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ECOLOGICAL RISK ASSESSMENTS FOR THE BASELINE CONDITION FOR THE PORT HOPE AND PORT GRANBY PROJECTS

Donald R. Hart[1] and Heather Kleb[2]
[1] EcoMetrix Incorporated
14 Abacus Road, Brampton, Ontario, CANADA L6T 5B7
[2] Low-Level Radioactive Waste Management Office
Suite 200, 1900 City Park Drive, Ottawa, Ontario, CANADA K1J 1A3

ABSTRACT

Baseline ecological risk assessments were completed in and around the areas where cleanup of low-level radioactive waste (LLRW) and marginally contaminated soil (MCS) is planned under the Port Hope Area Initiative (PHAI). Both aquatic and terrestrial environments were assessed, in the vicinity of the proposed waste management facilities near Welcome and Port Granby, in locations potentially influenced by LLRW and MCS that will be cleaned up in future, and in reference locations that are not potentially influenced. The calculated doses and risk quotients suggest potential radiation effects for pre-cleanup benthic invertebrates in Port Hope Harbour, for any ducks feeding exclusively in this area, and for soil invertebrates in some other waste sites. In addition, risk quotients suggest potential baseline effects from some elements, particularly uranium and arsenic, in localized areas that are influenced by LLRW and MCS.

I. INTRODUCTION

The PHAI includes two projects involving cleanup of LLRW and MCS. The Port Hope Project involves excavation of LLRW from various remediation sites in the Municipality of Port Hope, and placement of this material in a Ward 2 long-term waste management facility (LTWMF). The Port Granby Project involves excavation of LLRW and MCS from an existing WMF in the Municipality of Clarington, and placement of this material in a LTWMF which is further inland from Lake Ontario. Both projects are subject to an environmental assessment (EA) under the *Canadian Environmental Assessment Act*.

Ecological risk assessments (ERAs) were undertaken to address contaminant risks in the aquatic and terrestrial environments in and around the areas where cleanup activities are planned under the Port Hope Area Initiative. The ERAs facilitate risk-based interpretation of the measured radionuclide and non-radionuclide contaminant levels, derived from the baseline characterization studies[1,2,3,4]. They provide a risk baseline against which the significance of future changes arising from cleanup activities can be assessed.

Four separate ERAs were prepared – aquatic and terrestrial ERAs for the Port Hope Project, and aquatic and terrestrial ERAs for the Port Granby Project. The aquatic ERAs address aquatic biota, such as fishes, benthic invertebrates and aquatic plants. The terrestrial ERAs address

terrestrial biota, including upland wildlife (voles, rabbits), soil invertebrates and plants, and riparian wildlife (mink, muskrat, mallard) with food chain linkages to the aquatic environment.

II. CONCEPTUAL MODEL FOR ERA

Contaminants of potential concern (COPCs) were identified for ERA purposes to include ^{238}U and ^{232}Th series radionuclides, uranium, and other inorganic elements that have been (a) associated with LLRW and MCS, and (b) found to exceed ambient media guidelines or wildlife food consumption benchmarks. The locations of interest in the assessment include both aquatic and terrestrial locations potentially affected by contaminants from the sites, as well as reference locations in the local area that are unlikely to be affected. Locations are mapped with the ERA results in Sections IV and V below.

The conceptual model for exposure of aquatic receptors is illustrated as Figure 1. The conceptual model for exposure of upland terrestrial receptors is illustrated as Figure 2, and the corresponding model for riparian terrestrial receptors is illustrated as Figure 3. Some minor exposure pathways, such as external radiation dose from water for aquatic biota, and atmospheric pathways (internal and external) for terrestrial biota were omitted.

III. EXPOSURE AND RISK ESTIMATION

Exposure calculations utilized measured COPC concentrations in water, sediment and tissues of aquatic biota. When measured concentrations were unavailable, for some COPCs in some media and locations, the exposure concentrations were estimated using uptake factors from baseline study data or published literature[5,6,7,8,9], and secular equilibrium assumptions for some radionuclides. Transfer factors adjusted to body weight[10] were used to estimate wildlife tissue concentrations of radionuclides from daily ingestion intakes. Body weights and food and water intake rates for wildlife were taken from the U.S. EPA[11]. Dose coefficients from Amiro[12] were used for estimation of internal and external radiation doses.

Risk quotients were calculated for each receptor species at each location. For radionuclides, the risk quotient was an estimated radiation dose divided by a dose benchmark of 1 mGy/day, which was used for all receptor species. For non-radionuclide exposures of aquatic biota and soil-dwelling biota, the risk quotient was an exposure concentration divided by a benchmark or guideline concentration for water, sediment or soil, as appropriate to the organism[13,14,15,16,17]. For non-radionuclide exposures of wildlife, the risk quotient was an estimated chemical dose divided by a dose benchmark[18]. Mammalian dose benchmarks were adjusted to body weight.

In addition to the calculated risk quotients, other lines of evidence were considered. These included benthic community assessments and toxicity studies in Port Hope Harbour[6,19] and general observations on community health from the aquatic and terrestrial baseline studies.

IV. RESULTS FOR PORT HOPE PROJECT

The locations of interest in the Port Hope Project are shown in Figure 4. They include aquatic locations of potential current and/or future effects arising from contaminant releases from the proposed remediation sites (e.g., Port Hope Harbour, Highland Drive (Ward 1) site, Alexander Ravine), and from the LTWMF (Ward 2) site in the upper Brand Creek watershed where wastes from other areas will be placed. They also include upland terrestrial locations in and around the Ward 1 and Ward 2 sites, where waste excavations and/or placements will occur.

