INVESTIGATION OF TRITIUM IN GROUNDWATER AROUND A TRITIUM LIGHT MANUFACTURING FACILITY

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ABSTRACT

Routine environmental monitoring around the SRB Technologies property in Pembroke, Ontario, in 2004-05, found tritium in groundwater at concentrations above the federal/provincial drinking water limit of 7,000 Bq/L. An investigation was ordered to determine the source of these levels, and suggest strategies for source control. Point source leaks were suspected.

The investigation was undertaken by EcoMetrix from December 2005 to October 2007. The scope included gathering data on tritium levels in air, soil water, groundwater and nearby surface water, determining local groundwater uses and associated risks, identifying the tritium source as a basis for source control, predicting future transport of tritium in groundwater and estimating timeframes for improvement of groundwater quality.

Tritium in air was monitored using passive samplers, and modelled from annual emissions using the IMPACT code (CSA N288.1 model). Soil water from boreholes was analyzed for tritium, and concentrations were predicted from modelled air concentrations. Groundwater from 37 monitoring wells was analyzed for tritium, and concentrations were predicted from modelled historical air and soil water concentrations, allowing for decay during vertical transport to the well screen.

It was found that one-third of monitoring wells, mostly within the property boundary, had tritium in groundwater in excess of 7,000 Bq/L. The maximum tritium in groundwater was 50,000 Bq/L. Two water supply wells were hydraulically down-gradient of the stacks. One well at an office building (1,500 Bq/L) was used for drinking, and the other (5,000 Bq/L) was used for truck washing. The nearest residential supply well (450 m north-west) had tritium at 1,400 Bq/L, equivalent to approximately 2% of the public dose limit.

Tritium emissions to air peaked in the year 2000 (1.7E6 GBq/a) (well within licence limits) and have been declining since that time. Tritium in shallow soil water in 2007 was predictable from modelled tritium in air based on 2006 emissions, suggesting a time lag of about one year between air and shallow soil moisture. Tritium in groundwater was consistent with modelled concentrations based on previous years' emissions to air, with a depth-dependent time lag.

Since the tritium in groundwater issue seemed to be related to licensed emissions to air, the control strategy focused on reducing emissions to air. A new emission limit of 67,200 GBq/a was established, as a level that would produce soil water concentrations well below the drinking water limit at the facility boundary. Some deeper groundwater concentrations on site, produced by historical emissions, will continue to exceed the limit for decades. Tritium concentrations in groundwater are expected to be well below the drinking water limit prior to discharge at the nearest surface water body.

1. INTRODUCTION

SRB Technologies (SRBT) in Pembroke, Ontario has been manufacturing tritium lighting units since 1990. The facility's tritium emissions to air were licensed by the Canadian Nuclear Safety Commission (CNSC). Environmental investigations in 2004-2005 found tritium in groundwater on the site above the federal/provincial drinking water limit of 7,000 Bq/L. The CNSC ordered SRBT to investigate the tritium distribution in groundwater. It was suspected that subsurface leakage of tritium to groundwater might be occurring.

EcoMetrix was retained in 2005 to undertake further investigations of tritium in groundwater at and around the facility. The scope of these investigations [1] included gathering data on tritium levels in air, shallow soil water, deeper groundwater and nearby surface water, determining local groundwater uses and associated risks, identifying the tritium source to groundwater as a basis for source control, predicting future transport of tritium in groundwater, and estimating the timeframe for future improvement of groundwater quality.

2. METHODOLOGY

A search of water well records was completed in order to identify potentially influenced wells around the facility to be checked for tritium levels. In addition, a door-to-door survey was completed within a 400m radius of the facility. Fifteen water supply wells in the area were identified for sampling (10 residential, 3 commercial). The identified wells were sampled and the water was analyzed for tritium.

Tritium in air was monitored using passive air samplers located at 31 stations on site and around the facility out to a distance of just over 3km (Figure 1). A reference station at Petawawa, Ontario, over 9km away was also monitored. Samples were collected monthly for tritium analysis. The sampling and analysis were conducted by Atomic Energy of Canada Limited (AECL).

Tritium in air was also modeled from the annual emissions, using the CSA N288.1 air dispersion model [2], as implemented in the IMPACT code, with local meteorological data. The modeled and monitored air data were compared on an annual average basis in order to validate the model. The modeled air concentrations for soil and groundwater sampling sites were then utilized to explore the relationship between tritium in air, soil water and groundwater.

Soil samples were collected at and around the facility in 2006 and 2007 for analysis of tritium in shallow soil water. Shallow samples included soil to a depth of 10cm. The extraction and analysis of soil water was completed by AECL.

