Supporting Information for Grand Portage Proposed Nutrient Criteria

The nutrient criteria that Grand Portage is proposing are intended to protect existing aquatic life uses through prevention of degradation of current conditions, primarily undisturbed high quality habitat and water chemistry. One way to develop nutrient criteria " is to rely on the selection of appropriate reference conditions that represent a level of water quality at which there are no known impairments of a use due to nutrient over-enrichment" (EPA, 2001). Stoddard et al. (2006) defined reference conditions as "the condition of streams in the absence of significant human disturbance."

According to EPA thresholds for predicting nonpoint source impacts, adverse impacts to water quality are likely to occur when impervious cover in a watershed exceeds 10% of the catchment (EPA, 1997). The mean impervious surface cover in the catchments of Grand Portage inland waters is: 0.10% (range: 0-1.27%) for lakes and 0.02% (range: 0-0.14%) for streams (Midwest Biodiversity Institute, 2015). Based on percent impervious cover alone, Grand Portage inland waters meet the definition of "reference condition". Essentially, Grand Portage's approach for establishing nutrient criteria is to maintain strong antidegradation protection for waters that meet the commonly accepted definition of "reference condition".

Because there is so little human disturbance around any of the inland waters Grand Portage, a paleolimnological study was initiated with the US Geological Survey, the Science Museum of Minnesota, and the St. Croix Water Research Station to further validate that the inland waters represented reference conditions for nutrient criteria development. Lake sediments integrate inputs from the water column, catchment, and airshed that can be temporally apportioned. Therefore, paleolimnological methods can be used to reconstruct historical water quality characteristics. To that end, lake sediment cores were collected at Trout and Swamp lakes to determine the historical nutrient productivity of the lakes by characterizing the fossil remains of diatoms and chrysophytes. Using the diatom and chrysophte analysis with lead-210 dating of the sediment core sections the historical total phosphorus concentrations were inferred. Water-quality data including nutrients, DOC, major ions, collected between May and October from 2000-2008 was then compared to the inferred historical total phosphorus concentrations from 1781–2006.

Many rare species and several unknown taxa of diatoms were found in the diverse diatom flora of Swamp and Trout Lakes. Diatom-inferred total phosphorus concentrations ranged from 0.017 to 0.025 mg/L in Swamp Lake from sediment samples dated 1781–2005 and from 0.008 to 0.014 mg/L in the Speckled Trout Lake core based on sediments dated 1825–2006. Differences among the diatom-inferred total phosphorus concentrations and the median concentrations measured in the water column from 2000-2008 were not greater than the model error estimates. Therefore, we were able to reasonably conclude that no statistically significant changes in total phosphorus concentrations had occurred during the past 200 years in either Swamp Lake or Trout Lake.

Grand Portage is located in the southern range of the boreal forest. Boreal lakes are often dystrophic or humic, meaning they have stained water (rootbeer or tea colored). The source of "staining" is dissolved organic carbon (DOC) from slowly decaying vegetation in the catchment that results in high concentrations of humic acids and tannins being dissolved in the water. DOC

strongly affects chemical, biological and physical processes in boreal lakes. The increased color that results from DOC reduces light penetration, thereby impeding primary production and reducing harmful ultraviolet radiation (Morris *et al*., 1995). DOC is a nutrient that is required for many aquatic biological processes (Wetzel *et al*., 1995). DOC also affects thermal stratification (Snucins and Gunn, 2000), pH and alkalinity (Oliver *et al*., 1993). Although high concentrations of DOC may correspond with lower concentrations of dissolved oxygen, the reduction or loss of DOC in boreal lakes can have catastrophic effects on sensitive and rare aquatic life and the ecological balance that has evolved within these specific ecosystem types.

Most of the inland lakes within the Reservation are relatively small and shallow surrounded by large natural catchments. Catchment:lake area ratios strongly affect nutrient concentrations. At catchment:lake area ratios of 10:1, precipitation supplies about half of the total nitrogen and phosphorus to lakes, and the catchment supplies the other half (Schindler et al. 1976). However, nutrient uptake via forest and wetland vegetation can decrease the cathchment nutrient yields to the lake water column by roughly 90% (Schindler et al. 1976). Lake retention time is also shorter with larger catchment:volume ratios, creating a relatively quick response to chemical changes. The average catchment:lake ratio in Grand Portage is 36:1 (range 3.5:1-240:1).

Based on the information provided above, Grand Portage has proposed nutrient criteria for each waterbody using the 95th percentile of the measured concentrations for total nitrogen, total phosphorus, and chlorophyll-a, and the 5th percentile for DOC. We believe our 20-year dataset and supporting studies provide substantial evidence that our waterbodies exhibit high quality conditions, and by protecting this existing high quality condition we are taking the most effective approach possible for protecting these waterbodies and the aquatic communities they support for future generations.