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**A DIGITAL DATA BASE FOR THE PARTICLE SIZE DISTRIBUTION OF
BOTTOM SEDIMENTS IN LAKE MICHIGAN**

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APPENDIX 1. Link to data file (Excel format).

ftp://ftp.glerl.noaa.gov/publications/tech_reports/glerl-145/TM-145_Appendix1_LMichigan-bottom_sediments.xls

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A digital data base for the distribution of bottom sediments in Lake Erie

Nathan Hawley

ABSTRACT. This document describes a map of the size distribution of bottom sediments in Lake Michigan. The data set combines measurements of the bottom sediment size distribution made by several previous investigations. The results are presented on the same 2 km grid presently used for forecasting waves and currents in the lake.

1. INTRODUCTION

Since both nutrients and anthropogenic pollutants may absorb onto and be transported by fine-grained suspended material, modeling the transport and deposition of these sediments in the Great Lakes has become an area of active research. In addition to making these nutrients and pollutants available to the benthic ecosystem, high concentrations of suspended sediment may also affect the pelagic food web both by acting as a source of nutrients and by limiting the amount of light available. This makes modeling of fine-grained material a necessary component of the ecological models being developed as part of a basin-wide ecological forecasting system. Knowledge of the spatial distribution of the particle size of the bottom sediments in the lakes is a critical requirement for the development of these models.

2. METHODS

Field Measurements

Information on the particle size distribution of Lake Michigan bottom sediments is available from several sources: a lakewide survey conducted in 1975 (Cahill, 1981), two other lakewide surveys conducted in the 1990s (Eadie and Lozano, 1999), nearshore data from the southern basin collected by the United States Geological Survey (Poppe et al., 2005), and data collected at a limited number of stations in the southern basin (Hawley, unpublished data). The methods used to collect and analyze the samples varied, so a brief description of each set of measurements is given below and in [Table 1](#).

Sediment size measurements have been traditionally been reported in ϕ units

$$\Phi = -\log(d)/\log(2) \quad (1)$$

where d is the particle diameter in mm. The size distribution is usually reported at either half or whole ϕ intervals. Since the scale is logarithmic, the range of a ϕ interval in mm is not constant, but varies depending upon the actual value of ϕ . The dividing line between coarse, non-cohesive sediments (sand and gravel) and fine, cohesive sediments (silt and clay) is traditionally set at 0.062 mm or ϕ equal to 4. With the introduction of digital calculators, the need for ϕ units has diminished, but many measurements are still based on the ϕ scale. Here the measurements are given in mm whenever possible, but the size ranges used are based on ϕ units.

The first (and most comprehensive) lakewide survey of bottom sediments was conducted in 1975 (Cahill, 1981). Surface samples were collected using a Shipek grab sampler at points on a 12 km grid, except for Green Bay where a 7 km grid was used (Fig. 1a). Subsamples were removed with a 0.05 x 0.05 x 0.03 m box subsampler. The samples were first wet sieved through a 0.062 mm (4ϕ) screen to separate the sand and gravel fraction from the silt and mud. The coarse fraction was then dried and sieved at 0.5 ϕ intervals between 16 and 0.062 mm, while the silt and mud were analyzed at 1 ϕ intervals using pipetting techniques. Unfortunately, the original measurements have been lost, and the available data lists only the mean, standard deviation, skewness, and kurtosis in ϕ units, and the percentage of sand (diameter greater than 0.062 mm), silt (0.062-0.004 mm), and clay (less than 0.004 mm). Details of the analytical procedure are given in Cahill (1981). These samples were collected as part of a five-lake survey conducted by the Canadian National Water Research Institute. Data from all five of the Great Lakes are available (Raukavina, 2004).

Box cores and Ponar samples were retrieved as part of the Lake Michigan Mass Balance Study (LMMB, Fig. 1b) in 1995 and 1996, and Ponar samples were collected in 1994 for the Environmental Mapping and Assessment Program (EMAP, Fig. 1c). The particle size distribution for all of the samples was determined from the top 0.01 m interval of the samples. Sediments were first wet sieved through 2 mm and 1 mm sieves. Material retained on the sieves was dried and weighed, while the material that passed through the sieves was analyzed using a laser optical particle counter (Horiba LA900). The LMMB samples were measured at 1 ϕ intervals between 0.5 mm and 0.002 mm, but the EMAP samples were measured at non-standard intervals. Further details of the procedures are given in Eadie and Lozano (1999).

