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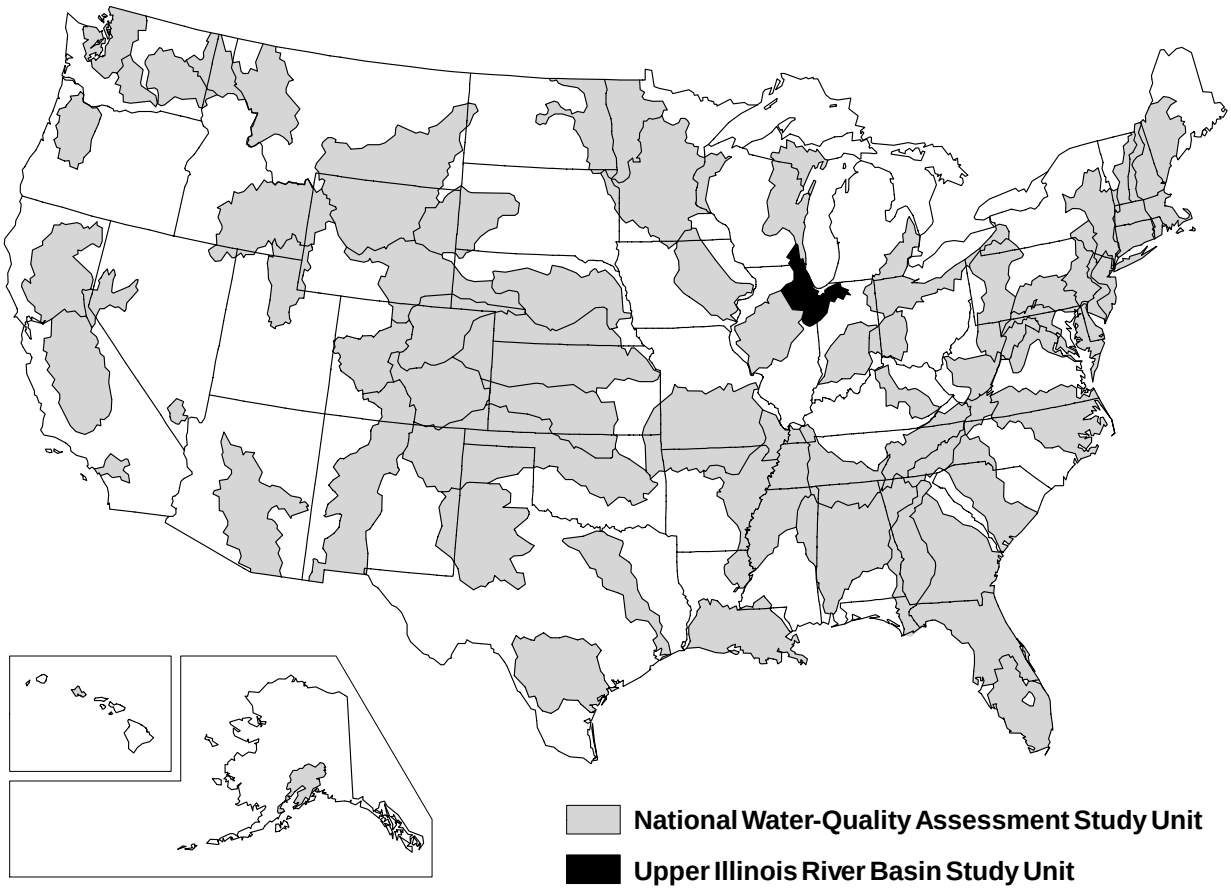
Surface-Water-Quality Assessment of the Upper Illinois River Basin in Illinois, Indiana, and Wisconsin—Spatial Distribution of Geochemicals in the Fine Fraction of Streambed Sediment, 1987



Water-Resources Investigations Report 98–4109

National Water-Quality Assessment Program

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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By Faith A. Fitzpatrick, Terri L. Arnold, *and* John A. Colman

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Urbana, Illinois
1998

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
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http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

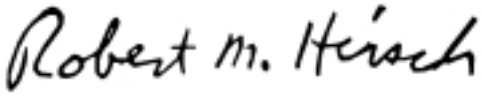
- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To Obtain
micrometer (µm)	0.00003937	inch
kilometer (km)	.6214	mile

Abbreviated water-quality units: Chemical concentration is given in micrograms per gram (µg/g). Micrograms per gram are metric units expressing the concentration of chemical constituents in solution as mass (micrograms) of constituent per unit mass (gram) of a dry sample. Screen sizes of sieves are given in micrometers (µm).

Surface-Water-Quality Assessment of the Upper Illinois River Basin in Illinois, Indiana, and Wisconsin—Spatial Distribution of Geochemicals in the Fine Fraction of Streambed Sediment, 1987

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Abstract

Geochemical data for the upper Illinois River Basin are presented for concentrations of 39 elements in streambed sediment collected by the U.S. Geological Survey in the fall of 1987. These data were collected as part of the pilot phase of the National Water-Quality Assessment Program. A total of 372 sites were sampled, with 238 sites located on first- and second-order streams, and 134 sites located on main stems. Spatial distribution maps and exceedance probability plots are presented for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, carbon (total, inorganic, and organic), cerium, chromium, cobalt, copper, gallium, iron, lanthanum, lead, lithium, magnesium, manganese, mercury, molybdenum, neodymium, nickel, niobium, phosphorus, potassium, scandium, selenium, silver, sodium, strontium, sulfur, thorium, titanium, uranium, vanadium, yttrium, and zinc. For spatial distribution maps, concentrations of the elements are grouped into four ranges bounded by the minimum concentration, the 10th, 50th, and 90th percentiles, and the maximum concentrations. These ranges were selected to highlight streambed sediment with very low or very high element concentrations relative to the rest of the streambed sediment in the upper Illinois River Basin. Exceedance probability plots for each element display the differences, if any, in distributions between high- and low-order streams and may be helpful in determining differences between background and elevated concentrations.

INTRODUCTION

The upper Illinois River Basin (UIRB) was one of four surface-water basins selected by the U.S. Geological Survey (USGS) in 1986 for the pilot phase of the National Water-Quality Assessment (NAWQA) program (Mades, 1987). One of the specific objectives of the NAWQA program (Cohen and others, 1988; Hirsch and others, 1988)—to describe the occurrence and distribution of trace elements in pilot study basins—was met in part by a synoptic survey of the geochemistry of streambed sediment (Colman and Sanzolone, 1991). This survey was conducted because streambed-sediment chemistry may affect the biological characteristics of a stream (Fitzpatrick and others, 1995; Batley, 1983; Luoma and Carter, 1991; Luoma, 1989; Sparks and Sandusky, 1983), can serve as an indicator of water-column conditions (Fitzpatrick and others, 1995; Kersten and Forstner, 1987), and can facilitate modeling of the sources and fate of chemicals in riverine systems (Salomons and Forstner, 1984).

The purpose of this report is to present maps of the spatial distribution and plots of exceedance probability for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, carbon (total, inorganic, and organic), cerium, chromium, cobalt, copper, gallium, iron, lanthanum, lead, lithium, magnesium, manganese, mercury, molybdenum, neodymium, nickel, niobium, phosphorus, potassium, scandium, selenium, silver, sodium, strontium, sulfur, thorium, titanium, uranium, vanadium, yttrium, and zinc in the fine (silt and clay) fraction of streambed sediment in the UIRB. The spatial distribution maps highlight streambed sediment with very low or very high element concentrations relative to the rest of the streambed sediment in the UIRB. The exceedance probability plots show differences in the distribution of concentrations in high- and low-order streams. Spatial distribution maps and probability plots of

seven additional elements (bismuth, europium, gold, holmium, tantalum, tin, and ytterbium) were not included in this report because concentrations of these elements were below or near the minimum reporting levels at most sites.

In addition to this report, three publications contain descriptions and interpretations of the geochemical-concentration data in streambed sediment in the UIRB. Tables of the geochemical concentration data and detailed methodology are presented in Colman and Sanzolone (1991). Interpretations of spatial distributions and possible human and natural effects are discussed in Colman and Sanzolone (1992). Fitzpatrick and others (1995) compare the element concentrations in streambed sediment with element concentrations in water and aquatic biota.

METHODS

Samples of streambed sediment were collected by the USGS in the fall of 1987 as part of the NAWQA pilot study of the UIRB. A total of 372 sites were sampled—238 were on low-order streams (first- and second-order) and 134 sites were on high-order streams (main stems) (fig. 1). Stream order refers to the number of tributaries intersecting upstream and was measured using the Strahler (1954) method. Low-order stream sites were selected randomly from a grid (with grid-element sides of 10 km) placed over a basin map. These sites were sampled in an attempt to establish baseline concentrations of geochemicals for small streams not affected by point sources. High-order stream sites were selected at 8-km intervals in urban areas and at 16-km intervals in rural areas. These sites were sampled to assess streambed geochemistry of large river reaches, many of which were affected by point sources; however, sites near obvious pollution sources were avoided. An additional 196 samples were collected for testing the sampling design and sampling methods (Colman and Sanzolone, 1991).

Colman and Sanzolone (1991) contains a detailed description of the sampling design, site locations, field methods, laboratory preparation, chemical analyses, minimum reporting levels, and analytical results. A total of 46 elements, including major and minor elements, trace elements, and three forms of carbon, were analyzed from the less than 63-μm fraction of streambed sediment samples at the laboratory of the U.S. Geological Survey, Branch of Geochemistry, Denver, Colorado. Total digestions were used in the chemical analysis, except for boron and uranium. Inductively coupled plasma atomic-emission spectrometry (ICP-AES) was used for detection of most elements; other methods were used when element determination could not be made by ICP-AES or when additional sensitivity was required (Colman and Sanzolone, 1991). Protocols for sample-handling procedures, sample preparation, analytical methods, use of instrumentation, and laboratory procedures are published in Arbogast (1990). Quality-assurance procedures and results are presented in Sanzolone and Ryder (1989).

Methods of sampling and analysis were similar at sites on high- and low-order streams, except that sediment from high-order streams was sieved wet and sediment from low-order streams was sieved dry (Colman and Sanzolone, 1991). An analysis of the variance at 22 sites indicated significant variations in median concentrations because of sieving methods for most of the 46 elements surveyed (Colman and Sanzolone, 1992). For most elements, element concentrations in wet-sieved sediment were larger than in dry-sieved sediment.

DATA PRESENTATION

Spatial distribution maps for each element (figs. 2A–42A) illustrate concentrations of each element grouped into three or four ranges approximately bounded by the minimum concentration, the 10th, 50th, and 90th percentiles, and the maximum concentration. These ranges were selected to distinguish sediment with very high or very low concentrations relative to the rest of the concentrations in the UIRB. The percentiles used to group the concentration data are based on concentrations from high- and low-order streams combined, because separate distributions for high- and low-order streams would greatly increase the complexity of the maps and decrease their readability.

Most of the geochemical concentrations are reported in micrograms per gram. However, concentrations of some major elements that are commonly found in the earth's crust are given as percentages. These major elements include aluminum, calcium, carbon (total, inorganic, and organic), iron, magnesium, phosphorus, potassium, sodium, sulfur, and titanium.

It was necessary to redefine the ranges for beryllium, cadmium, mercury, molybdenum, and silver because concentrations of these elements were

below the detection limit at greater than 10 percent of the sites. Spatial distribution maps and probability plots of bismuth, europium, gold, holmium, tantalum, tin, and ytterbium were not included in this report because concentrations of these elements were below or near the minimum reporting levels at most sites (Colman and Sanzolone, 1991).

For some elements, concentrations in sediment from high-order streams are much larger than concentrations in low-order streams. Spatial distributions of elements for low-order streams are not discernible. Exceedance probability plots (plots of the percentage of samples with concentrations greater than a given value) were done for each element (figs. 2B–42B). These plots display the differences, if any, in distributions between high- and low-order streams and may be helpful in determining differences between background and elevated concentrations (Fitzpatrick and others, 1995; Rickert and others, 1977).

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FIGURES

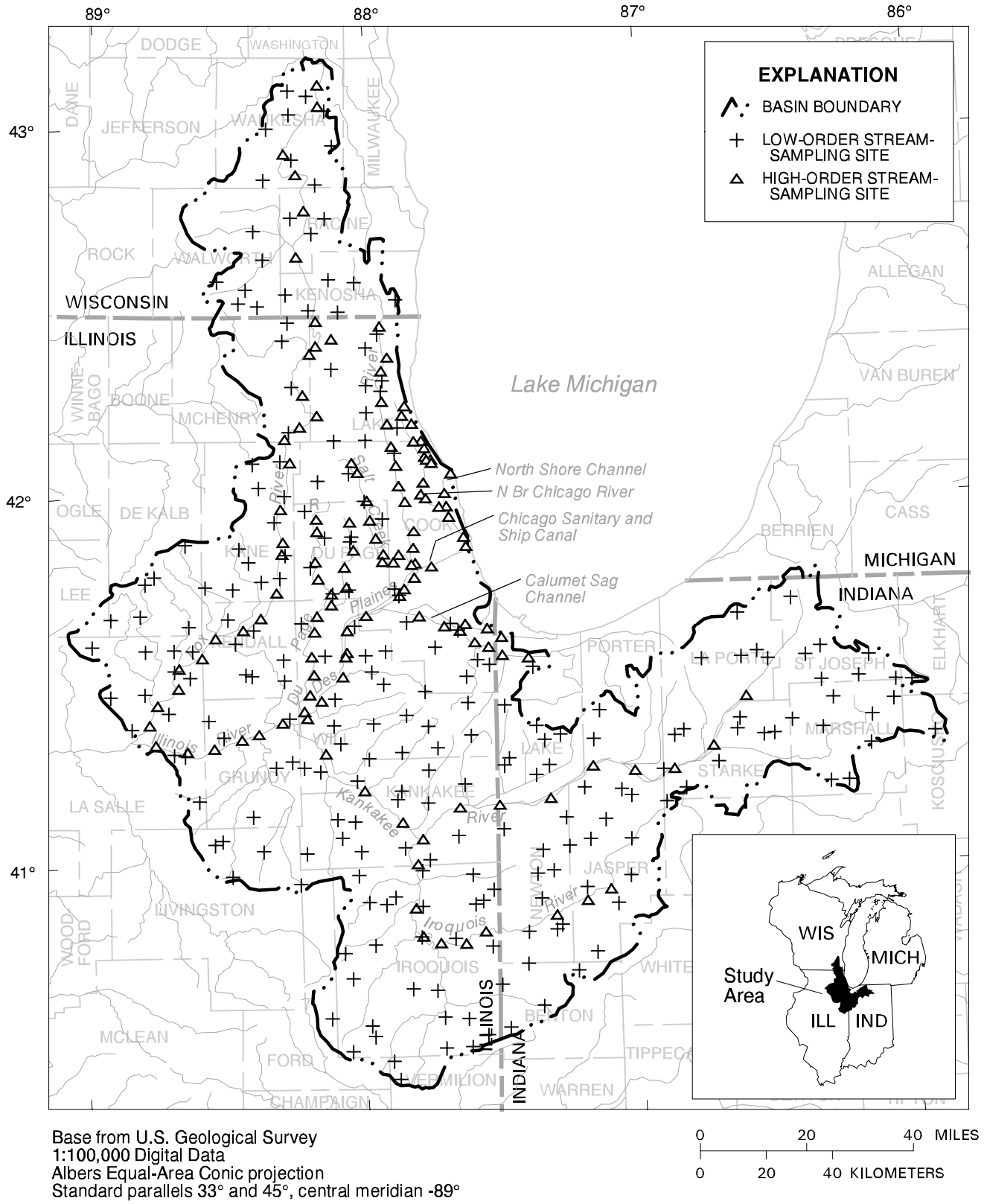


Figure 1. Locations of high- and low-order stream sites sampled for major and trace elements in streambed sediment in the upper Illinois River Basin, 1987.