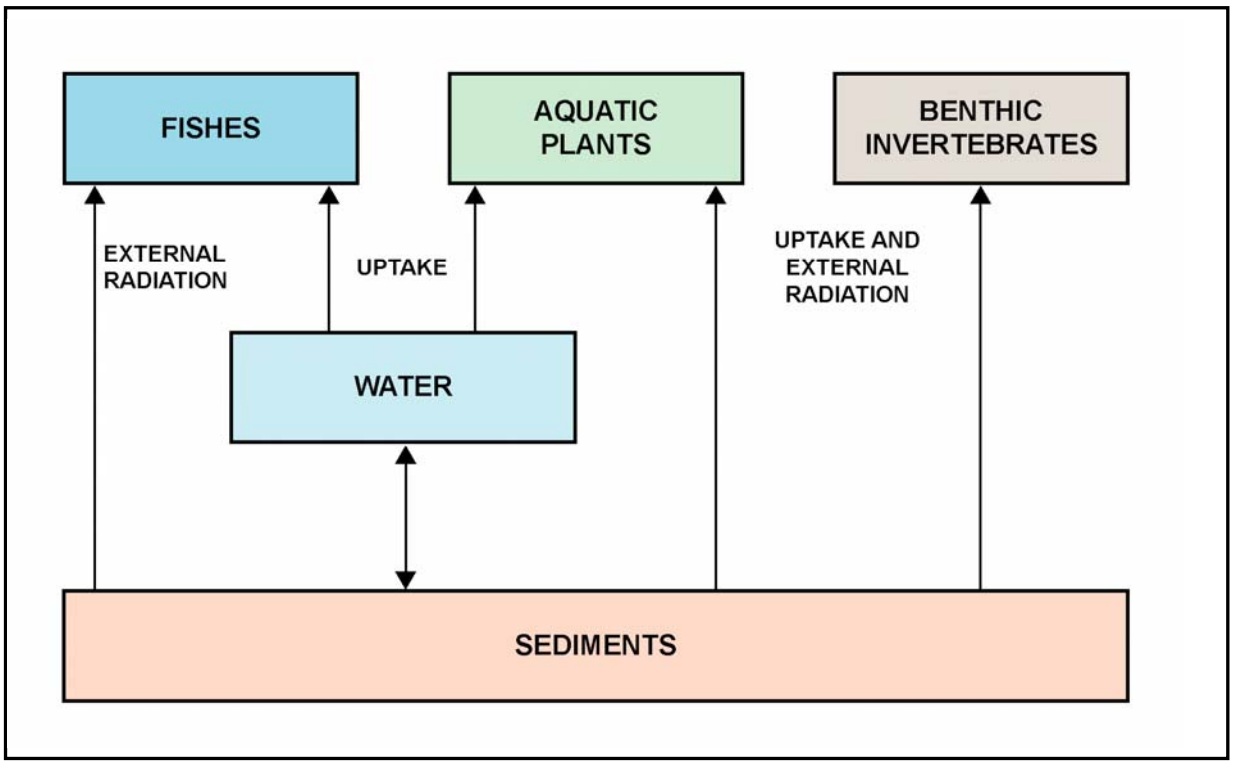

Figure 1: Conceptual model for exposures of aquatic biota.

