYPE**	**ROUNDS FIRED**	**DUDS REPORTED**	**DUDS DESTROYED**	**REMARKS**
1971	ALL	10,000	NOT AVAL	NOT AVAL	ESTIMATE
1972	ALL	10,800	NOT AVAL	NOT AVAL	
1973	ALL	11,000	NOT AVAL	NOT AVAL	
1974	ALL	12,000	NOT AVAL	NOT AVAL	
1989	66MM HEAT	331	1	2	ROCKET RANGE
	84MM HEAT	784	137	132	ROCKET RANGE
	105MM	11,457	26	36	ALL NATURES
	155MM	3,695	0	13	
	81MM	4,142	4	42	
	60MM	81	0	2	
YEAR TOTAL (LESS ROCKET RANGE)		19, 375	30 (0.2%)	93 (0.5%)	
1991	66 AND 84MM HEAT	984	NOT AVAL	41	ROCKET RANGE
	105MM	9,396	NOT AVAL	5	ALL NATURES
	155MM	2,878	NOT AVAL	13	
	81MM	3,006	NOT AVAL	11	
YEAR TOTAL (LESS ROCKET RANGE)		15, 280	NOT AVAL	70 (0.5%)	
1994	66MM HEAT	240	NOT AVAL	39 (16%)	FIELD FIRING
1997	105MM	4,289	6	NOT AVAL	4,010 RDS AREA B
	155MM	751	NOT AVAL		
	81MM	2,644	1	NOT AVAL	2,392 AREAS C,D,E

CANADA ***YEAR***	***AMMO TYPE***	***ROUNDS FIRED***	***DUDS REPORTED***	***DUDS DESTROYED***	***REMARKS***
					C,D,E
	60MM	291	0	NOT AVAL	ALL AREA B
YEAR TOTAL		7, 975	7 (0.01%)	NOT AVAL	53% AREA B
1998	105MM	3,815	3	NOT AVAL	2,944 RDS AREA B
	105MM TK	644	0	NOT AVAL	ALL AREA B
	155MM	1,077	2	NOT AVAL	827 RDS AREA B
	81MM	1,123	0	NOT AVAL	705 RDS AREA B
	60MM	59	0	NOT AVAL	ALL AREA B
	ERYX	24	0	0	ALL AREA B
YEAR TOTAL		6,742	5 (0.001%)	NOT AVAL	68% AREA B
1999	66MM HEAT	81	NOT AVAL	NOT AVAL	
	84MM TP RAP	137	NOT AVAL	NOT AVAL	
	84MM HEAT	50	NOT AVAL	NOT AVAL	
	105MM	5,049	NOT AVAL	NOT AVAL	
	105MM SH PRAC TK	85	NOT AVAL	NOY AVAL	
	105MM TPFSDST TK	282	NOT AVAL	NOT AVAL	
	155MM	4,204	NOT AVAL	NOT AVAL	
	81MM	1,471	NOT AVAL	NOT AVAL	
	60MM	223	NOT AVAL	NOT AVAL	
	TOW/ERYX	12	0	0	
YEAR TOTAL (LESS 66 AND 84MM)		11,326	NOT AVAL	NOT AVAL	

APPENDIX B

DEFENCE CONSTRUCTION CANADA – REPORT OF ACTIVITY

1. INTRODUCTION

This is a summary report on the follow-up fieldwork conducted as part of the DREV/INRS Shilo II project initiated in September, 2001. The DREV/INRS team was supported by DCC for the installation of ground water observation wells, and the conduct of both water sampling and biomass sampling, on the CFB Shilo Range, during the period of September 6 through September 22.

2. BACKGROUND

After completion of the initial field program in September, the decision was made by DREV/INRS that some additional fieldwork was required to fill data gaps. Arrangements were made by INRS with DCC to undertake a short program of additional work on the Range to conduct further field measurements primarily on the newly installed ground water observation wells. In addition, the DCC team was requested to take various water quality measurements in the field (water levels, ORP, YSI 95 and YSI 63 readings), as well as to collect surface water samples and select well samples for VOC analyses.

3. WORK PROGRAM

The additional fieldwork was conducted during the period of November 26 through 30, 2001. The work program, as per instructions from INRS, included the following:

1. various linear distance measurements relative to the construction of the water wells;
2. collection of ground water samples for VOC lab analyses at 3 wells;
3. various *in situ* ground and surface water quality parameter measurements using INRS provided field monitoring probes; and,
4. ground water elevation measurements at 3 ground water wells installed during Shilo I in 2000.

4. DCC FIELD TEAM

The fieldwork was undertaken by a two person DCC environmental services team from the DCC Western Region. It was decided by DCC that the work to be undertaken would not require the mobilization of the full DCC environmental team, as was the case in September. It was also recommended to INRS that DCC environmental services staff that were originally involved in Shilo II also conduct the follow-up work. Because of DCC staff familiarity with well locations, and Shilo Range protocol and field conditions, this resulted in the work being completed as expeditiously as possible.

Funding for the DCC team was provided by way of an extension to the original contract to DCC from DREV. The contract was managed out of DCC's Shilo Office, and the local DND OPI continued to be the CFB Shilo Eng.O.

5. PROCEDURES

5.1. Equipment and Supplies:

INRS provided DCC with a water level recorded, an ORP probe, a YSI Model 95 and YSI Model 63 probe, as well as pH 4,7 and 10 solutions for Model 63 calibration. Along with the probes and measuring equipment, INRS provided a VOC sampling device and pre-labelled VOC sample bottles.

DCC supplied: the tools required to access the wellheads; the distilled (deionized) water for probe decontamination washing between testing; the measuring equipment; and, protective items such as gloves

5.2. Laboratory Analyses:

EnviroTest Laboratories' Manitoba Technology Centre (ETL) was requested to undertake sample analyses for the work, as an extension of their contract for the entire Shilo I and II projects. Samples collected by DCC were kept in iced conditions, stored in a sample cooler with frozen ice pack, and delivered by DCC to ETL at the completion of the work on November 30. A chain-of-custody form was completed by DCC and signed by ETL.

ETL had been requested by INRS to manage and split the samples, after receipt, and to send whatever samples necessary to the DREV laboratories in Valcartier, Quebec, for their further analyses.

5.3. Ground water Well Measurement, Testing and Sampling:

For those wells requiring measurement work, a program of field access was developed and discussed with Seargent-Major Roeder, OC Range Control, CFB Shilo. Access was coordinated with Range activities, including live fire excercises and field training in each of the Range Areas. The program was altered to fit daily restrictions, and coordination was undertaken with Range Control at the outset of each day's planned activities. During the day, Range Control was kept advised of DCC movements from one Area to another.

The DCC proposed field program for accessing wells was as follows:

1. Area E - Deilinghofen Battle Run (GW-D-9, 11, 12 and 13)
2. Area 7 - Training Area (GW-Zone-7 and 7W)
3. Area D - Cologne Battle Run (GW-C-8 and 9)
4. Area B - Aachen and Essen Battle Runs (GW-A-9 and 10, GW-E-7,8,9 and 11)
5. Area 5 - Training Area (GW-Zone-5S and 5N)
6. Area 4 - Training Area (GW-Zone-4E and 4W)
7. Zone 9 - Training Area (GW-Zone-9S, 9N and 9W)
8. Area A - Danger Area (GW-RIF-1 and 3, GW-TR, GW-GRE, GRE-1 and 2, GW-ATR-1 and 2)
9. Ammo Area (GW-AMA-1 and 2)

10. Antenna Area (GW-Antenna)
11. Background (Carberry Area - GW-BGR-3)
12. Camp Hughes (GW-BGR-4)
13. Base Area (GW-SUP-5, 16 and 27, GW-OBS-SUP-16 and 27, GW- Gate-S)

The access sequence was altered daily in order to not enter off-limits areas for the day. This resulted in a lengthier program both temporally and in terms of total distance travelled. The background wells were located off-Base at Camp Hughes and at the Brandon Junction Tower, south of the town of Carberry on Highway 5 (extreme northeast corner of Range Zone 10), some 30 and 60 km from Base Shilo respectively.