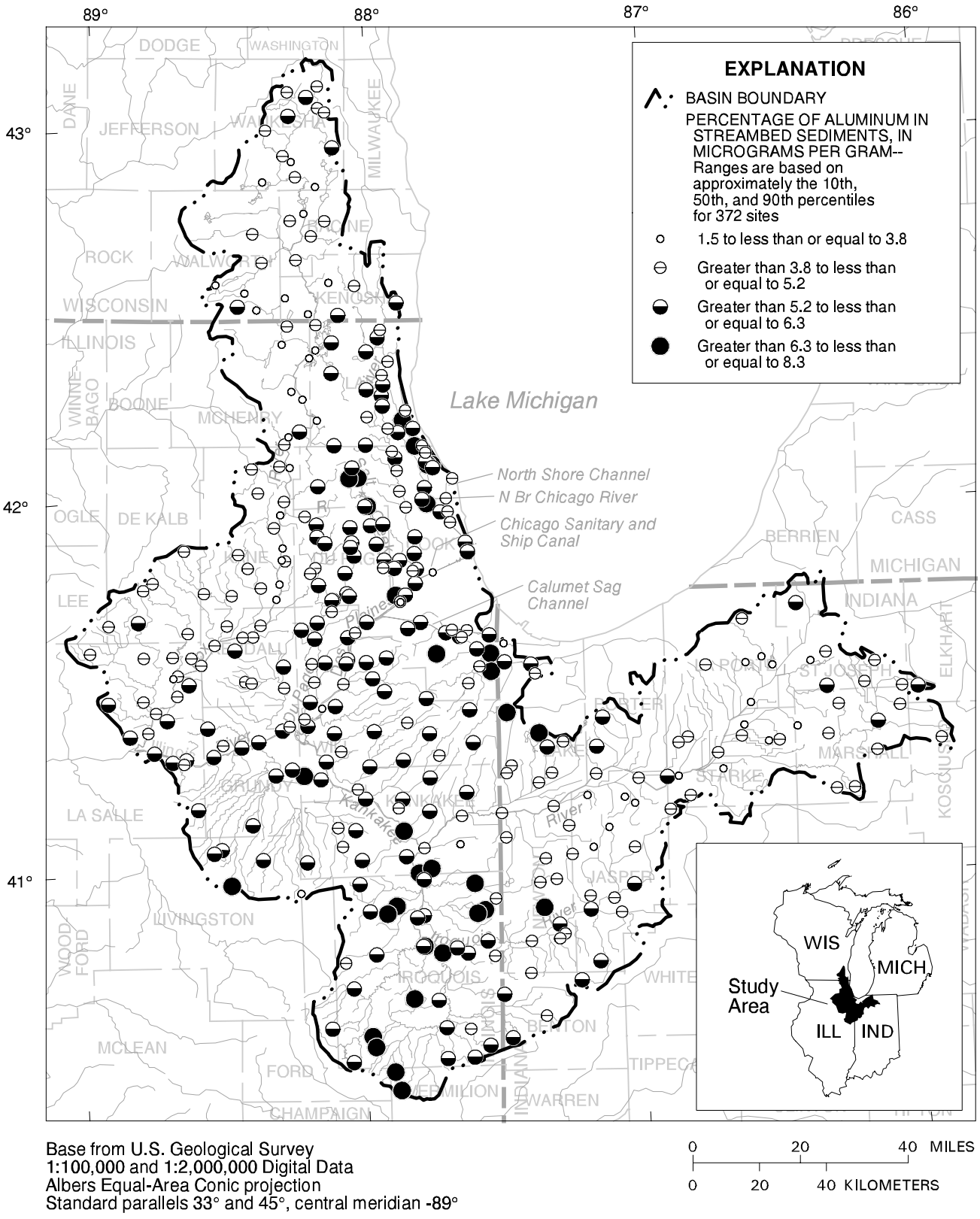


Figure 2. Percentage of aluminum in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

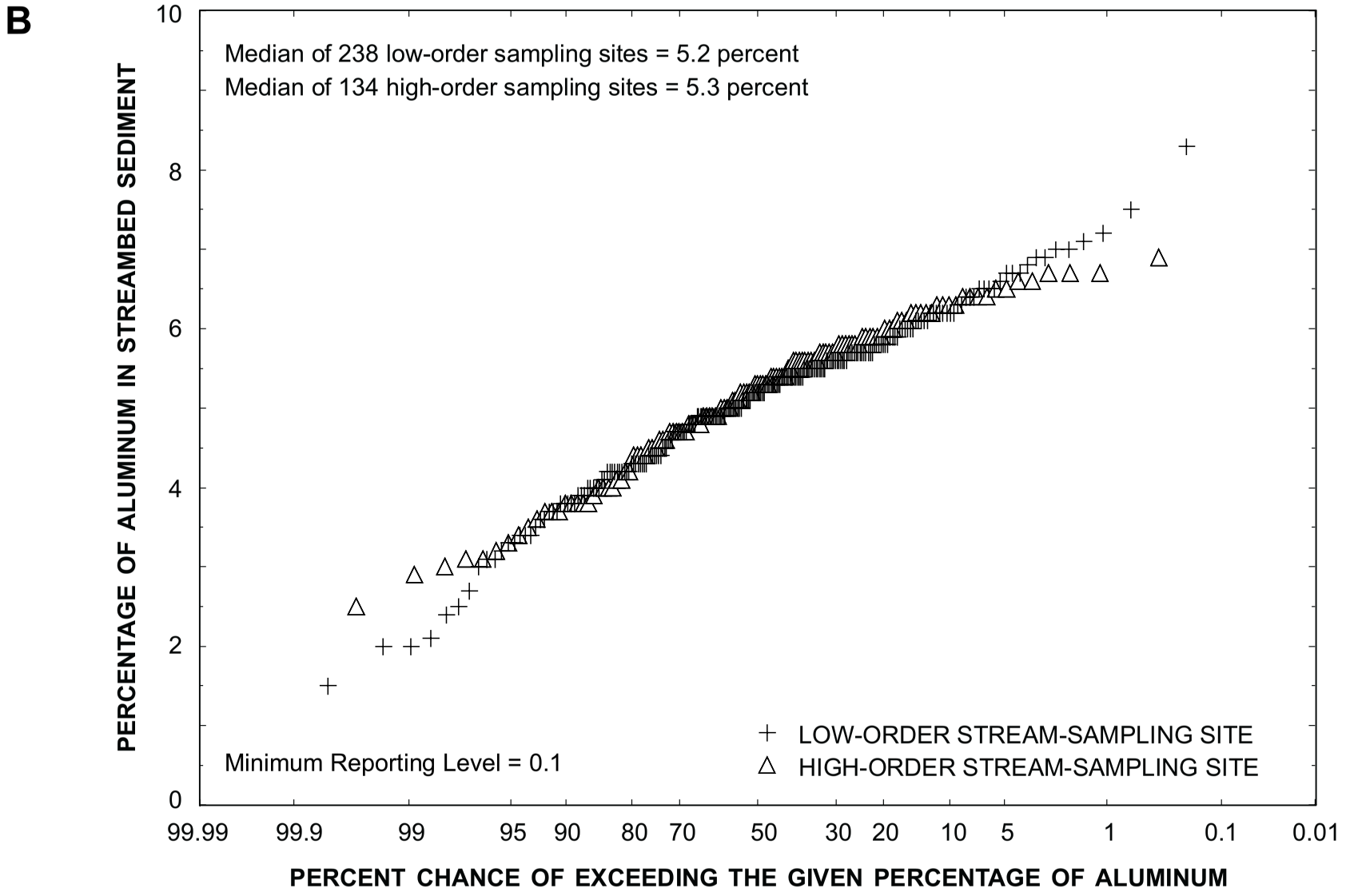
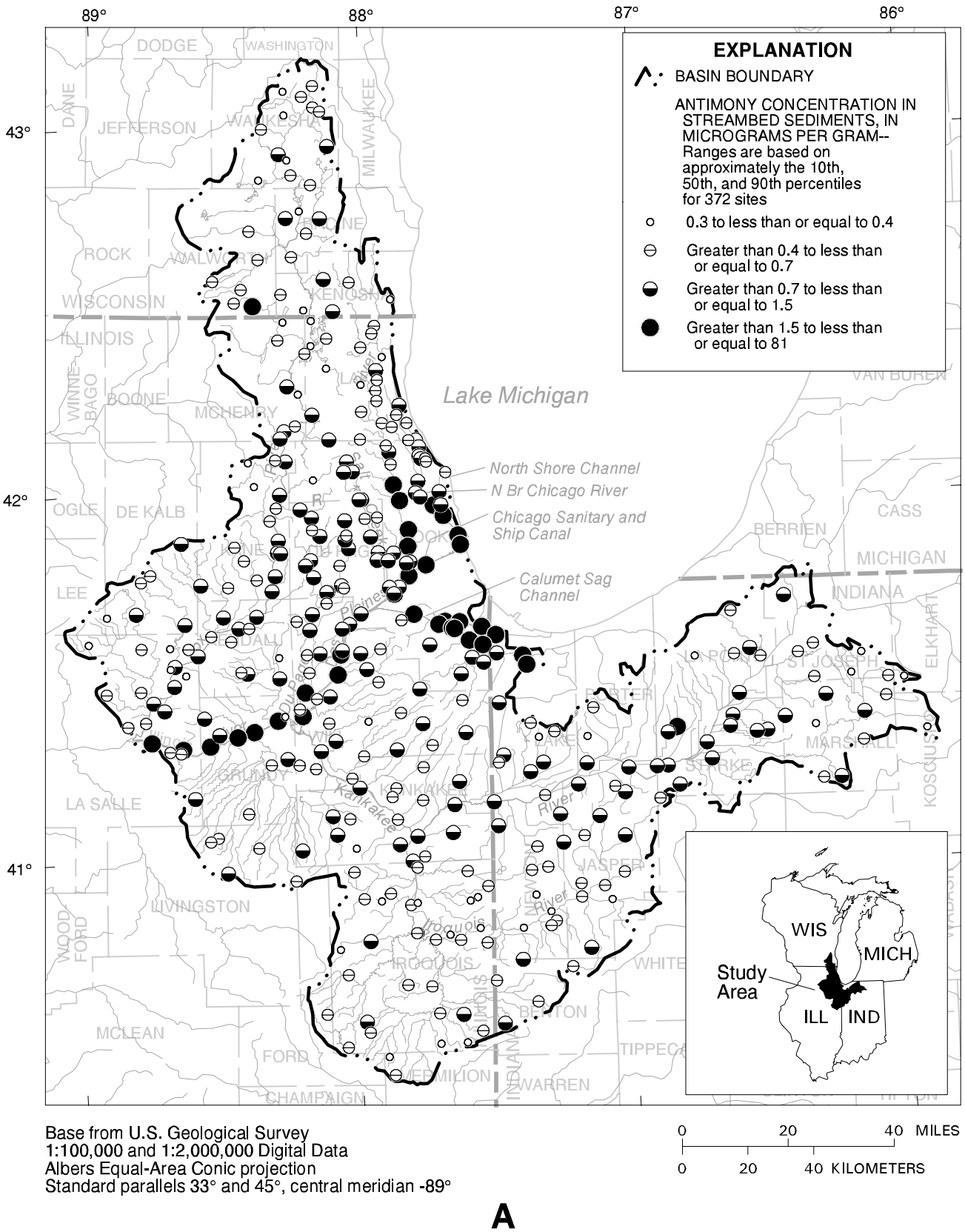


Figure 2. Percentage of aluminum in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 3. Antimony concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

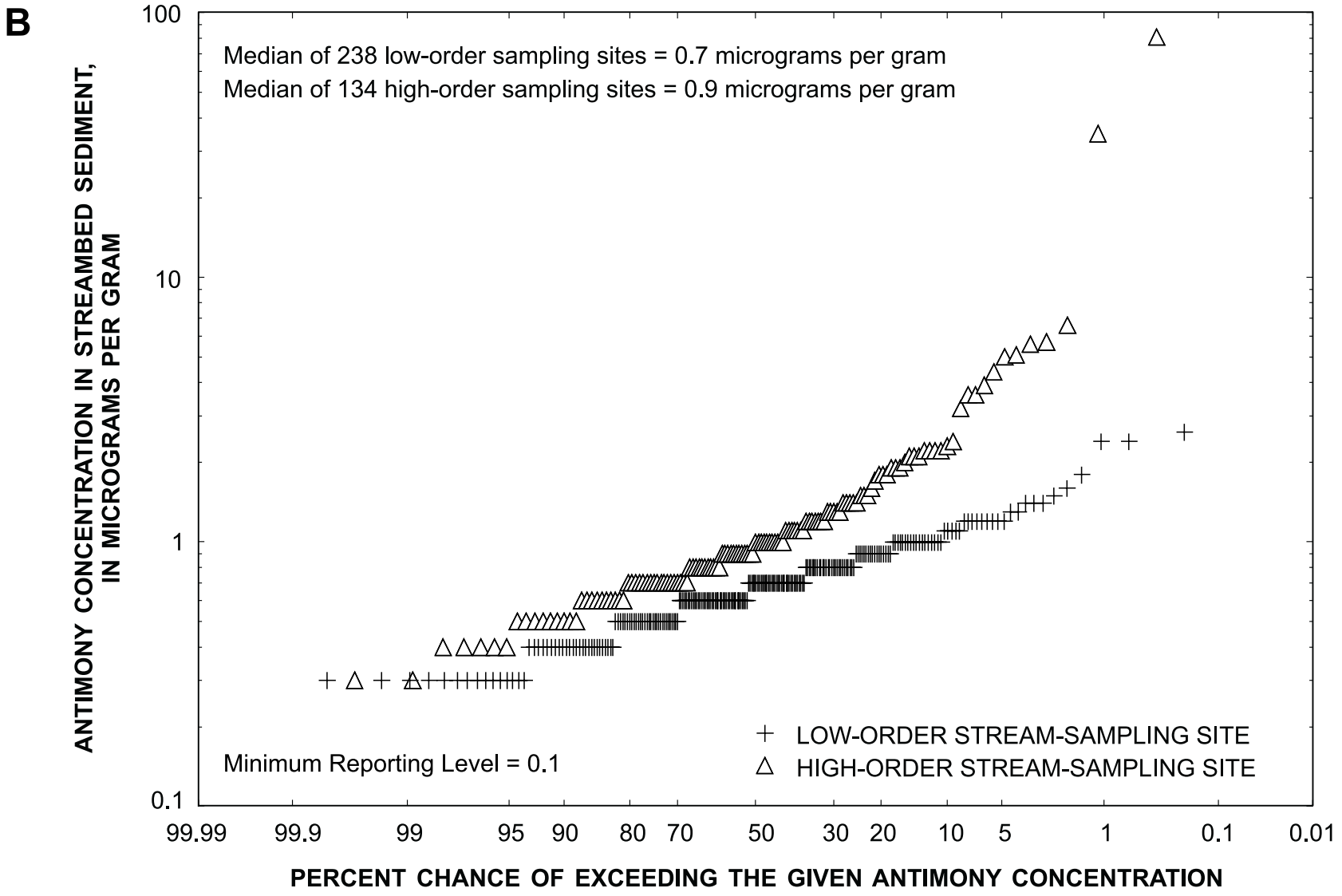
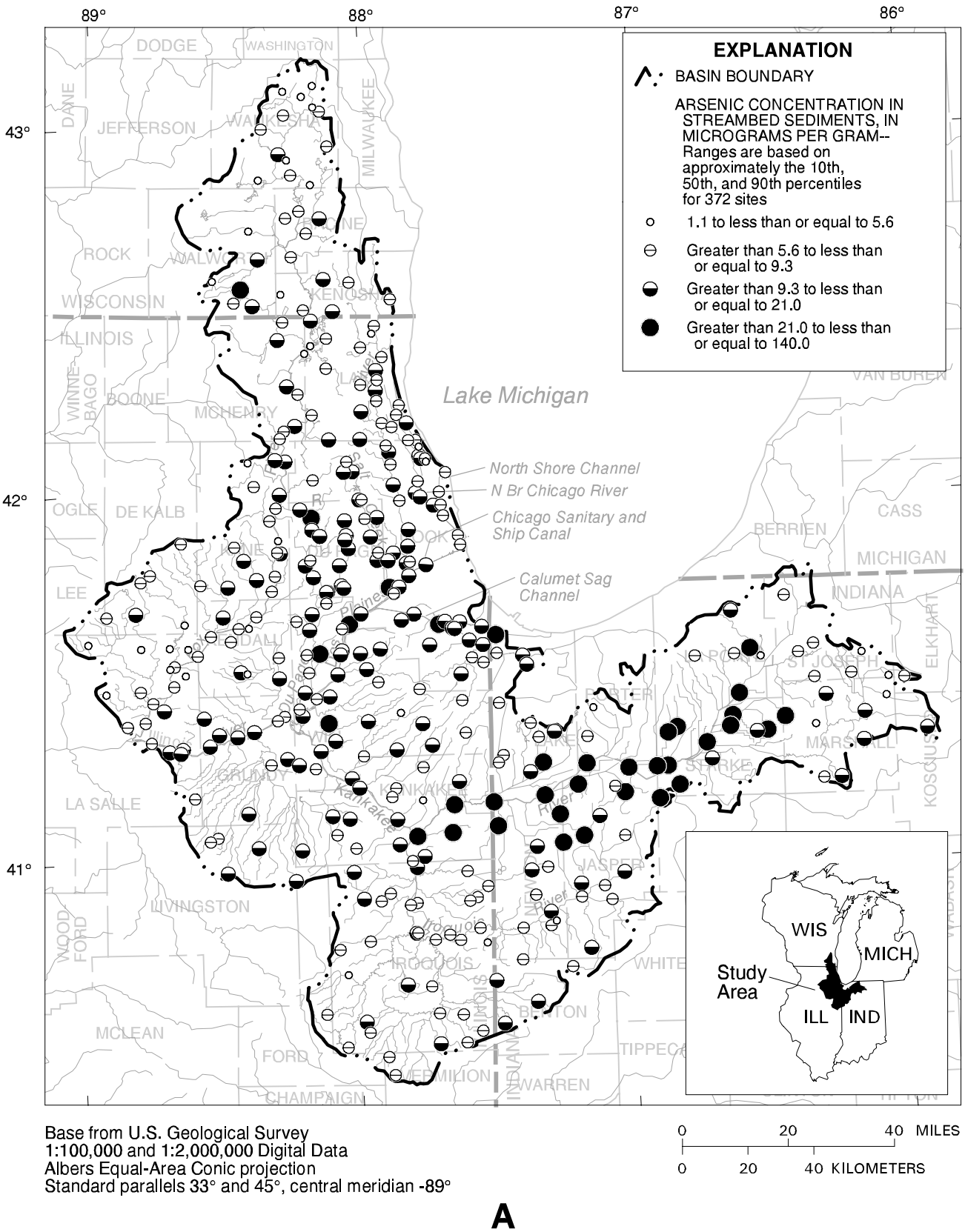


Figure 3. Antimony concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 4. Arsenic concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

