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FINAL REPORT

Report No. 1011688.

SCOPING STUDY TO ASSESS POTENTIAL HISTORICAL SURFACE AND GROUNDWATER MIGRATION ASSOCIATED WITH HERBICIDE SPRAYING OPERATIONS AT CFB GAGETOWN (TASK 2E)

PROJECT NO. 1002588.

PROJECT NO. 1002588. REPORT NO. 1011688.

REPORT TO	**Mr. Tony Gariano, PWGSC** **Technical Services** **Lorne Building, 90 Elgin St., 5th Fl.** **Ottawa, Ontario** **K1A 0S5**
FOR	**Lizanne Avon, Health Canada** **Pest Management Regulatory Agency** **Sir Charles Tupper Bldg, 2710 Riverside Dr.** **Ottawa, Ontario** **K1A 0K9**
ON	**Scoping Study to Assess Potential Historical Surface and Groundwater Migration Associated with Herbicide Spraying Operations at CFB Gagetown (Task 2E)**

May 25, 2006

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REPORT: GAGETOWN HERBICIDE MIGRATION

1.0 INTRODUCTION

1.1 Background

Jacques Whitford Limited (Jacques Whitford) was retained by Public Works and Government Services Canada (PWGSC), on behalf of the Department of National Defence (DND), to conduct an Environmental Site Assessment (ESA) related to historical herbicide use in the Range and Training Area (RTA) of Canadian Forces Base Gagetown (CFB Gagetown) in Oromocto, New Brunswick (NB), Canada. The ESA is in response to DND's Statement of Requirements (SOR) for Conducting a Site Assessment of the RTA at CFB Gagetown, originally submitted to Jacques Whitford by e-mail on July 18, 2005, and discussed in follow-up meetings between August 2, 2005, and September 29, 2005.

Jacques Whitford was contracted by PWGSC on August 18, 2005, to execute Call-up number 4 on the PWGSC National Capital Region (NCR) Standing Offer Agreement (SOA), which resulted in Task 2B, Stage 1 and Stage 2 Reports by Jacques Whitford dated December 14th and 16th, 2005, respectively. The recently completed field program ESA was also contracted through the PWGSC NCR SOA as call-up number 5 and is referred to as Task 2B, Stage 3, of the DND fact-finding initiative.

1.2 Introduction

Jacques Whitford Limited is submitting the following report to provide the results of a scoping study to examine the potential for assessing historical surface and groundwater migration that may have been impacted by herbicide spraying operations at CFB Gagetown, New Brunswick, from 1952 to 2005. This effort is known as Task 2E. The objective of this scoping study is to outline scientifically defensible approaches for the evaluation of this potential historical migration from source (application) areas to human receptor (potable water well and frequented surface water body) areas. The only transport medium being considered here is water (i.e., mobilization of herbicides and associated contaminants through surface runoff and through infiltration and subsequent groundwater flow) – herbicides that were applied through spraying operations (which were the majority of cases) would experience some airborne transport, potentially to areas outside of described application areas, and herbicides once adsorbed to soil particles or other matter with the potential for mobility could conceivably be transported by wind or other means to areas outside of described application areas.

In order to better establish the feasibility of executing the scoping study, available data covering the surface water and groundwater characteristics of the RTA were reviewed, as follows:

- Initial Environmental Evaluation of the Military Training Activities in the CFB Gagetown Training Area, Washburn and Gillis Assoc. Ltd., Jan. 28, 1994
- Research on the Environmental Conditions of Ground and Surface Water Prevailing in the Training Area at CFB Gagetown, New Brunswick – Part I, DRDC, Sep. 26, 2003
- Research on the Environmental Conditions of Ground and Surface Water Prevailing in the Training Area at CFB Gagetown, New Brunswick – Part II, DRDC, Apr. 18, 2005
- Interpretation of Baseline Stream Sediment and Water Quality Results CFB Gagetown, SNC Lavalin, 2005
- Vector Smart Map (VMAP) Level 2 Coverage Series: VMAP 2, MCE 24 Gagetown, 1997
- CFB Gagetown 1:10000 USGS Digital Elevation Model (DEM), DIIT, 1998

2.0 SCOPE OF WORK AND METHODOLOGY

2.1 Scope of Work

The scope of work for the scoping study was broken down into five tasks, as follows:

- Task 1: identification of potential human receptor (potable water well and frequented surface water body) locations
- Task 2: qualitative assessment of potential for surface water migration of herbicides and associated contaminants of concern to potential human receptor locations as identified in Task 2B through production of a sub-basin surface water drainage map using existing DEM
- Task 3: qualitative assessment of potential for groundwater migration of herbicides and associated contaminants of concern identified in Task 2B to potential human receptor locations through use of existing DRDC potentiometric surface map
- Task 4: preparation of a report and accompanying qualitative assessment results map that excludes areas where migration to potential human receptors is deemed highly unlikely
- Task 5: preparation of an abbreviated statement of work (SOW) for the quantitative evaluation of the potential for historical water migration associated

with herbicide spraying operations at CFB Gagetown, outlining appropriate methodologies for execution with the advantages and disadvantages of each that take into account the results of Tasks 1-4 and the limitations in available data.

