

Perch Lake Scenario Description EMRAS Tritium/C14 Working Group

BACKGROUND

Located on the site of Chalk River Laboratories (CRL), Perch Lake contains trace amounts of tritium due to leakage from a nearby waste management area. The releases have been going on for many years and concentrations in various parts of the lake ecosystem are likely to be in equilibrium. Tritium concentrations in lake water, sediments, aquatic plants, fish, clams and air were collected three times during the summer and fall of 2003 at three locations in the lake. These data are offered here as a test of models that predict the long-term average tritium concentrations in aquatic systems due to chronic releases.

SITE DESCRIPTION

Perch Lake (Figure 1) is a small, shallow freshwater Canadian Shield lake. Its largest fetch is 876 m and it has a surface area of $4.5 \times 10^5 \text{ m}^2$. It has a mean depth of 2.0 m, a maximum depth of 3.5 m and a total volume of $9.1 \times 10^5 \text{ m}^3$. It drains a watershed of area $5.65 \times 10^6 \text{ m}^2$. The lake can be considered unstratified, although there is weak stratification in deeper areas in the summer, when surface waters are approximately 5°C higher than those at lake bottom. The turnover time of lake waters is about two years.

Perch Lake is contaminated by tritium migrating through an extensive sand aquifer from a waste management area (WMA) located about 750 m to the north. The WMA was in operation for about 40 years until it was shut down in 1999. The tritium forms a well-defined underground plume that is narrow near the source but broadens to a width of about 1000 m at Perch Lake. Tritium discharges into the lake through the sediments from below and also through a stream (Inlet 2 in Figure 1) that flows above the underground plume. Inlet 1 shows slightly elevated levels of tritium but Inlets 3, 4 and 5 are all uncontaminated.

Sediments in the lake are composed of sand and gyttja (decomposing organic material). The average dry bulk density is 185 kg m^{-3} but this varies substantially across the lake depending on the local proportion of sand and gyttja. The sediments near Inlet 1 are largely organic in composition whereas those near Inlets 2 and 3 contain more sand. The sedimentation rate is $0.16 \text{ kg m}^{-2} \text{ a}^{-1}$ or 0.06 cm a^{-1} .

TRITIUM MEASUREMENTS

Water, sediment, plant and air samples were collected primarily from three locations in Perch Lake: at S1, located near Inlet 1; at S2, located near Inlet 2; and at S3, halfway between Inlets 3 and 4. A few samples were also taken at S4 near Inlet 4 and near the outlet of the lake. Some of the samples were taken by boat about 10-15 m from shore whereas others were taken from shore at the edge of the lake. Fish tend to feed on the east side of the lake and were caught in an extended area near the outlet, whereas clams were harvested between Inlet 3 and the outlet. Most samples were collected three times during the summer and fall of 2003 (May 27-28, July 28-29 and September 28-October 1). Additional measurements of water concentrations were made in early November. Air concentrations were measured only in August and September as monthly averages and algae were not available in September, as they had all died off. Replicate samples were taken in some cases.