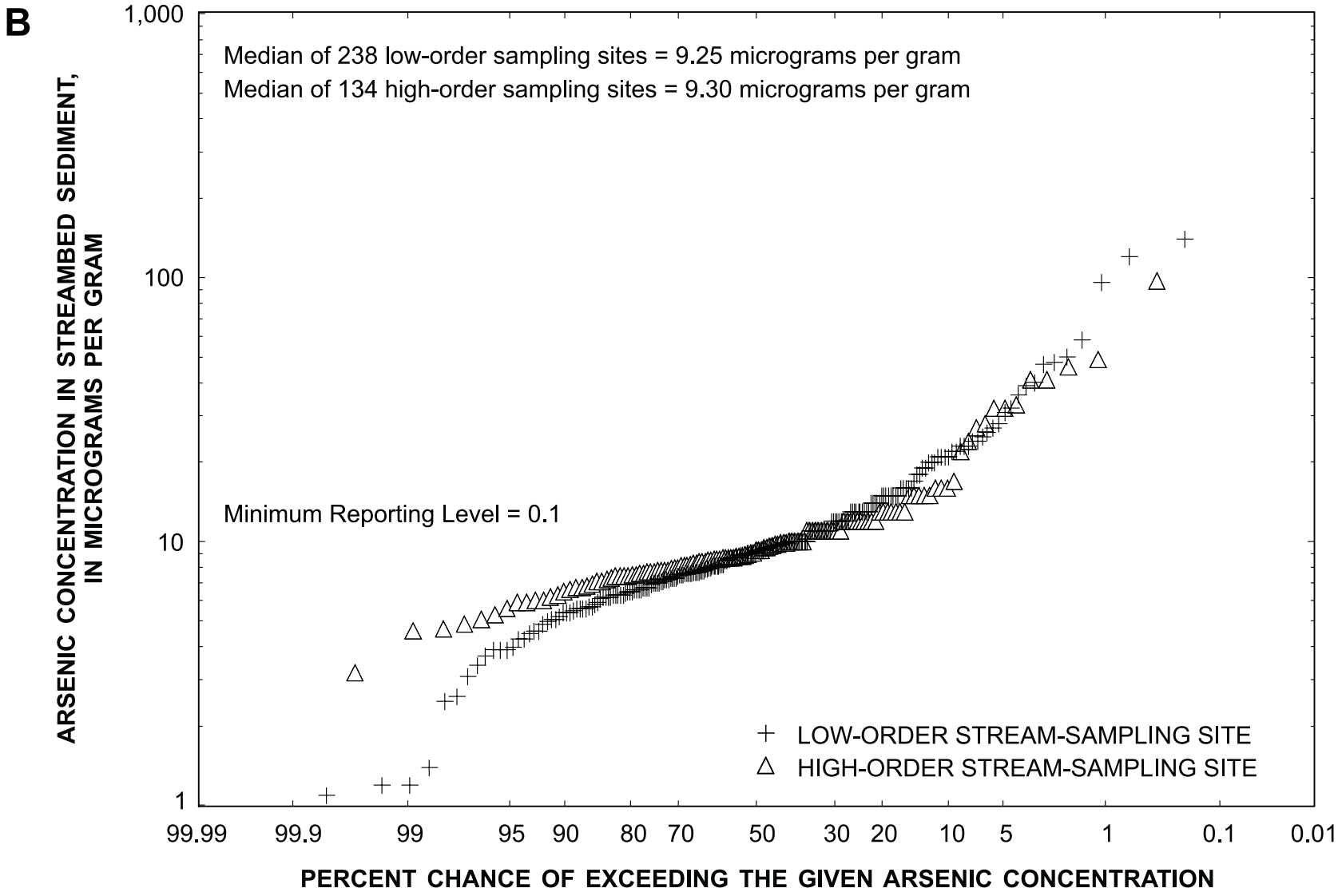


Figure 4. Arsenic concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

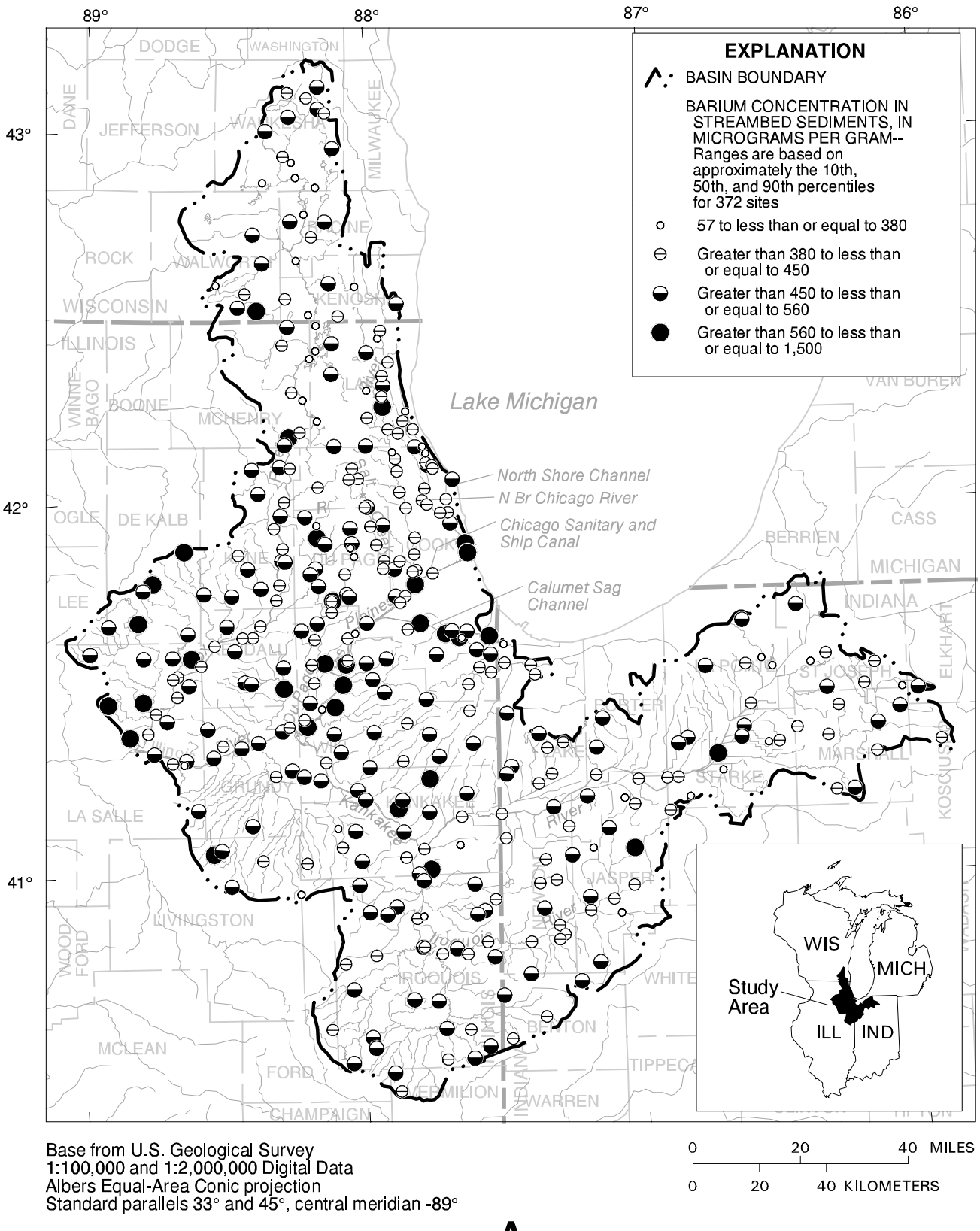


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Figure 5. Barium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

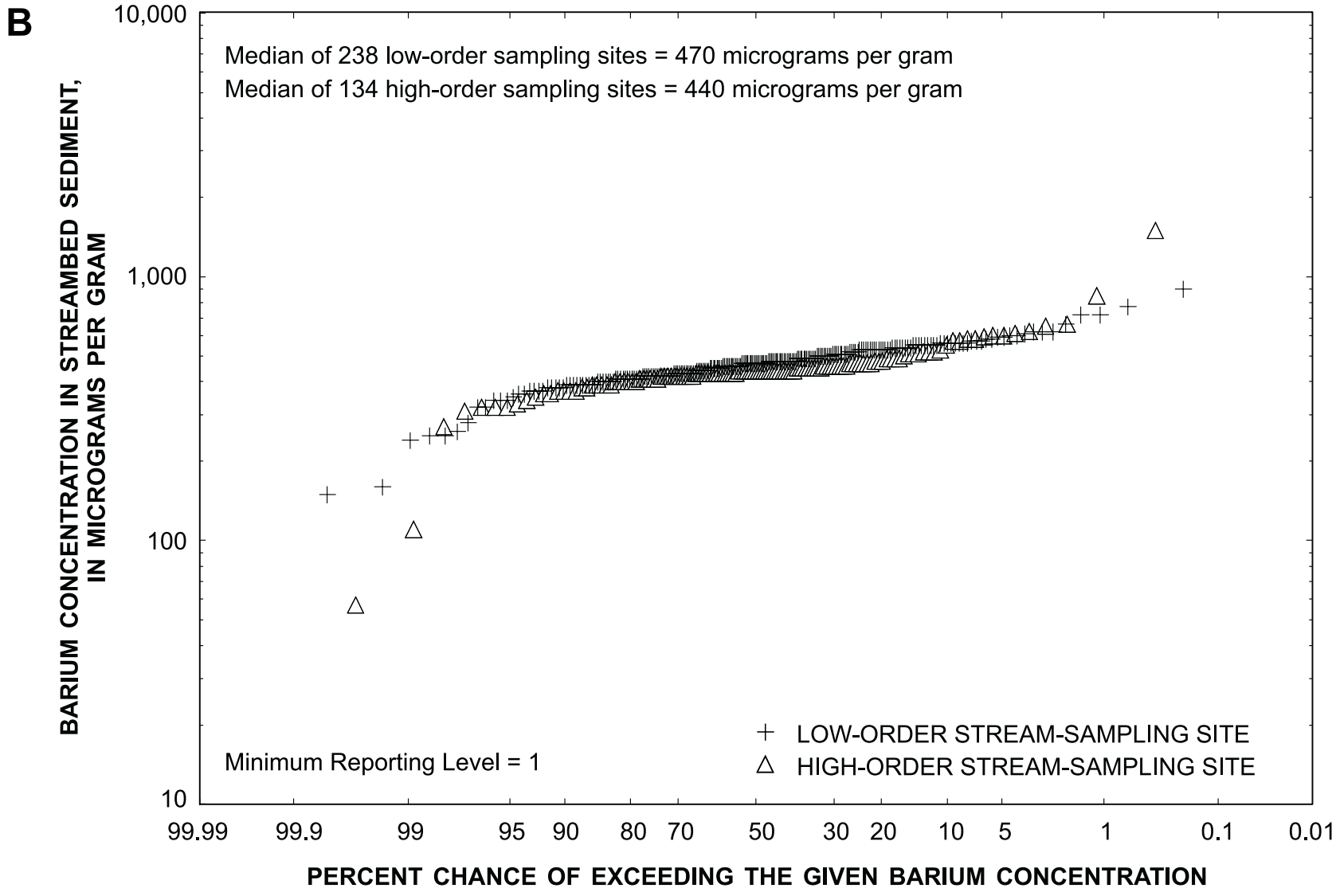

Figure 5. Barium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

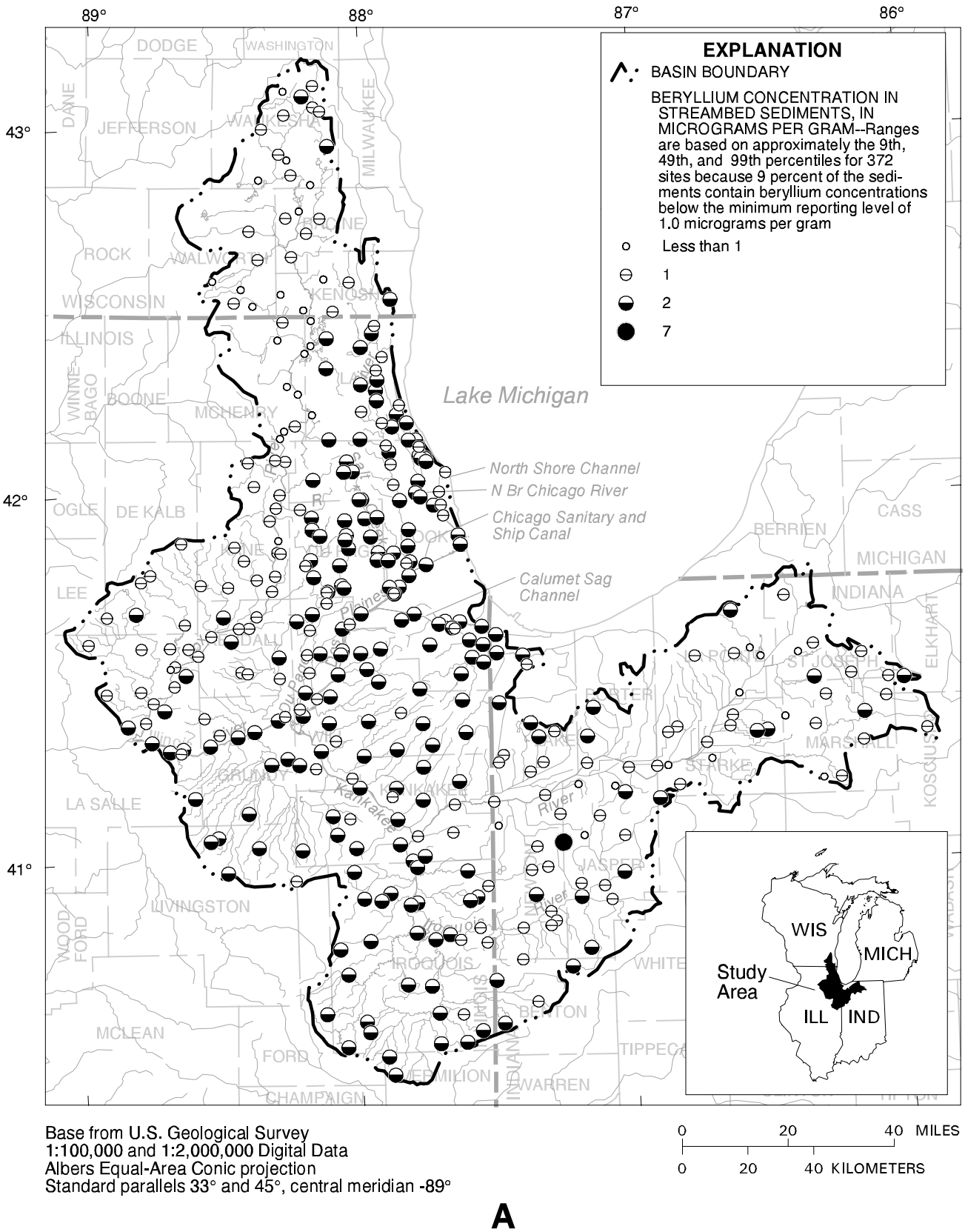

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Figure 6. Beryllium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