The total distance travelled during the field measurement phase of the program was approximately 650 km over anti-tank roads, Range trails and cut lines, tank trails and tracked routes, and main and secondary Highways.

5.4. Surface Water Testing and Sampling:

In addition, the field program required the collection of two surface water samples (SW-SE-1 and 2) from both Sewell Lake (dock location) and Epinette Creek (railway embankment location). The latter was inaccessible as a result of winter weather and ground cover conditions. A Lake sample was taken from a hole chipped through the ice at the dock.

5.5. Ground water Elevation Recording:

Three monitoring wells were listed in INRS instructions as requiring the measurement of water levels, as recorded from the top of the PVC well, with cap removed. These were monitoring wells MW-101, 102 and 108, installed in 2000 during Shilo I. MW-109, a fourth in the MW series of installations, was required to be tested only for ORP.

6. RESULTS

6.1. Climatic Conditions:

During the period of November 26 through 30, 2001, the weather at CFB Shilo consisted of light to heavy snow fall throughout the days, with continual cloud cover and periods of high winds, causing temporary visual "white-outs" on roadways and snow drifting on the Range. The daily temperatures were approximately -12 °C to -19 °C, not including the windchill factor.

The depth of snow on the ground throughout the Range varied from about 10 cm to 25 cm. The soils were frozen wherever mixed with snow, such as on the tracked routes and trails.

Hours of daylight were between approximately 07:30 hours and 16:30 hours, although work in and around the Base and Range could be continued until around 17:00 hours daily. Thereafter, work continued under lighted conditions as necessary.

6.2. Ground water Well Measurements:

At each well location, where GPS coordinates and elevations were determined by Lennon Surveys in September, a series of measurements were required in order to correct water level data for lengths of well stick-up or depths of wellhead below the ground level. At flush-mounted wells, the measurements required were: "A" - the distance between the top of the protective casing and the ground; and, "B" - the distance between the protective casing cap and the top of the PVC pipe constituting the screened well. For some wells, the casing extended just above the ground level, and at others the casing and well had sunk to below the ground level, although originally installed essentially flush with the ground. The two measurements will allow for a correction of water level data to a true ground water elevation relative to the surveyed elevations of September.

What is not known is whether the elevations tied-in by Lennon Surveys earlier were taken when the installation was still essentially flush with the ground or after differential settlement had taken place. Given the relatively thick strata of nearly homogeneous sandy soils, and the nature of the land-use in and around the wells, a certain amount of shifting of the well installation may have been anticipated at the outset of Shilo II.

The data from the current measurements (see Table 1) indicates that 16 of 34 wellheads had settled into the ground to depths varying from 0.9 cm to 18.30 cm below ground level, leaving depressions of various depths.

Of the " 3 ft stick-up" wells installed, fitted with protective steel covers, the distances of stick-up above ground varied from 88.1 cm to 98.8 cm to the top of the PVC tube.

The measurement data is being used by DCC to prepare ground water borehole logs indicating well installation information.

Table 1. Well Measurement Results at CFB Shilo - November, 2001

GW Well Location	**Distance "A" ***		**Distance "B" *****	**Stick-Up Distance** *(cm)* ********
	(cm above ground)	*(cm below ground)***	*(cm)*	
OBS-SUP-16	1.20		4.30	
OBS-SUP-27		5.10	5.10	
GW-Antenna				90.60
GW-Ammo-1				95.70
GW-Ammo-2				89.00
GW-Zone-4E				88.10
GW-Zone-9S		3.40	6.40	
GW-Zone-9W		6.90	5.10	
GW-Zone-7W	1.10		7.90	
GW-Zone-7	0.80		4.80	
GW-D-9	2.70		7.50	
GW-C-8	2.10		7.10	
GW-D-11	1.90		4.70	
GW-D-12	0.90		4.30	

GW-D-13	1.20		6.20	
GW-C-9		18.30	5.80	
GW-A-10		1.90	4.60	
GW-A-9		3.10	7.80	
GW-E-9		8.30	3.10	
GW-E-8	1.60		2.80	
GW-E-7		3.30	5.30	
GW-E-11	0.10		6.10	
GW-Zone-9N		2.60	5.70	
GW-BGR-3	2.60		4.20	
GW-BGR-4	1.60		5.80	
GW-RIF-3		12.10	5.70	
GW-RIF-1	not located			
GW-SUP-5	base supply well installation			
GW-SUP-16	base supply well installation			
GW-TR		9.50	6.30	
GW-GRE	0.00		8.10	
GW-GRE-2		0.90	5.80	
GW-GRE-1		6.10	11.80	
GW-Gate-S		8.80	10.30	
GW-Zone-4W				98.80
GW-Zone-5N		3.00	13.80	
GW-Zone-5S		8.70	12.80	

** distance "A" (above ground): between the top of the protective metal cap (above ground) and the soil surface*

*** distance "A" (below ground): between the soil surface and the top of the protective metal cap (below ground)*

****distance "B": between the top of the protective metal cap and the top of the PVC well*

*****stick-up distance: between top of PVC well and soil surface*

6.3. Water Testing Results - ORP:

The results of the testing program (which was conducted as a second priority after all ground water well measurements were obtained) are listed in Table 2. Testing was done with 3 probes provided by INRS. The ORP (oxidation reduction potential) probe required no calibration, and measured the redox potential of the ground water, which tend to decrease as the water migrates along the path of a regional flow system.

Table 2. Oxidation Reduction Potential Measurements at CFB Shilo - November, 2001

Ground water Well Location	*ORP Reading (millivolts)*
MW 109	- 094
GW-SUP-5	- 034
GW-SUP-16	- 039
GW-9W	093

The results indicate that three of four readings were slightly negative in value. These values will be used with all other measurements taken during Shilo II to present a regional depiction of flow system behaviour.

The ORP of the Lake Sewell sample was 047 mV, at a water temperature of 3.5 °C.

6.4. Water Testing Results - Dissolved O_2:

DO levels were measured with the YSI Model 95 probe, a handheld dissolved oxygen and temperature system. The results of this follow-up work are presented in Table 3.

Table 3. Dissolved Oxygen Readings at CFB Shilo - November 2001

Ground water Well Location	*DO Readings*		*Temperature*
	mg/l	*%*	*°C*
GW-SUP-5	1.76	14.8	8.0
GW-SUP-16	0	0	7.7
GW-TR	0	0	8.9
GW-9W	1.09	9.7	7.6
GW-Gate-S	7.46	63.7	8.6
GW-Zone-4W	12.06	101.6	7.7
GW-Zone-5N	9.52	82.1	8.7
GW-Zone-5S	11.04	91.6	7.0

The DO level of the lake sample (SW-SE-1) was recorded as 14.09 mg/l (97.4 %) at a water temperature of 0.3 °C.

6.5. Water Testing Results - pH, Conductivity and Salinity:

These parameters were measured downhole with the YSI Model 63 probe, calibrated daily, at the ground water well locations listed in Table 4. In addition, readings for pH, conductivity and salinity were also taken in Lake Sewell , by lowering the probe (along with the YSI Model 95 probe) through the open hole in the ice cover. For each reading, the indicated YSI 63 temperature was also recorded.

