

**Background**

Torch Lake, Houghton County, is contaminated with pollutants from copper mining and reclamation operations in the area. Copper mining and associated activities occurred from the 1840s to 1968. In addition to the stamp sands, a source of polychlorinated biphenyl (PCB) contamination exists in the lake, likely from disposal of electrical equipment or fluids used in stamp mills or the local electricity generation and distribution system. PCB presence in Torch Lake causes the restriction on fish consumption beneficial use impairment (BUI).

**Approach**

- PCB concentration data was obtained from the following sources: U.S. Environmental Protection Agency, Michigan Department of Environmental Quality; Weston Solutions, Inc., and AMEC.
- PCB concentration data was categorized by type: semi-permeable membrane device (SPMD), fish or ground (groundwater, upland soil and lake sediment).
- PCB concentrations in SPMDs were provided as total PCB and individual congener concentrations in the SPMDs at each sample location. The individual congeners were grouped together by chlorination. Average concentration for each isomer was determined. Isomer concentrations and total PCB concentrations are represented and displayed in Fig. 2.
- Groundwater, upland soil and lake sediment concentrations were reported as individual or total Aroclor concentrations. When total Aroclor concentration was not provided, it was determined by taking the sum of the individual Aroclor concentrations.

**Elevated Torch Lake Sediment, Groundwater, and Soil PCB Concentrations**

- Groundwater PCB concentrations ranged from 0.078—1.2 ppb (Fig.3). The EPA MCL for PCBs in drinking water is 0.5 ppb (EPA, 2012). The MDEQ cleanup criterion for contamination at the groundwater/surface water interface is 0.2 ppb (MDEQ, 2012).
- Sediment PCB concentrations ranged from 26—1131 ppb (Fig.3). An action level for Torch Lake sediments currently does not exist.
- Lakeshore soil PCB concentrations ranged from 24—1120 ppb (Fig.4). The EPA action level for remediation of PCB-contaminated soil is 1000 ppb (EPA, 2009).

**Potential In-lake and Upland PCB sources**

- The close proximity of elevated PCB concentrations to former industrial buildings suggests that likely sources of PCBs to Torch Lake are mining-related electrical equipment and/or fluids on the lakeshore or in lake sediments. (Fig. 3).
- PCBs are found in close proximity to the site of a former Calumet & Hecla electrical powerhouse. PCBs are also found near a former Calumet & Hecla smelter complex site in Hubbell (Fig. 3).
- Elevated sediment PCB concentrations are found near locations that were in operation when use of PCBs as dielectric fluids in electrical equipment such as transformers and capacitors occurred (deVoogt and Brinkman, 1989).

**Polychlorinated Biphenyls (PCBs)**

PCBs are mixtures of anthropogenic and extremely stable chemicals. They are comprised of 209 individual molecules (congeners), each having from 1 to 10 chlorines attached to carbon atoms in any position in the two phenyl rings. Heavier congeners contain more chlorine atoms. PCBs are harmful to human and ecosystem health (Thomas, 2008).

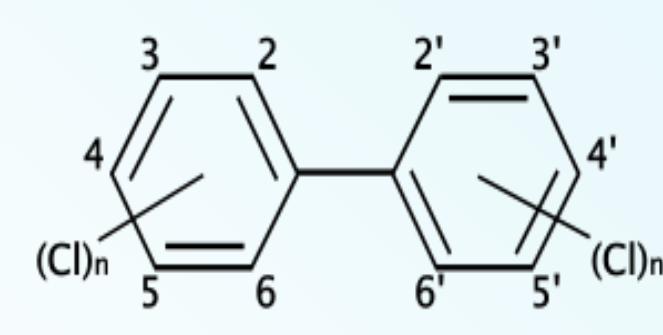


Figure 1: PCB Molecular Structure. Source: www.wikipedia.org

**Elevated Concentrations and Distinct PCB Mixtures in Torch Lake Water and Fish as Compared to Nearby Lakes**

- SPMDs were used to measure water column PCB concentrations at 10 locations within and near Torch Lake.
- SPMDs are composed of polymeric tubes with transport cavities whose interior surface is coated with a protein that absorbs PCBs (Huckins et al., 1993).
- PCB concentrations in Torch Lake are higher than in nearby waterbodies.
- As shown in Figure 2, heavier congeners have a more prominent presence in Torch Lake than in non-Torch Lake sample sites.
- As found for SPMDs, total PCB concentrations in Torch Lake fish are higher than total PCB concentrations in nearby waterbodies (not shown).