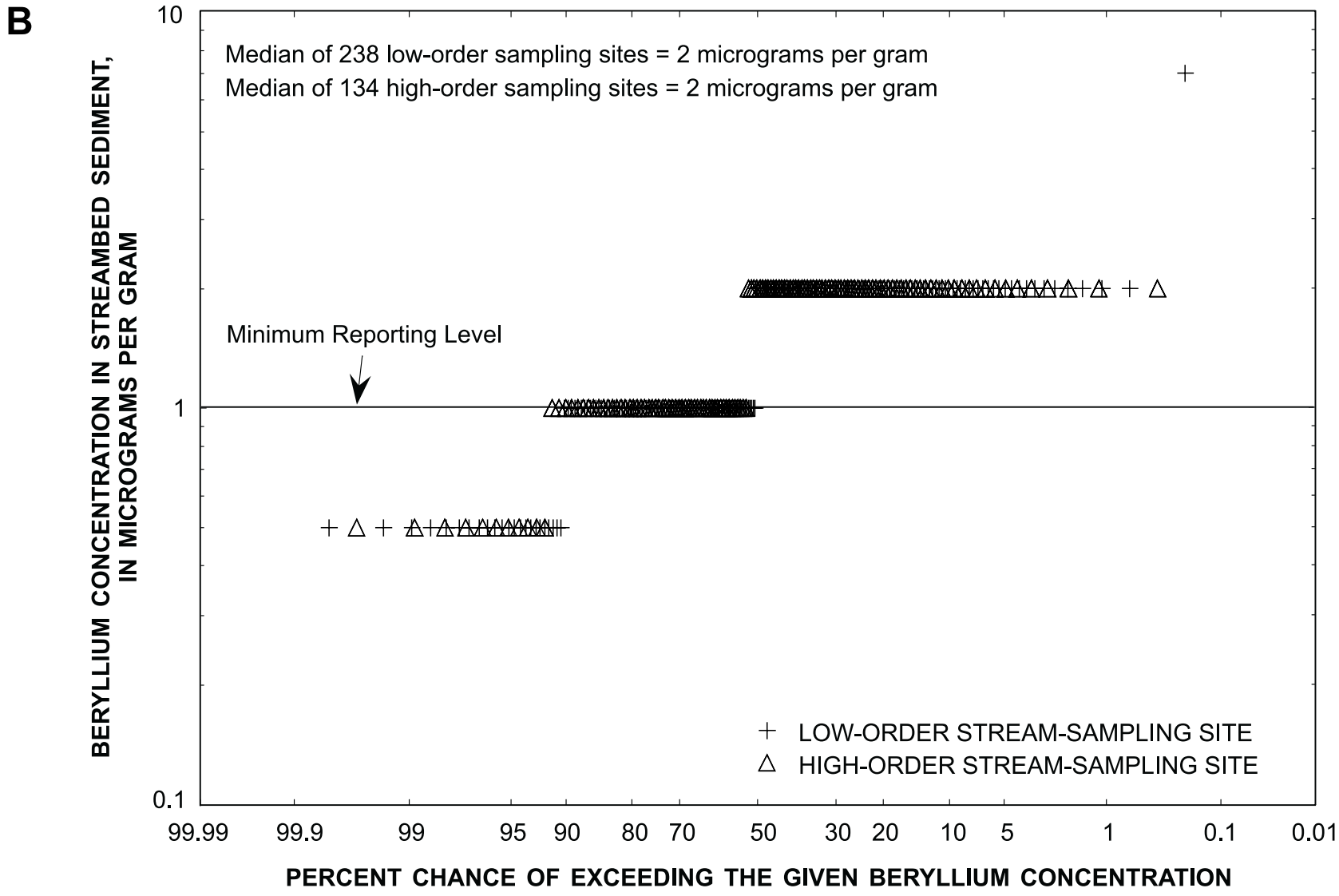


Figure 6. Beryllium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

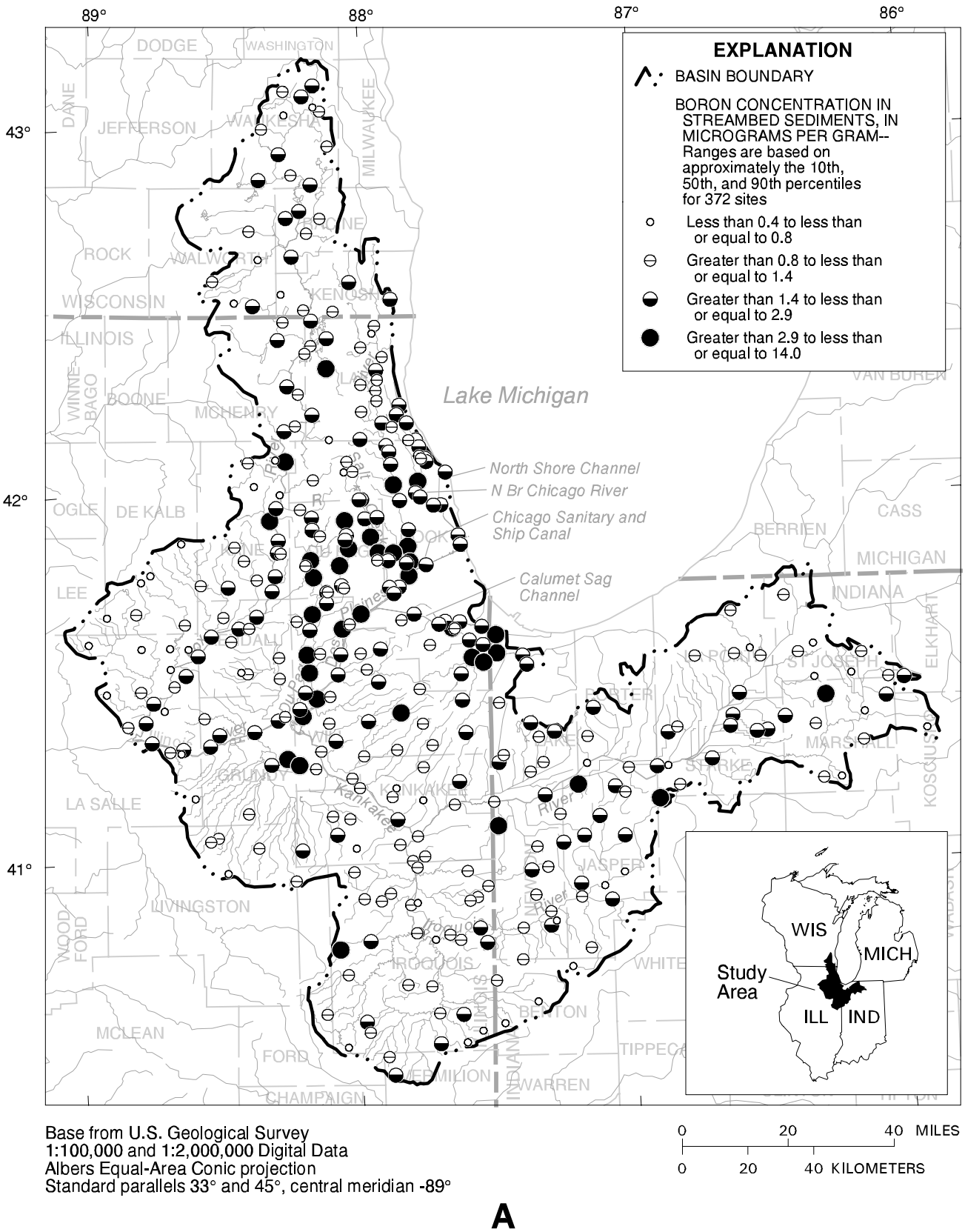


Figure 7. Boron concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

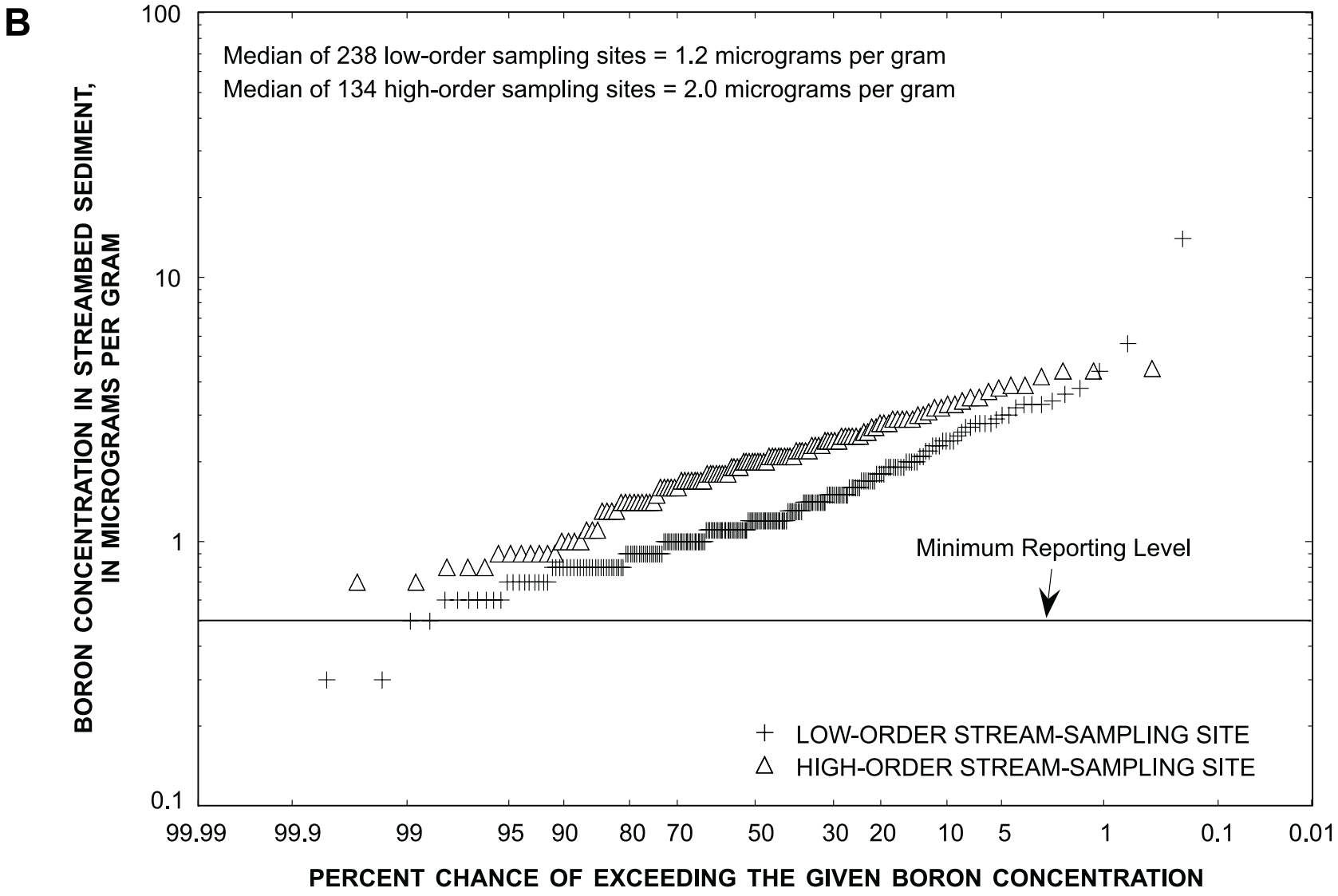
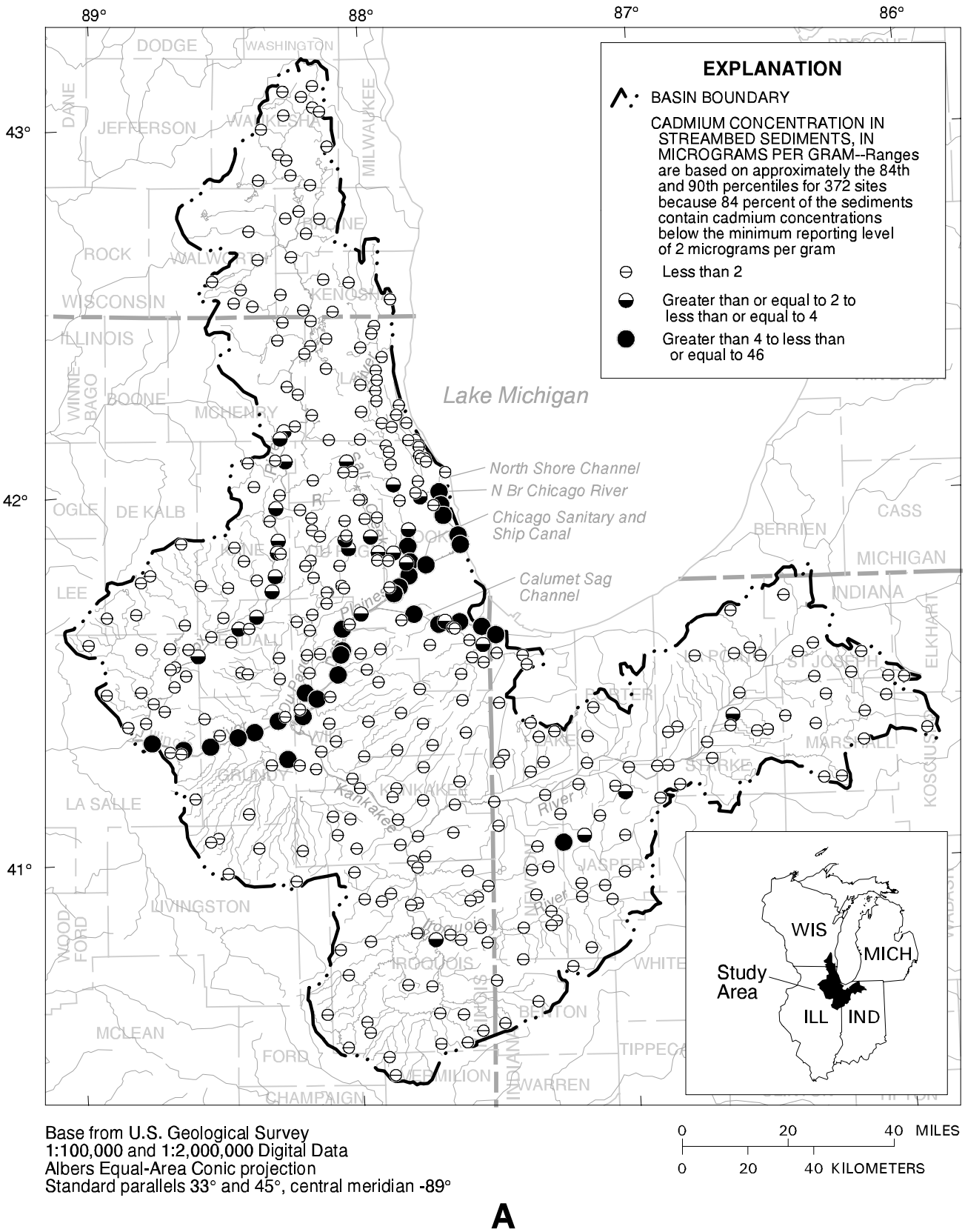


Figure 7. Boron concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 8. Cadmium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

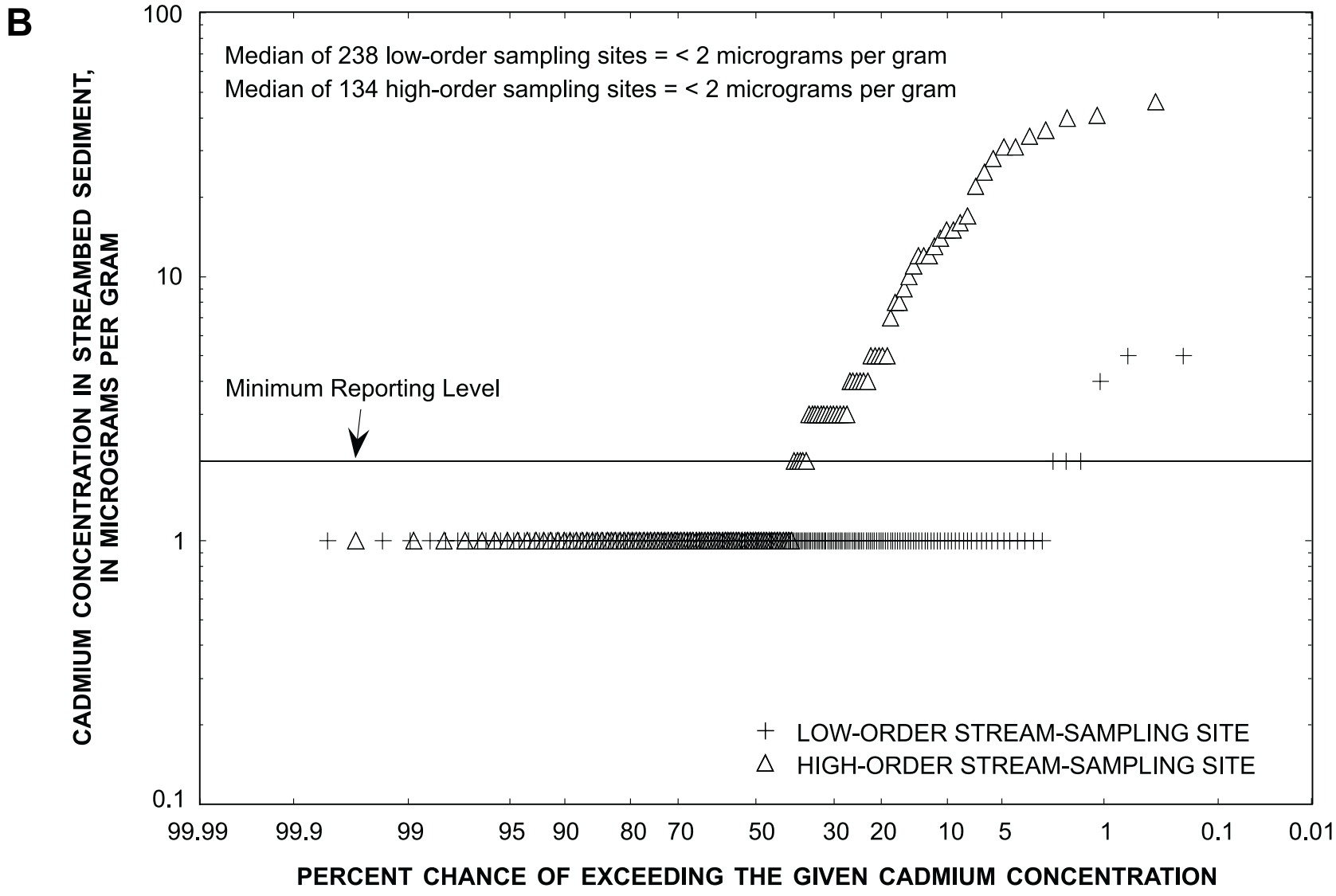


Figure 8. Cadmium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

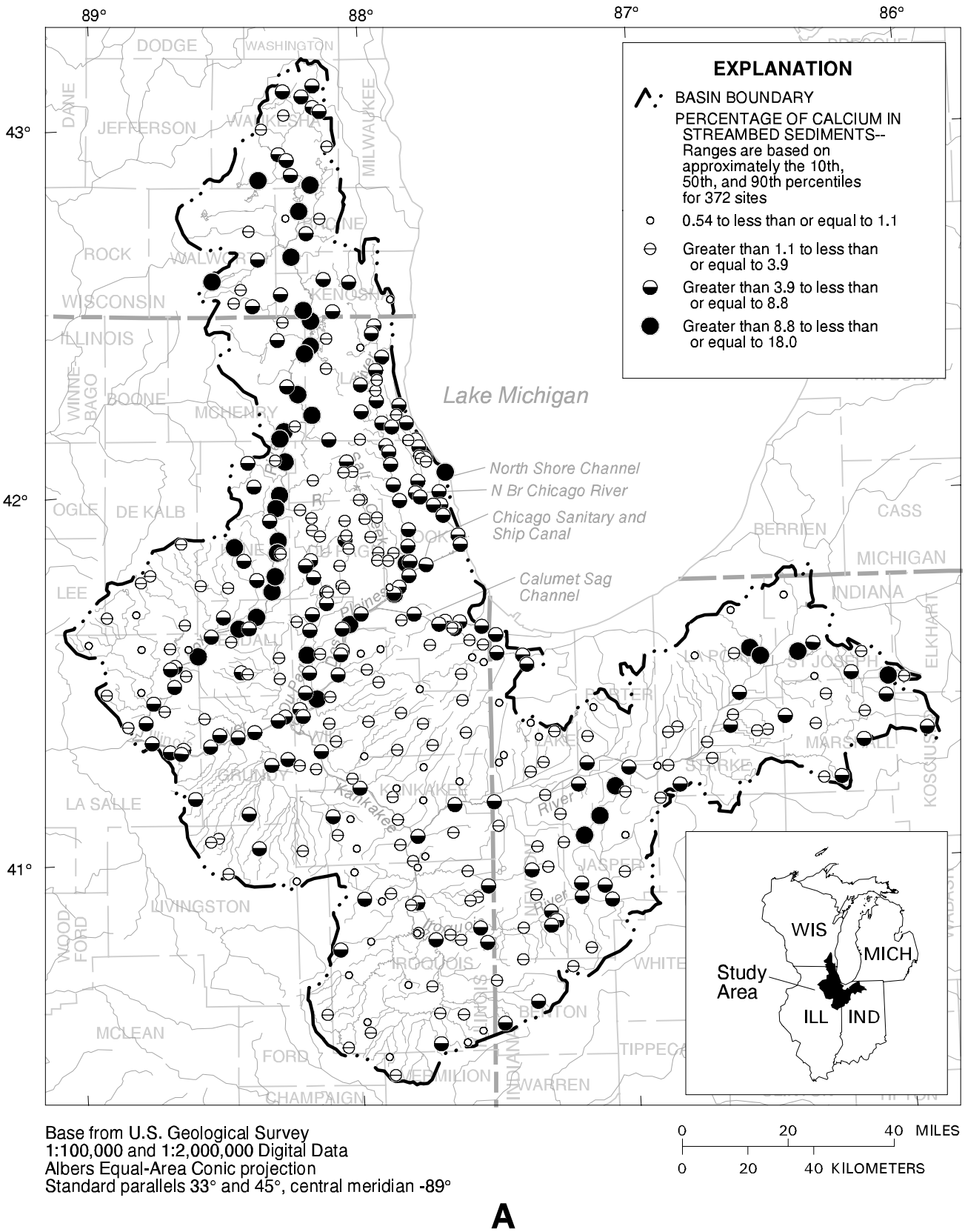


Figure 9. Percentage of calcium in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