Table 4. pH, Conductivity and Salinity Readings at CFB Shilo - November, 2001

GW Well Location	**Temperature *°C***	**pH**	**Salinity *(ppt)***	**Conductivity *(mS or (μS)***
GW-SUP-5	7.0	7.00	0.0	1.5 mS
GW-SUP-16	7.1	6.99	0.0	1.7 mS
GW-TR	8.9	6.38	0.2	336.4 μS
GW-9W	7.6	6.86	0.2	355.6 μS
GW-Gate-S	8.0	7.35	0.3	359.7 μS
GW-Zone-4W	8.2	7.41	0.2	367.8 μS
GW-Zone-5N	7.5	7.26	0.2	257.1 μS
GW-Zone-5S	5.3	7.33	0.0	1.1 mS

Three of the readings for conductivity were recorded as millisiemens/cm while the rest were in microsiemens/cm.

The readings for the above parameters on the lake water, just below the ice cap, were as follows: pH - 6.79; salinity - 0.2 ppt; and, conductivity - 193.8 uS. The temperature at the depth and time of reading with the YSI 63 probe was recorded at 3.5 °C.

6.6. Ground water Elevation Readings:

The level of standing water in the observation wells was measured using the water level probe provided by INRS. The wells requiring measurement were identified as MW 101, MW 102, and MW 108. In addition, water level was measured in GW-A-5, a 2000 Shilo I installation. Although the latter well required sampling for analyses, the waterra tubing could not be extracted, and probes (other than the water level probe) could not be lowered into the 5cm diameter well.

The readings are summarized in Table 5.

Table 5. Water Level Measurements Recorded at CFB Shilo - November 2001

Monitoring Well Location	Water Level Reading (m from top of well)	Top of Well Stick-up Distance (cm above ground level)
MW 101	5.133	70.5
MW 102	4.705	36.4
MW 108	6.080	87.7
MW 109	Not taken	62.0
GW-A-5	6.310	- Protective cap 0.8 cm above grade - 2.42 cm between cap and well top

APPENDIX C

Grain size analysis, hydraulic conductivity, borehole logs
and ground water samples analyses

<u>CD ON BACK COVER</u>

APPENDIX D

Maps of CFB Shilo

Chart held at DRDKIM

If you would like to view chart, please contact DRDKIM 2-2

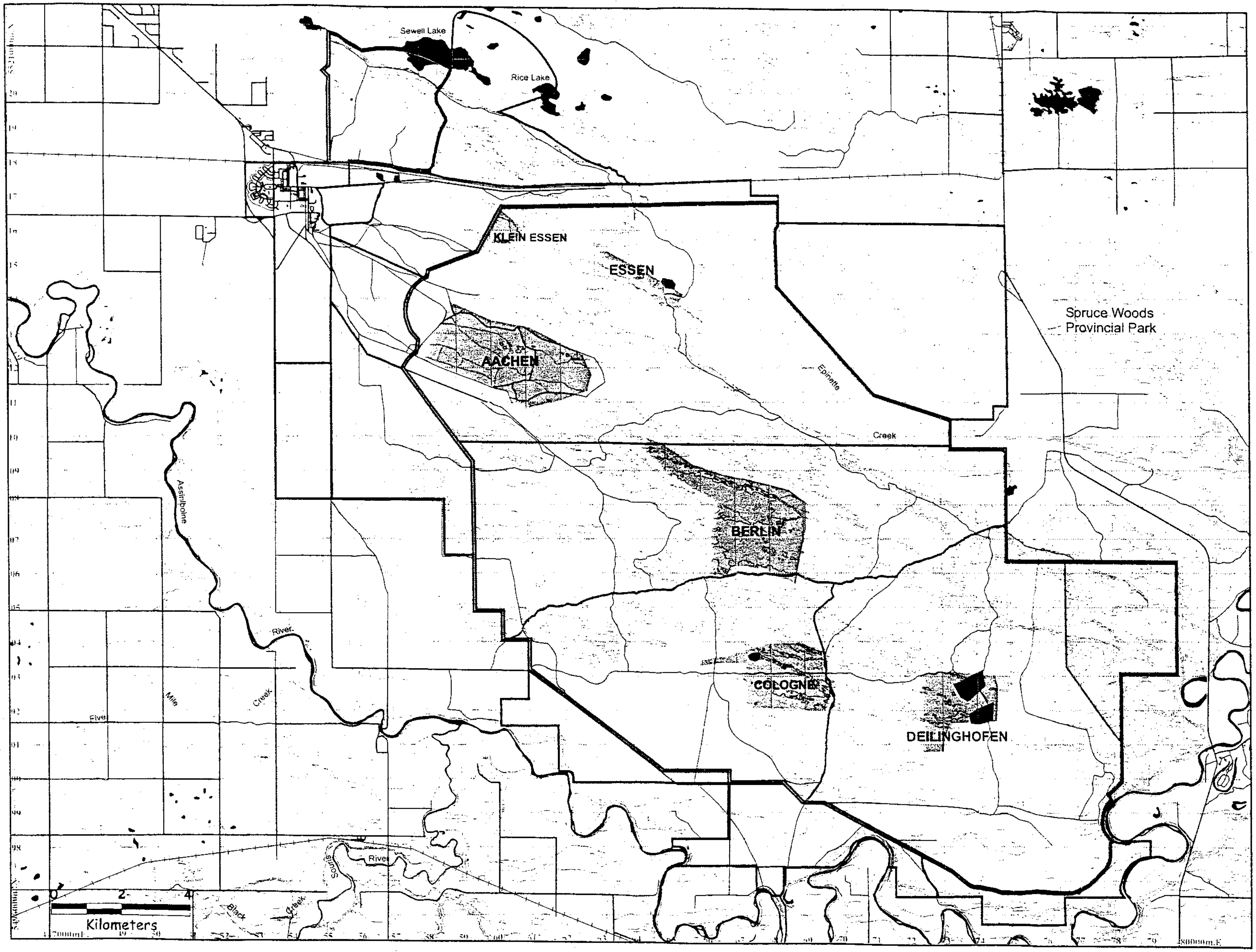


Plate 1

General View of
Canadian Forces Base
Shilo

CFB SHILO
Manitoba

Legend

A joint research project by
Defense Research and
Development Canada (DRDC)
and
Institut National de la
Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

[illegible]

Sources: Geomatique Canada, Natural Resources
Canada, 1999-2000 and Mapping and Charting
Establishment, Department of National Defence,
Canada, 1994, MCE 21