2.2 Methodology

This assignment was carried out in accordance with the relevant methodologies outlined below:

- Task 1: Potable water wells were identified using the water well theme from the vector map (VMAP) dataset for CFB Gagetown[1], and frequented surface water body locations were identified using the Environmental Evaluation report. Contaminant of Potential Concern (COPC) source areas were identified using the results of the application areas listing from the Task 2B, Stage 1 and 2 reports.

- Task 2: Production of a sub-basin surface water drainage map commenced with a data integrity review of the existing digital elevation model (DEM) for CFB Gagetown[2]. The 36 tiles were merged in ArcView, from which a grid elevation raster was generated and used with the software's hydrology tools to generate slope, flow accumulation and then sub-watershed zones. For the qualitative assessment of the potential for surface water migration of herbicides and associated contaminants of concern to potential human receptor locations, the contributing surface drainage zones for these receptor locations were delineated.

- Task 3: The existing DRDC potentiometric surface map was used for the qualitative assessment of the potential for groundwater migration of COPCs to potable water well locations by delineating upgradient zones for an assumed capture radius.

- Task 4: Preparation of the map that excludes areas where migration to potential human receptors is deemed highly unlikely was accomplished by removing the zones where there was an intersection of application areas with either contributing surface drainage zones for surface water receptor locations or upgradient zones for the assumed capture radius of groundwater receptors.

- Task 5: Appropriate methodologies for the quantitative evaluation of the potential for historical water migration associated with herbicide spraying operations at CFB Gagetown were selected based on the results of Tasks 1-4 and the limitations in available data. The advantages and disadvantages of each as a function of the data requirements and expected outputs are listed. A draft SOW for the most feasible approach is prepared as an appendix.

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[1] Vector Smart Map Level 2 Coverage Series: VMAP 2, MCE 24 Gagetown, 1997
[2] CFB Gagetown 1:10000 USGS DEM, DIIT, 1998

3.0 RESULTS

This section includes the results of the work completed in accordance with the methodology outlined in Section 2. Based on the review, there is a significant amount of information relating to surface water features and drainage. This information was sufficient for use in ascertaining likely surface water flows and catchments for sub-basins throughout the RTA. Surficial soils have been mapped throughout the RTA, including qualitative characterization of permeability. Subsurface information is significantly less detailed – general bedrock geology is described, however the number of confirmation points (i.e., borehole logs such as those provided with water well records) is low (on the order of 40 to 50) for areas within the RTA, while available historical records are concentrated at bivouac areas. The 2005 DRDC report did include completion of a groundwater model (inferred flow directions generally match surficial drainage), however the plot of head differences between model and well record results shows a poor fit, insufficient for quantitative assessment of flow directions or velocities. It can be expected that the model fit is even poorer for areas with few/no well records (south part of RTA).

The qualitative assessment of the potential for surface water and groundwater migration of herbicides and associated COPCs to potential human receptor locations made use of the COPCs listing from the Task 2B, Stage 1 and 2 reports, reproduced as Table 3.1 for reference.

Table 3-1: Prioritization of COPCs based on relative toxicity, environmental fate, and persistence in the environment.