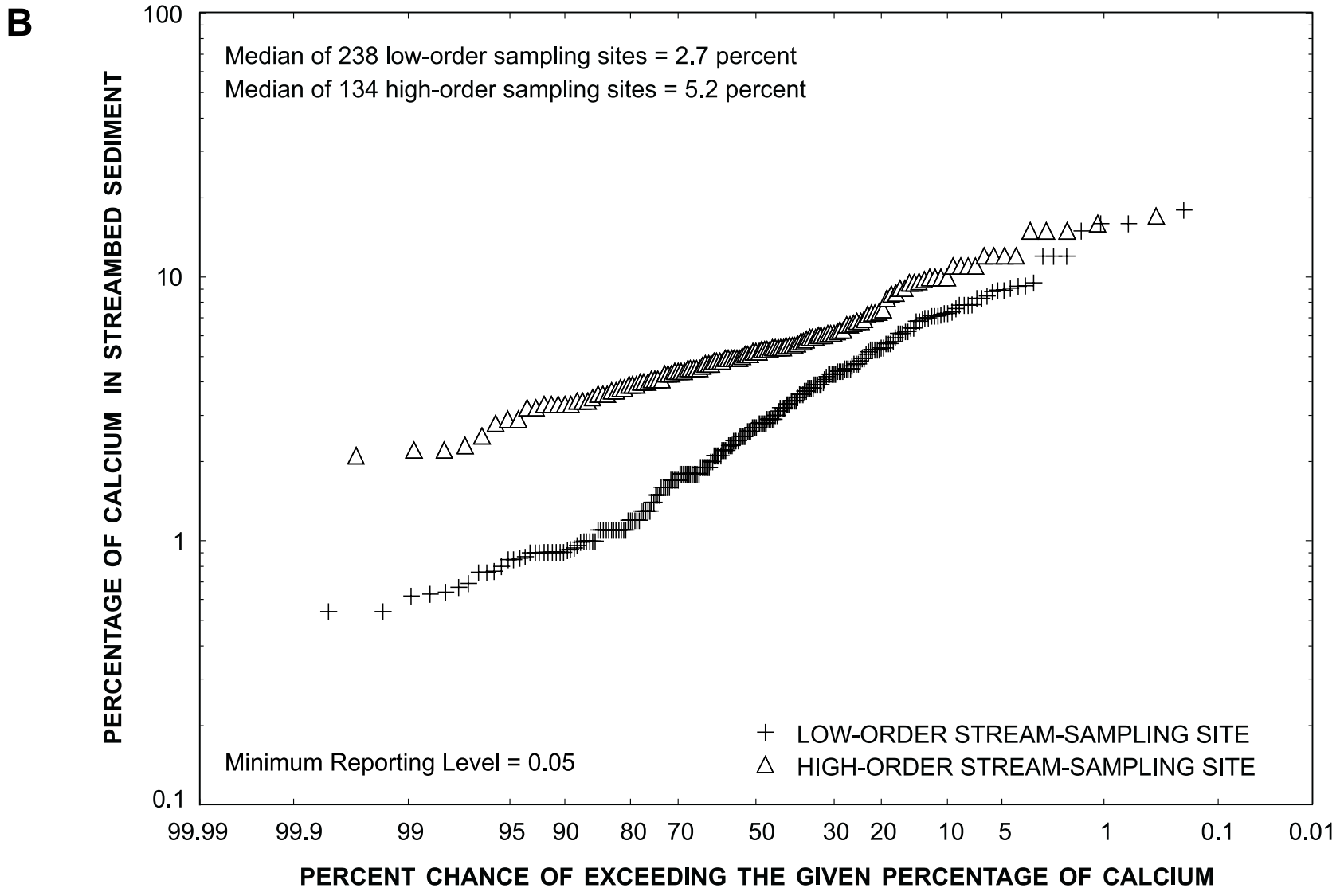
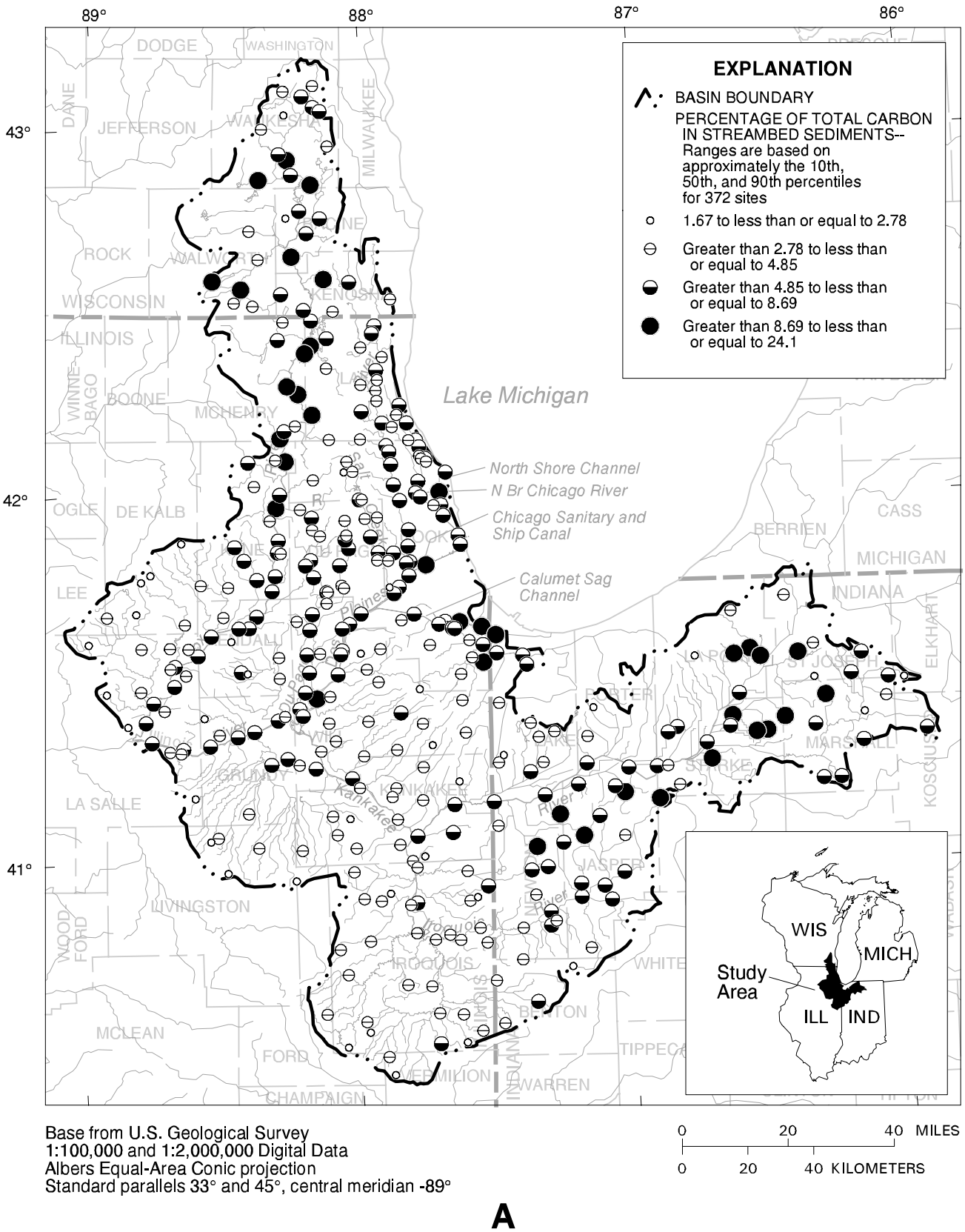


Figure 9. Percentage of calcium in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 10. Percentage of carbon (total) in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

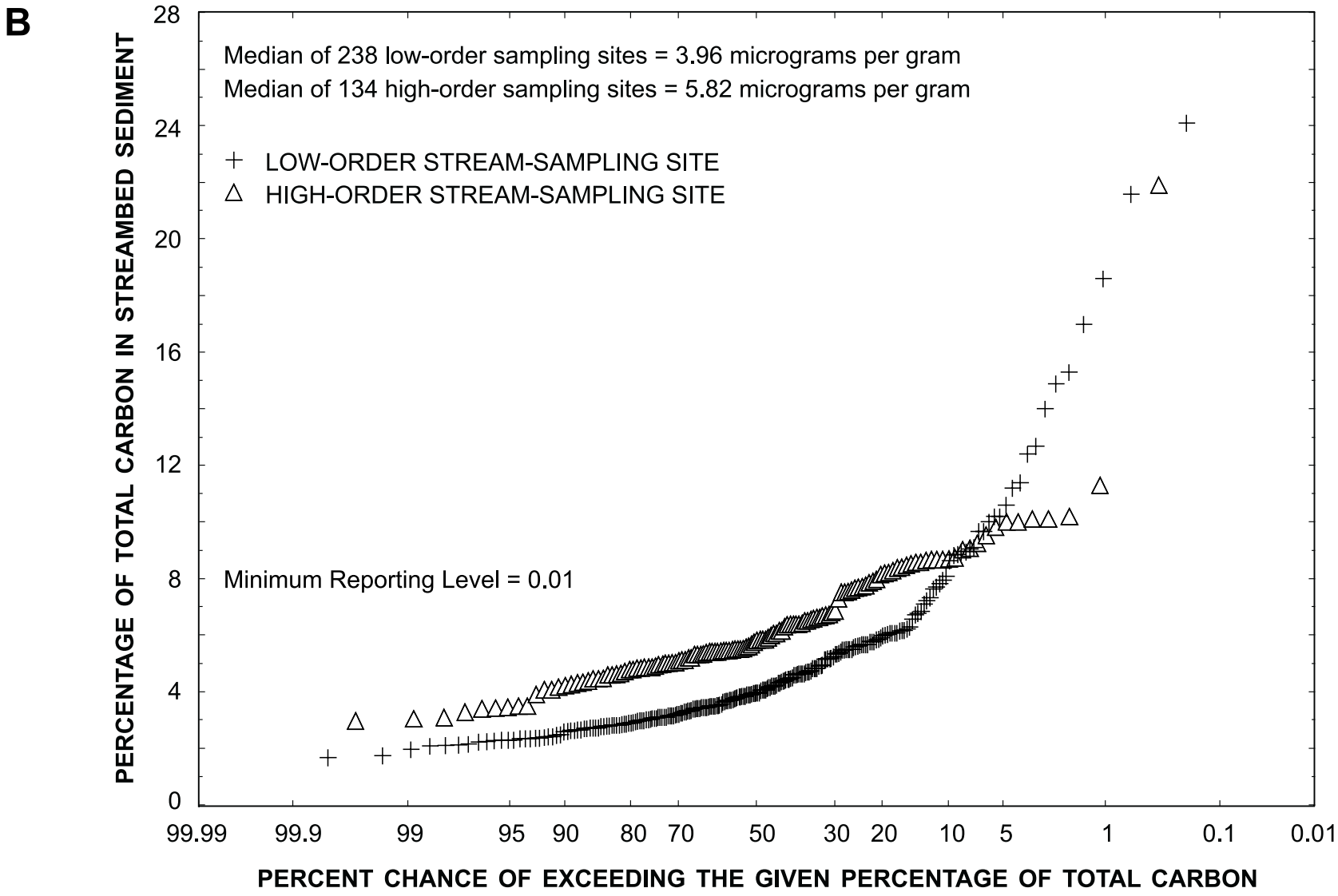


Figure 10. Percentage of carbon (total) in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

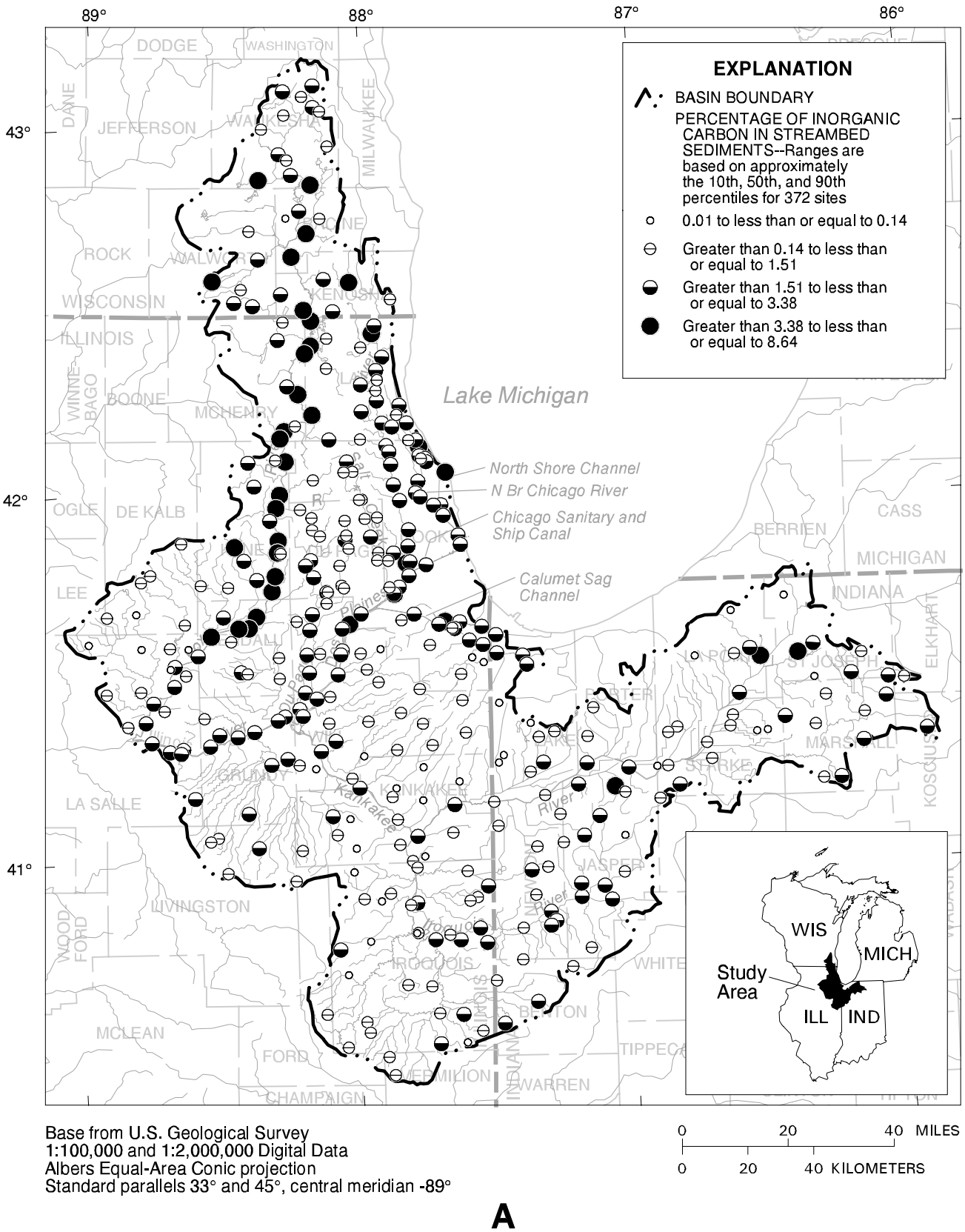


Figure 11. Percentage of carbon (inorganic) in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

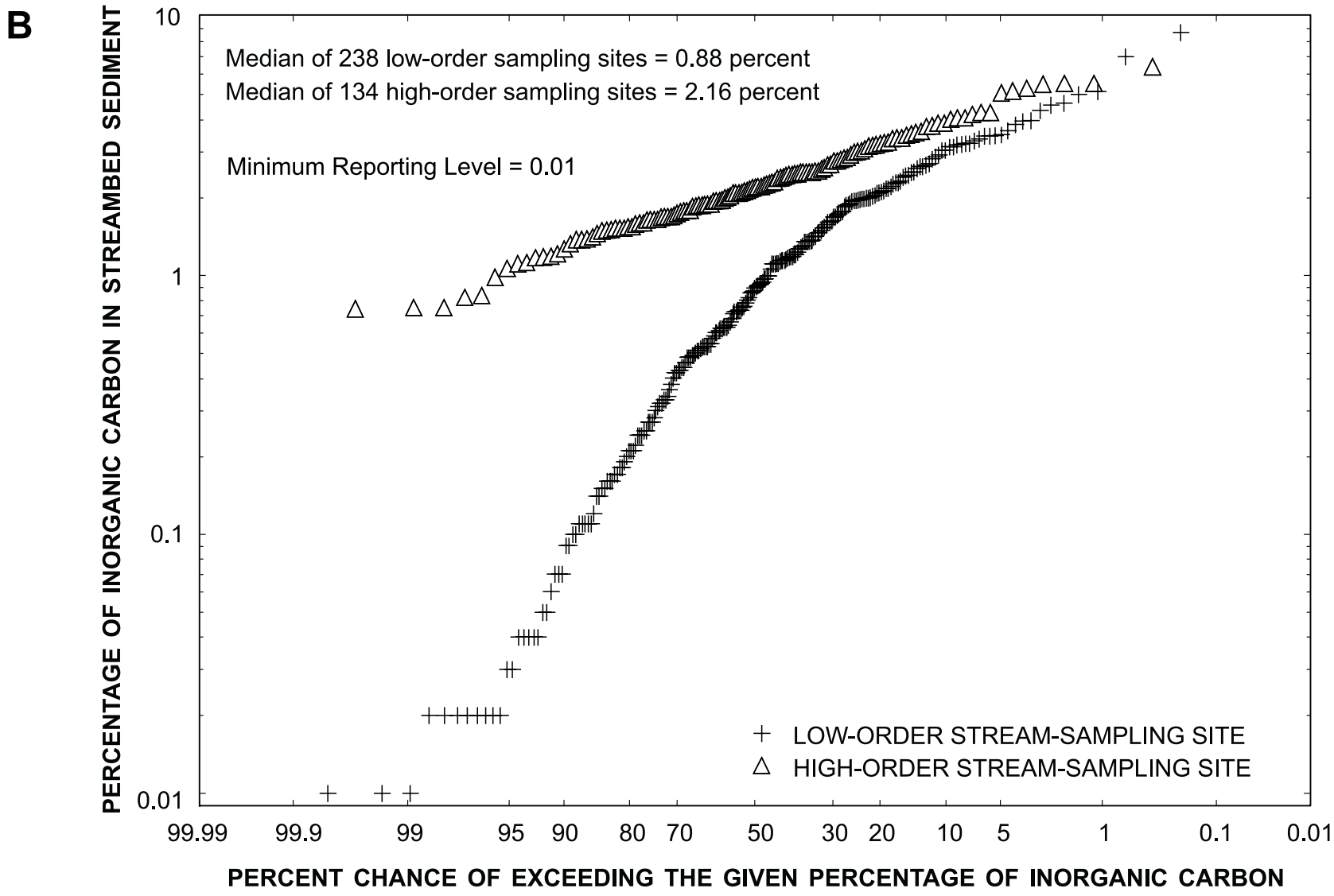


Figure 11. Percentage of carbon (inorganic) in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