Drawn by Catherine Gauthier
Revised by René Lefebvre/Richard Martel

03/2003

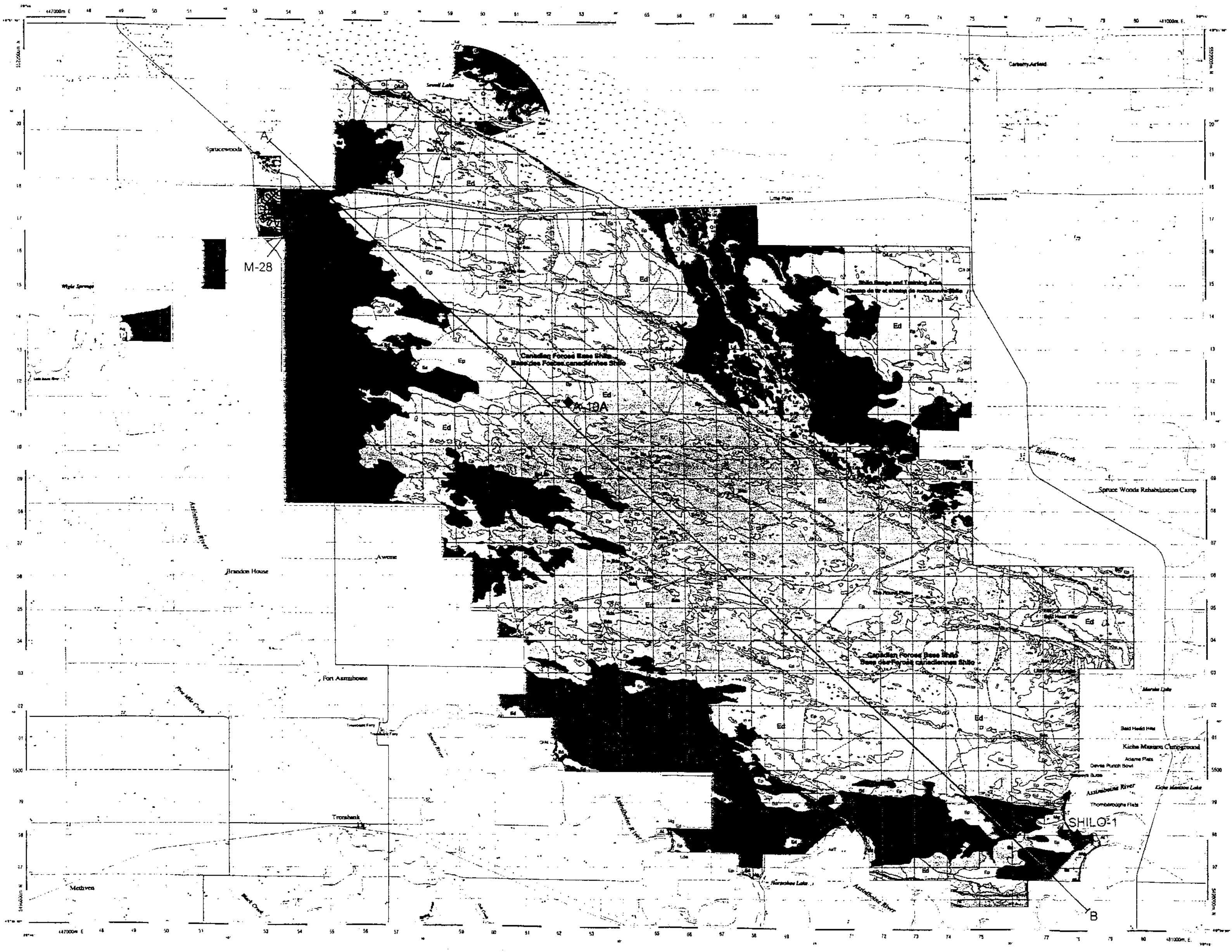


Plate 2

Surficial Geology

CFB SHILO
Manitoba

Legend
Quaterny Statigraphic Units

CENOZOIC

Slope sediments

■ Reworked sediments, silty clay and sand reworked by slumps along the Assiniboine River valley

Organic sediments

O Organic and organo-detrital sediments; thickness ranging from 0.3 to 1.5 m

Alluvial sediments

Aa Modern alluvium; poorly sorted sand, sandy silt, gravelly sand and gravel; thickness ranging from 0.5 to 3.0 m

At Terraced alluvium; gravel and sandy silt; thickness ranging from 0.5 to 5.0 m

Aeolian sediments

Sediments deposited by wind activity, mainly derived from proximal deltaic sediments; consisting mainly of well sorted fine to medium sand, minor coarse silt; observed thickness up to 10 m but inferred to reach 30 m under some dune crests

Ep Ep, flat to undulating subzone;

Ed Ed, dune subzone (deflation hollows and associated parabolic dunes and crests); stabilized by vegetation or active (stippled)

Glaciolacustrine sediments

Sediments deposited in Glacial Lake Agassiz

■ Deltaic sediments; coarse to medium sand, minor gravel and silt, cross- and plane-stratified; thickness ranging from 10 to 30 m; flat surface generally reworked by aeolian processes (Lde)

■ Prodeltaic sediments; silt, clay and silty sand; plane- to cross-laminated and locally interstratified with sand or sandy gravel; observed only in boreholes; thickness up to 26 m

Glacial sediments

Till; compact, gray diamicton, with silty, carbonate-rich matrix containing some clasts and a few boulders; deposited by glacier ice

■ Till exposed at the base of scarps along the Assiniboine River; observed thickness ranging from 3 to 11 m

Well defined geological limit

Area of active dunes

Terrace scarp cut in surficial sediments

Alluvial levee

Alluvial bar

Paleochannel : direction of flow in abandonned fluvial channels

◆ *Location of stratigraphic section or borehole*

A——B *Location of surficial geologic cross-section*

Kilometres

North American Datum 1983 (NAD 83)
Transverse Mercator Projection

Authors: Cloutier, M. R.
(Cogeo Consultants Inc.)
Parent, M.
(Geological survey of Canada)
Natural Ressouces Canada

