



Lake Union and the Ship Canal – A history of pollution and work toward a solution

By Tim Clark

Lake Union is often considered the focal point of Seattle. Its central location, photogenic framing of downtown, the Space Needle and the city's past and current industries, and calm waters make it the ideal setting for Fourth of July fireworks and a hub for kayakers and paddle boarders.

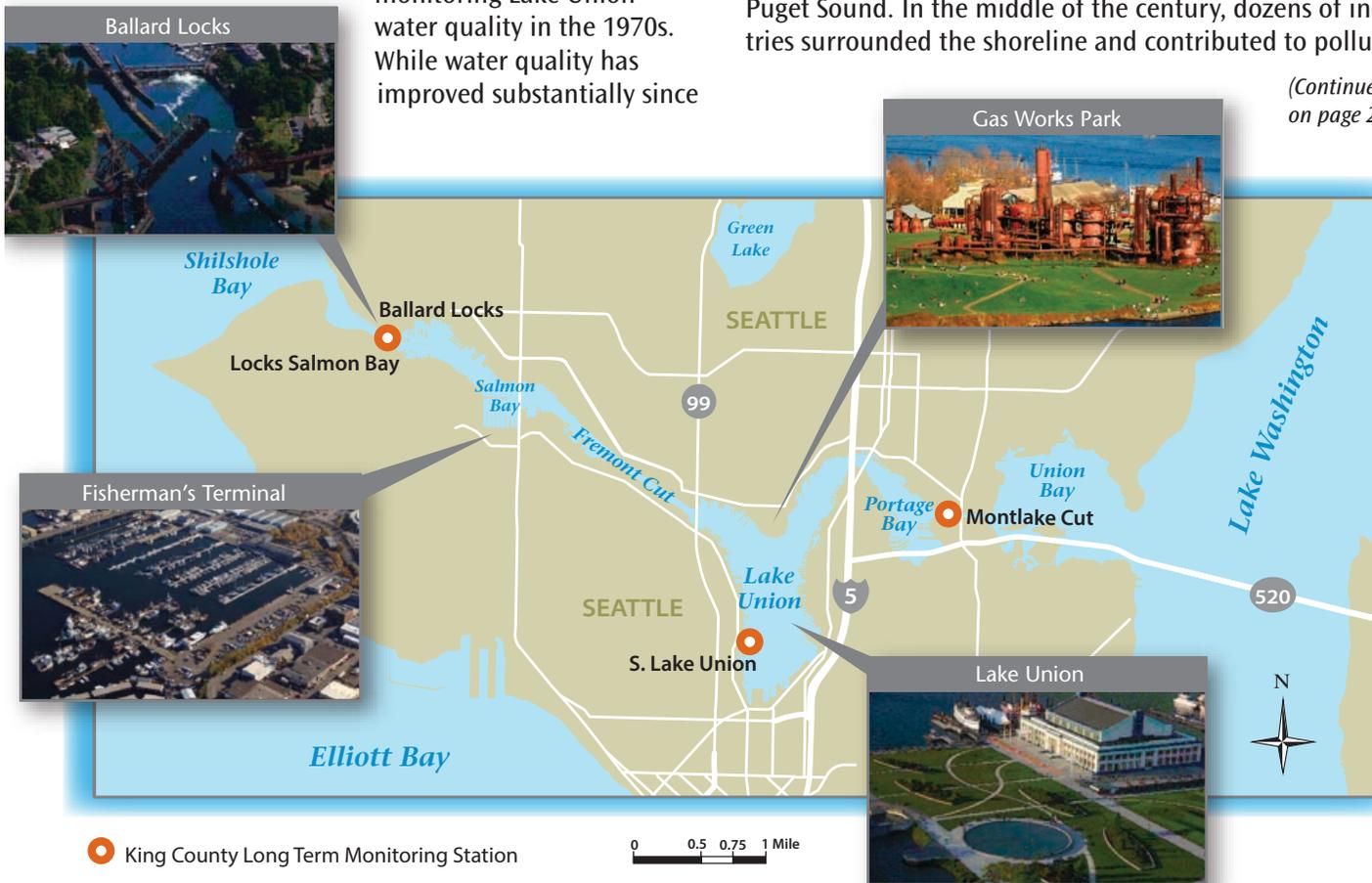
Lake Union serves as a migration route for salmon to reach their spawning grounds in the Cedar River-Lake Washington watershed. The fish ladder viewing window located at the Ballard Locks is one of Seattle's must-see attractions. Unfortunately, Lake Union and the Ship Canal were historically subjected to industrial, wastewater, and stormwater pollution for many decades.