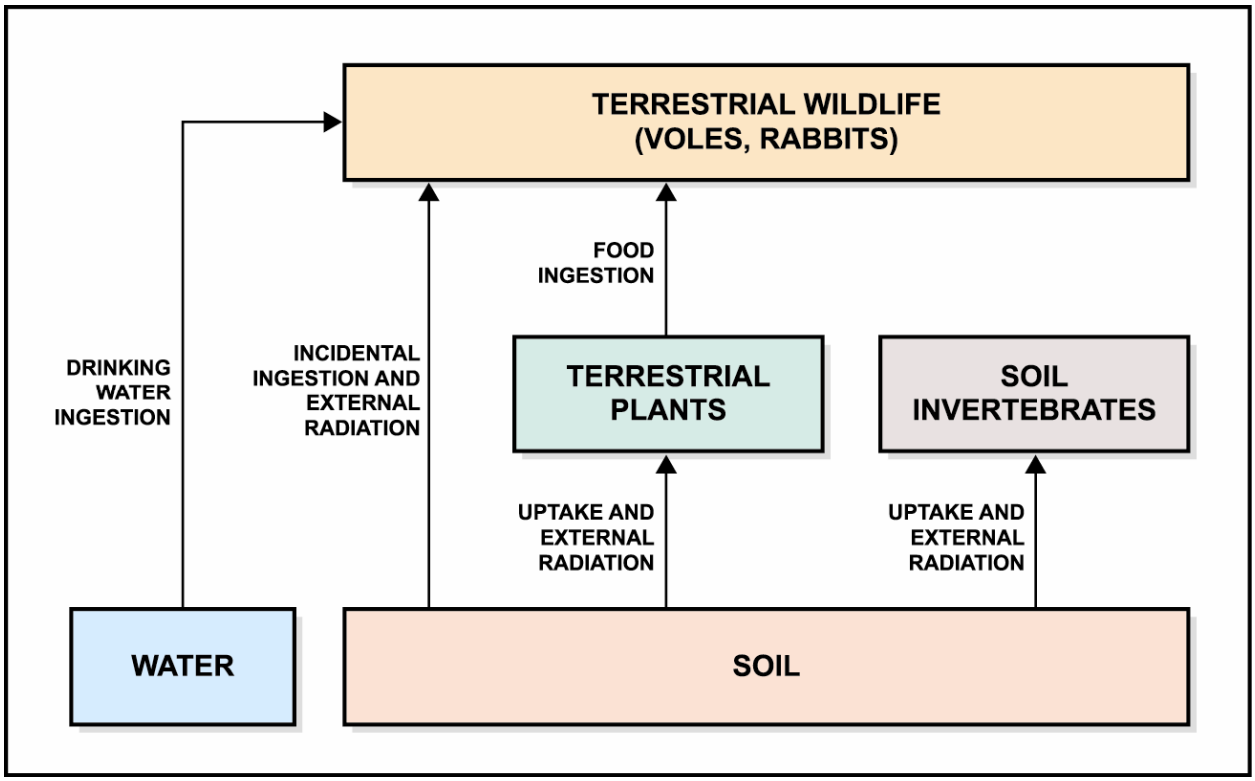

Figure 2: Conceptual model for exposures of upland biota.

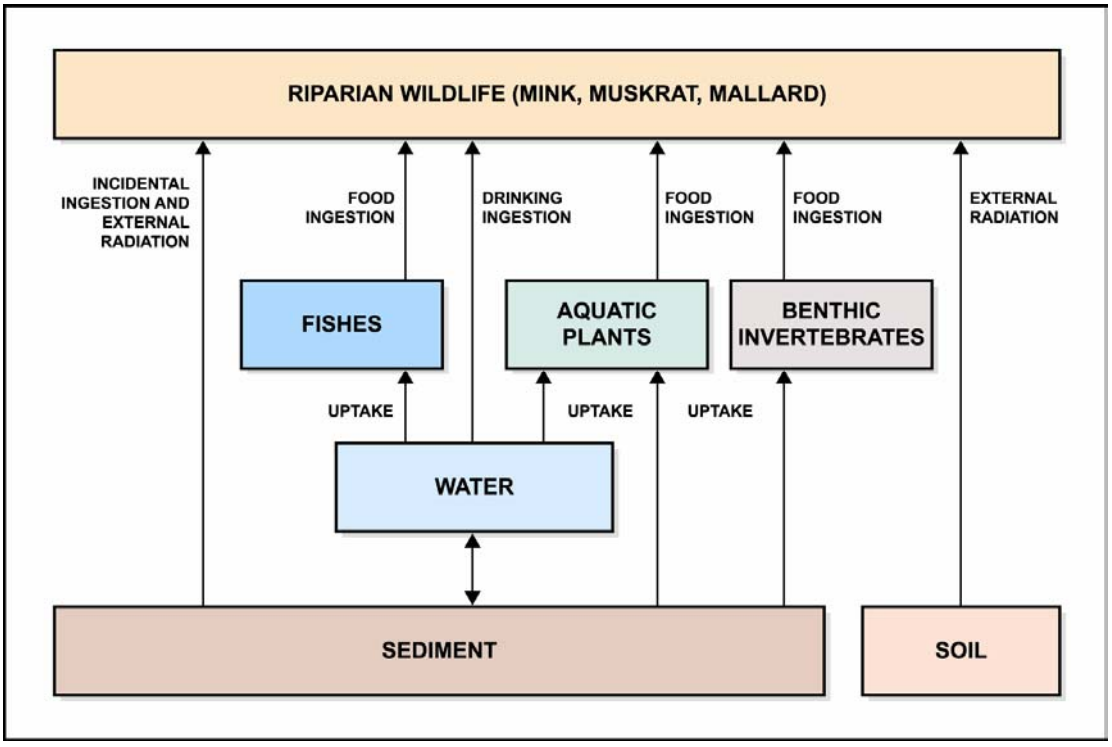

Figure 3: Conceptual model for exposures of riparian wildlife.