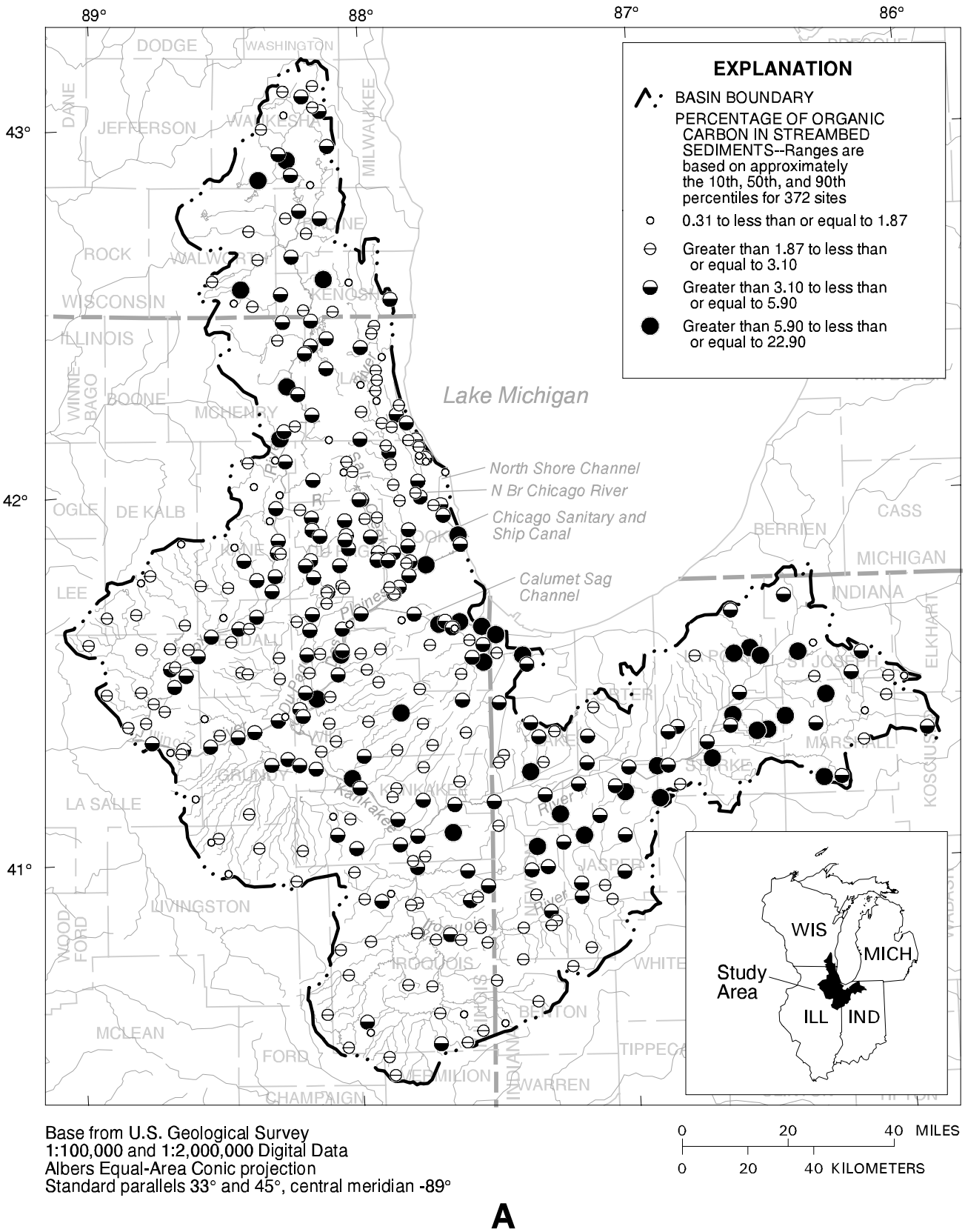


Figure 12. Percentage of carbon (organic) in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

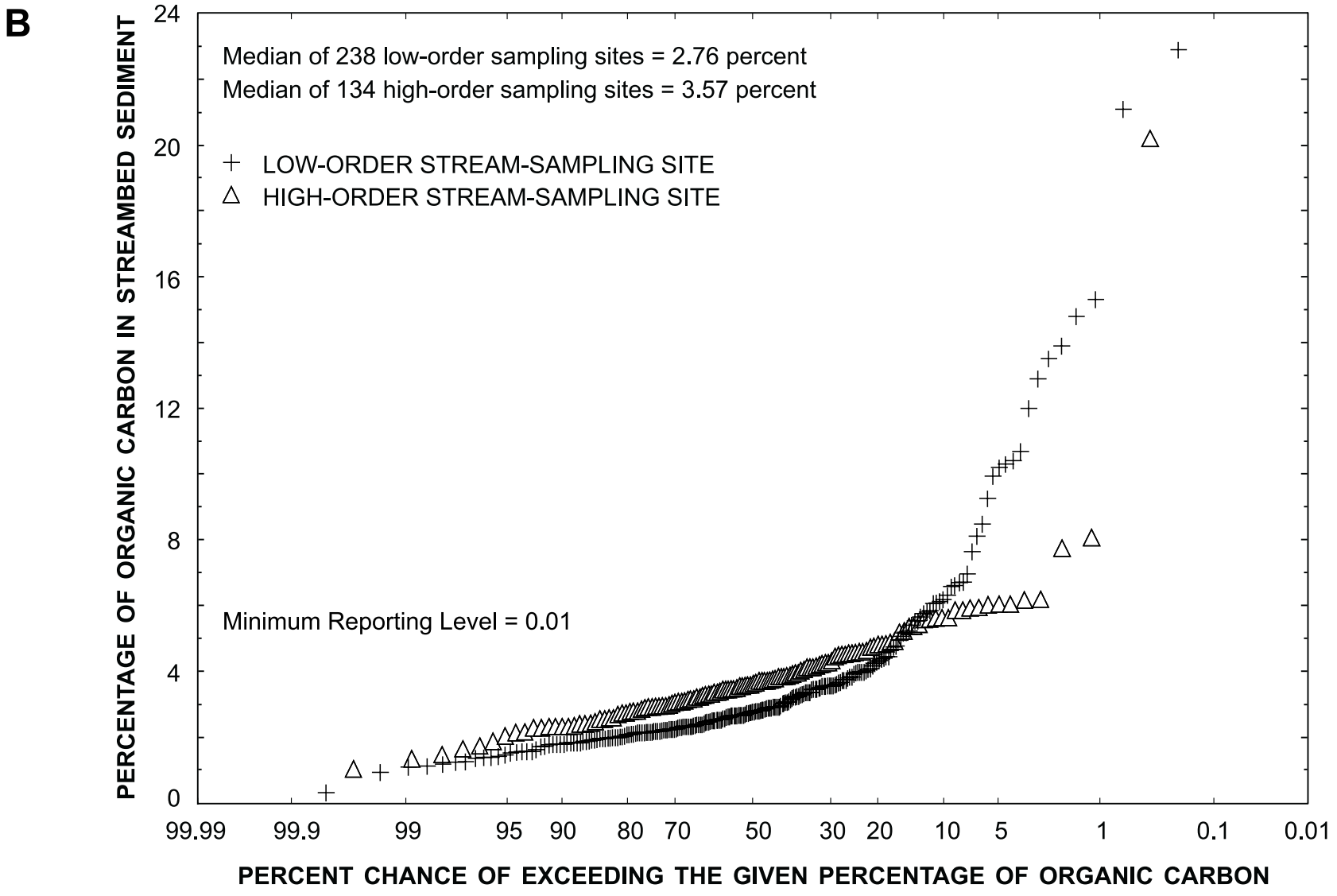
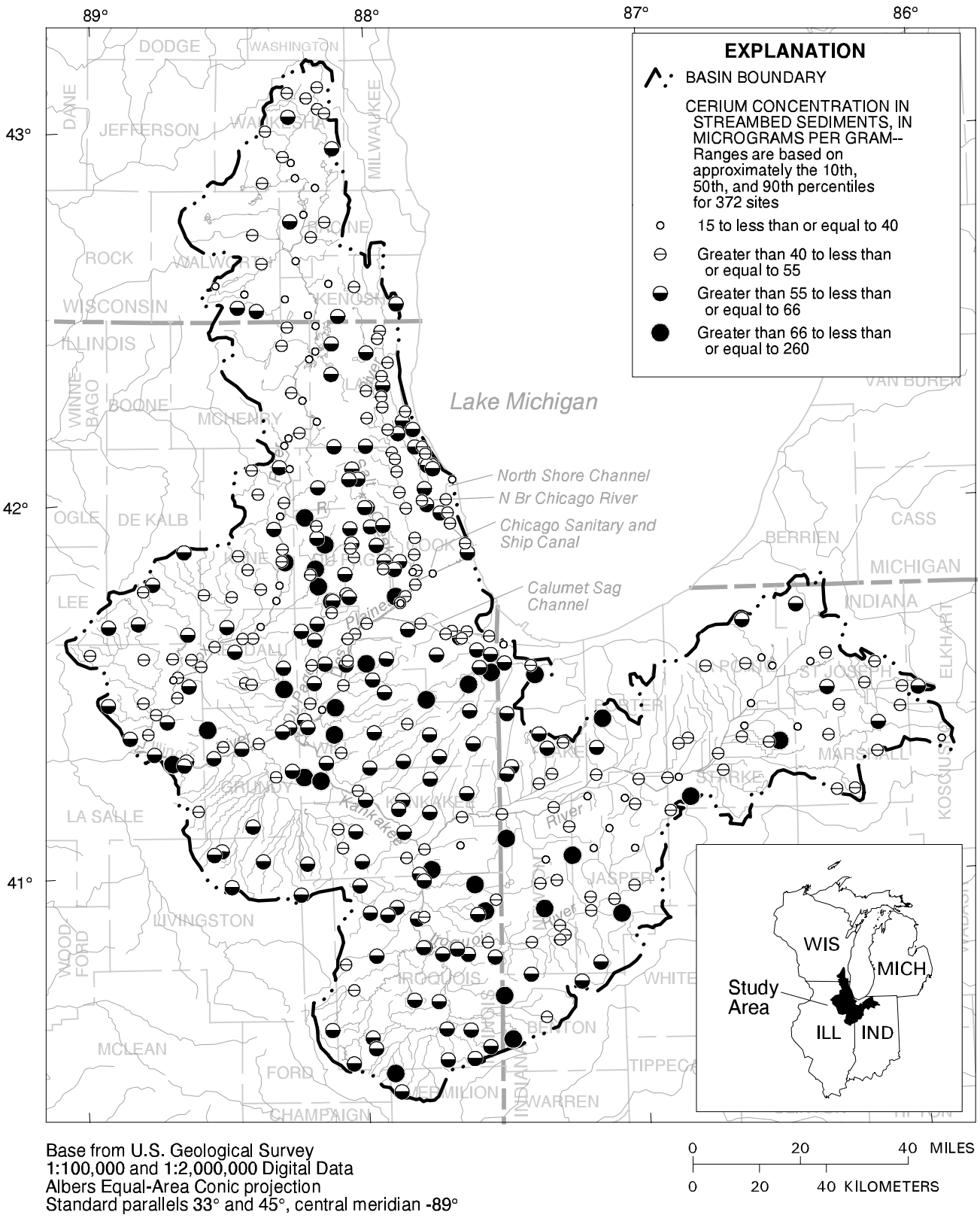


Figure 12. Percentage of carbon (organic) in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 13. Cerium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