Groundwater monitoring wells were installed at 37 locations in and around the facility, screened in various subsurface strata, including the overburden, the soil-bedrock interface and the shallow or deep bedrock. Overburden samples were collected during drilling and water was extracted for tritium analysis. Groundwater samples were collected in 2007 and submitted to AECL for tritium analysis. Soil water and groundwater sampling locations are shown in Figure 2.

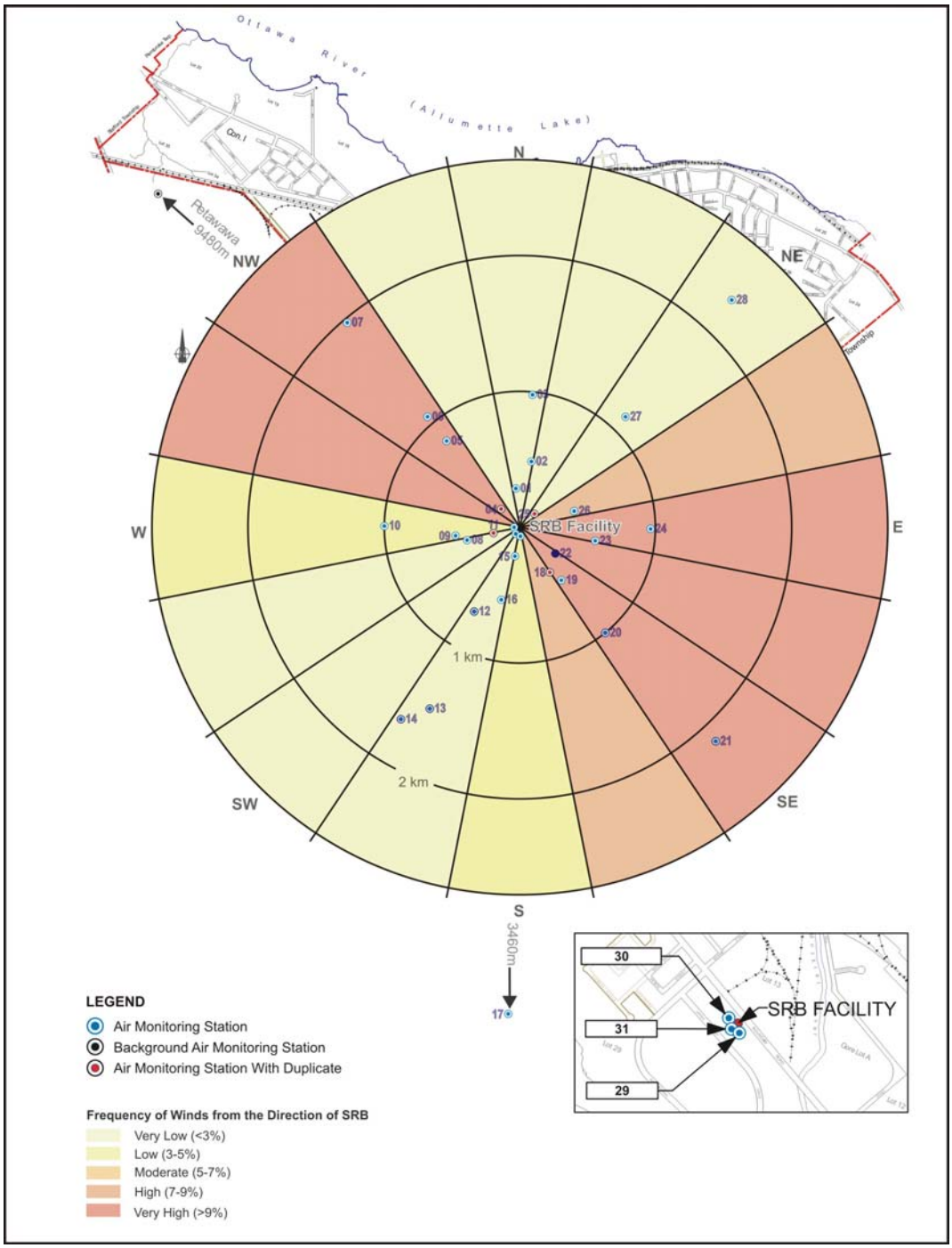


Figure 1. The Site with Air Monitoring Locations

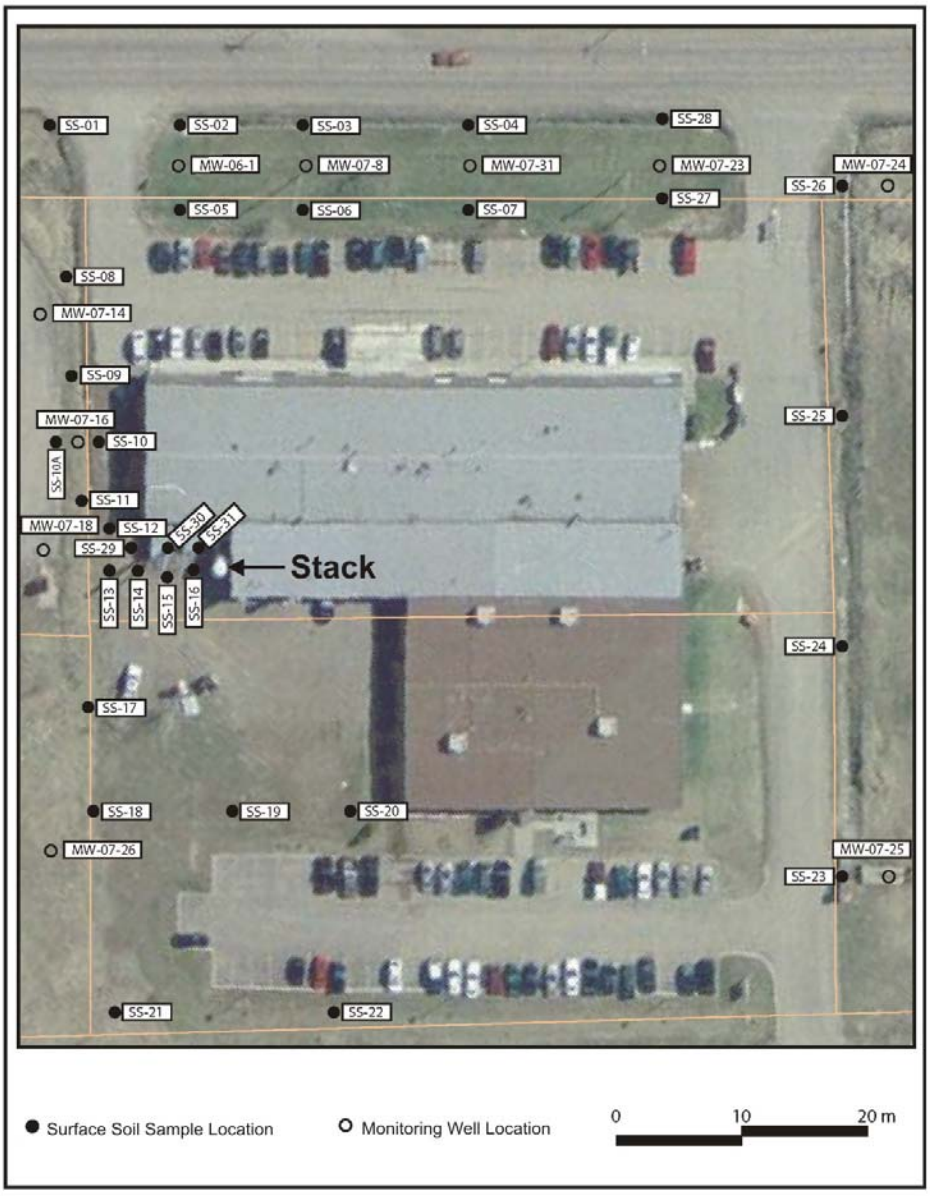


Figure 2. Groundwater and Soil Water Monitoring Locations

Tritium in shallow soil water and deeper groundwater was also modeled, for each monitoring location, based on previous year's emissions and modeled air concentrations, allowing for decay during vertical transport of soil water down to the well screen depth. This permitted evaluation of whether observed groundwater concentrations were attributable to the historical atmospheric releases.

Roof runoff, stack drippings and standing water near the stack were sampled in 2006, during processing and at other times. These samples were analyzed for tritium as an indication of possible point source releases to groundwater at the facility.

Surface samples were collected in the Muskrat River, down-gradient of the facility, both upstream and downstream of the likely zone of groundwater discharge to the river (Figure 3). These samples were analyzed for tritium to indicate whether a facility influence was detectable at the river, and as a baseline against which to judge any future influence.

Rates of tritium migration toward the river were estimated as a basis for predicting possible future effects on the river due to tritium in groundwater at and around the facility today.

A source control strategy was developed, and the timeframe for future improvement of groundwater quality at the facility was estimated, based on decay of present-day levels.