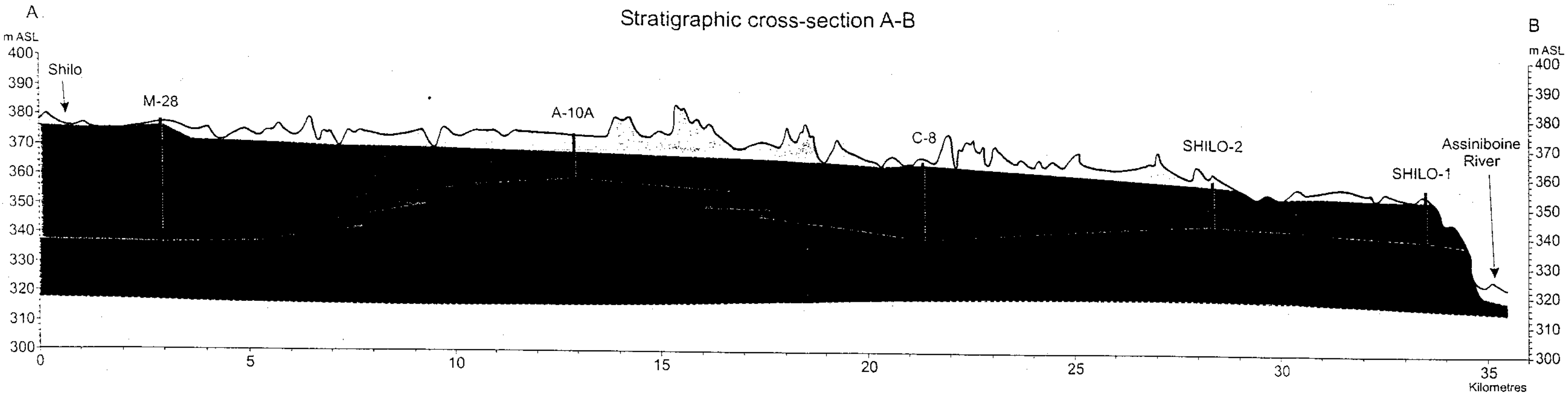
03/2003

Plate 3

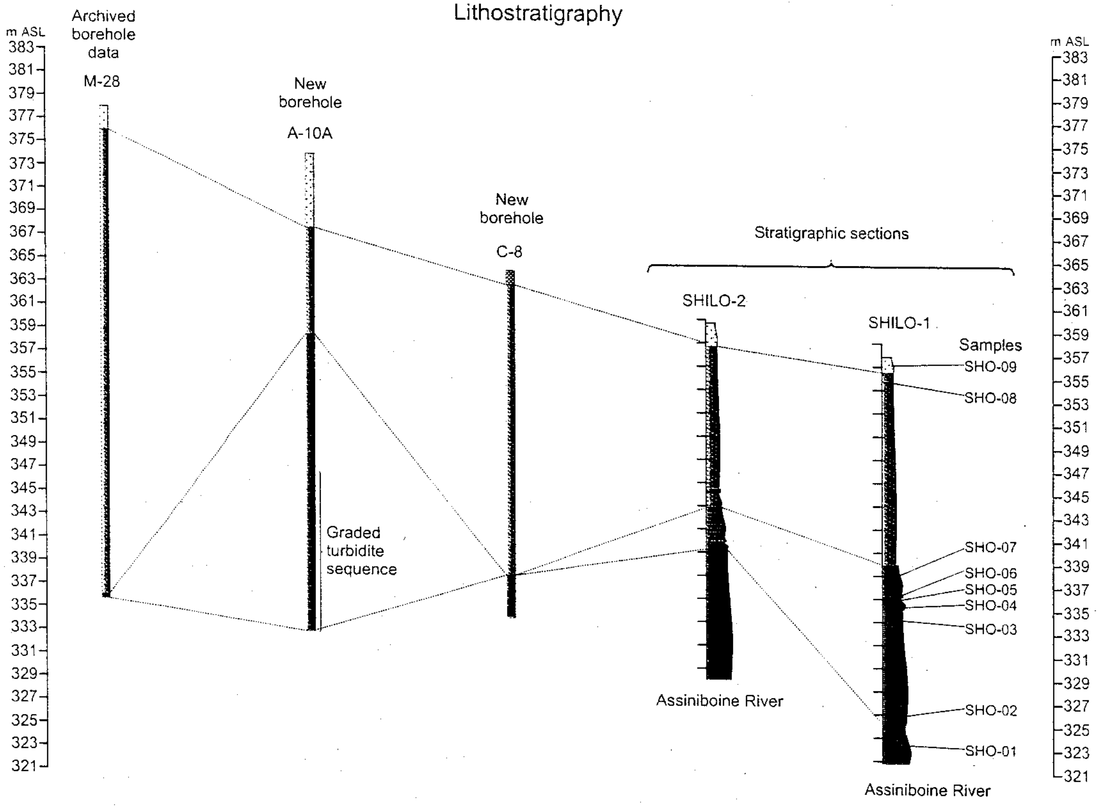
Stratigraphic section and lithostratigraphy

CFB SHILO
Manitoba

Stratigraphic cross-section A-B



Lithostratigraphy



Legend

- Ap Alluvial sediments
- Ed Aeolian sediments
- ■ Deltaic sediments
- ■ Prodeltaic sediments
- ■ Till
- ▩ Paleosol
- ▩ Gravelly horizon
- ▩ Brecciated horizon: Silty clay with clay intraclasts
- ░ Fine sand
- ░ Coarse to medium sand, minor gravel
- ▒ Silty sand (cross-laminated)
- ▒ Silty sand (plane-laminated)
- ▤ Clayey silt
- ▨ Silty clay
- ░ Till: compact, Silty sandy clay matrix; < 1% boulders

Authors:
Cloutier, M. R.
(Cogeo Consultants Inc.)
Parent, M.
(Geological survey of Canada)
Natural Ressouces Canada

03/2003

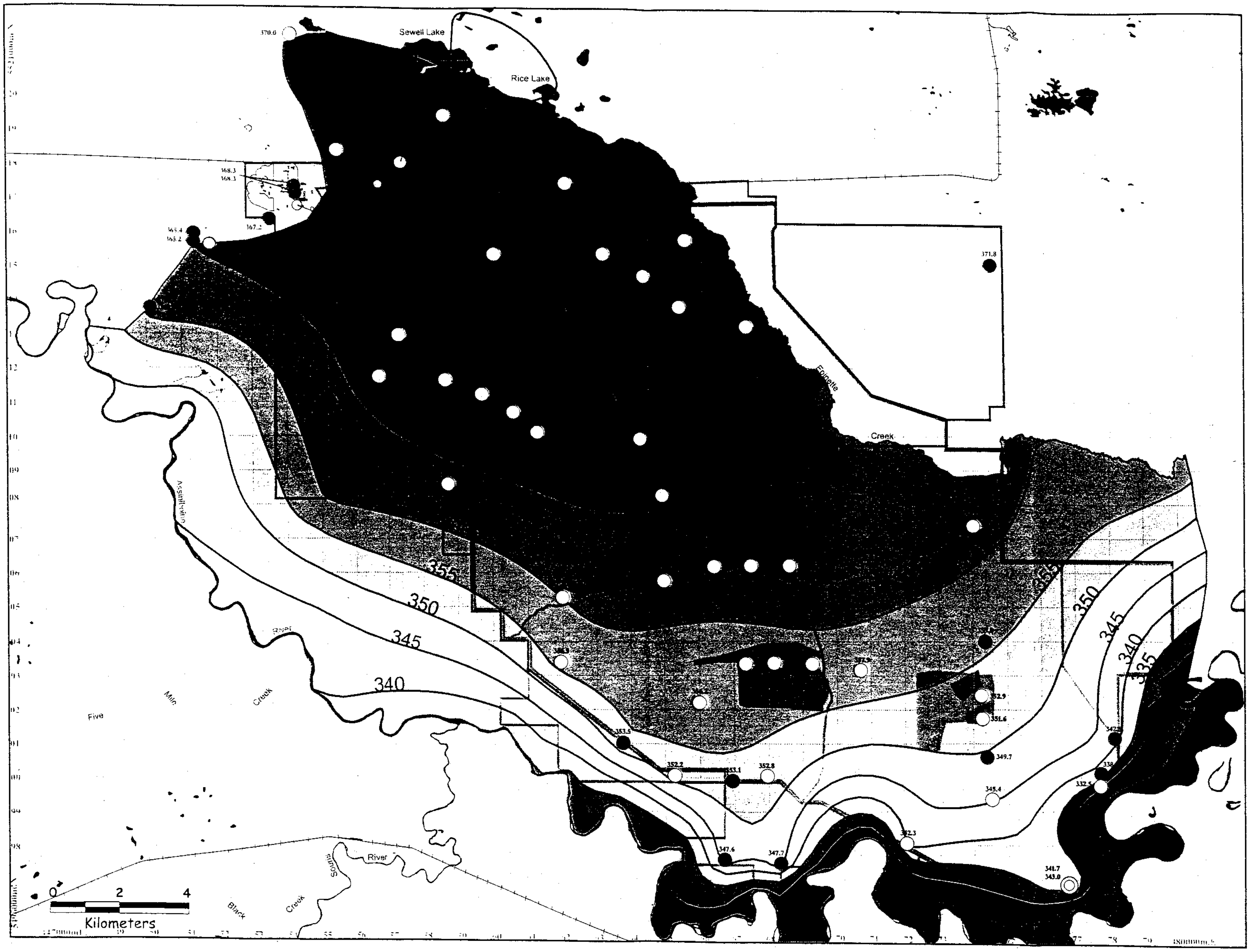


Plate 4

Water Table Elevation in the Unconfined Assiniboine Aquifer

CFB SHILO
Manitoba

N
W
E
S

Legend

Water Table Elevation (m)
Interval: 5 m

Water Table Measurement Point
Measurement Date: September 2001

● 2001 INRS Well

○ 2000 INRS Well

○ Existing Base Wells

Training Area Boundary - Area
Danger Area Boundary - Area
Roads
Secondary Roads and Trails
AACHEN Battlerun Name
Contour, with elevation (10 m interval)
Dump
Conventional Ammunition Impact Area
MILAN Missile Impact Area

