III. BEST PRACTICES RECOMMENDATIONS / TANGIBLE PROJECT OUTCOME

Best Practices Recommendations are defined as "*a set of guidelines, ethics, or ideas that represent the most efficient or prudent course of action*". Best Practices herein are related to the derivation of WQG with and without hardness adjustment, as well as how the WQGs and associated adjustments can be implemented. Tangible Project Outcomes are defined as "*outcomes that the industry can take and use and put into practice*". These definitions were contractually set by PTAC. The two definitions overlap, but essentially encompass key aspects of the guideline derivation process as well as how the guidelines can be used or implemented.

i. Toxicological Database Criteria

The guidelines are built on the solid and thorough toxicological database, compiled from individual peer-reviewed articles, government guideline deviation documents and online databases, technical reports, and presentations by reputable researchers at major conferences and forums. The aquatic toxicological database was comprised of literature examining the toxicity of key chloride salts NaCl, $CaCl_2$, and $MgCl_2$ – the guidelines were derived primarily based on the extensive NaCl dataset with a protectiveness evaluation for the other two chloride salts Studies identified in the literature searches, and toxicity data collected and cited by CCME, as part of their guideline derivation process in 2011, were obtained and critically reviewed. Unpublished data generated from 3rd party researchers under contract to EEI, and funded via PTAC (WSLH, 2016, UGARF; 2016, Nautilus, 2016 and 2019), were included. Some critical grey literature (*e.g.*, presented by reputable researchers, but not published yet in a peer-reviewed journal) data were added for sensitive species, as anticipation of future publications that could influence the final guidelines. In total, 633 long-term data points were evaluated.

Studies were classified as primary or secondary (CCME, 2007), and unacceptable data were excluded. Data was deemed to be unacceptable when experimental controls were not reported, environmental conditions were inappropriate (*e.g.,* test temperatures were too high), the ionic composition of the test medium was unknown, the species tested was not appropriate for Canadian waters (*e.g.,* tropical species), an inadequate number of animals per exposure group was used, or high adverse effect levels were observed in the control group.

ii. Best Practices Recommendations

Should toxicity data be identified in the future that is sufficiently rigorous, with hardness data reported, the data should be evaluated for integration into the SSD. The figures within this report can be used to visually assess the potential influence of any new data on the SSD. An example of the datapoints that could potentially significantly alter the WQG would be a study where adverse effects occurred at relatively low chloride concentrations higher hardness levels, which would potentially shift the lower portion of the hardness-adjusted SSD curve.

iii. Hardness Adjustment

Water hardness has been identified as an ameliorating factor in aquatic guideline policy. To explore potential relationships between chloride toxicity and water hardness, long-term data was compiled for species, studied in the same laboratory with effect concentrations across a wide range of water hardness. Natural logarithms were used to characterize hardness-toxicity relationship following the methods outlined by Stephen *et al.* (1985), and in approaches utilized by the Canadian Environmental Protection Act (CEPA), CCME, and the US EPA in the hardness-adjusted guidelines for cadmium, cobalt, copper, lead, manganese, and nickel (CCME, 2017 and 2019; CEPA, 2020 and 2021; US EPA, 1998 and 2016). Effect concentrations were selected within a range, where the highest hardness is at least three times greater than the lowest one, and at least 100 mg/L higher than the lowest one (CCME, 2014, US EPA, 2001, Stephen *et al.*,1985). To avoid the potential introduction of variability due to differences in inter-laboratory experimental conditions, data points for each species were grouped and analysed by each laboratory independently.

Data points that met these criteria across comparable endpoints, exposure durations, life stages, and laboratory environment, were plotted together with natural log (hardness) and natural log (chloride effect concentration) as the independent (x-axis) and responding (y-axis) variables, respectively. The mathematical guideline calculations were completed using EasyFit 5.6 Professional software (Mathwave Technologies, 2015).

