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Future land-use and salt-management controls on long-term chloride accumulation in Lake Simcoe, Ontario, Canada

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Chloride (Cl^-) contamination from winter de-icing salts is an increasingly persistent water-quality issue in cold-region lakes, where long residence times promote accumulation and slow recovery. Lake Simcoe (Ontario, Canada) has shown sustained long-term increases in Cl^-, raising concern for aquatic ecosystem health. We evaluate how current conditions and plausible future land-use trajectories affect long-term in-lake Cl^- concentrations through 2100, and how much improved parking-lot salt management could alter those trajectories. We use a spatially resolved modelling framework that links watershed Cl^- loading to a five-segment lake mass-balance representation capturing major lake regions and their hydrologic connectivity. The lake model is calibrated against observed in-lake Cl^- concentrations and reproduces historical segment-scale trends with high accuracy. Scenario results show that even if Cl- load were held at its current rate, Cl^- would continue to rise in urban-influenced lake regions. Under future full urban build-out, accumulation accelerates and Kempenfelt Bay reaches ~120 mg/L (the CCMC chronic target) by ~2088, indicating heightened long-term risk in nearshore regions with strong watershed influence. In contrast, reduced Cl- runoff from parking lots substantially lowers projected concentrations and delays threshold exceedance. These findings highlight that significant reductions of Cl- inputs to Lake Simcoe are needed to maintain Cl- levels below the CCME target of 120 mg/L.