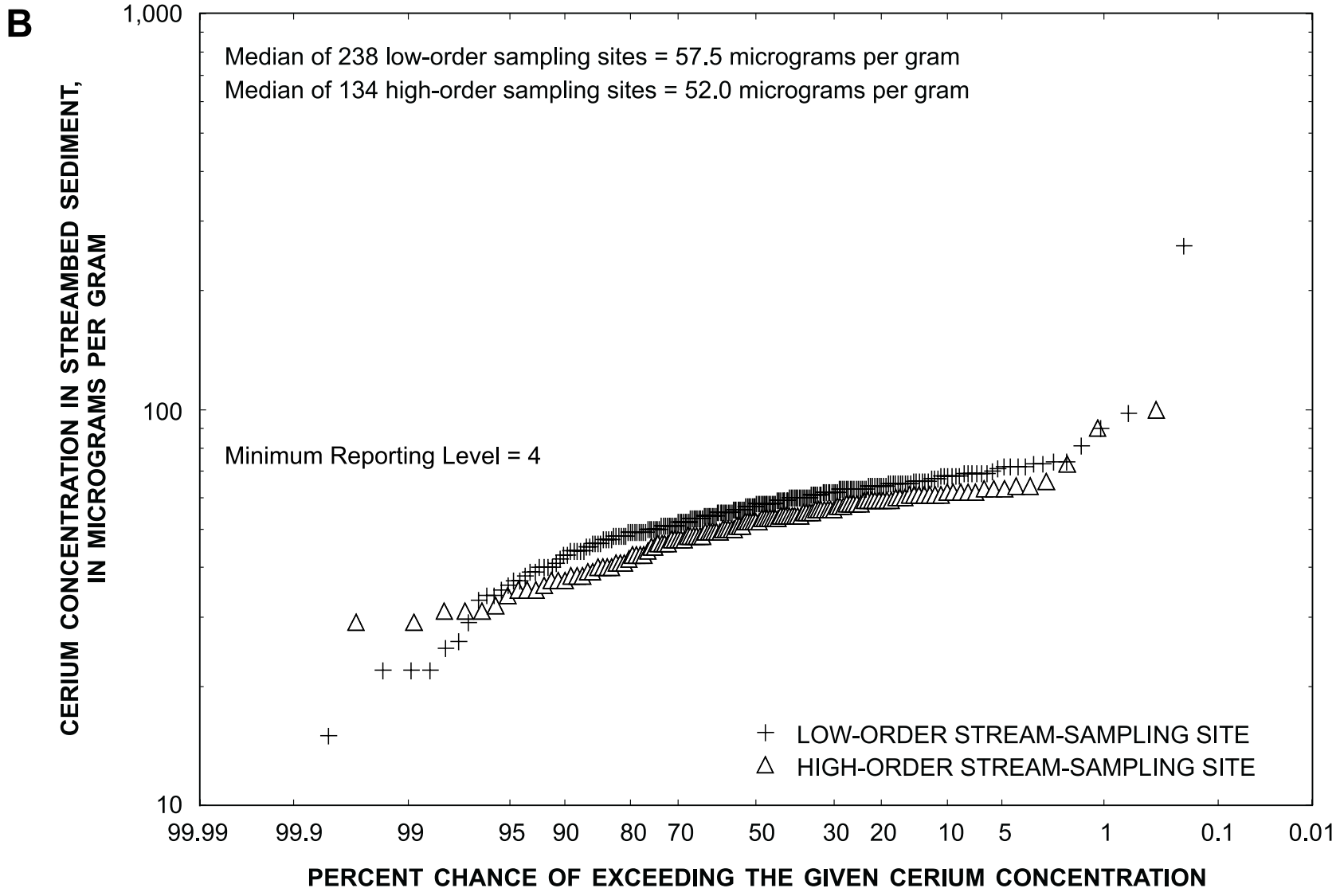


Figure 13. Cerium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

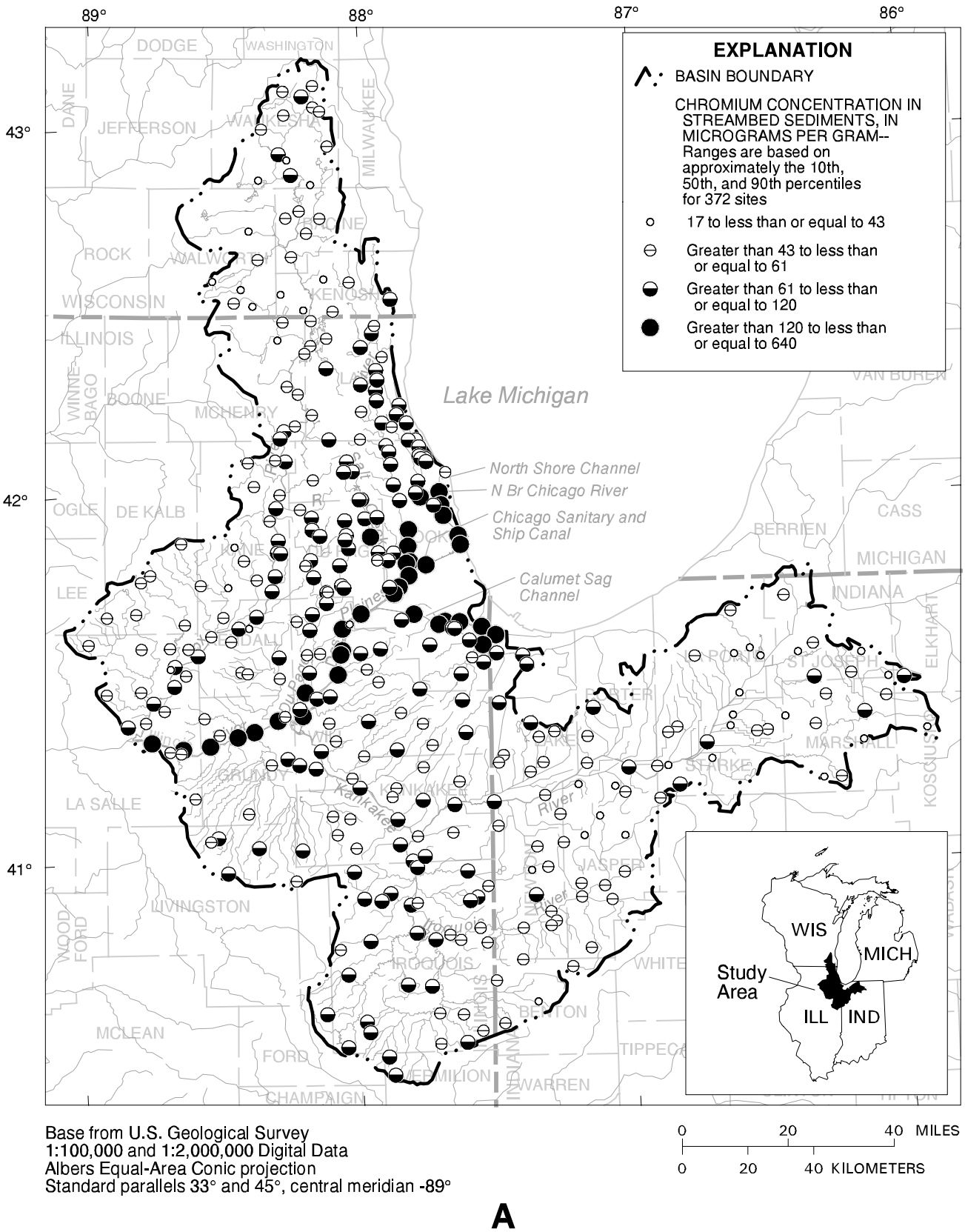


Figure 14. Chromium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

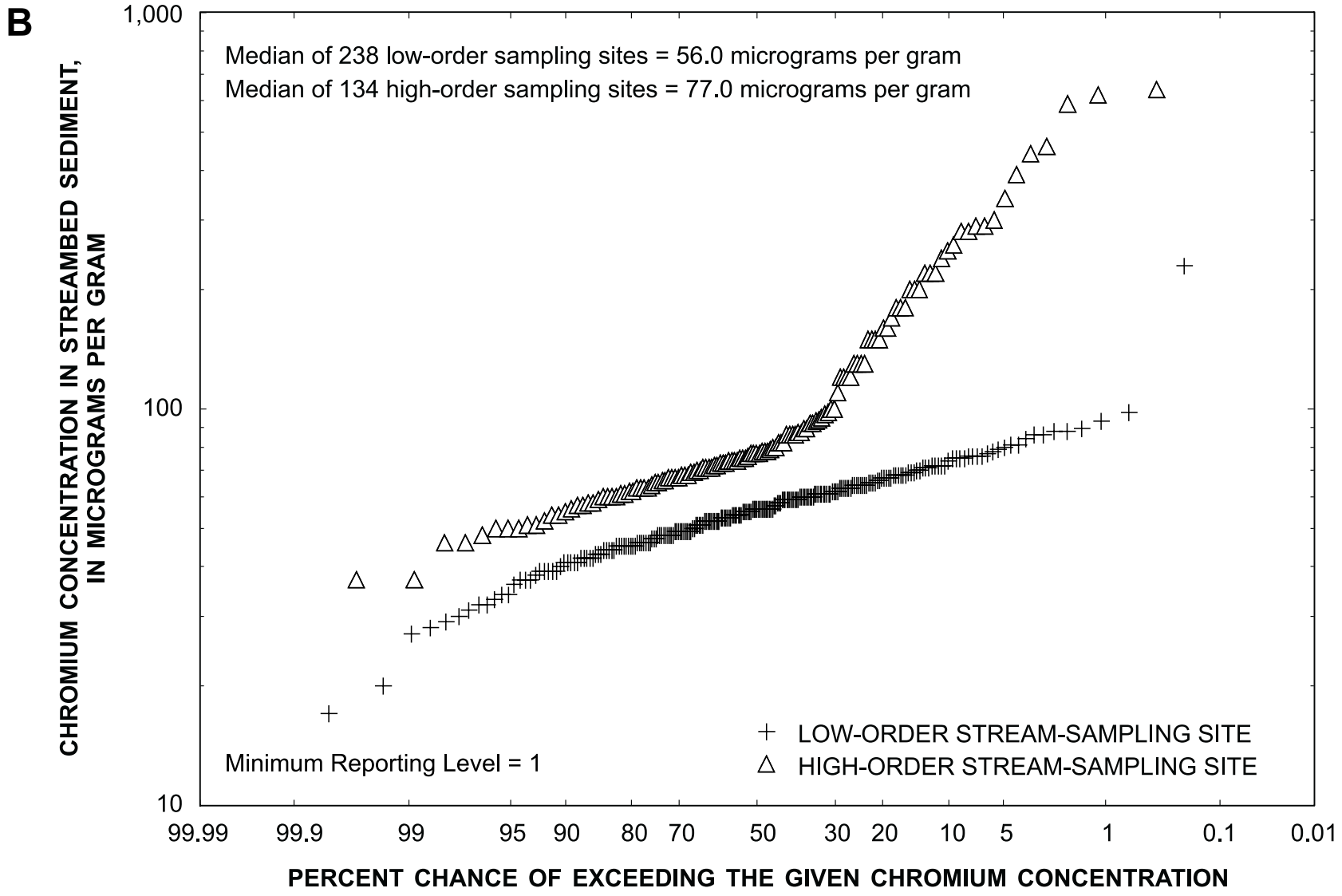


Figure 14. Chromium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

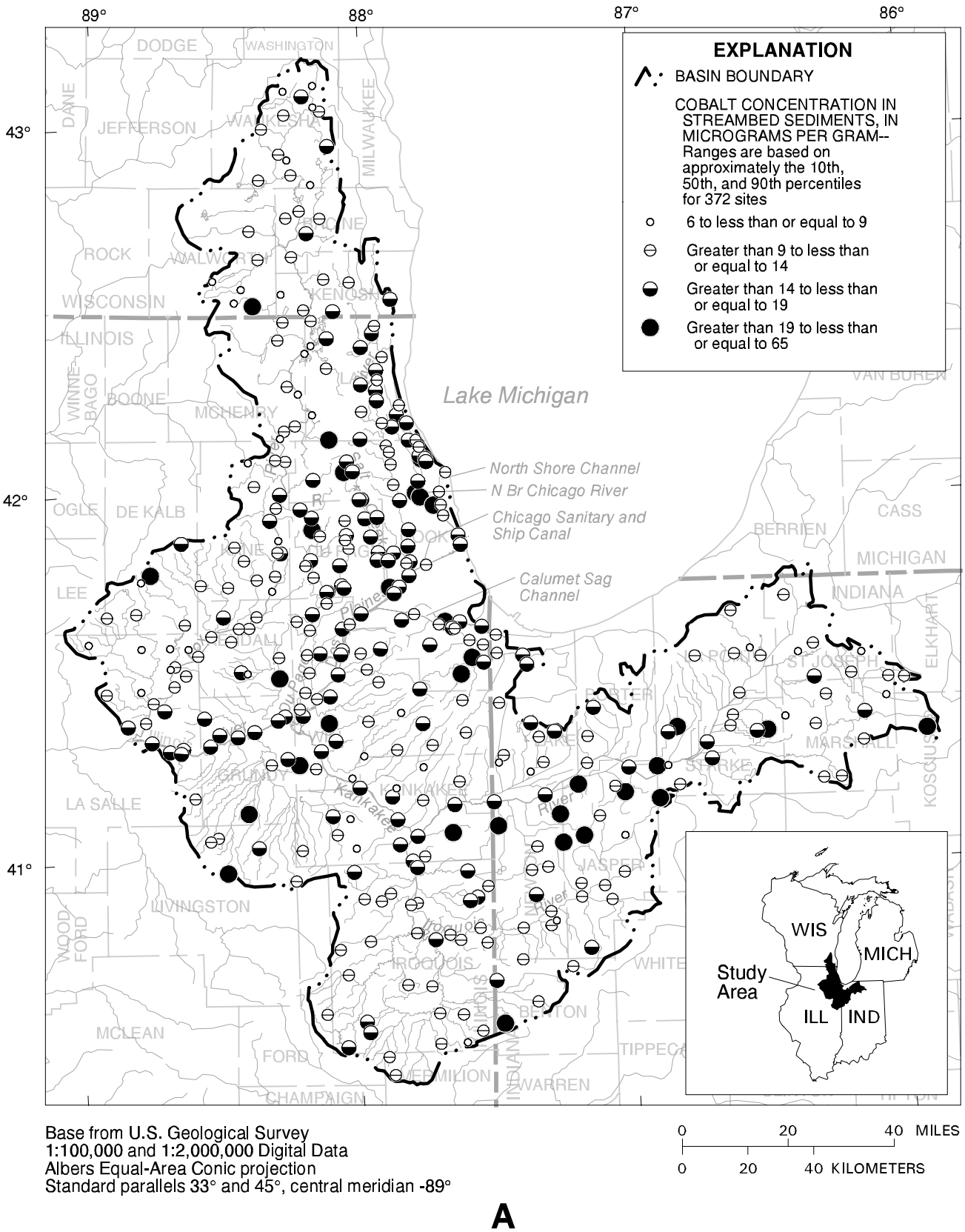


Figure 15. Cobalt concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

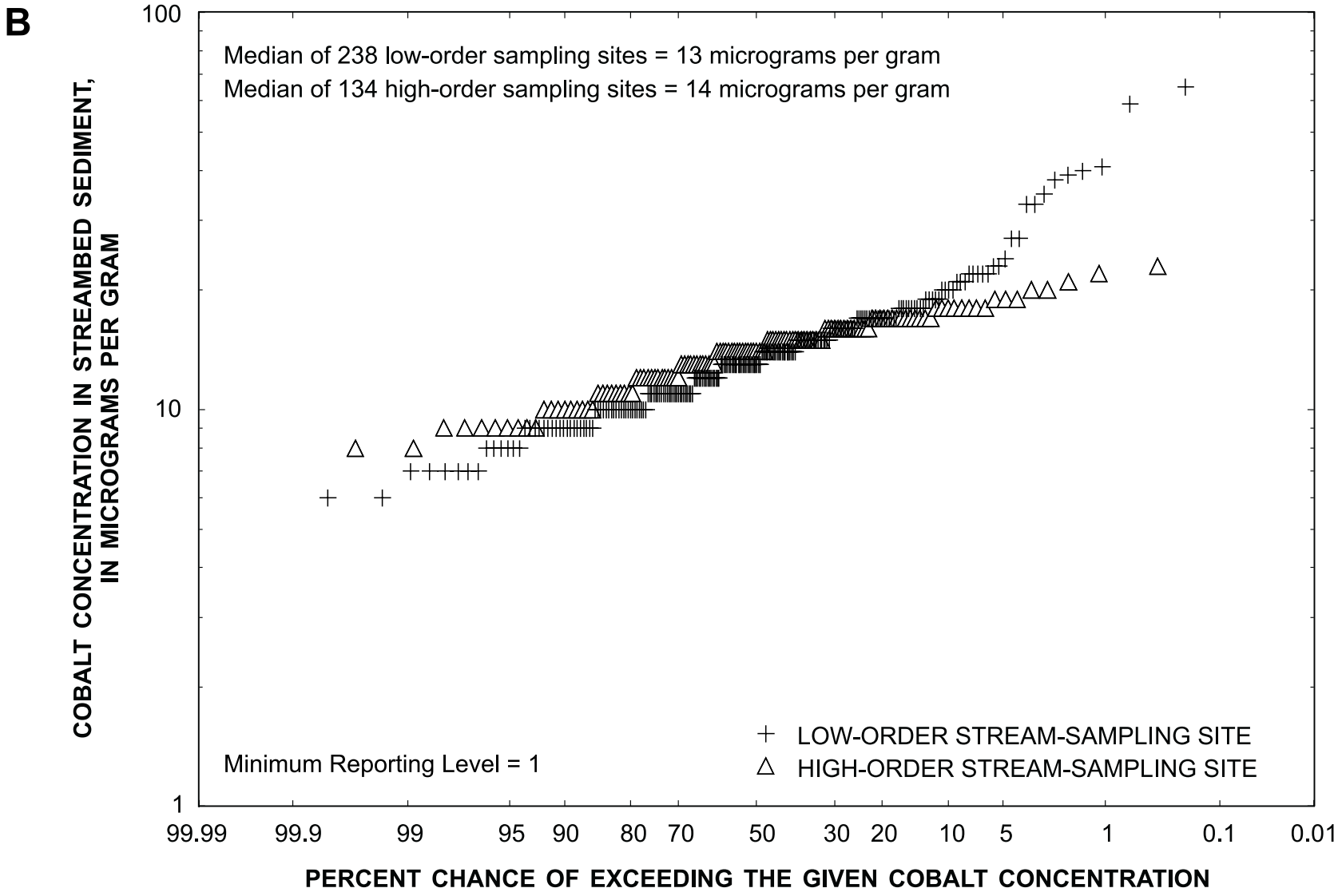
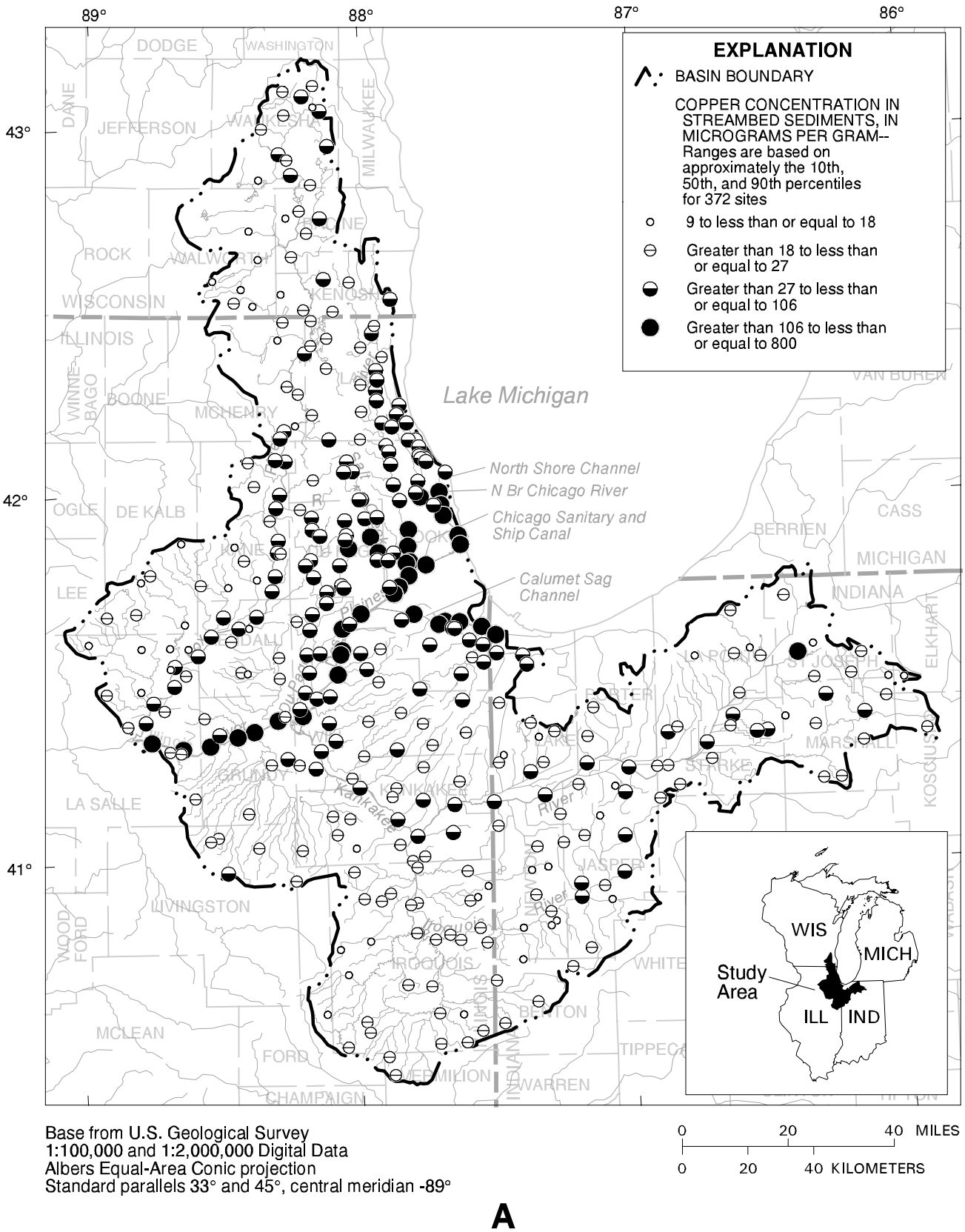


Figure 15. Cobalt concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 16. Copper concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

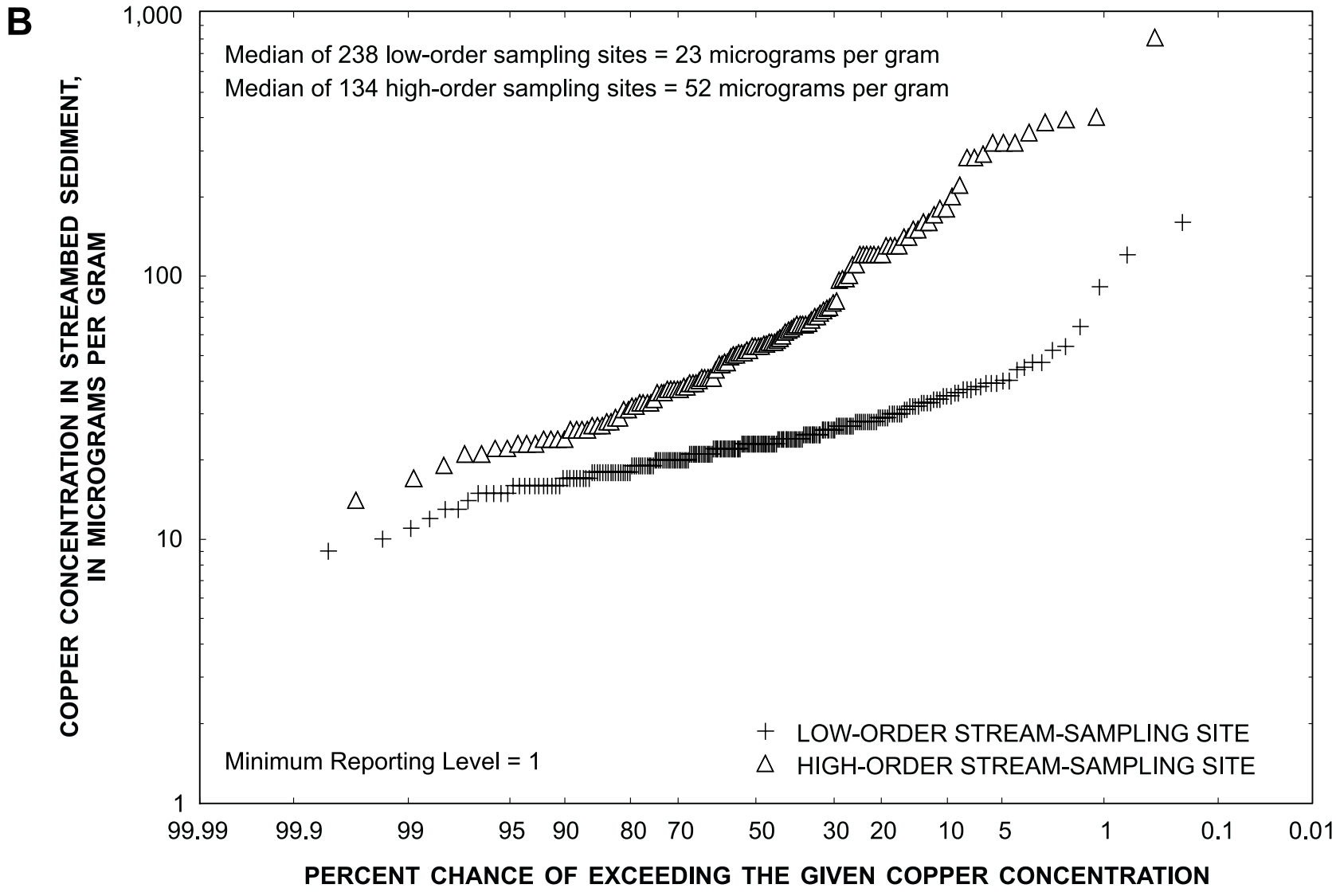
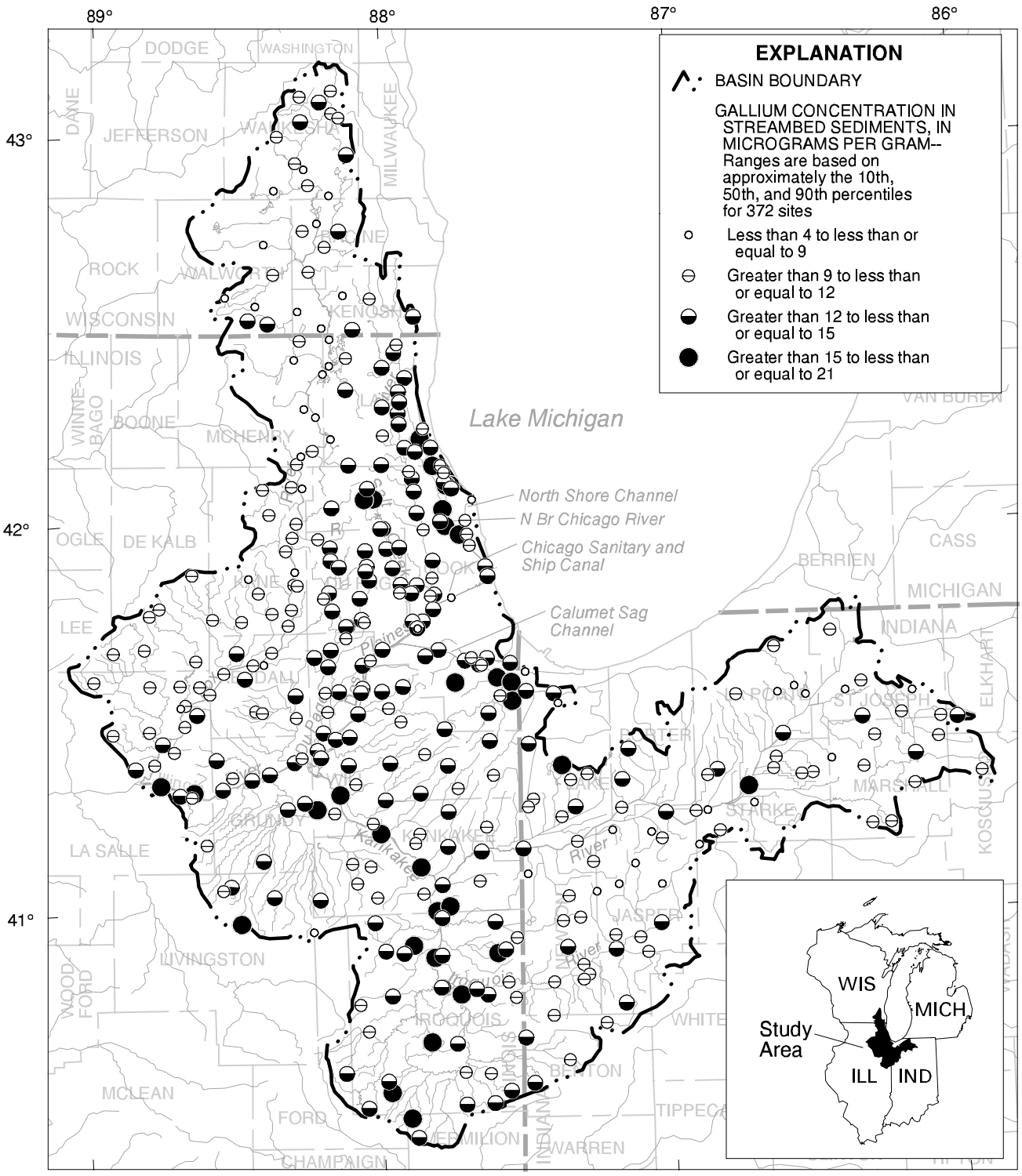