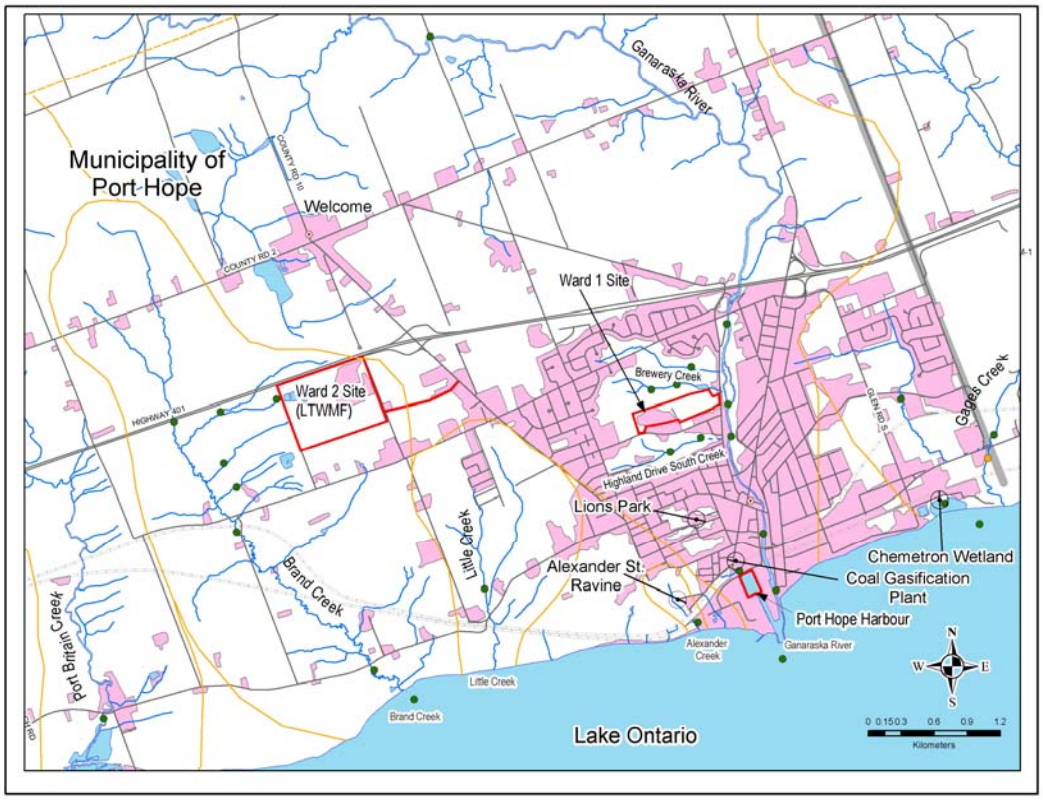

Figure 4: Locations of interest in the Port Hope Project.

II.A. Aquatic ERA

The aquatic ERA for the Port Hope Project found baseline risk quotients above 1, suggesting potential adverse effects, for radiation exposures of benthic invertebrates in Port Hope Harbour (2.1 mGy/day) (Table 1). Radiation risk quotients approached 1 for aquatic plants in the harbour, and were well below 1 for fishes. No other locations showed radiation risk quotients approaching the benchmark value.

Uranium risk quotients slightly above 1 were found for aquatic life in the water column in Port Hope Harbour, Highland Drive South Creek, the Brand Creek tributaries, and the Chemetron Wetland (Table 2). It should be noted that the benchmark concentration used for uranium was not specific to hard water, and may lead to overestimation of risk.

Risk quotients above 1 were also found for aquatic life in the sediments of Port Hope Harbour, based on sediment benchmarks for arsenic, lead, copper, nickel and cadmium (Table 3). The cadmium quotients were generally above 1 across the study area, but were elevated in Port Hope Harbour relative to reference locations. Arsenic risk quotients for sediment-dwelling biota were above 1 at several locations outside Port Hope Harbour, including Highland Drive South Creek, the Brand Creek tributaries, and the Chemetron Wetland. This baseline condition has likely been influenced by LLRW storage in upgradient locations.

IV.B. Terrestrial ERA

The terrestrial ERA for the Port Hope Project considered riparian wildlife, and only mallards in Port Hope Harbour produced radiation risk quotients above 1 (Table 4). This calculation is quite conservative, since it does not allow for mallard foraging in locations outside the harbour. The calculations for upland locations produced radiation risk quotients above 1 only for soil invertebrates at the Alexander Street Ravine (Table 5). The invertebrate quotient approached 1 for the Chemical Waste area of the Ward 2 site, where waste is currently stored, and the terrestrial plant quotient approached 1 for the Alexander Street Ravine. The radiation risk quotients do not approach 1 for voles or rabbits at upland locations.

Uranium risk quotients exceed 1 for soil invertebrates and plants at Alexander Street Ravine and Highland Drive South Ravine (Table 6). The arsenic quotients for these soil biota also exceed 1, at these locations and at several other LLRW sites. The lead quotient for these soil biota exceeds 1 at Alexander Street Ravine.

Arsenic risk quotients for voles and rabbits exceed 1 at Highland Drive South Ravine, and the rabbit quotient also exceeds 1 at the Ward 2 site (Table 7). Arsenic quotients for muskrats approach 1 at Highland Drive South Creek and Brewery Creek (Table 8). Non-radionuclide risk quotients are not substantially elevated for wildlife at other locations.

An assessment of Project effects[20] predicts that soil concentrations of ^{230}Th, arsenic and cobalt will be measurably increased around the perimeter of the Ward 2 site as a result of atmospheric deposition from dust that is released during the period of waste excavation and placement. A post-cleanup ERA for this location indicates that future risk quotients for terrestrial biota still will not approach 1, and thus no adverse ecological effects are expected.