**NOAA Sea Grant Project Objectives Related to this Research**

- Summarize existing data for Torch Lake (e.g., contaminants in water column, fish and sediments);
- Summarize remedial actions performed, problems remaining, and future remediation options;
- Inform government agencies and local stakeholders of our findings and facilitate dialog on future options.

**Objectives of this Research**

- Identify sources of PCB contamination to Torch Lake;
- Quantify relative magnitudes of sources;
- Model PCB delivery to lake and accumulation in fish.

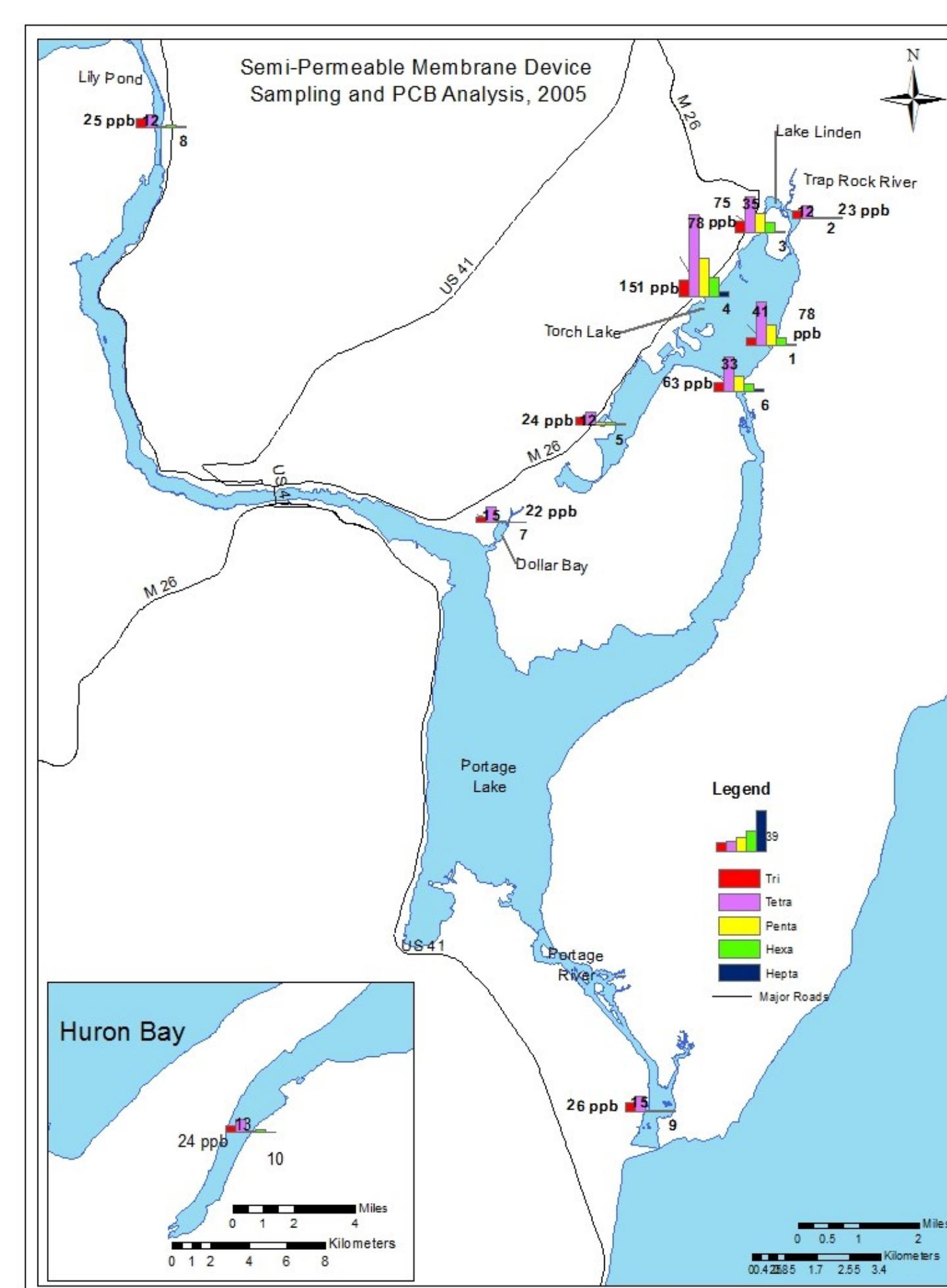


Figure 2: Semi-Permeable Membrane Device sampling showing PCB congener distributions and total PCB concentrations.