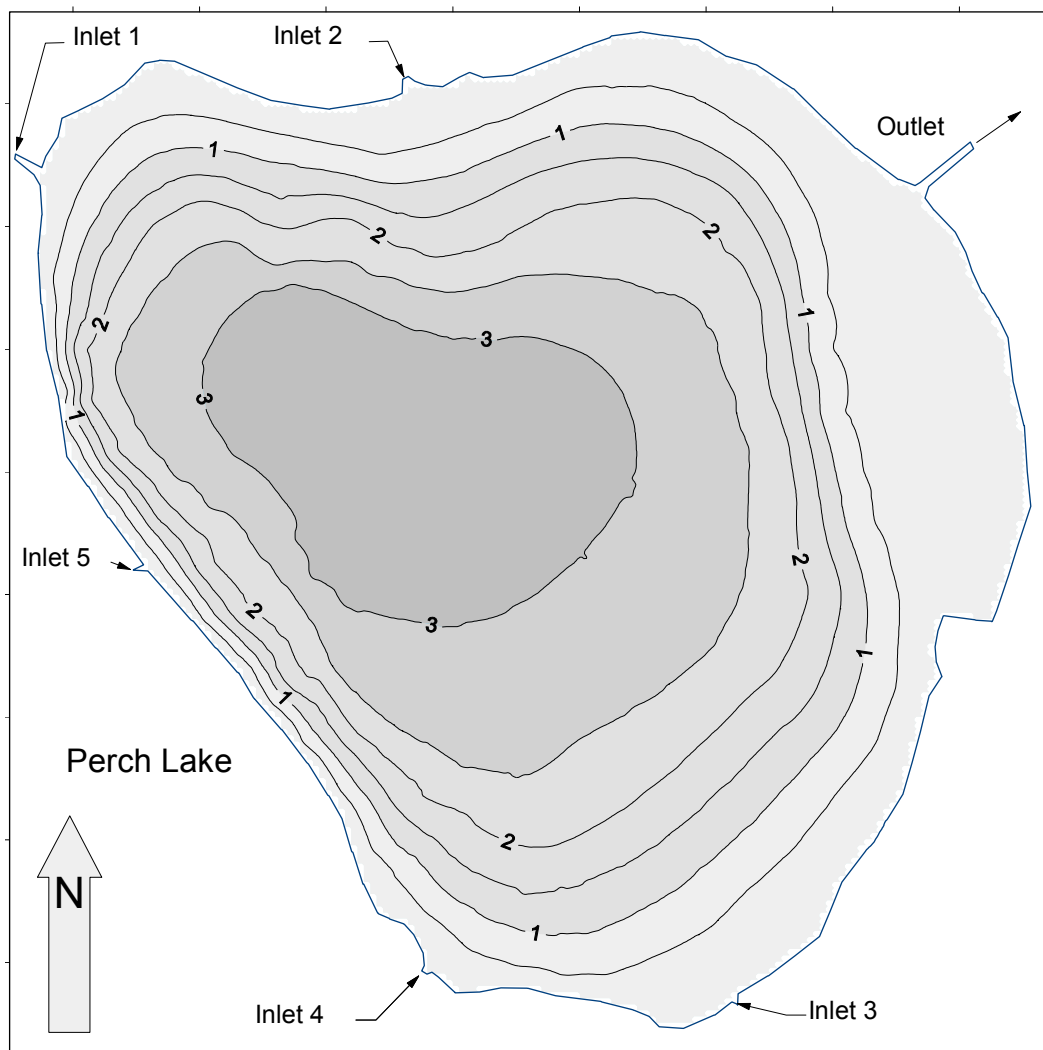


FIG. 1. Map of Perch Lake showing inlets and outlet and depth contours in m.

Water: Water samples were collected near the surface of the lake and at deeper levels by opening sampling bottles at the desired depth. The samples were left standing to allow suspended sediments to settle out and then 10 ml of water was transferred into scintillation vials. HTO concentrations were determined by liquid scintillation counting (LSC).

Sediments: Sediment samples were scooped up by hand and placed in vinyl bags that were sealed at depth. This provided samples averaged over the top 15 cm or so of sediments. Water was extracted from the sediments by freeze-drying and analyzed for HTO concentration by LSC. The remaining solid material was washed with tritium-free water to remove the exchangeable OBT and was then completely dried in an oven and combusted in a combustion tube. The combustion water was analyzed by LSC to give OBT concentrations.

Plants: Samples were taken of bladderwort (*Utricularia* spp.), hornwort (*Ceratophyllum demersum*) and cattails (*Typha latifolia*), and of algae belonging to the phylum Chlorophyta. Bladderwort and hornwort are both unrooted plants that are completely submerged and obtain their nutrients from the water. These two species were composited for analysis. The cattails are rooted in the top 5-10 cm of the sediments, from which they draw their nutrients. They extend above the water into the air, and the submerged and emergent parts were analysed separately. Algae were scooped out of the water by hand and placed in a sampling jar after allowing the water to drain away. The water in all plant samples was extracted by freeze-

drying and HTO concentrations were determined by LSC. The solid matter was washed with tritium-free water and was then oven-dried and combusted in a combustion bomb. LSC of the combustion water yielded non-exchangeable OBT concentrations.

Aquatic Animals: The aquatic animals collected included clams (*Elliptio complanata*), bullheads (*Ameiurus nebulosus*) and pike (*Esox lucius*). Bullheads are small benthic fish and pike are large piscivores. Both types of fish likely move throughout the lake, eating other fish and invertebrates. The fish were caught in nets and the clams were pulled individually from the sediments by hand. The fish samples were divided into three parts (flesh, head and internal organs), each of which was analyzed separately. About five pike, 20 bullheads and 12 clams were combined to provide enough mass for each analysis. The fish used in the composites were all roughly equal in size (about 15-20 cm long and 20-30 g in weight for the bullheads and 30-40 cm long and 200 g in weight for the pike) and thus presumably the same age. Water was extracted from the samples by freeze-drying and analyzed by LSC. The solid matter was washed with tritium-free water, oven-dried and combusted in a combustion bomb for subsequent OBT analysis by LSC.