Chemical (Active Ingredient or manufacturing impurity)	Priority Ranking	Human Carcinogen	Biomagnification [3]	Bioaccumulation [3]	(Log Kow) [4]	Persistence in Soil [5]	Soil $t_{1/2}$ [5]	Available Soil Guidelines (range mg/kg) [6]
2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD)	**1**	**X**	**X**	**X**	6.80	**X**	1 yr to 3 years (surface soils) 12 years (subsurface soils)	0.000004
2,4-D	**1**	POSSIBLE			2.81		< 7 days	690 - 782
2,4 DP (dichlorprop)	2	POSSIBLE			3.43		10 days	---
2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)	**1**	Indirect through contaminant TCDD.	Indirect through contaminant TCDD.	Indirect through contaminant TCDD.	3.31		< 7 days	610 - 782
2-(2,4,5-T) Trichlorophenoxy propionic acid	2				3.80		< 7 days	490 - 625
Ammonium sulfamate	2				-4.34		6-8 weeks	12,000 - 12,400
Bromacil	2	POSSIBLE			2.11	**X**	60 days to 8 months (depending on soil conditions)	---
Dicamba	2				2.21		1 to 4 weeks (depending on soil conditions)	1,800 - 2,346
4,6-dinitro-o-sec-butylphenol (Dinitro) [1]	2				3.56		No data available	
1,1'-ethylene-2,2'-dipyridinium dibromide (Diquat)	2				-4.60		> 1000 days	130 - 170
Diuron	**2**	**X**			2.68	**X**	43- 1000 days (depending on soil conditions)	120 - 156
Fosamine ammonium	2				-5.98		1-6 weeks (depending on soil conditions)	6,100 - 7,821
Glyphosate	2				-4.00		1-174 days (depending on soil conditions)	---
Hexachloroacetone [1]	2				2.48		No data available	---
Hexachlorobenzene (HCB)	**1**	POSSIBLE	**X**	**X**	5.73	**X**	2.7-7.5 years	0.05 - 2.0
Hexazinone	2		LOW		1.85		30 to 180 days	2,000
Imazapyr	2				0.22	**X**	1 to > 4 years (depending on soil conditions)	---
Mecoprop	2	POSSIBLE	LOW		1.26		2 months	---
1,1'-dimethyl-4,4'-dipyridinium dibromide (Paraquat)	2	POSSIBLE			4.47	**X**	1-13 years	270 - 350
Pentachlorophenol (PCP)	2	POSSIBLE	NO [2]	NO [2]	5.12		45 days	0.5 - 11
Picloram	**1**	Indirect through contaminant HCB.	Indirect through contaminant HCB.	Indirect through contaminant HCB.	0.30	**X**	20-300 days	4,300
Sodium cacodylate; Cacodylic acid (Phytar 160 and 560G)	2				-2.37		quickly inactivated in soil	1,800 - 2,346
Sodium trichloroacetate (Trichloroacetic acid)	2	POSSIBLE			-2.37			---
Tebuthiuron	2				1.79	**X**	12 to > 15 months	50 - 4,300
Triclopyr	2	POSSIBLE			2.53		30 to > 90 days	---
Trichlorobenzoic acid [1]	2				2.71			10,000 - 310,000

1 - No data available for this herbicidal active ingredient.
2 - Bioaccumulation and biomagnification have not been observed and are not expected to be an important source of exposure because PCP breaks down rapidly in living organisms.
3 - Biomagnification is considered to result from the direct uptake of a substance by an organism via food and the bioaccumulation (uptake of pollutants via food and water) of a contaminant at increasingly higher trophic levels.
4 - Non-polar organic substances are lipid soluble and passively bioaccumulated. Consequently octanol-water partition coefficients (log K_{ow}) have been widely used as a surrogate to estimate bioaccumulation.
The criteria of $K_{ow} > 5$ indicating bioaccumulation is in accordance with the Persistence and Bioaccumulation Regulations (CEPA 1999).
5 - The soil criteria equal to or greater than 182 days (~6 months) indicating persistence is in accordance with the Persistence and Bioaccumulation Regulations (CEPA 1999).
6 - Taken from Appendix F. US EPA soil quality guidelines allow for 100% soil allocation factor in their derivation. In Canada, soil quality guidelines are derived using a 20% (0.2) soil allocation factor.
Therefore, if US EPA Region soil quality guidelines are to be used in screening, then they will be multiplied by 0.2.

3.1 Task 1: Identification of Potential Human Receptor Locations

Potential human receptor locations are shown in Figure 1. Potential human receptor locations considered are as follows:

- Potable (bivouac) water wells
- Buildings (which may have private water wells associated with them)
- Surface water bodies with known recreational use (bathing, fishing)
- Natural areas for human use

There are fourteen potable water wells within the RTA that are either directly in or are within 1 kilometer of plotted herbicide application areas, mostly associated with bivouac sites. Buildings that fall within application areas are confined to the east portion of the base proper, while some additional buildings near the base boundary fall outside application areas but within drainage basins that intersect application areas. Surface water bodies with known significant recreational uses include three lakes, French Lake which is approximately 5 km west of the northwest RTA boundary, Otnabog Lake which is approximately 2 km east of the central-east boundary, and Swan Creek Lake that has also reportedly seen some recreational use historically. Stream and river courses within the RTA are not open to visitor use, however some fishing in the Nerepis River is known to take place by base personnel. The Lindsay Valley natural area has also been established for use by base personnel – it is located within the RTA immediately east of the base.

The comprehensiveness of potential human receptor location information is fair. Good information is available covering potable water wells, buildings and natural areas for human use. Recreational use of surface water bodies is less well understood – off-site uses of French and Otnabog Lakes are well established, however information regarding on-site uses of bodies like the Nerepis River and Swan Creek Lake is mostly anecdotal in nature.

3.2 Task 2: Qualitative Assessment of Potential for Surface Water Migration of COPCs

Surface water drainage is detailed in Figure 2. The sub-watershed discretisation is shown, with the relevant watersheds (i.e., watersheds with recreational uses) highlighted, those being Lindsay Valley, French Lake – Rockwell Stream, Otnabog Lake and Stream, Swan Creek and Lake, and the Nerepis River and tributaries. Together, these basins include more than 70% of the RTA. The sub-watershed discretisation generated through the hydrology toolset in ArcView shows a good match to catchments as evident through creek/stream courses.