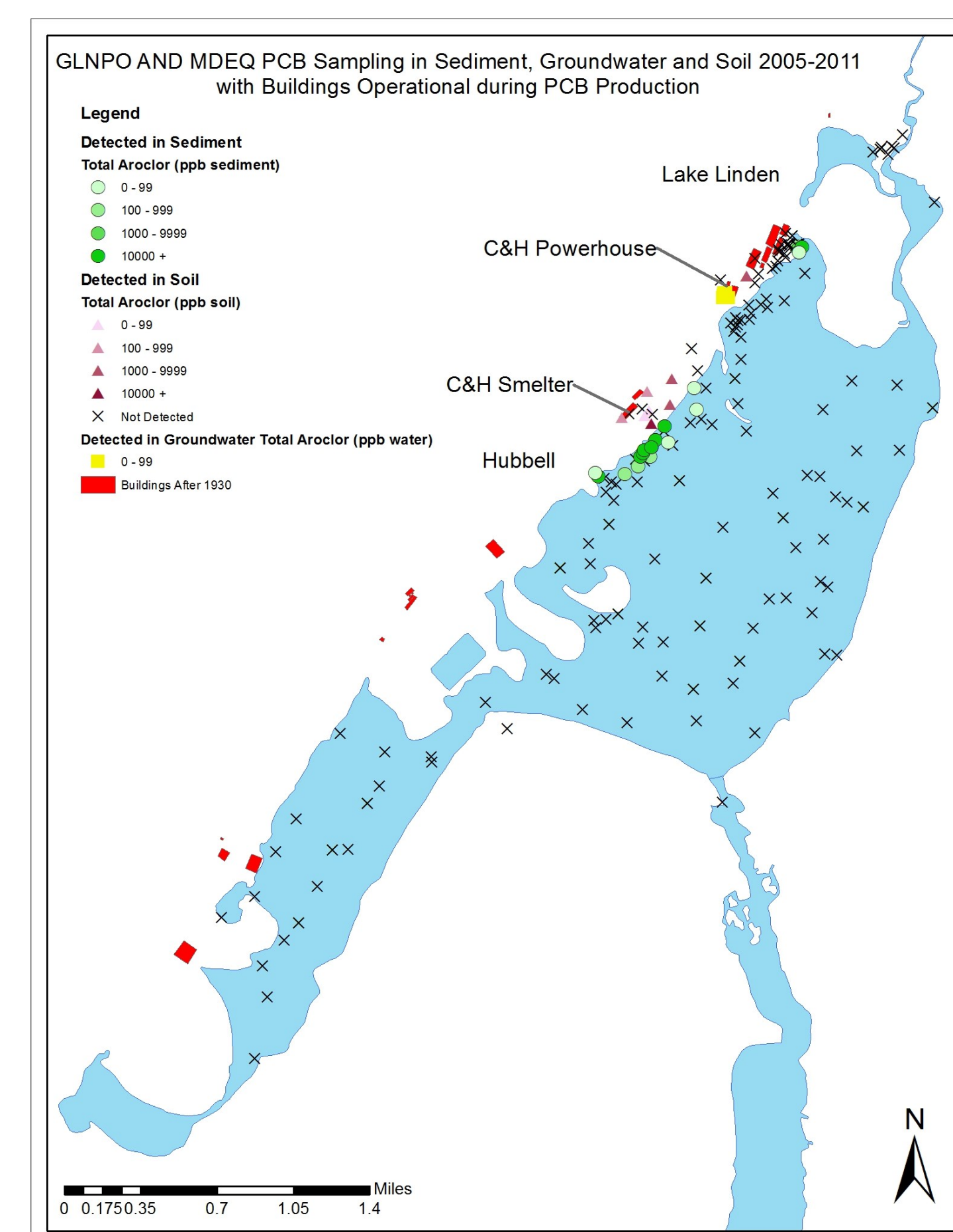


Figure 3: Sediment and Groundwater Sampling showing elevated PCB concentrations.

**Torch Lake Steady-State PCB Mass Balance Model**

The model identifies significant sources of PCBs to Torch Lake and enables evaluation of remediation strategies. Air-phase concentrations and wet deposition values were taken from International Atmospheric Deposition Network data. Areas and PCB concentrations of contaminated sediments were taken from the site map (Fig.3) Groundwater flow into Torch Lake was calculated using Darcy's Law and measured hydraulic gradients. The PCB concentration in the groundwater was measured by MDEQ (Fig. 3). Five individual congeners were modeled (Table 1).

- Known sources cannot account for the PCB concentrations measured in the lake. The model predicts lake water PCB concentrations ~1-27 times lower than measured concentrations (Table 1).
- A large, unidentified input of PCBs to the lake must exist to explain the measured concentrations. For congener 52, this input must be ~10 times larger than the rate of atmospheric deposition (Figure 4).
- The ratios of measured to modeled congener concentrations in the lake range from ~1 to ~27 and suggest that the missing source is heavier than atmospheric inputs and is likely the Aroclors (1254, 1260) used by the mining industry.