Table 1: Radiation risk to benthic invertebrates in sediments

Radionuclide	Port Hope Harbour	Lake Ontario	Chemetron Wetland	Brewery Creek	Highland Dr. S. Creek	Ganaraska River	Alexander Creek	Gages Creek	Brand Cr. Tributaries	Brand Creek
U-238	1.7E-02	1.7E-04	2.4E-03	1.4E-04	1.3E-04	1.1E-04	5.1E-04	1.1E-04	1.9E-04	1.2E-04
Th-234*	2.3E-03	1.8E-04	2.4E-03	1.5E-04	1.4E-04	1.2E-04	5.3E-04	1.2E-04	2.0E-04	1.1E-04
U-234	1.9E-02	2.0E-04	2.7E-03	1.6E-04	1.5E-04	1.3E-04	5.8E-04	1.2E-04	2.2E-04	1.3E-04
Th-230	3.6E-01	3.7E-04	1.5E-02	2.1E-04	3.2E-04	2.1E-04	3.0E-03	4.2E-04	3.2E-04	4.8E-04
Ra-226	2.2E-01	2.9E-03	2.0E-02	2.6E-03	2.6E-03	1.3E-03	1.0E-02	1.4E-03	3.9E-03	2.7E-03
Rn-222*	1.2E-01	2.1E-03	1.5E-02	1.9E-03	1.9E-03	9.5E-04	7.6E-03	1.3E-03	2.9E-03	2.1E-03
Pb-210	7.4E-04	4.0E-06	3.0E-04	3.2E-06	6.4E-06	4.8E-06	2.4E-05	6.9E-06	3.2E-06	5.6E-06
Bi-210	1.1E-02	7.6E-05	5.7E-03	6.1E-05	1.2E-04	9.1E-05	4.6E-04	1.1E-04	6.1E-05	1.1E-04
Po-210	4.9E-01	1.2E-03	3.8E-02	1.3E-03	2.0E-03	1.3E-03	8.6E-03	5.2E-03	1.3E-03	4.5E-03
Th-232	1.5E-02	1.0E-03	7.4E-03	9.3E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04	9.3E-04
Ra-228*	4.4E-03	5.2E-04	3.7E-03	4.6E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04
Th-228	1.3E-01	1.6E-03	3.8E-03	1.3E-03	1.3E-03	1.3E-03	2.5E-03	1.5E-03	1.3E-03	1.5E-03
Ra-224*	7.2E-01	9.2E-03	2.2E-02	7.3E-03	7.3E-03	7.3E-03	1.5E-02	9.1E-03	7.3E-03	8.8E-03
Total	**2.1E+00**	2.0E-02	1.4E-01	1.7E-02	1.7E-02	1.4E-02	5.0E-02	2.1E-02	1.9E-02	2.2E-02

* Signifies that daughters are included.

Table 2: Chemical risk to aquatic life in the water column

Chemical Parameter	Port Hope Harbour	Lake Ontario	Chemetron Wetland	Brewery Creek	Highland Dr. S. Creek	Ganaraska River	Alexander Creek	Gages Creek	Brand Cr. Tributaries	Brand Creek
Arsenic	0.08	0.04	0.04	0.04	0.25	0.04	0.06	0.04	0.15	0.04
Boron	0.00	0.00	0.01	0.01	0.06	0.00	0.03	0.01	0.00	0.00
Cadmium	0.16	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.20	0.14
Copper	0.80	0.55	0.80	0.40	0.40	0.40	0.60	0.60	0.40	0.40
Fluoride	-	0.01	0.10	-	-	-	-	-	0.08	0.08
Lead	0.19	0.10	0.13	0.07	0.07	0.04	0.08	0.04	0.06	0.04
Nickel	0.12	0.09	0.08	0.60	0.08	0.08	0.08	0.08	0.08	0.08
Selenium	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Uranium*	0.37	0.02	**1.40**	0.04	**1.08**	0.04	0.56	0.05	**1.20**	0.14
Vanadium	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Zinc	0.47	0.40	0.50	0.67	0.27	0.20	0.87	0.23	0.33	0.17

- No fluoride data were available.
* Uranium risk may be overstated since the benchmark does not give credit for water hardness

Table 3: Chemical risk to benthic invertebrates in sediments

Chemical Parameter	Port Hope Harbour	Lake Ontario	Chemetron Wetland	Brewery Creek	Highland Dr. S. Creek	Ganaraska River	Alexander Creek	Gages Creek	Brand Cr. Tributaries	Brand Creek
Arsenic	**5.33**	0.29	**1.18**	0.17	**5.17**	0.17	**2.50**	0.18	**1.57**	0.57
Boron	-	-	-	-	-	-	-	-	-	-
Cadmium*	**3.33**	1.49	0.50	1.45	**2.00**	0.72	**1.83**	1.63	1.38	1.22
Copper	**3.81**	0.08	**1.19**	0.09	0.53	0.18	0.88	0.49	0.31	0.31
Fluoride	-	-	-	-	-	-	-	-	-	-
Lead	**5.48**	0.06	**3.19**	0.11	0.55	0.42	0.61	0.20	0.16	0.14
Nickel	**1.31**	0.13	0.38	0.13	0.29	0.18	0.53	0.41	0.35	0.29
Selenium	-	-	-	-	-	-	-	-	-	-
Uranium	0.14	0.01	0.16	0.01	0.01	0.01	0.04	0.01	0.01	0.01
Vanadium	-	-	-	-	-	-	-	-	-	-
Zinc	0.92	0.06	0.69	0.08	0.38	0.13	0.83	0.23	0.44	0.19

- No sediment benchmark was available.
* Cadmium is naturally elevated, Gages Creek serves as a reference.