Figure 1. Potential Human Receptor Locations

Sub-watershed boundaries generated from a dense DEM in this manner are often more representative of surface drainage than those that would be produced by mapping out stream/creek catchments when the instances of anthropogenic drainage manipulation (e.g., agricultural drainage ditching, roadside ditching, etc.) are frequent. Ground-truthing of results is always of benefit – note for example the fact that this automated delineation segregated Swan Creek from Swan Creek Lake, which is not the case.

The density of surface water information is high. The DEM topography at 1:10000 provides an elevation point every 100 meters. The intersection of application areas with sub-watersheds is discussed in Section 3.4. Note that the presence of potable water wells within surface drainage areas that intersect application areas is also of concern, in the event that any wells have improper or faulty seals or casings permitting ingress of surface water.

Figure 2. Contributing Surface Drainage Zones for Surface Water Receptors

3.3 Task 3: Qualitative Assessment of Potential for Groundwater Migration of COPCs

The simulated[3] potentiometric surface (water table, assuming a single, continuous, unconfined aquifer) from the 2005 DRDC report is shown in Figure 3, along with the potable water wells and assumed upgradient zones. These zones are a fixed shape, 1 kilometer in length, 500 meters in width at the well and 300 meters in width opposite the well. These zones are meant to represent potential contribution zones for the wells (i.e., subsurface zones within the aquifer where groundwater flow over a certain time would pass within the capture zone of the well), and are shaped to consider both potential advective and dispersive transport. Well accepted methodologies for the delineation of well capture zones are available, which should be referenced for any quantitative treatment of groundwater migration potential[4]. A large number of factors do in fact influence the actual upgradient contribution zones (often called capture zones or time-of-travel zones) of a well, as follows:

- Nature of local stratigraphy (depth of overburden, hydraulic conductivity of overburden and bedrock materials)
- Well type (dug vs. drilled well, bedrock vs. overburden well, screened vs. unscreened well)
- Well pumping (usage) rate (which drives drawdown radius)
- Water table (level, gradient, confined vs. unconfined aquifer, overburden vs. bedrock aquifer, seasonal variations)

For reference purposes, the assumed 1 km upgradient contribution zone would correspond to approximate times-of-travel ranging from over 3000 years through a material with a hydraulic conductivity of 1 x 10^{-5} cm/s down to under six years through a material with a hydraulic conductivity of 3 x 10^{-3} cm/s. The geometric mean

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[3] The simulated surface is used, rather that the measured surface, as it smoothes the discontinuities generated by sparse data points that may indicate differing aquifer formations
[4] For example, US EPA (1987) Guidelines for delineation of wellhead protection area, EPA 440/6-87-010, Washington, DC: Office of Groundwater Protection; and Ontario MOE (2001) Protocol for Delineation of Wellhead Protection Areas for Municipal Groundwater Supply Wells under Direct Influence of Surface Water PIBS 4168e

hydraulic conductivity from the DRDC reports[5] slug tests is 5×10^{-3} cm/s, with a range varying by two orders of magnitude. Realistically, however, at small length scales (10's and even 100's of meters), subsurface flow is better defined by considering preferential flow paths through fractures than by considering flow through a uniform porous media.

[5] Conducted in DRDC Report TR 2004-456

The density of subsurface information, as expressed in Section 3.0, is low. The area bounded by the ten well records covering the bivouac sites from Petersville to Clones to Hibernia to Manor to Lyons, for instance, is approximately 250 square kilometers – properly characterizing the subsurface would require a density of information (i.e., well/borehole logs) at least two orders of magnitude greater than what is available.

3.4 Task 4: Reporting and Delineation of Areas with Minimal Migration Potential

Figure 4 represents the intersection of sub-watersheds with known recreational uses and well upgradient zones with herbicide application areas. Creek/stream courses downstream of application areas are highlighted. Areas outside of those highlighted are qualitatively considered to have minimal potential for having received migrated herbicides and associated contaminants.

Given that this is a qualitative assessment, no thought has been given to the mobility of COPCs. The compounds listed in Table 3-1 have widely varying soil adsorption, persistence, water solubility, and reactivity attributes, all of which will impact their transport from application areas to receptor locations.