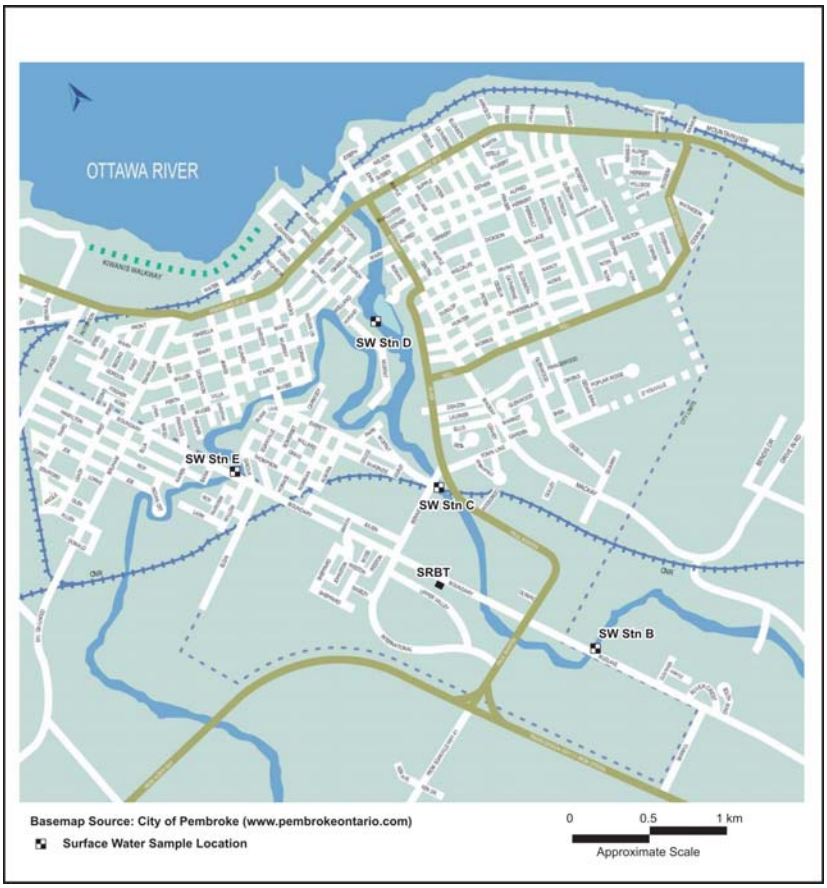


Figure 3. Surface Water Sampling Locations

3. RESULTS AND DISCUSSION

3.1 Stratigraphy and Groundwater Flow

The site stratigraphy is illustrated in Figure 4. Topsoil overlies a sand or gravel fill which overlies a predominantly silty clay overburden. Below this, at a depth of approximately 6m, the bedrock consists of dolomitic limestone. The bedrock is fractured at the surface, allowing for horizontal groundwater flow along the zone at the bedrock surface, and in the shallow bedrock.

Water infiltrates vertically downward to the bedrock; subsequent groundwater flow is mainly horizontal through the fractured bedrock zone. The competent bedrock has a much lower hydraulic conductivity than the fractured upper zone. The horizontal flow is dominantly to the east, toward the Muskrat River, as illustrated by the water level contours in both spring and fall. However, a groundwater divide occurs just north of the property, with flow to the north from that area in the fall, as illustrated by the water level contours for November 2007 (Figure 5).