Valcartier

A joint research project by
Defense Research and
Development Canada (DRDC)
and
Institut National de la
Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

Scale: 1:100 000

Sources: Geomatique Canada, Natural Resources Canada, 1999-2000 and Mapping and Charting Establishment, Department of National Defence, Canada, 1994, MCE 21

Drawn by catherine Gauthier
Revised by Rene Lefebvre/Richard Martel

03/2003

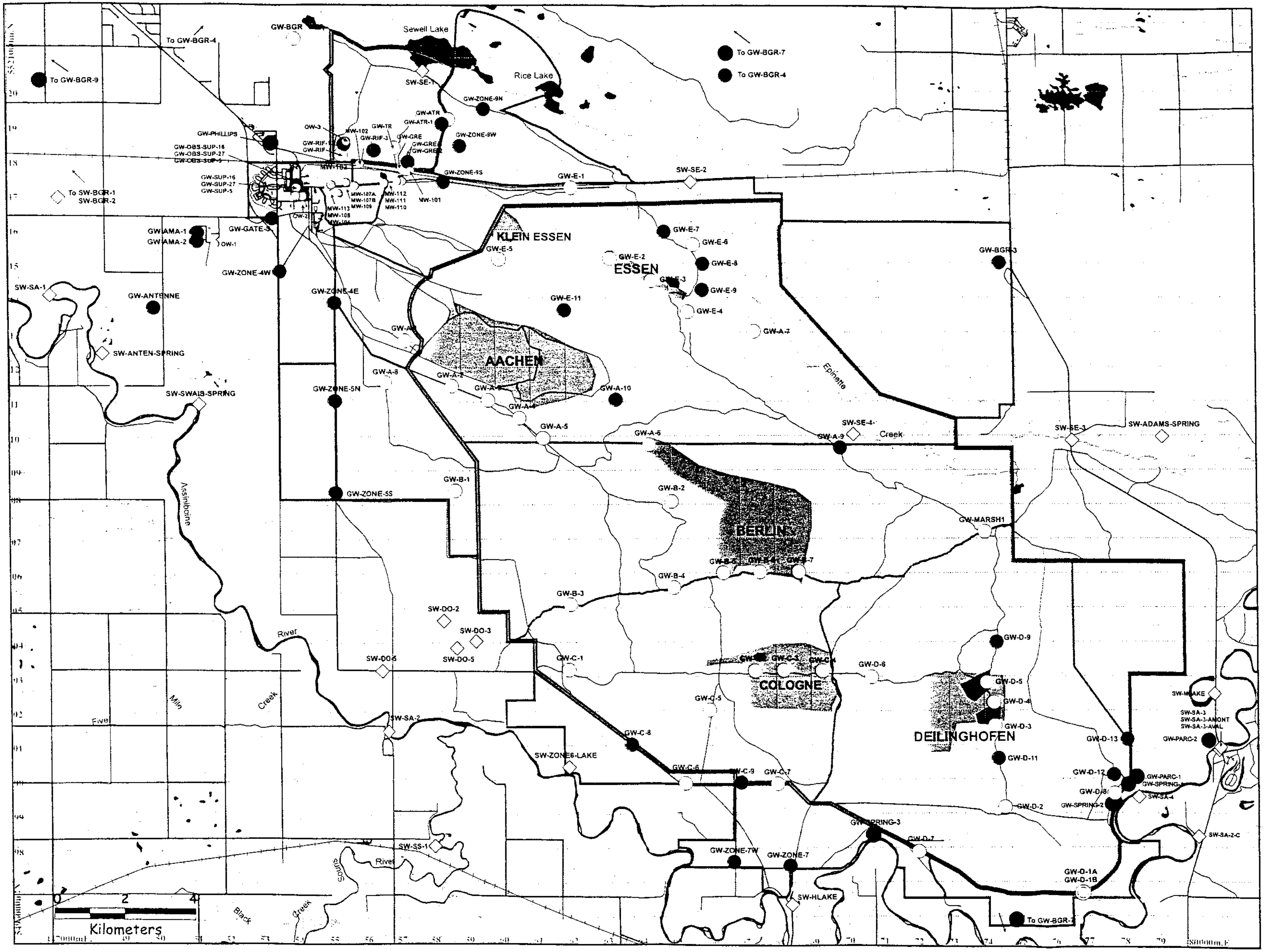


Plate 5

Sampling Locations for Surface and Ground Water

CFB SHILO
Manitoba

Legend

●	2001 INRS Well
○	2000 INRS Well
●	Private Wells and Springs
○	Existing Base Wells
◇	Surface Water

Training Area Boundary - Area
Danger Area Boundary - Area
Roads
Secondary Roads and Trails
AACHEN Battlerun Name
Contour, with elevation (10 m interval)
Dump
Conventional Ammunition Impact Area
MILAN Missile Impact Area

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Defense Research and
Development Canada (DRDC)
and
Institut National de la
Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

Sources: Geomatique Canada, Natural Resources Canada, 1999-2000 and Mapping and Charting Establishment, Department of National Defence, Canada, 1994. MCE 2

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Revised by Rene Lefebvre Richard Martel

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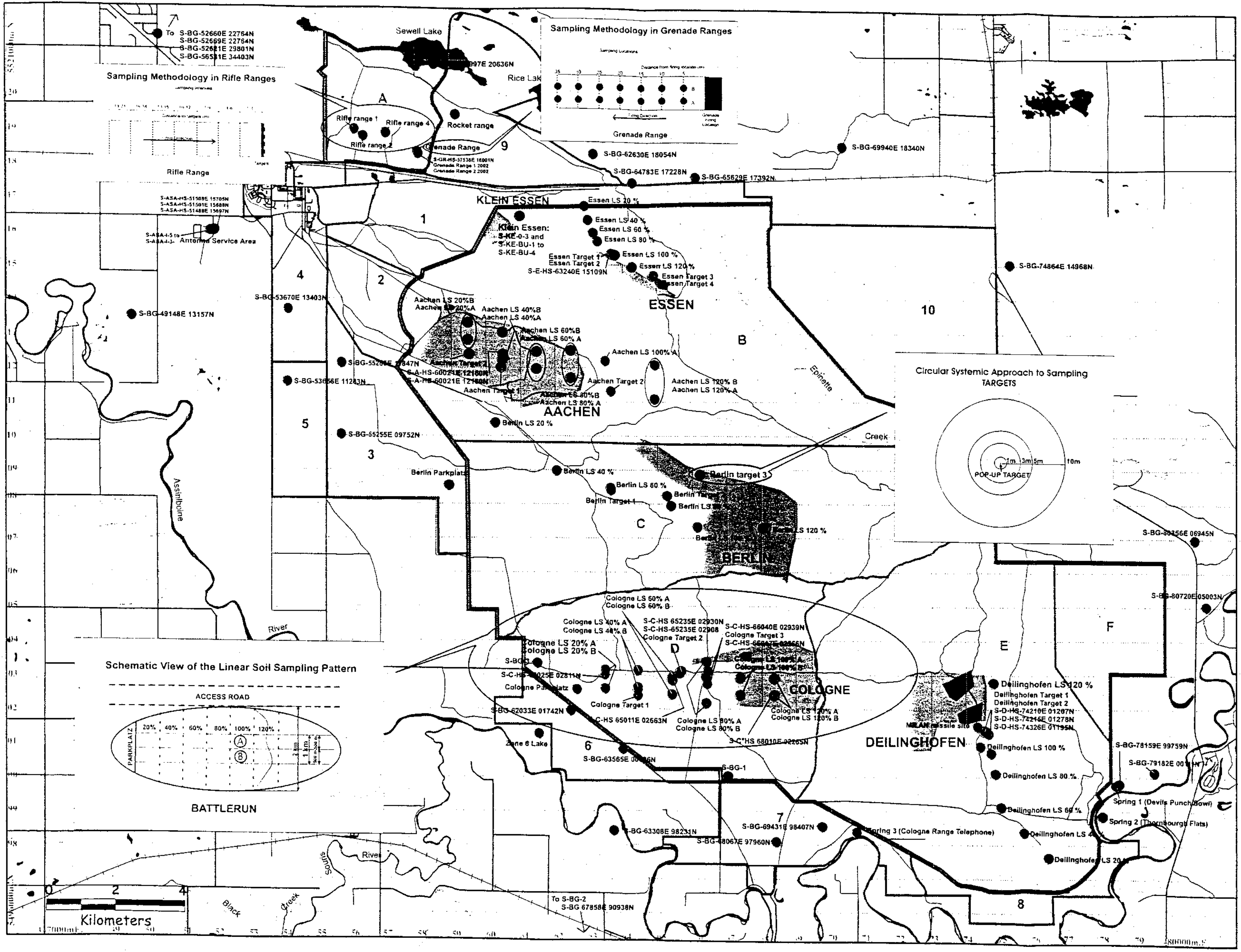