3.5 Task 5: Appropriate Methodologies for the Quantitative Evaluation of the Potential for Historical Water Migration of COPCs

Having refined areas of interest for assessing the potential of historical migration of COPCs, the final task called for outlining appropriate methodologies for quantifying this potential that are scientifically defensible (i.e., that are reproducible, verifiable and within acceptable margins of error). COPCs migration is determined by both the fate and the transport of COPCs. Recall that the only transport medium being considered here is water (i.e., mobilization of COPCs through surface runoff and through infiltration and subsequent groundwater flow) – COPCs that were applied through spraying operations (which were the majority of cases) would experience some airborne transport, potentially to areas outside of described application areas, and COPCs once adsorbed to soil particles or other matter with the potential for mobility could conceivably be transported by wind or other means to areas outside of described application areas.

Quantitative methodologies can be broadly classes into stochastic and deterministic approaches. Stochastic approaches attempt to fit mathematical models to observed phenomena in order to predict or extrapolate additional results (e.g., empirical or statistical models), whereas deterministic approaches attempt to use mathematical models representing governing equations of relevant physical phenomena (e.g., mass balance, conservation of energy, conservation of momentum, chemical equilibrium) to predict the behaviour of systems (that result in fate and transport processes). Deterministic approaches can be further divided into analytical and numerical approaches. Analytical approaches attempt to solve the governing equations (e.g., the Laplace equation for flow in unconfined aquifers, Darcy's Law for groundwater velocity, etc.) – these require closed, simple systems that are not representative of large-scale real world scenarios, such that numerical approaches are required. Table 3-2 provides the categorization, description, inputs/outputs, advantages/disadvantages and feasibility of some relevant methodologies for quantifying potential COPCs migration. The list is preliminary and would be expanded as part of the requirements in the draft SOW, focused on appropriate selection criteria for models/modeling systems.

Figure 3. Upgradient Zones (Assumed Capture Radius) for Groundwater Receptors

Figure 4. Area with Minimal Migration Potential

Table 3-2: Categorization, description, inputs/outputs and advantages/disadvantages of methodologies for quantifying potential COPCs migration.

Methodology					Inputs	Outputs	Advantages/Disadvantages	Feasibility
Class	Sub-category	Medium	Description	Tools				
Stochastic	Statistical	Epidemiology	Known health effects from COPCs	Medical records	• Human receptor location usage history and illness history	• Location of persons with related illness	• Directly relates COPCs to human illness • Publically sensitive	• Data availability unknown, very unlikely • Linkage to a given source difficult to ascertain
	Fate and Transport	Empirical	COPCs concentrations in pathway and receptor locations	Surface water and groundwater monitoring, sediment sampling	• Mass of COPCs deposited by area by date along with measured COPCs concentrations in representative human receptor locations for each medium after deposition	• COPCs concentrations in representative human receptor locations	• Mass of COPCs deposited can be predicted, however data covering COPCs concentrations in representative human receptor locations unlikely	• Item essentially completed through other tasks; extension of ESA or HHRA results to consider migration may be an option
Deterministic (Analytical)	Transport	Unsaturated zone (infiltration)	Chemical equilibrium equations (partitioning) along a generic dilution factor at groundwater	CCME Groundwater Check, DRASTIC	• COPCs concentration in soil, partitioning coefficients • Surficial soil characteristics in areas of interest (depth, type, porosity, density, infiltration rate, saturation, recharge) • Bedrock/well characteristics in areas of interest (pumping rate, (transmissivity/ hydraulic conductivity, hydraulic gradient)	• Deposition-location specific predictions of COPCs concentrations at the water table	• Simplest deterministic approach • Analytical equations are suitable for sand and gravel aquifers where conditions are uniform and there is sufficient subsurface information. • Transport outside of well capture zones not predicted • COPCs degradation not considered • Scientific defensibility likely to be poor (many variables not considered)	• This method unsuitable for fractured bedrock aquifers. • Provides a very incomplete picture
		Saturated zone (groundwater)	Simple transmissivity-based calculation	Derived equations for width of capture zone, time-of-travel				
Deterministic (Numerical)	Fate	Surface water (in-stream)	Mass balance, chemical equilibrium equations (aqueous)	QUAL2E, SMADA	• Mass of COPCs deposited by area by date along with COPCs equilibrium and reaction attributes, or measured COPCs concentrations in each medium after deposition • Relevant historical chemical concentrations by media (pH, dissolved oxygen, temperature) • Human receptor location usage history	• Time series of COPCs degradation/transformation concentrations at modeled locations	• Mass of COPCs deposited can be predicted as can attribute information, however data covering COPCs concentrations after deposition and receiving body parameter information unlikely to exist • Mobilisation of COPCs not considered • Exposure effect on human receptor not considered	• Level of uncertainty of COPCs fate in surface water likely to be much lower than groundwater, due to differing impacts of data density • Provides an incomplete picture without parallel prediction of transport
		Surface water (runoff)	Mass balance	HEC-1, HEC-HMS, HSP-F, EUTRO, AGNPS, CFS Toolset, SWMM				
		Unsaturated zone (infiltration)	Mass balance, chemical equilibrium equations (multi-phase)	LEACHM, SESOIL				
		Saturated zone (groundwater)	Mass balance, chemical equilibrium equations (aqueous)	MT3D				
	Transport	Surface water (in-stream)	Mass balance, conservation of momentum or conservation of energy equation approximation (1-D) or grid (2,3-D)	QUAL2E, SMADA, HEC-2, HEC-RAS, WASP, AGNPS	• COPCs solubility attributes • Historical seasonal precipitation levels and stream flows • Stream/riverbed roughness and sediment levels • Surface topography • Surficial soil characteristics in areas of interest (depth, type, porosity, density, percent clay) • Bedrock characteristics in areas of interest (type, storativity and transmissivity/ hydraulic conductivity, hydraulic gradient) • Potable well characteristics (type, casing, screens)	• Time/space series of medium (water) transport predictions along modeled pathways • Time/space series of COPCs degradation/transformation concentrations along modeled pathways	• Surface water data available (and additional data can be predicted using available meteorological data) • Density of surficial soil and subsurface information very low • Rigorous quantification is restricted to conservative substances • Exposure effect on human receptor not considered • Scientific defensibility improved (most variables are considered)	• Level of uncertainty of surface water migration likely to be much lower than groundwater, due to differing impacts of data density • Provides an incomplete picture without parallel prediction of fate
		Surface water (runoff)	Mass balance	HSP-F, EUTRO, AGNPS, SWMM				
		Unsaturated zone (infiltration)	Pore pressure transport	LEACHM, SESOIL				
		Saturated zone (groundwater)	Mass balance, Bousinessq equation approximation using finite element or difference grid	MODFLOW, MODPATH, ZONE BUDGET, FEM-WATER, PLASM				
		Sediment Transport	Conservation of momentum or conservation of energy	HEC-6, CH2D				