Air: The tritium in the air above Perch Lake comes primarily from evapotranspiration from the lake and the adjacent wetland. Fluxes from the wetland to the air during daytime in the summer are about $1-3 \text{ Bq m}^{-2} \text{ s}^{-1}$. Monthly-averaged air samples were collected with passive diffusion samplers in the months of August and September at sites S1, S2 and S3. The samplers were located 1-2 m from the shoreline at a height of 1 m. Analysis by LSC provided concentrations in Bq m^{-3} air, which were converted to Bq L^{-1} air moisture using the measured average monthly temperature and an estimated relative humidity of 75%.

Uncertainties: Counting errors in the HTO concentrations in lake water, plants and aquatic animals were generally less than 2% but reached 10% in some cases of low concentrations. Total uncertainties in the HTO concentrations in sediment water were somewhat larger because of the difficulties in keeping lake water out of the sample. Replicate sediment samples from the same location showed differences of about 30%. A similar variation among individual plant and animal samples would be expected because of natural variability but may not be evident in the composite samples that were analysed. Uncertainties in air concentrations arose due to counting errors, and to uncertainties in the performance of the passive samplers and in determining the volume of air sampled. The total uncertainties in the air concentrations are estimated to be less than about 30%.

Counting errors for OBT concentrations were usually less than 5% but additional uncertainty arose due to difficulties in removing exchangeable OBT from the samples and in the combustion process. The total uncertainty in the OBT measurements is estimated to be about 20%. Differences among replicate samples from the same location may be larger because of natural variability.

INPUT DATA

Measured HTO concentrations in water, sediment water and air moisture are shown in Table 1. Concentrations of the water and sediment samples collected from shore may not reflect concentrations in the main body of the lake. At sampling sites S1, S3 and S4, the near-shore samples were taken close to the inlets of the associated streams and concentrations may have been diluted by the relatively clean inflow. In contrast, the onshore samples taken at S2 may be higher than those further out in the lake since concentrations in Inlet 2 are relatively high. Air concentrations were highest near S2, which is directly over the underground plume, and decreased from August to September.

SCENARIO CALCULATIONS

Using the information provided above, calculate

- (i) HTO and non-exchangeable OBT concentrations in bladderwort and hornwort combined, cattails and algae for the May sampling period for sites S1, S2 and S3. For cattails, give concentrations for both the above water and below water parts of the plant. Give the results in Bq L⁻¹ for HTO and Bq L⁻¹ water equivalent for OBT.
- (ii) HTO and non-exchangeable OBT concentrations in clams, bullheads and pike for each of the three sampling periods. For bullheads and pike, give concentrations in head, flesh and internal organs. Give the results in Bq L⁻¹ for HTO and Bq L⁻¹ water equivalent for OBT.
- (iii) non-exchangeable OBT concentrations in sediments for the May sampling time for sites S1, S2 and S3, in units of Bq L⁻¹ water equivalent.
- (iv) 95% confidence intervals on all predictions in (i) - (iii).

TABLE 1. MEASURED HTO CONCENTRATIONS IN SURFACE WATER, SEDIMENT WATER AND AIR MOISTURE

Month	Compartment	HTO Concentrations (Bq L ⁻¹)				
		S1	S2	S3	S4	Outlet
May	Surface water - offshore	4350	5450	4730		
	Sediment water - offshore	4730	10890	1320		
		3330	13570			
		3830	13210			
July	Surface water - offshore	4640	4590	4620		4660
	- from shore near inlet	4150	3330	3800	91	
	Deep water - offshore*	4480	4460	4420		4620
		- from shore near inlet‡	3900	2570	3580	
	Sediment water - from shore near inlet	2300	7120	70		
Sept	Surface water - from shore near inlet	2030	9290	139		
	Deep water - from shore near inlet‡	2080	9190	113		
	Sediment water - from shore near inlet	1500	7420	84		
		1650	4550			
	Air - August	740	1970	510		
- September	660	1770	260			
Nov	Surface water - offshore	3840	5270	3770		
	Deep water - offshore*	3480	9350	3770		

* collected at a depth of about 1.5 m

‡ collected at a depth of about 0.4 m