Table 4: Radiation risk to mallard[1]

Radionuclide	Port Hope Harbour	Chemetron Wetland	Brewery Creek	Highland Dr. S. Creek	Ganaraska River	Alexander Creek	Gages Creek	Brand Creek
U-238	3.7E-03	7.2E-04	3.7E-05	5.9E-05	3.4E-05	1.6E-04	2.7E-05	3.9E-05
Th-234*	8.2E-04	7.8E-04	9.2E-05	4.5E-03	9.0E-05	6.7E-04	9.0E-05	9.0E-05
U-234	4.2E-03	8.2E-04	4.2E-05	6.9E-05	3.9E-05	1.8E-04	3.1E-05	4.5E-05
Th-230	5.8E-04	6.1E-05	1.4E-06	1.7E-05	1.2E-06	1.4E-05	1.7E-06	2.2E-06
Ra-226	7.1E-02	7.4E-03	7.8E-04	9.6E-04	4.8E-04	3.8E-03	5.8E-04	9.6E-04
Rn-222*	4.9E-02	7.9E-03	1.3E-03	1.5E-03	9.5E-04	5.1E-03	1.2E-03	1.5E-03
Pb-210	1.2E-04	4.1E-05	1.9E-06	2.3E-06	1.8E-06	6.8E-06	2.2E-06	1.9E-06
Bi-210	1.4E-03	5.5E-04	4.0E-05	4.9E-05	4.1E-05	1.4E-04	4.4E-05	4.1E-05
Po-210	1.2E+00	1.2E-01	6.2E-03	6.2E-03	4.1E-03	2.7E-02	1.3E-02	1.1E-02
Th-232	1.9E-05	1.2E-05	1.9E-06	1.7E-06	1.6E-06	1.7E-06	1.6E-06	1.8E-06
Ra-228*	1.0E-03	5.2E-04	2.6E-04	2.6E-04	1.9E-04	2.6E-04	2.2E-04	2.6E-04
Th-228	1.8E-04	6.3E-06	2.9E-06	2.6E-06	2.4E-06	4.6E-06	3.0E-06	3.0E-06
Ra-224*	1.9E-03	3.5E-04	3.9E-04	3.9E-04	2.7E-04	4.3E-04	3.5E-04	3.9E-04
Total	**1.3E+00**	1.4E-01	9.2E-03	1.4E-02	6.2E-03	3.8E-02	1.5E-02	1.4E-02

[1] These RQs assume the mallard resides and feeds only in the stated area; the large home range would preclude this.
* Signifies that daughters are included.

Table 5: Radiation risk to soil invertebrates

Radionuclide	Ward 1 Site	Ward 1 Perimeter	Ward 2 (LTWMF) Site	Ward 2 (LTWMF) Perimeter	Ward 2 ChW Area	Highland Dr S. Ravine	Alexander St Ravine
U-238	3.3E-04	3.3E-04	8.8E-04	9.5E-04	4.7E-03	1.8E-02	6.7E-03
Th-234*	1.9E-04	1.9E-04	5.1E-04	5.6E-04	2.8E-03	1.0E-02	3.9E-03
U-234	3.7E-04	3.7E-04	1.0E-03	1.1E-03	5.4E-03	2.0E-02	7.6E-03
Th-230	5.7E-04	1.0E-03	1.5E-03	7.8E-04	6.8E-02	3.1E-02	4.0E-01
Ra-226	9.5E-03	8.0E-03	1.1E-01	3.1E-02	2.6E-01	1.1E-02	3.5E+00
Rn-222*	5.4E-03	4.5E-03	6.4E-02	1.8E-02	1.5E-01	6.4E-03	2.0E+00
Pb-210	4.1E-06	4.8E-06	4.8E-05	1.8E-05	6.8E-04	4.8E-06	1.5E-03
Bi-210	8.5E-05	9.9E-05	9.9E-04	3.8E-04	1.4E-02	9.9E-05	3.1E-02
Po-210	2.0E-03	2.0E-03	2.0E-02	3.5E-03	2.9E-01	2.0E-03	6.5E-01
Th-232	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	5.3E-04	3.5E-04
Ra-228*	6.9E-04	6.9E-04	6.9E-04	6.9E-04	6.9E-04	6.9E-04	4.6E-04
Th-228	7.2E-04	7.2E-04	7.2E-04	7.2E-04	7.2E-04	7.2E-04	4.8E-04
Ra-224*	4.6E-03	4.6E-03	4.6E-03	4.6E-03	4.6E-03	4.6E-03	3.1E-03
Total	2.5E-02	2.3E-02	2.1E-01	6.3E-02	8.0E-01	1.1E-01	**6.7E+00**

* Signifies that daughters are included.

Table 6: Chemical risk to plants and soil invertebrates

Chemical Parameter	Ward 1 Site	Ward 1 Perimeter	Ward 2 (LTWMF) Site	Ward 2 (LTWMF) Perimeter	Ward 2 ChW Area	Highland Dr S. Ravine	Alexander St Ravine	Lions Park Rec Centre	Coal Gas Plant
Antimony	0.005	0.005	0.005	0.01	0.16	0.04	0.18	**1.34**	0.25
Arsenic	0.10	0.05	**1.83**	0.08	**3.92**	**8.00**	**1.03**	0.28	0.20
Barium	0.14	0.05	0.09	0.06	0.07	0.63	0.18	0.47	0.40
Cobalt	0.18	0.09	0.43	0.10	0.74	0.14	0.26	0.16	0.28
Copper	0.06	0.06	0.08	0.05	0.11	-	0.10	0.13	**1.76**
Lead	0.05	0.13	0.08	0.12	0.30	-	**1.27**	**1.90**	**3.66**
Molybdenum	0.04	0.05	0.05	0.06	0.07	0.13	0.02	0.05	0.05
Nickel	0.09	0.02	0.11	0.04	0.22	0.11	0.21	0.09	0.22
Selenium	0.01	0.01	0.01	0.01	0.01	0.32	0.08	0.03	0.30
Uranium	0.05	0.05	0.14	0.15	0.74	**2.79**	**1.05**	0.05	-
Vanadium	0.24	0.08	0.16	0.09	0.12	0.24	0.09	0.15	0.27
Zinc	0.09	0.08	0.08	0.09	0.09	0.18	0.09	0.78	**1.28**

- No soil data were available.