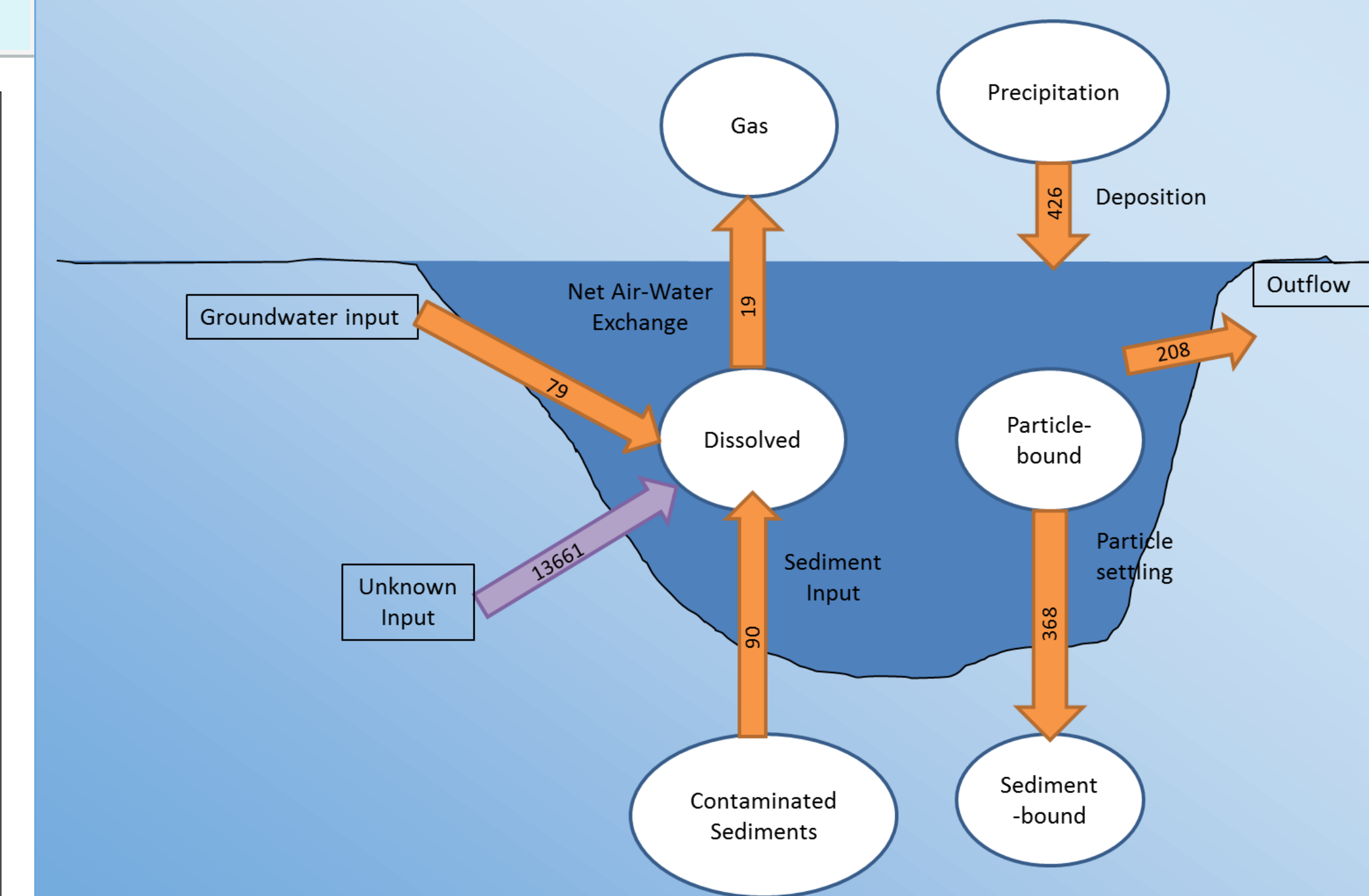


Figure 4: Torch Lake mass balance for PCB Congener 52, mg/yr. Arrows indicate direction of PCB movement. Pink arrow shows estimated required additional input to cause the modeled lakewater concentration to equal the measured lakewater concentration shown in Table 1.

Table 1: Comparison of 2005 aqueous PCB concentration levels in Torch Lake to model-predicted steady-state concentrations.

Congener Number	33	52	99	101	180
Number of Chlorines	3	4	5	5	7
2005 Measured Aqueous Concentration (pg/L)	4	16	8	6	1
Model-Predicted SS Aqueous Concentration (pg/L)	3	2	0.3	1	0.05
Ratio Measured Concentration / Model Concentration	1.33	8	26.67	6	20

**Conclusions**

- PCB concentrations are elevated in the fish and water of Torch Lake compared to nearby lakes.
- Likely sources of PCBs are located along the western shore of Torch Lake. PCBs from contaminated soils may flow via conduits or groundwater into the lake.
- Localized elevated PCB concentrations in lake sediments, likely resulting from disposal of industrial waste, may also diffuse into the overlying lake water; this represents another potential source of contamination to the fish.
- PCB concentrations in Torch Lake are higher than safe levels according to the EPA.
- Heavier congeners are found in Torch Lake more commonly than in surrounding waterbodies, which shows that atmospheric deposition is not the most significant source of PCBs into Torch Lake (otherwise only lighter congeners would have been detected by the SPMDs).
- Modeling suggests that a significant PCB source to the lake has not yet been identified.
- Comparison between modeled and measured lakewater PCB concentrations suggest that the unidentified source is likely the Aroclors used by the mining industry.

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