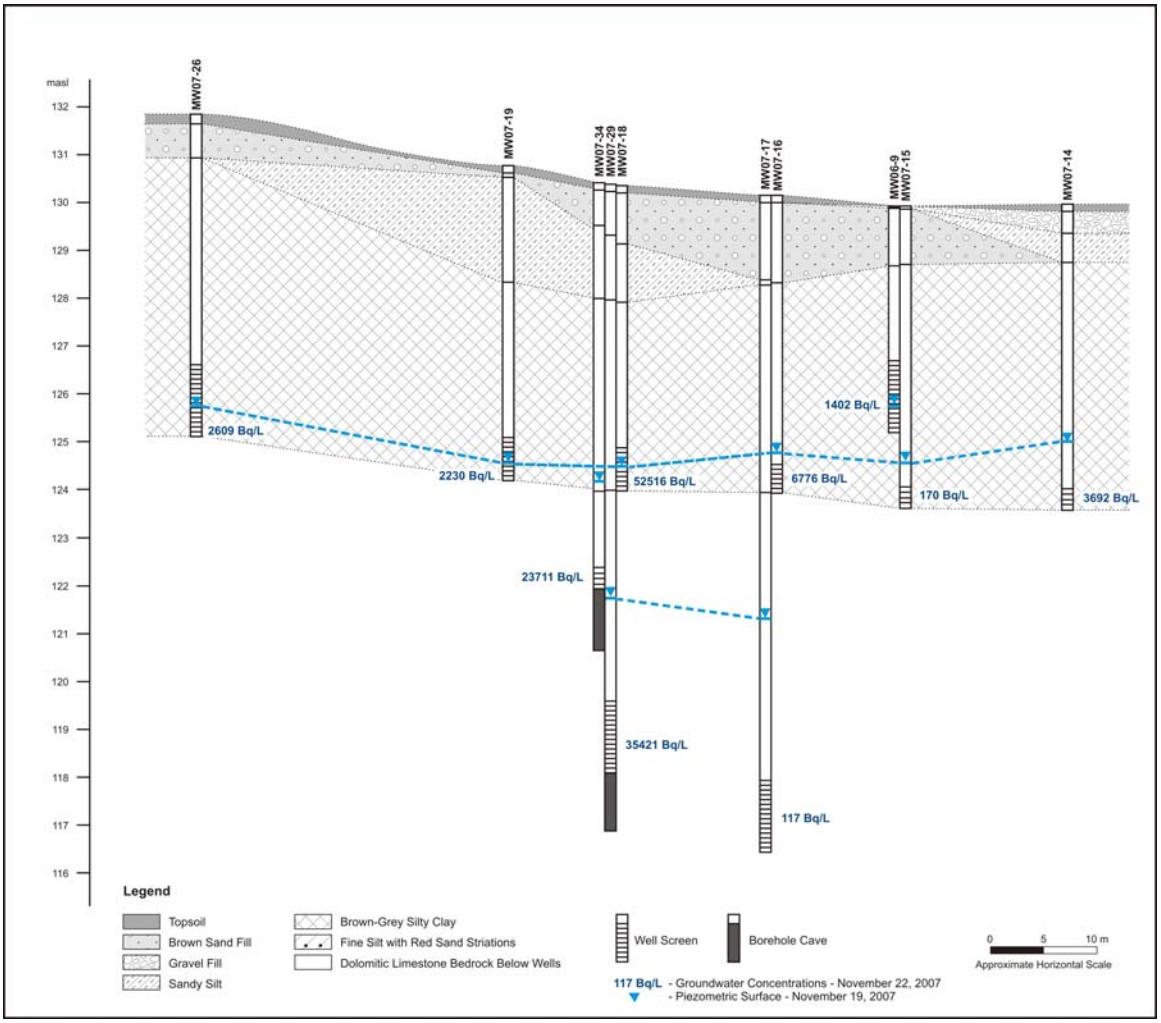


Figure 4. Site Stratigraphy

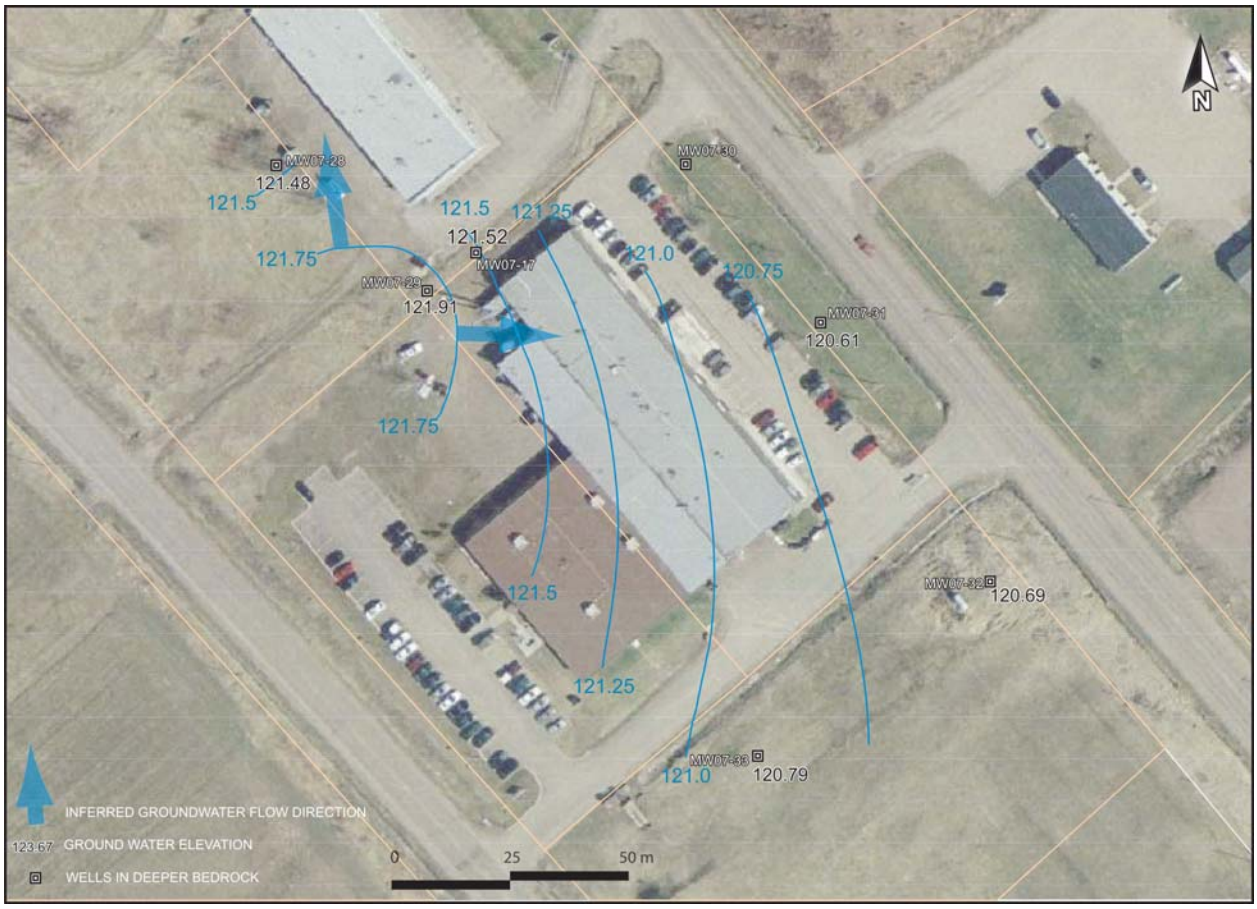


Figure 5. Groundwater Flow Patterns

3.2 Tritium in Groundwater

Approximately one-third of the monitoring wells sampled had tritium levels in excess of the drinking water guideline of 7,000 Bq/L. Most of these were within the property boundary, particularly near the stacks or just north-west of the stacks or in a winter snow storage area. The maximum measured tritium in groundwater was 50,000 Bq/L.

Two water supply wells are hydraulically down-gradient from the facility, 100m to the east. One of these, in an office building was used for drinking and contained tritium at 1,500 Bq/L. The other was used for truck washing and contained tritium at 5,000 Bq/L. The nearest residential water supply well (450m northwest of the facility) contained tritium at 1,400 Bq/L, or 20% of the drinking water limit, or approximately 2% of the public dose limit.

3.3 Modeling from Emissions

The annual average tritium in air at a given location was readily predicted by modeling from the facility emissions. Figure 6 shows the modeled vs measured tritium in air for 2006. The N288.6 model is slightly conservative, as intended [2].

The tritium in shallow soil water in 2007 was predicable, generally within a factor of two, from the modeled air concentrations based on licensed emissions to air in 2006 (Table 1). Tritium emissions, and therefore air concentrations, have been declining since 2000. The data suggest that soil concentrations lag somewhat behind, agreeing better with predictions based on last year's air concentrations.

The tritium in groundwater in 2007 was generally consistent with modeled air and soil water concentrations (Figure 7) based on previous year's emissions, with a depth-dependent time lag. The appropriate time lag was determined based on the vertical travel time to the well screen, at an estimated vertical velocity of 0.5m/a. Actual vertical velocities may vary among locations based on the strata and their thicknesses at each location.

A few wells were substantially over-predicted (e.g. MW07-23 and MW07-24 in Figure 7). These wells were screened at the bedrock surface and may have been subject to dilution from up-gradient flow along the bedrock. One well (MW07-18) was substantially under-predicted. This well was near the snow storage area and was likely influenced by tritium in snow-melt. The latter was measured at 14,698 Bq/L.