Table 7: Chemical risk to rabbits

Chemical	Ward 1		Ward 2		Ward 2	Highland Dr	Alexander	Lions Park	Coal Gas
Parameter	Site	Perimeter	Site	Perimeter	ChW Area	S. Ravine	St Ravine	Rec Centre	Plant
Antimony	0.002	0.002	0.002	0.002	0.04	0.01	0.05	0.36	0.07
Arsenic	0.03	0.02	0.44	0.03	**1.40**	**2.86**	0.37	0.10	0.07
Barium	0.06	0.03	0.04	0.04	0.07	0.60	0.17	0.46	0.39
Cobalt	0.02	0.01	0.06	0.01	0.11	0.02	0.04	0.02	0.04
Copper	0.10	0.02	0.06	0.01	0.03	-	0.02	0.03	0.43
Lead	0.002	0.004	0.002	0.004	0.01	-	0.04	0.06	0.11
Molybdenum	0.06	0.08	0.08	0.13	0.23	0.42	0.07	0.15	0.16
Nickel	0.002	0.001	0.002	0.001	0.005	0.002	0.005	0.002	0.005
Selenium	0.02	0.02	0.02	0.02	0.02	0.70	0.18	0.07	0.66
Uranium	0.01	0.01	0.02	0.02	0.08	0.26	0.10	0.01	0.01
Vanadium	0.19	0.06	0.13	0.07	0.10	0.19	0.08	0.12	0.21
Zinc	0.004	0.004	0.004	0.003	0.01	0.02	0.01	0.07	0.12

- No soil data were available.

Table 8: Chemical risk to muskrats

Chemical	Port Hope	Chemetron	Brewery	Highland Dr.	Ganaraska	Alexander	Gages	Brand
Parameter	Harbour	Wetland	Creek	S. Creek	River	Creek	Creek	Creek
Antimony	-	0.01	0.14	0.02	0.02	0.02	0.14	0.03
Arsenic	-	0.12	0.95	0.54	0.02	0.26	0.08	0.23
Barium	-	0.06	0.16	0.09	0.03	0.10	0.21	0.14
Cobalt	-	0.01	0.02	0.02	0.01	0.03	0.04	0.04
Copper	-	0.02	0.01	0.01	0.003	0.01	0.02	0.03
Lead	-	0.01	0.003	0.002	0.001	0.002	0.001	0.003
Molybdenum	-	0.11	0.01	0.04	0.04	0.04	0.04	0.02
Nickel	-	0.002	0.001	0.001	0.001	0.002	0.002	0.002
Selenium	-	0.21	0.16	0.21	0.21	0.21	0.16	0.16
Uranium	-	0.19	0.01	0.02	0.01	0.04	0.01	0.01
Vanadium	-	0.05	0.20	0.17	0.10	0.19	0.16	0.19
Zinc	-	0.01	0.01	0.004	0.001	0.01	0.01	0.01

- Habitat unsuitable for muskrats.

V. RESULTS FOR PORT GRANBY PROJECT

The locations of interest in the Port Granby Project are shown in Figure 5. They include aquatic locations of potential current and/or future effects arising from contaminant releases from the existing WMF site and the future LTWMF site in the lower Port Granby Creek watershed. They also include upland terrestrial locations in and around the WMF and LTWMF sites, where waste excavations and/or placements will occur.