Samples from southern Lake Michigan were collected by the U.S. Geological Survey during several studies conducted in the 1980s and early 1990s. These data have been compiled in a data base and are available to the public (Poppe et al., 2005). The samples were primarily collected using either a Van Veen or a Shipek sampler, although some box cores were collected in deeper water (Fig. 1d). A limited number of samples were also collected using divers or an underwater vehicle. The particle size distribution was measured on samples collected over vertical intervals ranging from 0-0.02 m (box cores) and 0-0.03 m (submersible), to 0-0.08 m (Van Veen) or 0-0.1 m (Shipek). For some of the samples, the depth interval was not recorded. Particle size distribution was measured using either a rapid sediment analyzer or sieves for the coarser material and a Coulter particle counter for the finer material (K. McMullen, personal communication). Size is reported at one ϕ intervals between 16 mm and 0.0005 mm.

A few samples were collected by Hawley (unpublished data) in conjunction with deployments of bottom-resting tripods at several sites in southern Lake Michigan during 1998-2002 (x in Fig. 1c). Material was collected either by using a Ponar sampler, or from the feet of the tripods as they were retrieved, and the top 0.02 cm was analyzed. Samples were wet sieved through a 1 mm screen. The material retained on the screen was dried and sieved at 0.5 ϕ intervals between 2 mm and 0.7 mm. The material that passed through the screen was measured using a Malvern 2000 optical particle counter. Results from the two size fractions were merged and recorded at one ϕ intervals between 0.5 mm and 0.001 mm.

Numerical Methods

The field measurements described above were used to interpolate the particle size distribution on a 2 km grid covering the entire lake (Schwab and Sellers, 1996) using a two-dimensional linear interpolation function available in Matlab. Schwab and Sellers (1996) also provided the lake bathymetry for each grid point, and vectors of latitude and longitude that represent the lake shoreline and the areas of the larger island in the lake. These values have been used as input to generate the figures.

Although the data reported by Cahill (1981) is the most complete geographically, the size distribution is only reported for three intervals: sand (greater than 0.062 mm), silt (0.004-.062 mm), and clay (less than 0.004 mm). Therefore the integration of the various data sets was done in two steps. First each set of measurements used to compute the percentages of coarse (> 0.062 mm) and fine (<0.062 mm) material throughout the lake. A comparison of the results using only the Cahill data and the results using all of the other data showed that the patterns are very similar, so all of the data sets were combined and used to interpolate the percentage of fine and coarse material throughout the lake. Then all of the data except the Cahill measurements were used to subdivide the interpolated coarse and fine percentages into four size ranges each. The characteristics of the eight size classes are given in [Table 2](#).

3. RESULTS

[Figures 2 and 3](#) show the depth and mean particle size (in ϕ units) throughout the lake, while [Figures 4 and 5](#) show the percentage of material with diameters greater than and less than 0.062 mm. Similar contour maps for each of the eight size classes listed in [Table 2](#) are shown in [Figures 6-13](#). The data are also presented in digital form in the excel spreadsheet in [Appendix 1](#). The spread sheet also includes the latitudes and longitudes for each of the grid points. The array includes many positions on land. Values for these locations are represented by zero for the water depths and -99 for all of the other parameters.

Several previous investigators have assumed a relationship between water depth and particle size to determine the mean particle size at a particular location. The data presented here ([Figures 14 and 15](#)), however, show that there is no consistent relationship between the water depth and either the mean particle size or the fraction of material larger than 0.062 mm. Although in general both measures decrease with increasing depth, the trend is by no means uniform. The data presented here may allow one to determine such a relationship for a limited geographical area within the lake, or they can be used as a base map to interpolate the size distribution at other points within the lake.

4. REFERENCES

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Table 1: Characteristics of the measured particle size data.

Data base	Collection date	Number of samples	Collection method	Depth Interval (m)	Analysis Method For coarse Material	Analysis method for fine material
Cahill	1975	283	Shipek	0-0.03	Sieves	Pipette
LMMB	1995-1996	68	Box core	0-0.01	Sieves and laser counter	Laser counter
EMAP	1994	35	Ponar	0-0.01	Sieves and laser counter	Laser counter
USGS	1988-1992	490	Van Veen, shipek, and others	Up to 0-0.1	Sieves and Rapid sediment analyzer	Coulter counter
Hawley	1998-2000	16	Ponar	0-0.02	Sieves and laser counter	Laser counter

Table 2: Size intervals reported in the data base.