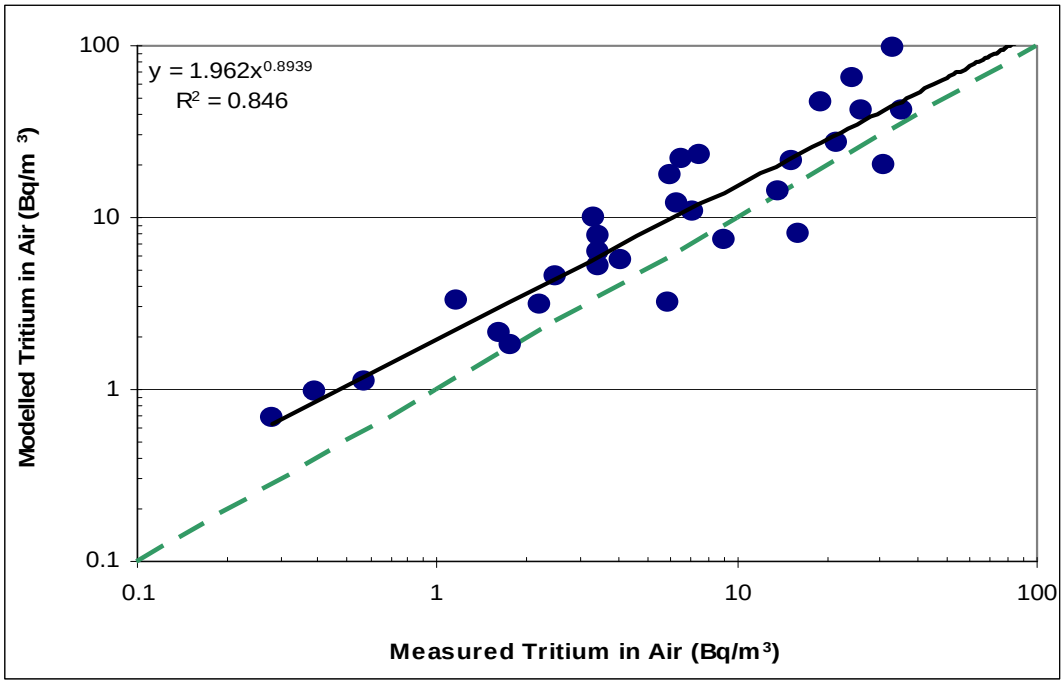


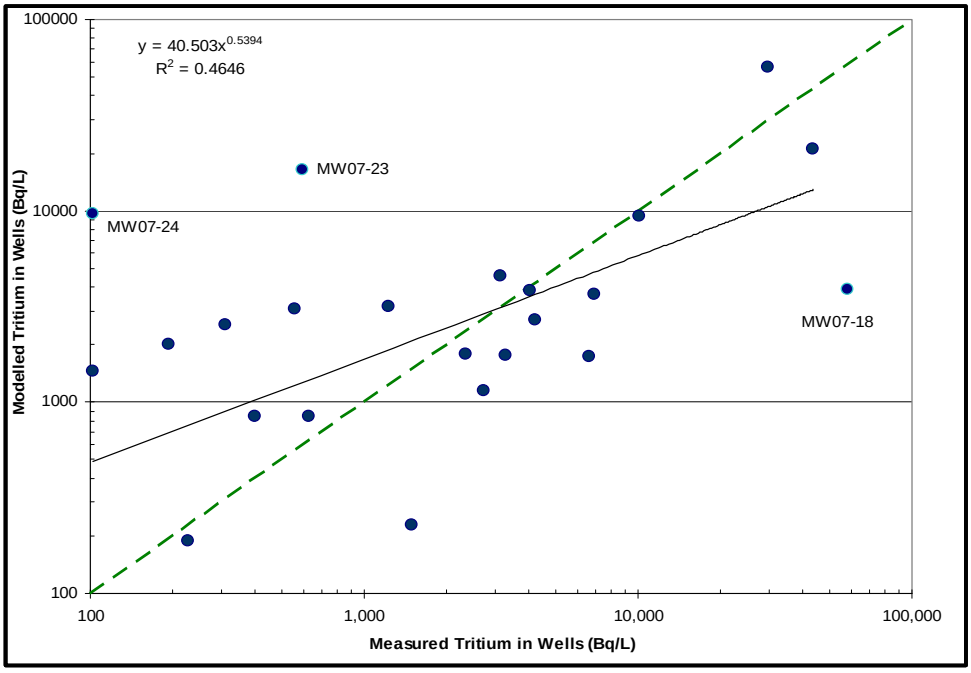
Figure 6. Modeled vs Measured Tritium in Air (0-3 km)