In line with its water quality mission, King County began monitoring Lake Union water quality in the 1970s. While water quality has improved substantially since

the mid-1970s, elevated bacteria levels, chemical contamination in the sediment, elevated summer surface temperatures, and low oxygen levels combined with elevated salinity in deeper waters during the summer remain issues for the waterbody. Detailed information about King County's Lake Union monitoring program can be found at www.kingcounty.gov/lake-union-monitoring.

Lake Union and the Ship Canal are heavily modified waterbodies. In 1916, the 8.6-mile-long Lake Washington Ship Canal was completed, which included construction of the Montlake Cut, Fremont Cut, and Hiram M. Chittenden Locks (Ballard Locks). The new canal provided the first navigable passage for deep-draft commercial vessels, barges, and recreational boaters between Lake Washington and Puget Sound. In the middle of the century, dozens of industries surrounded the shoreline and contributed to pollution

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King County Long Term Monitoring Station

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in the lake. Untreated sewage from hundreds of houseboats and nearby homes, along with untreated stormwater drainage, also contributed to pollutant loading in the lake. As the sewage system became overwhelmed during large rain events, combined sewer overflows released even more untreated sewage.

Since routine water quality monitoring began in 1976, fecal coliform bacteria levels have decreased significantly ($p < 0.01$) (Figure 2). Fecal coliform levels still exceed the 90th percentile state water quality criterion, but at a lower

SINCE THE 1950S, NUMEROUS ACTIONS HAVE IMPROVED WATER QUALITY IN LAKE UNION AND THE SHIP CANAL, INCLUDING:

- *Closure of the gas (1956) and steam (1987) plants*
- *Formation of Metro and completion of the regional sewer system around Lake Washington in the 1960s;*
- *Connecting houseboats to the sewer line in 1967;*
- *Sewage and drainage improvements in the basin funded by the 1968 Forward Thrust bonds; and*
- *Ongoing efforts by Metro, King County, and Seattle to reduce combined sewer overflows, as well as implementation of Seattle's municipal stormwater National Pollutant Discharge Elimination System permit.*



frequency and magnitude than observed during previous decades. Similar decreasing trends have been observed for nutrient levels in the lake.

In the summer, warm surface water temperatures, low dissolved oxygen concentrations and elevated salinity at depth, are a concern in Lake Union and the Ship Canal. Summer surface temperatures routinely exceed 20 °C (68 °F) and can result in higher predation rates on juvenile salmon and create a thermal barrier for fish movement. Summer surface temperatures also periodically exceed 23 °C (73 °F), which can cause adult salmon mortality.

Furthermore, the cold-water refuge at depth during the summer contains low levels of dissolved oxygen and elevated salinity and cannot be fully utilized by juvenile and adult salmon. Temperatures have increased significantly since the 1970s (Figure 3), and continued warming is expected due to climate change. The U.S. Army Corps of Engineers, who operate Ballard Locks, are investigating methods to improve temperature conditions for salmon migrating through the locks, but a long-term solution has not yet been identified.

Sediment chemistry in Lake Union and the Ship Canal was evaluated in the early 1980s, in the 1990s, in 1999-2001, and again in 2014. The results from these investigations confirmed that sediments are contaminated with several toxic chemicals.