Size class	Size range	Phi range	Standard terminology
1	>2 mm	<-1	Granule or gravel
2	2-0.5 mm	-1- +1	Very coarse and coarse sand
3	0.5-0.125 mm	1-3	Medium and fine sand
4	0.125-0.062 mm	3-4	Very fine sand
5	0.062-0.031 mm	4-5	Coarse silt
6	0.031-0.016 mm	5-6	Medium silt
7	0.016-0.004 mm	6-8	Fine and very fine silt
8	<0.004 mm	>8	Clay

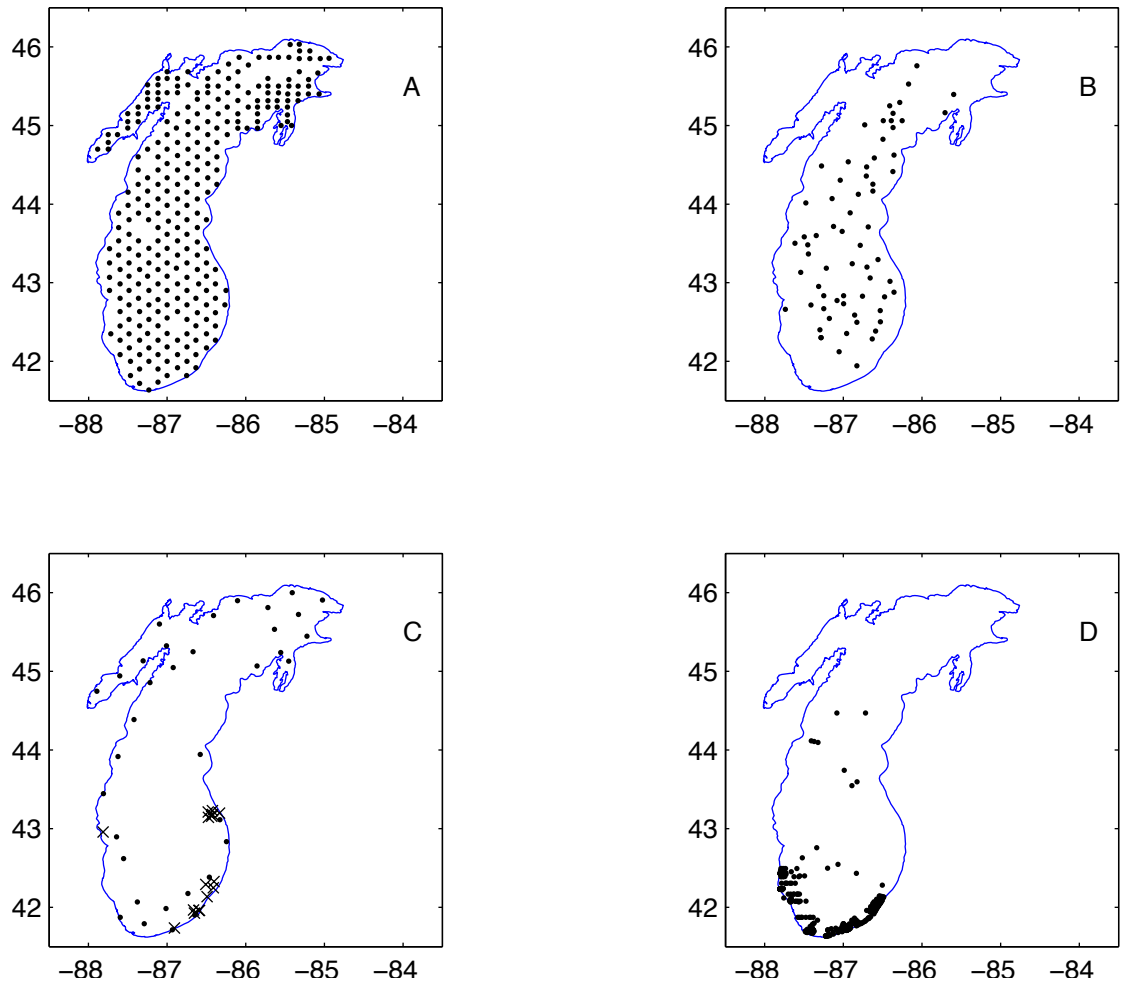


Figure 1. Locations of the bottom samples. A. Cahill collected by Cahill. B; Samples collected as part of the Lake Michigan Mass Balance Program. C. Samples collected as part of the Environmental Mapping and Assessment Program (●) or by Hawley (x). D. Samples collected by the U. S. Geological Survey.