4.0 CONCLUSIONS, DISCUSSION AND STATEMENT OF WORK

4.1 Conclusions

In examining the results of the scoping exercise, the following conclusions are drawn:

- The number of potential receptor locations is large for contact (i.e., recreational) receptors and small for ingestion (i.e., potable water well) receptors
- Data is much more plentiful for surface features including surface water bodies than it is for subsurface features
- The qualitative assessment of potential for surface- and groundwater migration has removed approximately 30,000 ha of the RTA's 110,000 ha from immediate interest as it relates to quantitatively assessing historical migration
- Given the constraints imposed by data availability, and the need to offer scientifically defensible assessment approaches, the only quantitative approach offering feasibility is a numerical determination of potential surface water migration of herbicides and related COPCs from application areas to human receptor locations
- A more rigorous qualitative treatment of potential groundwater migration of herbicides and related COPCs from application areas to human receptor locations would aid in interpreting overall results

4.2 Discussion

A quantitative surface water assessment of migration potential would need to focus on the following sub-watersheds and surface water bodies:

- Rockwell Stream sub-watershed, French Lake
- Lindsay Valley Creek sub-watershed
- Swan Creek sub-watershed, Swan Creek Lake
- Otnabog Stream sub-watershed, Otnabog Lake
- Nerepis River watershed down to RTA boundary

Areas outside of those above, but within application areas, would potentially also need to be considered, but with a lower degree of scrutiny. For completeness a qualitative description of the comparative mobilization of COPCs to human receptor locations via subsurface transport (i.e., infiltration through the vadose zone to the saturated zone and subsequent transport with groundwater) would need to accompany the quantitative results.

4.3 Statement of Work

A first draft of the proposed SOW for what would become Task 2F is provided at Appendix 1, for modification as required.

5.0 CLOSURE

This report has been prepared for the sole benefit of Public Works and Government Services Canada (PWGSC), their client the Department of National Defence (DND) and their partner Health Canada (HC). The report may not be used by any other person or entity without the express written consent of Jacques Whitford, PWGSC, DND and HC, for any purposes other than those deemed necessary by them.

Any use that a third party makes of this report, or any reliance on decisions made based on it, is the responsibility of such third parties. Jacques Whitford accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgement of Jacques Whitford based on the data obtained from the work. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein. We would like to thank you for the opportunity to submit this report. Please do not hesitate to contact David Wilson (613-738-0708) extension 231 or e-mail, dwilson@jacqueswhitford.com should you have any questions.

Yours truly,

JACQUES WHITFORD

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Distribution: One PDF copy to each addressee, two hard copies to Health Canada

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APPENDIX 1

Draft SOW

Draft Statement of Work for the Quantitative Evaluation of Potential Historical Herbicide and Associated Contaminants of Concern Surface Water Migration that May Have Been Impacted by Herbicide Spraying Operations at CFB Gagetown, New Brunswick, from 1952 to 2005

Introduction

CFB Gagetown houses an 110,000-ha training area where a significant amount of live-fire military training occurs within designated Ranges and Training Area (RTA) Impact Areas. This activity and the areas used for it are tightly controlled; however, the live fire training exercises in the Impact Areas (including maneuver and dry training areas) occasionally result in fires in areas where there is an abundance of flammable material (e.g., dry grass, stumps, shrubs, and forest re-growth). As a result, there is a requirement to keep open areas free of softwoods and hardwoods to provide the military with line-of-sight during operations and reduce the risk of wildfires resulting from live firing.