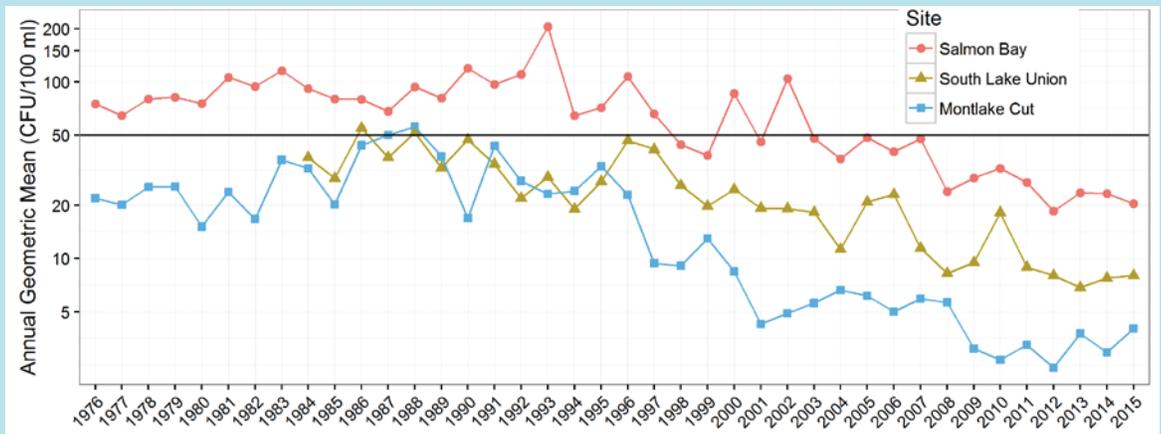
Notable contaminated sediment hot spots are located near Gas Works Park, in southeast Lake Union, and throughout Salmon Bay. The most widespread contaminants are metals, such as arsenic, mercury, and silver; tributyltin (a banned vessel-bottom antifouling agent); polycyclic aromatic hydrocarbons (PAHs [found in fossil fuels and are byproducts of combustion]); phthalates (plasticizers); and polychlorinated biphenyls (PCBs [a persistent organic pollutant]).

Lake Union and the Ship Canal will continue to be important pieces of Seattle's character. The urban lake is a reflection of the region's industrial legacy, but steps taken to restore and protect these waterbodies show the region's commitment to environmental stewardship and remediation. The region continues to improve management of wastewater and stormwater discharges, and multiple sediment cleanups are underway or planned within Lake Union and the Ship Canal, including near Gas Works Park.

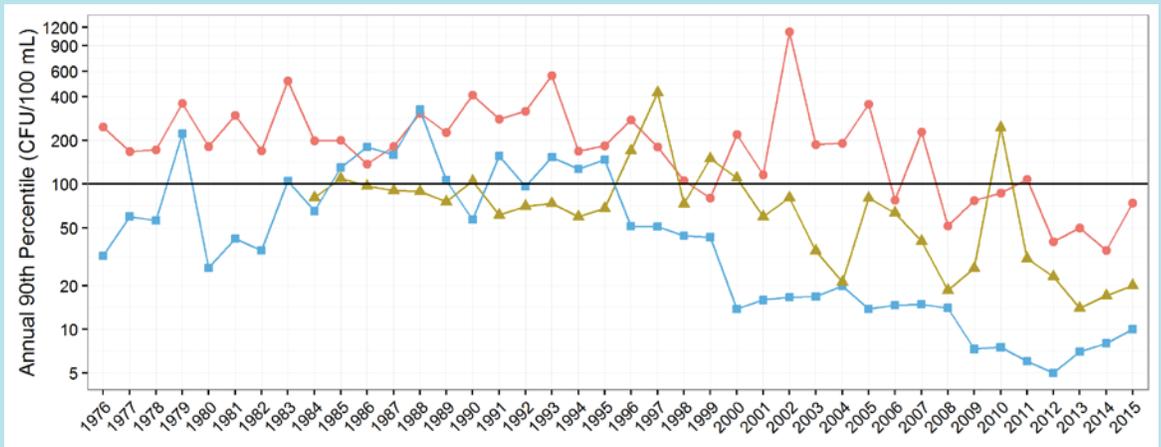
King County will continue to monitor Lake Union and the Ship Canal and evaluate changes in water quality resulting from current and future efforts. Look for King County's monitoring results for Lake Union from January 2014 through March 2016 to be published January 2017:

www.kingcounty.gov/science-library
(search for "Lake Union").