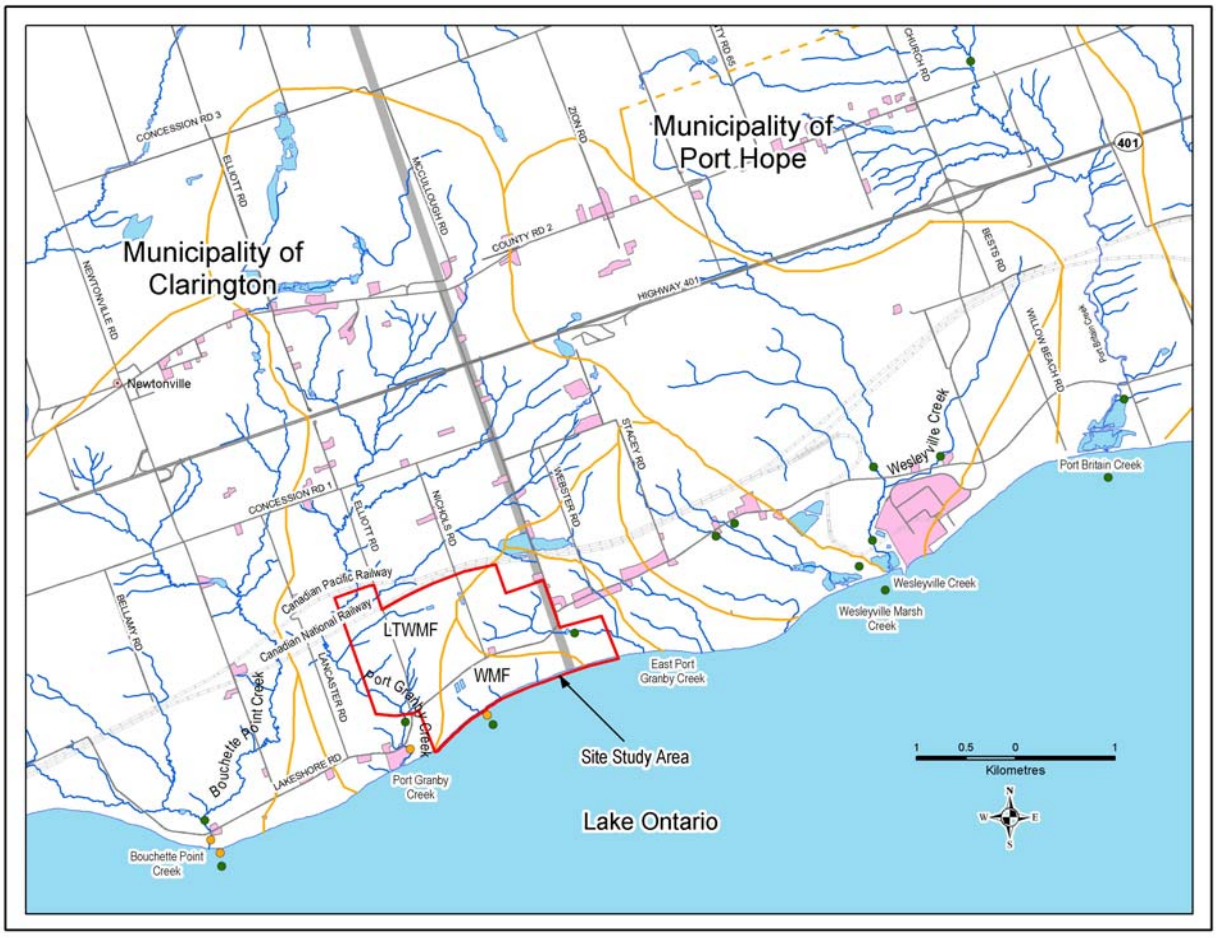

Figure 5: Locations of interest in the Port Granby Project.

V.A. Aquatic ERA

The aquatic ERA for the Port Granby Project found radiation risk quotients well below 1 for all aquatic receptors at all locations. For non-radionuclides, only the cadmium risk quotients for sediment-dwelling biota exceeded 1, and this was a general condition across the study area. The spatial pattern of risk quotients does not suggest any effects on aquatic life from the existing Port Granby WMF under baseline conditions.

V.B. Terrestrial ERA

The terrestrial ERA for the Port Granby Project found radiation risk quotients above 1 for soil invertebrates in the West Gorge area (Table 11). The radiation risk quotients did not exceed 1 for plants or for any wildlife receptors.

Arsenic risk quotients exceed 1 for soil invertebrates and plants at the existing WMF locations, including the West Gorge. Quotients for several other metals (cobalt, copper, nickel) also exceed 1 for soil-dwelling biota in the West Gorge.

Arsenic risk quotients exceed 1 for voles and rabbits in the West Gorge. The quotient for cobalt also exceeds 1 for rabbits in the West Gorge (Table 12). Wildlife risk quotients do not exceed 1 for any other Port Granby locations.

Table 9: Chemical risk to plants and soil invertebrates

Chemical	Existing WMF		West Gorge	LTWMF
Parameter	AMEC 04a	STF 93	Area	Area
Antimony	0.01	0.10	0.56	0.01
Arsenic	**2.57**	**1.87**	**15.50**	0.09
Barium	0.06	0.07	0.06	0.05
Cobalt	0.79	0.38	**9.85**	0.08
Copper	0.16	0.11	**1.23**	0.03
Lead	0.11	0.20	0.98	0.05
Molybdenum	0.08	0.11	0.02	0.05
Nickel	0.22	0.11	**2.53**	0.03
Selenium	0.01	-	-	0.01
Uranium	0.27	0.82	0.82	0.04
Vanadium	0.14	0.12	0.15	0.10

- No selenium in soil data were available.

Table 10: Chemical risk to rabbits

Chemical	Existing WMF		West Gorge	LTWMF
Parameter	AMEC 04a	STF 93	Area	Area
Antimony	0.01	0.03	0.15	0.01
Arsenic	0.90	0.84	**5.70**	0.03
Barium	0.05	0.07	0.06	0.02
Cobalt	0.12	0.05	**1.40**	0.03
Copper	0.08	0.03	0.30	0.02
Lead	0.00	0.01	0.03	0.004
Molybdenum	0.21	0.35	0.06	0.08
Nickel	0.01	0.003	0.06	0.003
Selenium	0.02	-	-	0.02
Uranium	0.02	0.08	0.08	0.004
Vanadium	0.21	0.09	0.12	0.18

- No selenium in soil data were available.

VI. CONCLUSIONS

In summary, for both Port Hope and Port Granby projects, some risk quotients above 1 have been estimated for baseline conditions in the vicinity of existing LLRW storage areas. The suggested potential for adverse effects is spatially limited and is therefore unlikely to result in measurable effects at the population or community level. Nevertheless, some localized risk reduction can be expected as a result of cleanup activities.

Levels of contaminants in and around the cleanup areas and long-term waste management areas are generally expected to be reduced after cleanup, or not measurably increased. Where localized soil increments are expected around the LTWMF perimeter, risk assessment indicates that there will be no adverse ecological effects.

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