Because of the risk of these training-induced fires, especially during the annual forest fire season (15 April – 15 October), live fire training is sometimes restricted and/or cancelled during extreme fire conditions, which can cause major disruptions to training programs and problems with scheduling. While fire ignitions are inevitable if training is to be conducted, the threat from these fires must remain manageable in order to proceed responsibly.

Controlling vegetation growth is a major component of the CFB Gagetown Fire Prevention Plan. Firebreak roads must be kept clear of vegetation to maintain effective fire barriers. Reducing the amount of vegetation in the Impact Areas and on the Ranges in turn reduces material that could be ignited by the firing of ordnance, lightning, another fire source, or carelessness. In addition, for safety reasons, in some cases targets must be visible from distances as far as 4 kilometers (km). In order for this visibility to be achieved, vegetation height and type has to be controlled.

CFB Gagetown uses a variety of methods to manage vegetation growth in the training areas, including mechanical methods (e.g., cutting, crushing, or grubbing), burning, or chemical methods (i.e., spraying herbicides through ground or aerial applications). Chemical vegetation control has generally been the preferred method to manage secondary vegetation in the Impact Areas and firebreak roads because of personnel safety, its effectiveness, and cost per hectare. Prescribed burning is generally not considered an appropriate method of vegetation management in these areas because of issues related to environmental impact, cost, and personnel safety (including the risk arising from unexploded explosive ordnance (UXO)). In addition, burning is ineffective in removing secondary vegetation (i.e., hardwoods and softwoods); however, it is occasionally used for removal of spring brush and grasses.

Herbicide applications at CFB Gagetown were completed in compliance with the standard of the time, as specified in all federal and provincial environmental regulations. Prior to 2001, herbicide applications were completed under the direction of provincial regulator oversight. Since 2001, applications have been overseen by independent monitors. An Environmental Assessment (EA) of the vegetation control program has been carried out annually since the coming into force of the Canadian Environmental Assessment Act (CEAA). These EAs have been registered with the Canadian Environmental Assessment Agency (CEAA) to ensure that any possible impacts to the local environment, including effects on wildlife and water quality, are understood and properly mitigated.

Background

CFB Gagetown land use totals approximately 110,000 hectares (ha), including 65 lakes, 365 wetlands, and 251 permanent and intermittent streams. The active ranges in the RTA represent approximately 30,000 ha of this land use. A variety of non-military land uses occur within the approximately 80,000 ha of non-RTA land, including forest management, hunting, fishing, camping, and various other recreational activities.

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

For the purpose of health and safety of individuals coming into the RTA, non-military land uses are controlled by CFB Gagetown Range Control. Non-military land uses are also restricted to areas outside RTA Impact Areas and active ranges. Civilians and military personnel wishing to enter these areas must obtain clearance through Range Control so that designated areas can be selected away from military activities and allow for safe use of the land.

The Lindsay Valley Conservation Area, in the northwest corner of CFB Gagetown, near the main entrance of the Base, was developed as part of a comprehensive natural resources management program for CFB Gagetown. The objectives of this management program were to develop the Lindsay Valley Area in a manner such that enjoyment of the natural environment with respect to outdoor activities could be achieved while maintaining the natural aesthetics and natural ecosystems of the Valley. A variety of recreational activities take place here, including cross-country skiing, snowmobiling, snowshoeing, hiking, biking, and biathlon training.

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

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

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

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

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

The surficial geology around the periphery of CFB Gagetown from the northwest to the south (i.e., along the banks of the Saint John River), as well as along the banks of the Oromocto River to the west and the Nerepis River in the south, is mainly composed of terraces and floodplains made up of sand, gravel, some silt, minor clay and organic sediments, generally more than 2 m thick, and deposited as channel, overbank, and flood basin deposits. The surficial geology of the central portion of the RTA is fairly consistent and is comprised of loamy lodgment till, minor ablation till, silt, sand, gravel, and rubble, ranging from a discontinuous veneer over rock less than 0.5 m thick to a blanket of up to 3 m thick. The northwest portion of the RTA contains some organic sediment, including bogs, fens, swamps, peat, and muck, with minor silt and fine sand, generally 1 to 5 m thick, deposited in shallow basins on poorly drained surfaces. The southeastern portion in the mountainous region of the RTA is Pre-Quaternary rock of various lithologies and ages. They are generally weathered and partially disintegrated, with a glacially moulded surface.

