**PROJECT TITLE: Role of submarine groundwater altering Lake Superior’s shore**

**I. PROJECT STATEMENT**

How well can you run a household or State without knowing the budget? The purpose of this project is to assess the role of deep groundwater inputs to the water budget of Lake Superior. This will allow better forecasting of lake levels and allow consideration of options for stabilizing them, so we can compensate for rates of change to preserve environmental and recreational quality. Improved predictions of lake levels will help Minnesotans to make better choices about natural resource management along the coast of Lake Superior. Lake Superior is 10% of Earth’s surface freshwater and gives Minnesota the most inland seaport in the world yet its water budget (inflows and outflows that determines lake-level) is based only on measures of surface water, evaporation and precipitation (see attached figure). Over the past 60 years, the Lake has seen some of its highest and lowest levels in recorded history while, in spite of very high and damaging water levels now, it is losing 1.5” overall every 3-4 years. Wide swings in water level causes damage to parks and North Shore recreation areas, unpredictably altered fish habitat, and danger to recreationists at the 8 important North Shore parks (including 4 of Minnesota’s most popular). High waters drown river mouths and damage shore ecosystems whereas low water can destroy spawning habitat, shore wetlands, and increase distances between recreational resources and water. This project will measure the role of North Shore submarine groundwater in determining future levels of Lake Superior.

Current forecasting models used to design parks, recreation areas, shore installations, and manage fish habitat are inaccurate because they ignore the role of deep, submarine groundwater discharge to the lake. There is ample evidence (e.g., North Shore seeps, springs, ice faces on cliffs, waterfalls from rocks, etc.) that groundwater can be an important water source (or loss) especially along the North Shore of the lake where relief is highest (see figure). In fact, other large water bodies, even seas, have been shown to have important deep groundwater inflows. In the Mediterranean Sea, for example, groundwater inflow is 16-times as large as the water brought in by rivers. Ignoring groundwater inflows and outflows to large water bodies makes it impossible to protect shore environments, especially during a period of changing weather patterns.

 This project will use isotopic measures of radon (228Ra) in deep and shallow lake water and groundwater sources to calculate how much water enters Lake Superior along the North Shore and how this compares to surface water inflows and outflows as well as losses or gains via evaporation or precipitation. The reason radon is useful for measuring groundwater input is the same reason it ends up in houses. It is a breakdown product from rocks and soils so will be most concentrated in water that has been in contact with them. This works because 228Ra is much more concentrated in groundwater than in precipitation or surface water inputs. We expect North Shore submarine groundwater to represent the majority of that entering the lake because the topographic relief is very high northwest of the lake and groundwater flow is generally fastest where relief is high (see dark arrows along North Shore in accompanying graphic).

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1** Collect and concentrate isotopes from groundwater, surface water, and deep lake water. | **Budget: $135,637** |

We will collect 40 sets of lake water samples from Lake Superior’s surface and near-bottom. Lake samples will be taken from the R/V Blue Heron. We will also collect 20 samples of deep groundwater from wells along the North shore. Because 228Ra concentrations are very low, we will take large samples (100-360 liters) and these samples will be filtered through columns loaded with manganese oxide impregnated acrylic fibers that will concentrate 228Ra. These fibers will be combusted to ash, ground up, and sealed in counting vessels. Work will be shared by Downing and a graduate student (yet to be named). Research vessel cruise costs will be discounted because Downing is a member of the Large Lakes Observatory research faculty.

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| **Outcome** | **Completion Date** |
| 1. Seven cruises of the R/V Blue Heron to collect samples from surface and deep water | October 2020 |
| 2. Concentration of 228Ra lake water samples | October 2020 |
| 3. Collection of groundwater samples from existing wells | June 2021 |
| 4. Concentration of 228Ra in groundwater samples | June 2021 |

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| **Activity 2:** Determination of 228Ra activity and calculation of submarine groundwater inflow rates | **Budget: $63,006** |

Samples collected in activity 1 will be counted in a gamma spectrometer with a well-type, high-purity germanium detector. The spatial distribution of 228Ra in the lake will be interpolated and, by comparison with groundwater reference data, inflow rates of submarine groundwater will be calculated. These will be compared with surface inputs/outputs, precipitation inputs, and evaporative loss. Work will be shared by Downing and a graduate student (yet to be named).

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| **Outcome** | **Completion Date** |
| 1. Complete gamma spectrometry | December 2021 |
| 2. Calculate submarine groundwater inputs/outputs | April 2022 |
| 3. Compare with traditional budget data. | June 2022 |

**III. PROJECT PARTNERS AND COLLABORATORS:**

**John A. Downing, Sea Grant College Program, Large Lakes Observatory, and Department of Biology, University of Minnesota (Duluth)**

**IV. LONG-TERM IMPLEMENTATION AND FUNDING:**

We expect that the results will substantially alter the way we model and predict shore and coastal effects of alterations in lake water level. Therefore, we will work with NOAA offices including the Great Lakes Environmental Research Lab (GLERL) to use the results to leverage federal funds to perform similar analyses across the Great Lakes. We will work with GLERL to use this research on Lake Superior to result in updated models that will allow us to better forecast lake levels and consider options for stabilizing them, so we can compensate for rates of change to preserve environmental and recreational quality on the North Shore of Lake Superior.