Plate 6

Location of Soil Samples and Description of Sampling Methods

CFB SHILO
Manitoba

N
W E
S

Legend

● Aachen LS 100% A
Sample Location
Sample Name

Training Area Boundary - Area
Danger Area Boundary - Area
Roads
Secondary Roads and Trails
AACHEN Battlerun Name
Contour with elevation (10 m interval)
Dump
Conventional Ammunition Impact Area
MILAN Missile Impact Area

RDDC Valcartier

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Defense Research and Development Canada (DRDC)
and
Institut National de la Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

Scale 1:100000

Sources: Geomatique Canada, Natural Resources Canada, 1999-2000 and Mapping and Charting Establishment, Department of National Defence, Canada, 1994. MCE 21

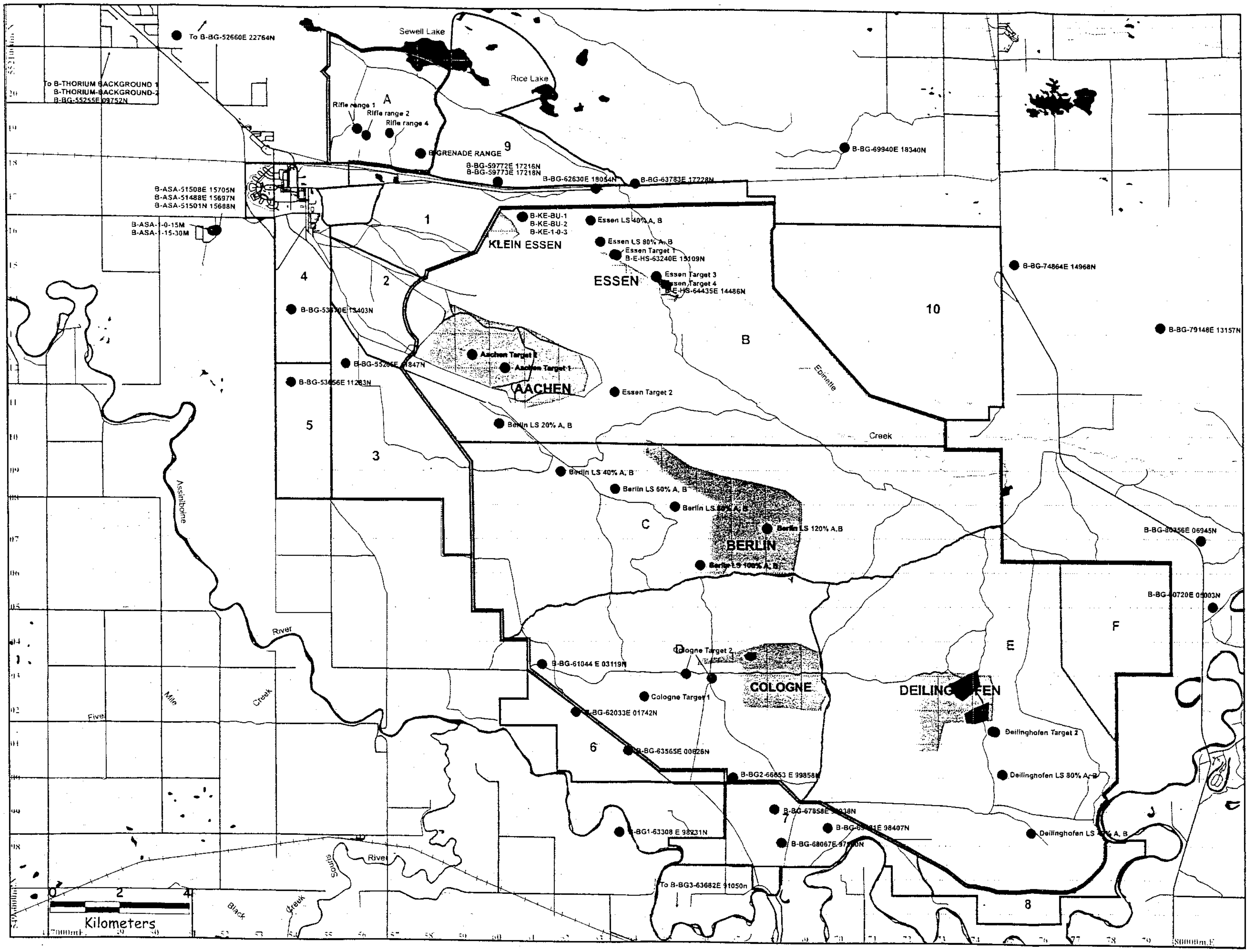
Drawn by Catherine Gauthier
Revised by Rene Lefebvre/Richard Martel

03/2003

Plate 7

Location of Biomass Samples

CFB SHILO
Manitoba



Valcartier

A joint research project by
Defense Research and
Development Canada (DRDC)
and
Institut National de la
Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

Scale

Sources: Geomatique Canada, Natural Resources Canada, 1999-2000 and Mapping and Charting Establishment, Department of National Defence Canada, 1994, MCE 21