The regional aquifer underlying CFB Gagetown is primarily a fractured bedrock aquifer. The hydraulic property of the bedrock aquifer is fairly variable and related to the diverse lithology of the area. Reported horizontal hydraulic conductivities varied from 10^{-5} to 10^{-6} m/s. It should be noted that it is possible in the highly fractured bedrock or permeable conglomerate horizons to encounter localized high horizontal hydraulic conductivities within the bedrock aquifer. Reported average water table depth corresponds approximately to the mean depth to bedrock value of 4.7 m, indicating that the flow within the aquifer is influenced by the bedrock topography to a certain extent in addition to the surface topography.

Scope of Work

An Environmental Site Assessment (ESA) was undertaken in CFB Gagetown in late 2005/early 2006. The ESA forms part of a commitment made by the Federal Government of Canada to identify and report on the historical use of herbicides sprayed in the RTA at CFB Gagetown. As an additional task, DND wishes to quantify the potential for historical surface water migration that may have been impacted by these herbicide spraying operations. This effort is known as Task 2F.

This assignment will be completed through execution of the following five tasks:

1. Review and compilation of background information and data

2. Selection of surface water transport model(s)

3. Collection of model calibration data

4. Modelling

5. Reporting of results

Note that the focus of this assignment is on the transport of contaminants of potential concern (COPCs), not on the fate of those contaminants. It will therefore be necessary to select a conservative substance to act as an analog to COPCs and to therefore represent the worst case transport scenario, through use of a scientifically defensible methodology. Once the transport modeling system is calibrated, It must be possible to assign a COPCs source area concentration and depositional history (e.g., 100 grams per square meter applied to a given one hectare area on May 12, 1956), from which the calibrated model(s) would then produce a prediction of the time/mass migration (transport) of COPCs through the surface water system. Derivation of defensible source area historical COPCs concentrations falls outside the scope of this assignment.

In addition, given the potential for adsorbed COPCs to migrate through the system as sediment, the model(s) will need to include sediment transport as part of the output. As a rigorous, quantitative assessment, the sources of and magnitude of error for the transport predictions will need to be described. Finally, the model(s) time and space domains must be described. For model(s) incapable of representing time-varying input parameters (i.e., steady-state models), sufficient runs will be required in order to build an output history that matches the COPCs application history.

As a companion description to the quantitative surface water results, a qualitative description of the potential for sub-surface migration will be provided. This description will make use of existing surficial soil and sub-surface overburden and bedrock information to cover the potential for migration of a COPCs analog through the vadose (unsaturated) zone to the water table, and subsequent transport within groundwater. Note that unlike the surface water assessment (and based on the fact that sub-surface information outside of bivouac areas is extremely sparse), this description does not need to be specific to each potable water well location, however it should consider the known characteristics of wells and sub-surface conditions present within the RTA. Proposals will need to identify completion of this companion task as either a part of the quantitative surface water evaluation, or as a stand-alone effort.

Deliverables

This deliverables required for this assignment will be as follows:

1. Baseline Report: the output from Tasks 1 and 2 will be a baseline report that annotates the background information compiled on the surface water features within the RTA that will be treated as part of the modeling effort. Surface water feature information will include as a minimum:

   a. All creeks and streams, classed as persistent and non-persistent, throughout the RTA

   b. A listing or estimate of flows (monthly means, minimums, maximums) dating back to 1952 for all persistent streams within the French lake – Rockwell Stream, Lindsay Valley, Swan Lake and Creek, Otnabog Lake and Stream, and Nerepis River sub-watersheds

   c. A listing of available water quality and sediment data for the above water bodies covering parameters analysed and sampling date(s)

   In addition, the report will include a listing of available surface water transport models (modeling systems) covering both runoff and in-stream transport processes, with an assessment of the model(s) selected for follow-on modeling execution and the requirements for calibration. Model selection shall be based on defined criteria that are reflective of model suitability, which may include data requirements, cost, ease of integration, and extent of use within the scientific community.

2. Migration Modelling Results Report: the second and final deliverable will begin by describing the results of the model calibration data collection efforts. Calibration data will be sorted by surface water body, and as a minimum will include those parameters considered as essential for the selected model(s). Model outputs will be represented graphically with at least one plot per year showing at least the leading edge and peak concentrations of the COPCs analog.

3. Either accompanying the surface water results or as a stand-alone report will be the description of the potential for sub-surface migration, citing applicable surficial soil and sub-surface features and characteristics.

Schedule

The schedule for this assignment is as follows (weeks after contract award):

1. Review and compilation of background information and data: 2 weeks

2. Selection of surface water transport model(s): 4 weeks

3. Collection of model calibration data: 6 weeks

4. Modelling: 10 weeks

5. Reporting of results: 12 weeks

Submission Requirements

As per PWGSC standards.