Figure 2. Annual geometric mean (top) and 90th percentile (bottom) of fecal coliform bacteria levels since 1976.



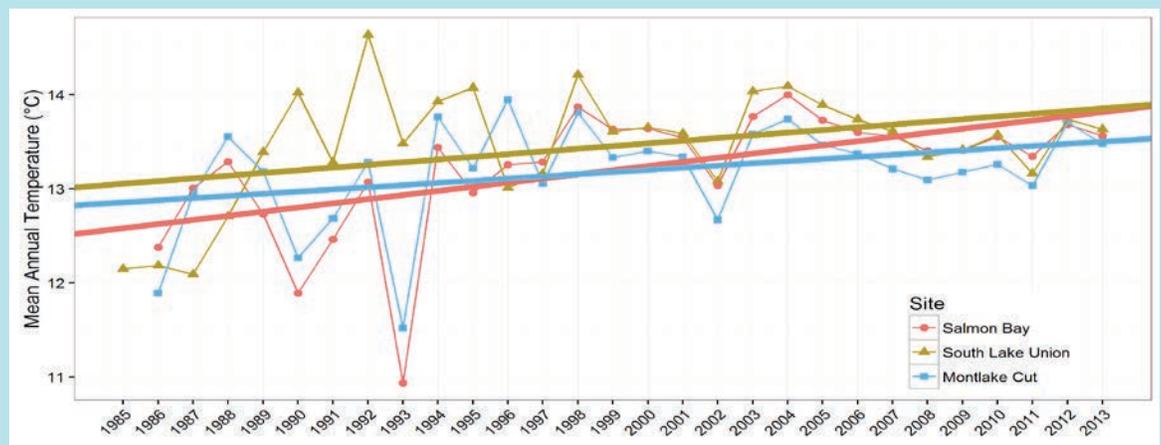
Black lines signify WA water quality standard geometric standard (top) of 50 CFU/100 mL and 90th percentile standard (bottom) of 100 CFU/100 mL.



Washington state water quality standards for fecal coliform have two components: (1) a threshold not to be exceeded by the geometric average of recent samples, and (2) a threshold not to be exceeded by more than 10 percent of samples (90th percentile standard).

Figure 3. Annual mean surface temperature since 1985 and observed long-term trends.

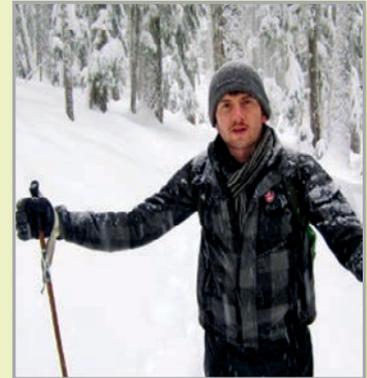
All warming trends were significant ($p < 0.05$).



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Tim specializes in analyzing and interpreting water quality data for lakes and streams. His work spans from managing a floating wetlands project in a small, eutrophic lake in White Center to large-scale pollutant loading estimates as part of the County's Combined Sewer Overflow Control Program. Tim has an MS in Environmental Sciences and an MPA from the Indiana University School of Public and Environmental Affairs. His analytical toolbox includes R, ArcGIS, Access, Stata, MATLAB, SAS, WinSLAMM, and MinEQL. His limnological interests include stormwater pollution modeling and management, exploring applications of remote sensing using satellite imagery (e.g., Landsat, Sentinel) and unmanned aerial vehicles, and fostering environmental stewardship through civilian science, education, and effective communication.



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