Sampling Location	Measured (Bq/L) 2006	2007		Modelled (Bq/L)[1] 2005	2006	Modelled Location	06Modeled / 07Measured[2]
SRB-SS2	1,634	1,340	L	5,738	1015	MW06-1	0.76
SRB-SS3	1,004	535	L	3,108	369	MW07-12	0.69
SRB-SS4	804	566	L	5,271	902	MW07-31	1.59
SRB-SS5	1,598	599	L	5,738	1015	MW06-1	1.69
SRB-SS6	1,293	592	L	3,108	369	MW07-12	0.62
SRB-SS7	1,285	706	L	5,271	902	MW07-31	1.28
SRB-SS18	1,439	961		1,719	293	MW07-26	0.31
SRB-SS24	-	612	L	5,309	1,164	MW07-25	1.90
SRB-SS26	-	610	L	6,533	1,414	MW07-24	2.32
SRB-SS27	-	637		6,147	1,236	MW07-23	1.94
SRB-SS28	-	692		6,147	1,236	MW07-23	1.79

[1] Based on emissions: 2005 - 2.7E14 Bq/a; 2006 - 7.4E13 Bq/a

[2] 2007 measurements in the range of predictions from 2006 air

Table 1. Modeled vs Measured Tritium in Soil Water



Outliers at MW07-23, MW07-24 and MW07-18 omitted from the fit line

Figure 7. Modeled vs Measured Tritium in Groundwater (10-100m)

3.4 Point Sources to Groundwater

Other possible point sources of tritium to groundwater include roof runoff via downspouts and drippings down the stack wall during precipitation events. Table 2 shows measured tritium concentrations in these waters, and in standing water near the stack, during processing and at other times. High soil water concentrations within a few meters of the stack show the influence of these sources. However, locations further down-gradient seem to be primarily influenced by the atmospheric plume.

Operating Condition	Roof Runoff [1] (Bq/L)	Stack Drippings [2] (Bq/L)	Standing Water (Bq/L)
Processing	15,288	2,298,133	19,339
Not Processing	540	3,009	664
2006 Average	5,107	-	-

[1] April - August, 2006

[2] October - December, 2006

Table 2. Tritium in Roof Runoff, Stack Drippings and Standing Water near Stacks During Precipitation Events

3.5 Tritium in Surface Water

Water samples from the Muskrat River, 420m down-gradient of the facility, contained tritium at concentrations of 5 to 14 Bq/L. The average was 7.5 Bq/L upstream from the point where groundwater from the facility would discharge, and 9.7 Bq/L downstream. This was not a statistically significant difference.

The tritium levels in the river are likely due to the atmospheric plume. There has been insufficient time for groundwater from the facility to reach the river at an estimated horizontal velocity of 4 m/a. Based on the maximum concentration in facility groundwater (50,000 Bq/L), and a travel time of 8.5 half-lives to the river, the maximum future breakthrough concentration would be approximately 138 Bq/L, conservatively ignoring lateral dispersion.

3.6 Source Control

Since the tritium in groundwater at and around the facility was primarily related to the atmospheric plume, the source control strategy was focused on reduction of emissions to air. A new emission limit was developed that would be expected to produce shallow soil water within

the drinking water limit of 7,000 Bq/L on-site, and much lower concentrations off-site. Figure 8 shows the modeled soil water concentration contours, based on the average 2000-2006 emissions, and based on the new tritium emission limit (67,200 GBq/a) which was ten times lower.

Figure 8. Predicted Soil Water Contours Based on Average 2000-2006 Emissions and Based on the New Emission Limit

4. CONCLUSIONS

Tritium in groundwater at the SRBT site in excess of the drinking water limit of 7,000 Bq/L is attributable mainly to the influence of the atmospheric plumes of earlier years, which arose from licensed releases to air. The maximum tritium in groundwater was found to be 50,000 Bq/L. Two water supply wells were hydraulically down-gradient of the stacks. One well at an office building (1,500 Bq/L) was used for drinking, and the other (5,000 Bq/L) was used for truck washing. The nearest residential supply well (450 m north-west) had tritium at 1,400 Bq/L, equivalent to approximately 2% of the public dose limit.

Since the tritium in groundwater appeared to be related to licensed emissions to air, the control strategy focused on reducing emissions to air. A new emission limit of 67,200 GBq/a was established, as a level that would produce soil water concentrations well below the drinking water limit at the facility boundary. Some deeper groundwater concentrations on site, produced by historical emissions, will continue to exceed the drinking water limit for decades. The maximum tritium concentrations may be transported approximately 100m down-gradient of the facility by the time they fall below the drinking water limit.

5. REFERENCES

[1] EcoMetrix Incorporated. 2008. Comprehensive Report – Groundwater Studies at the SRB Technologies Facility, Pembroke, ON. Report to SRB Technologies (Canada) Inc. January, 2008.

[2] Canadian Standards Association (CSA). 2008. Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities. N288.1-08. September 2008.