<u>**Best Practices Recommendations**</u>

WQGs are generally applied to surface water bodies inhabited by aquatic life. Measurements of hardness subsequently used to determine a hardness-adjusted chloride WQG should be taken from where the WQG is considered applicable (*i.e.*, the point of compliance). For example, hardness should be measured in a water sample taken from a surface water body for evaluating measured chloride concentrations in the water body. Most accredited laboratories are capable of measuring hardness in water samples.

In some jurisdictions (*e.g.*, Alberta), the WQGs are also implemented at the point of groundwater discharge into a surface water body (essentially the point of discharge into the hyporheic zone (mixing zone of groundwater and surface water)) when developing soil or groundwater remediation guidelines protective of aquatic life. In this instance, the hardness measurement(s) should be from groundwater considered representative of conditions at the point of discharge into the hyporheic zone of a surface water body. The proponent may want to consider the additional layers of protectiveness when developing Risk Management strategies.

iv. Assessment of Guideline Protectiveness

To assess the protectiveness of the long-term hardness-dependant guidelines, the acceptable chloride effect concentrations (log transformed and non-adjusted for hardness) were plotted against log hardness. The respective WQGs were plotted as the straight line. Any values occurring below these guidelines were examined in detail. This analysis was an important component of the overall guideline derivation as it incorporated $CaCl_2$ data which could not be assessed by Type A SSD methods. Including the $CaCl_2$ data provided a measure of the effectiveness of the guidelines towards Ca^{2+} chloride toxicity. In addition, a guideline protectiveness chart was used to assess the upcoming data from soft water aquatic organisms.

v. Guideline Application Range

The hardness equation for calculating long-term water quality guidelines is applicable between the 5 and 350 mg $CaCO_3$/L, and should not be applied outside of this range. Lower and upper hardness limits reflect the minimum and maximum hardness values beyond which WQG should not be extrapolated. The lower limit comes from the minimum values reported by the national survey of Canadian surface waters, conducted over the period 1975 to 1977 (Health Canada, 1979; CCME, 2011). The upper limit of 350 mg/L is linked to increased species sensitivity in extremely hard waters.

vi. Special Concern and Endangered Species Protectiveness/ Additional Safety Factor

To ensure protectiveness of the sensitive freshwater mussels *Epioblasma torulosa rangiana* and *Lampsilis fasciola*, the Protection Clause (CCME, 2007) can be applied. It means that in the areas where the COSEWIC special concern mussel (*L. fasciola*) or the COSEWIC endangered mussel (*E. torulosa rangiana*) are present, the WQGs are based on the lowest toxicity values observed (24 mg/L for the regions with the most sensitive broods of *L. fasciola*, and 42 mg/L for *E. torulosa rangiana*).

An approximately 2-fold greater sensitivity to laboratory waters may be expected for daphnids, freshwater mussels, and frogs. Since current guidelines were derived based on laboratory data, the greater sensitivity may serve as an additional safety factor, and make the guidelines more conservative.

Since chloride salts appear to be less toxic in natural waters compared to experiments with re-constituted laboratory waters, the natural water studies were excluded from the database. This approach led to more conservative WQGs that are applied to natural waters.

vii. Recommendations/ Outcomes

The current equation may be applied for direct calculation within a range between 5 and 350 mg $CaCO_3$/L, resulting in guidelines from 44 mg/L to 222 mg/L. For the very soft waters (0-5 mg $CaCO_3$/L), the lowest limit of 44 mg/L is applicable. This lowest limit covers the 90th percentile of the surface waters in Nova Scotia, with 4.6 mg/L of hardness. For the rest of Canada, the upper value covers the 90th percentile of the major surface waters, except Manitoba and Saskatchewan, where the median hardness was equal to 287 mg/L, and 300 mg/L, and 90th percentile was equal to 402 mg/L, and 531 mg/L, respectively (CCME, 2011). For these extremely hard waters (hardness >350 mg $CaCO_3$/L), the maximum of 222 mg/L chloride guidelines may be utilized, assuming a plateau of the ameliorating effect in extremely hard waters.