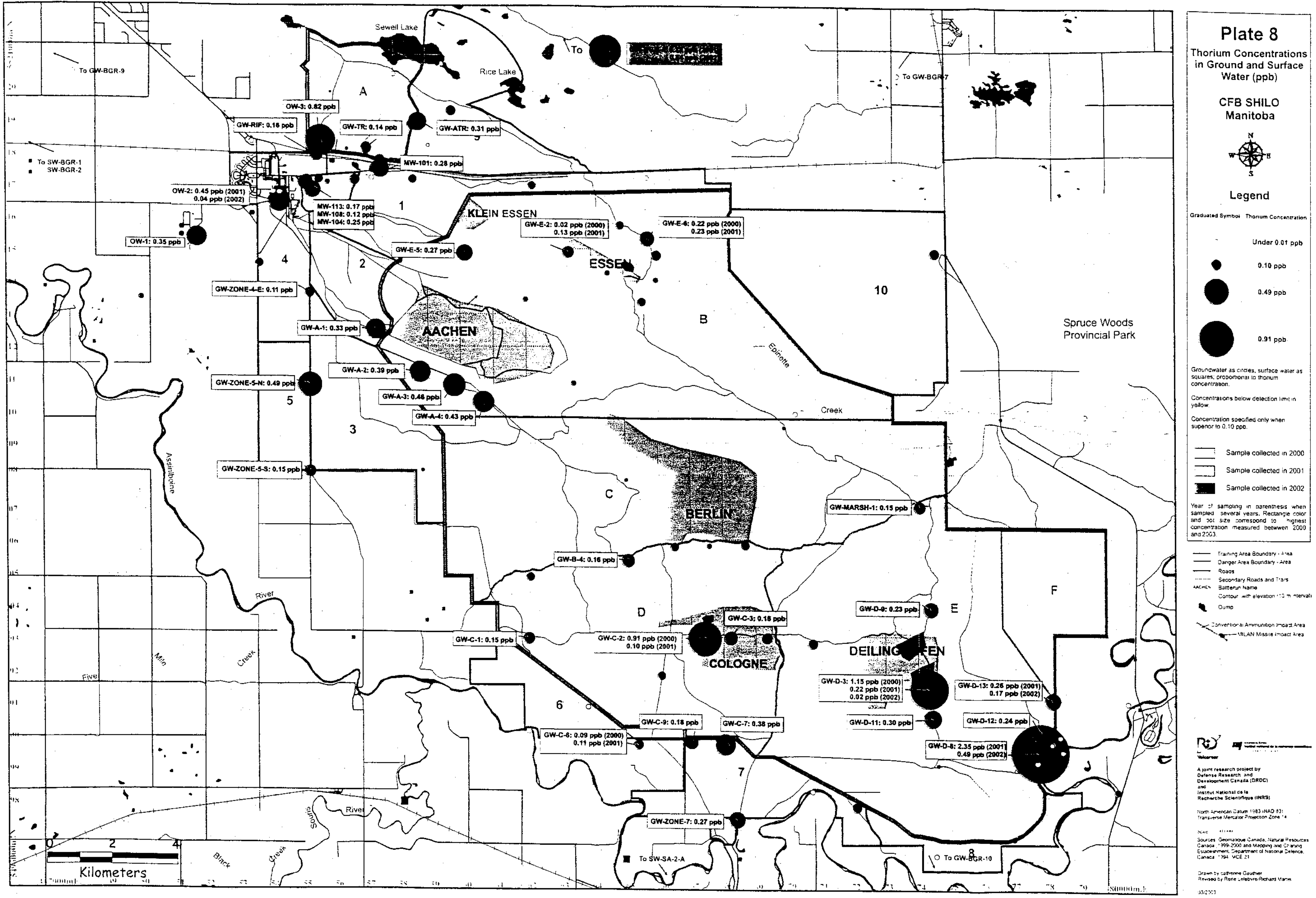
Drawn by Catherine Gauthier
Revised by Rene Lefebvre/Richard Martel

03/2003

Plate 8

Thorium Concentrations in Ground and Surface Water (ppb)

CFB SHILO
Manitoba



A joint research project by Defense Research and Development Canada (DRDC) and Institut National de la Recherche Scientifique (INRS)

North American Datum 1983 (NAD 83)
Transverse Mercator Projection Zone 14

Sources: Geomatique Canada, Natural Resources Canada, 1999-2000 and Mapping and Charting Establishment, Department of National Defence, Canada, 1994, MCE 21

Drawn by Catherine Gauthier
Revised by Rene Lefebvre/Richard Martel

03/2003

APPENDIX E

ppb à Bq/L Conversion Calculations

definition : 1 Bq = 1 radioactive disintegration per second

dN/dt = -k*N

where: k = disintegration constant (1/seconds)
N = number of thorium atoms

t = time (seconds)

Find k

k = ln(2) / t1/2

where : t1/2 = half life of thorium
= 1.4 x 1010 years
= 4.4 x 1017 seconds

therefore,
k = ln (2) / 4.4 x 1017 sec
k = 1.57 x 10-18 1/sec

Find N

definition: 1 ppb = 1 mg/1000 kg = 1µg/kg

Recall that 1 kg water = 1 litre

à 1µg/kg = 1 µg/L

1 mol Th = 232.04 g

à 1 µg Th = 4.31 x 10-9 mol

mols x Avogadro's constant gives the number of individual atoms.

Avogadro's Constant = 6.033 x 1023

à 4.31 x 10-9 mol x 6.033 x 1023 = 2.6 x 1015 atoms thorium = N

Find dN/dt

k x N = (1.57 x 10-18) 1/sec x (2.6 x 1015) atoms thorium

= 0.00408 atoms/second

à 1 ppb = 0.00408 Bq / L

CCME threshold criteria = 0.1 Bq/L

so, 0.1/0.00408 = 24.5ppb

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This work describes the evaluation of the impacts of the training activities in CFB Shilo training area and is the continuation of the first phase done in Sept 2000. During the first phase, three battleruns were sampled for energetic materials, metals, VOCs and petroleum products to measure their impacts on soils and biomass, as well as on subsurface soils, surface water and ground water in the training areas. Such an assessment required an appropriate definition and understanding of the geological and hydrogeological context of the site. During the second phase, the two remaining battleruns, the rifle and the grenade ranges were sampled according to procedures described in this report. Since some trends were encountered in phase I around target areas, more specific sampling, including biomass samples was conducted. Explosives, 232Thorium and heavy metals analyses revealed some localized problems related to environmental contamination and trends were observed that could be related to the firing activities. Some mitigation techniques are proposed for the identified problematic areas. Thorium analyses revealed a localized impact close to the targets both in surface soils and in ground water. The distribution of this chemical was not fully understood and more analyses were done at the end of the summer 2002 to establish if the concentrations in ground water are increasing or decreasing. Nevertheless, the concentrations of thorium in groundwater do not represent a threat being 10 times below the CCME criteria.

Ce travail décrit l'évaluation de l'impact des activités d'entraînement faites au secteur d'entraînement de la BFC Shilo et est la suite de la phase I, effectuée en septembre 2000. Durant la première phase, trois champs de bataille avaient été échantillonnés pour évaluer la contamination par les explosifs, les métaux, les COVs et les produits pétroliers afin de mesurer l'impact de ceux-ci sur les sols, la biomasse, la sous-surface, les eaux de surface ainsi que sur l'eau souterraine dans les aires d'entraînement. Une telle évaluation avait requis une définition appropriée et une compréhension du contexte géologique et hydrogéologique du site. Durant la seconde phase, les deux derniers champs de bataille ainsi que les sites de tir à armes légères et de grenade ont été échantillonnés selon la procédure décrite dans ce rapport. Compte tenu que des tendances avaient été observées autour des cibles dans la biomasse durant la phase I, plus d'échantillons autour des cibles ont été prélevés durant la phase II. Les analyses pour les explosifs, les métaux lourds et le thorium 232 ont révélé des problèmes locaux de contamination et des tendances d'accumulation de certains contaminants qui sont reliées aux activités de tir ont été observées. Les analyses pour le thorium ont révélé des impacts localisés près des cibles et un patron de contamination a été observé et ce, tant pour les sols de surface que pour les eaux souterraines. La contamination par le thorium n'était pas complètement comprise et des analyses complémentaires ont été effectuées à la fin de l'été 2002 pour évaluer si les concentrations augmentaient ou diminuaient. Néanmoins, les concentrations en thorium dans l'eau souterraine ne représentent pas un problème, celles-ci étant dix fois inférieures au critère CCME

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Characterization
Unexploded Ordnance
UXO
anti-tank
grenade
energetic materials
environmental impacts
contaminated range
firing range
demolition range

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