Figure 16. Copper concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 17. Gallium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

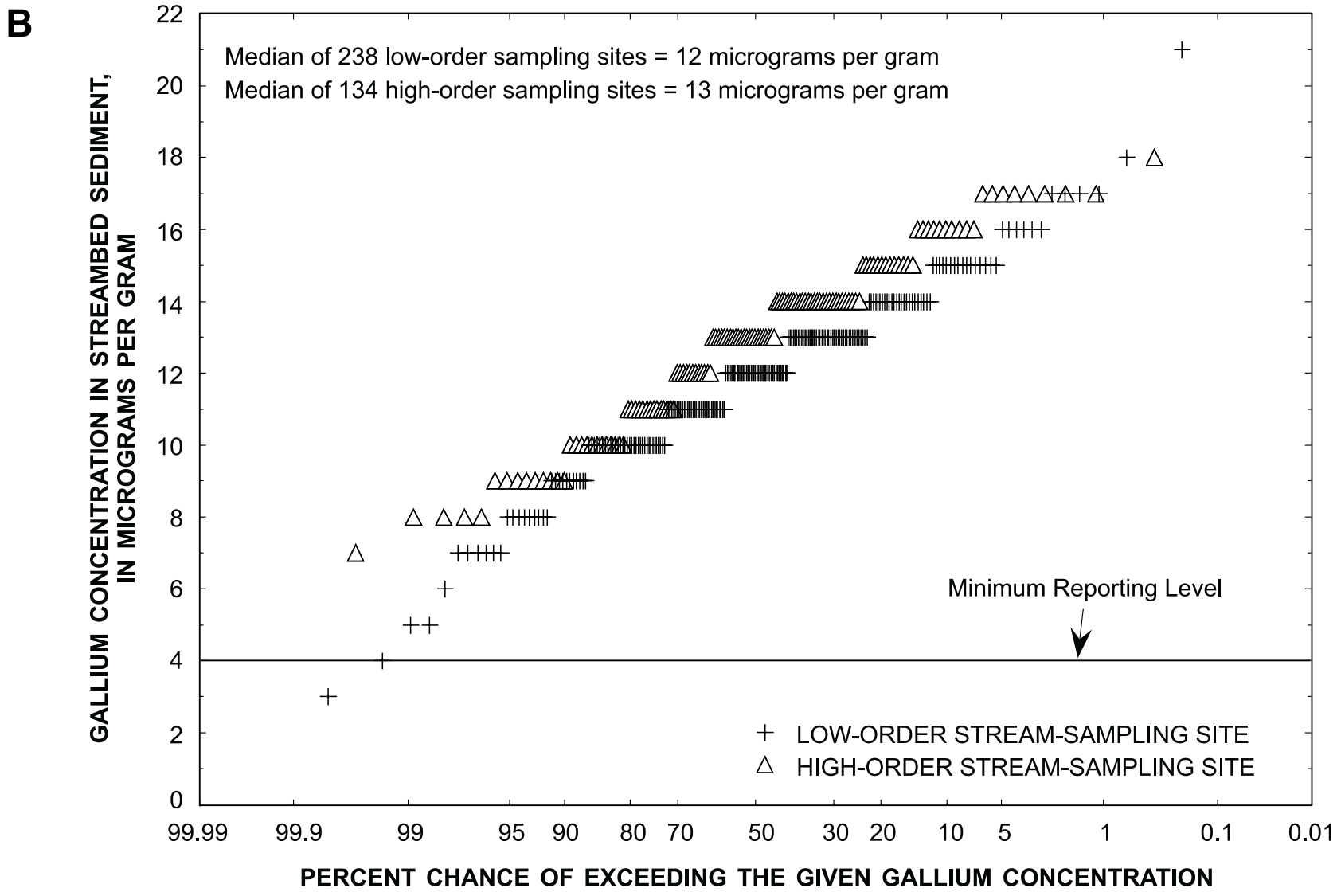


Figure 17. Gallium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

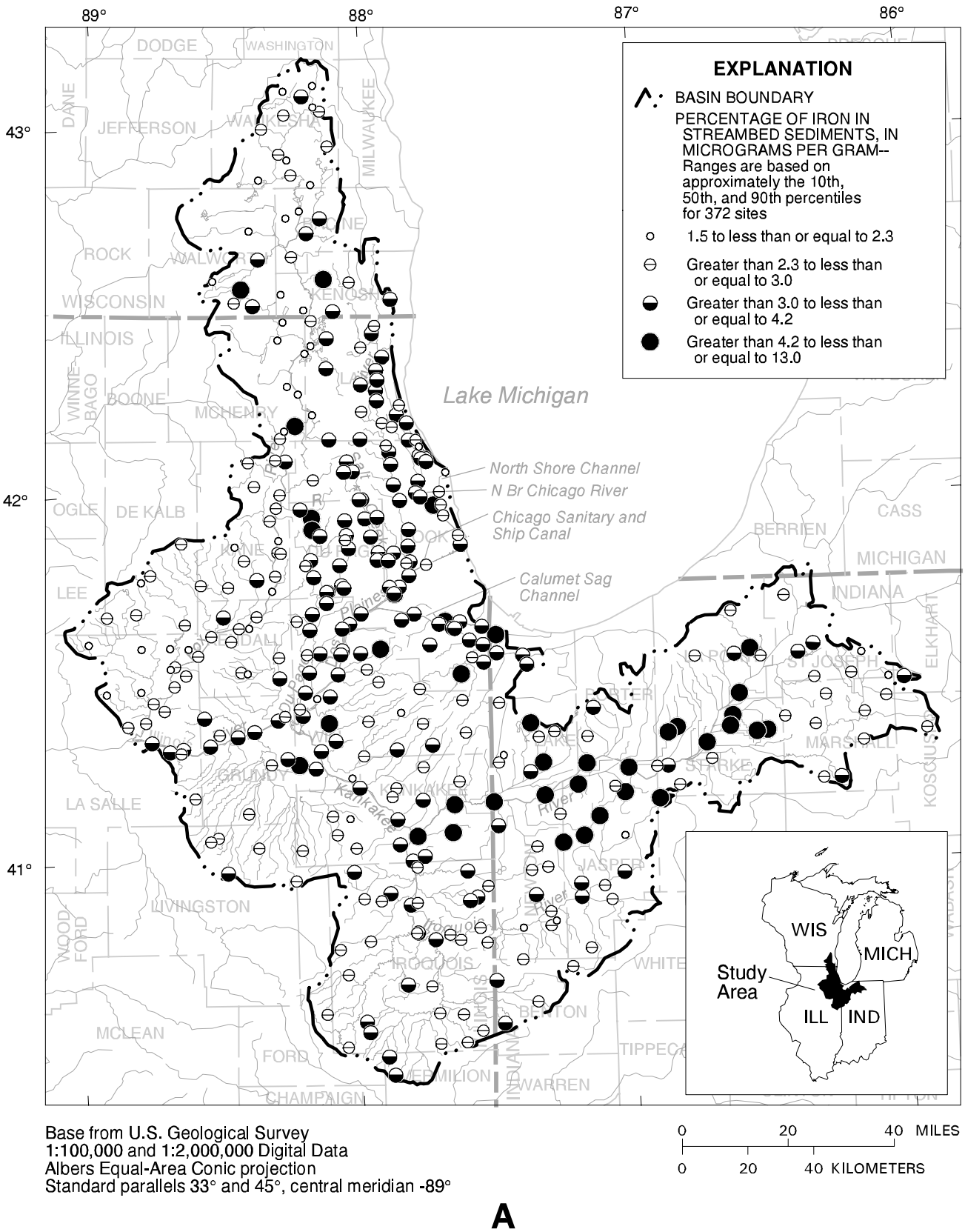


Figure 18. Percentage of iron in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

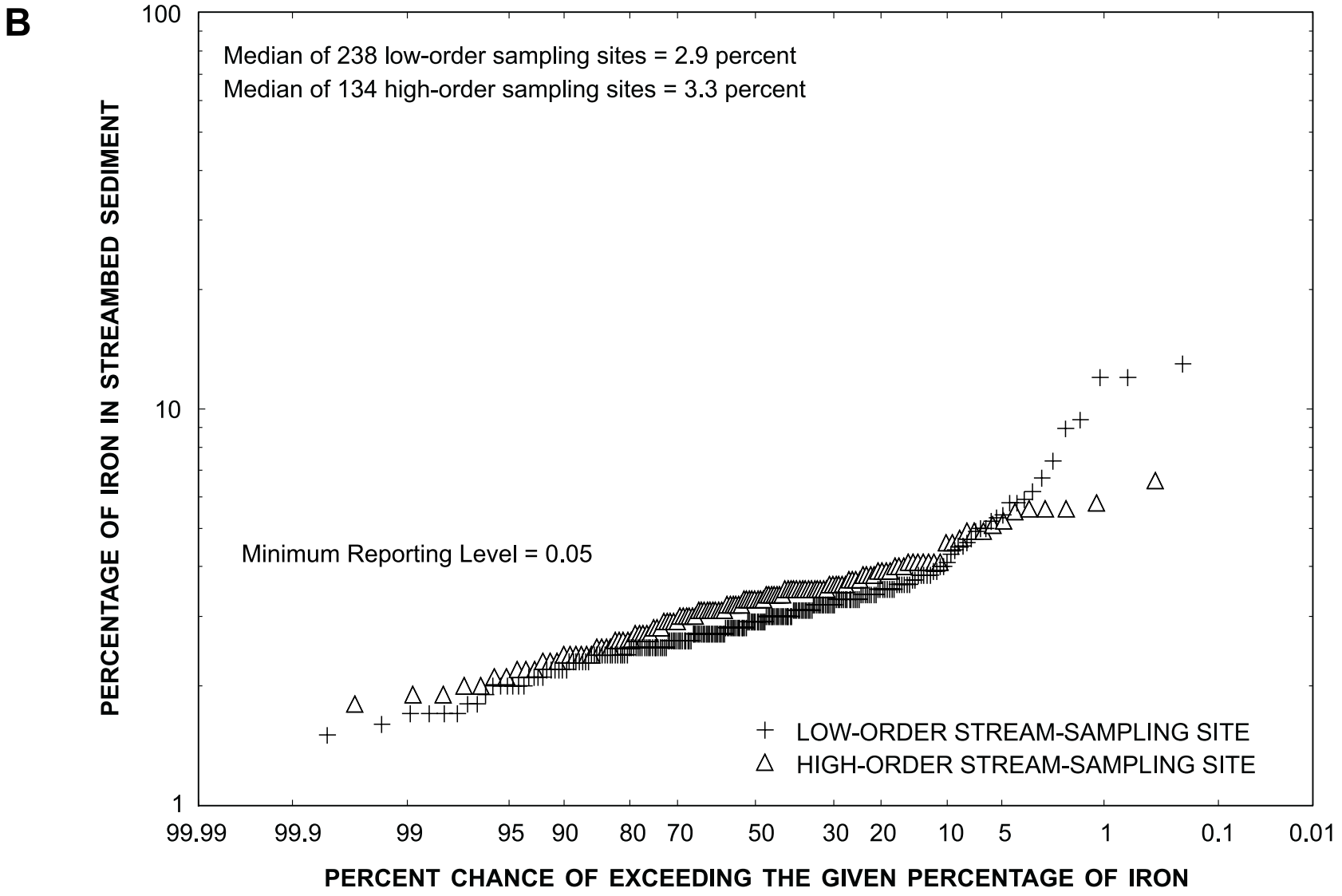
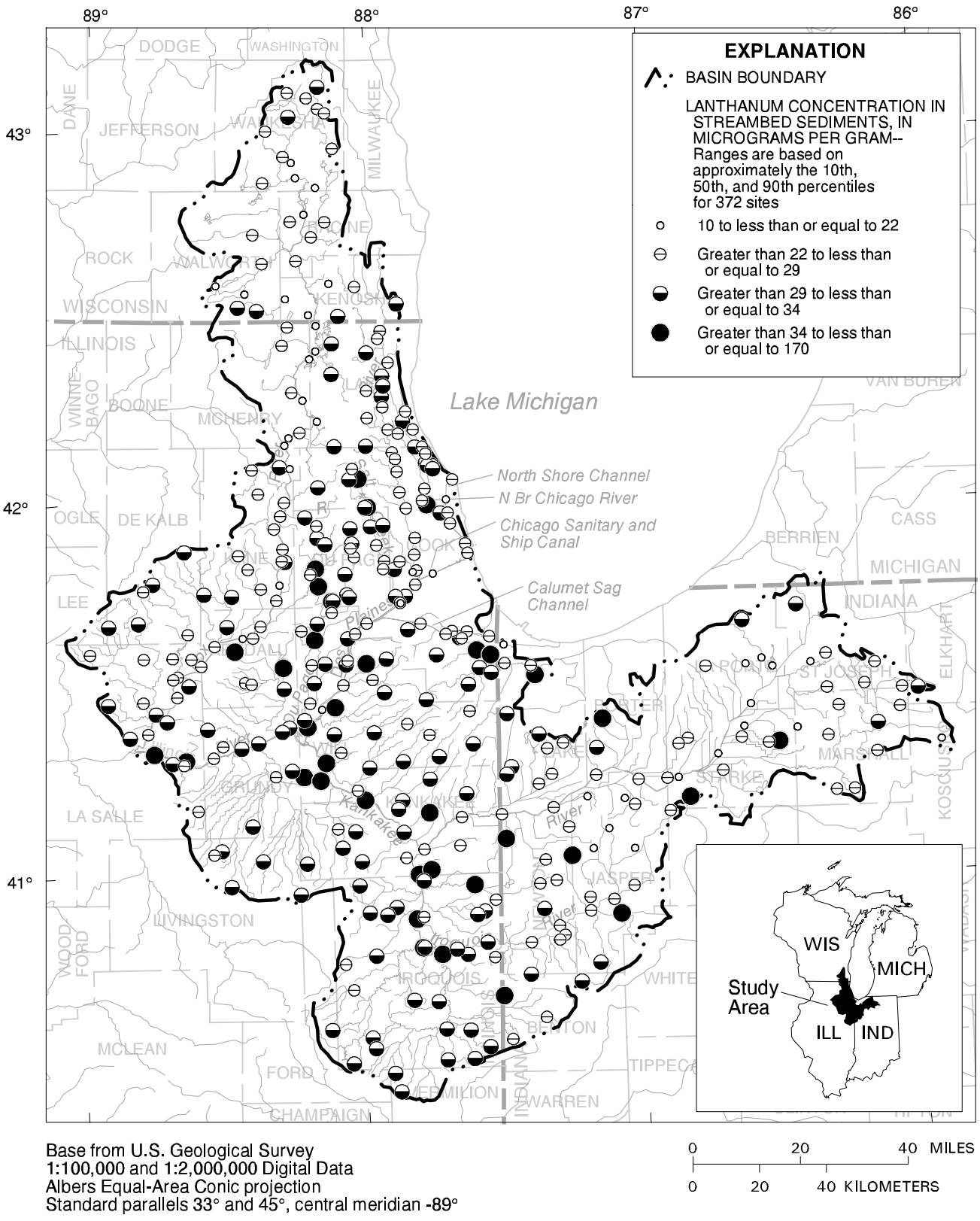


Figure 18. Percentage of iron in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 19. Lanthanum concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

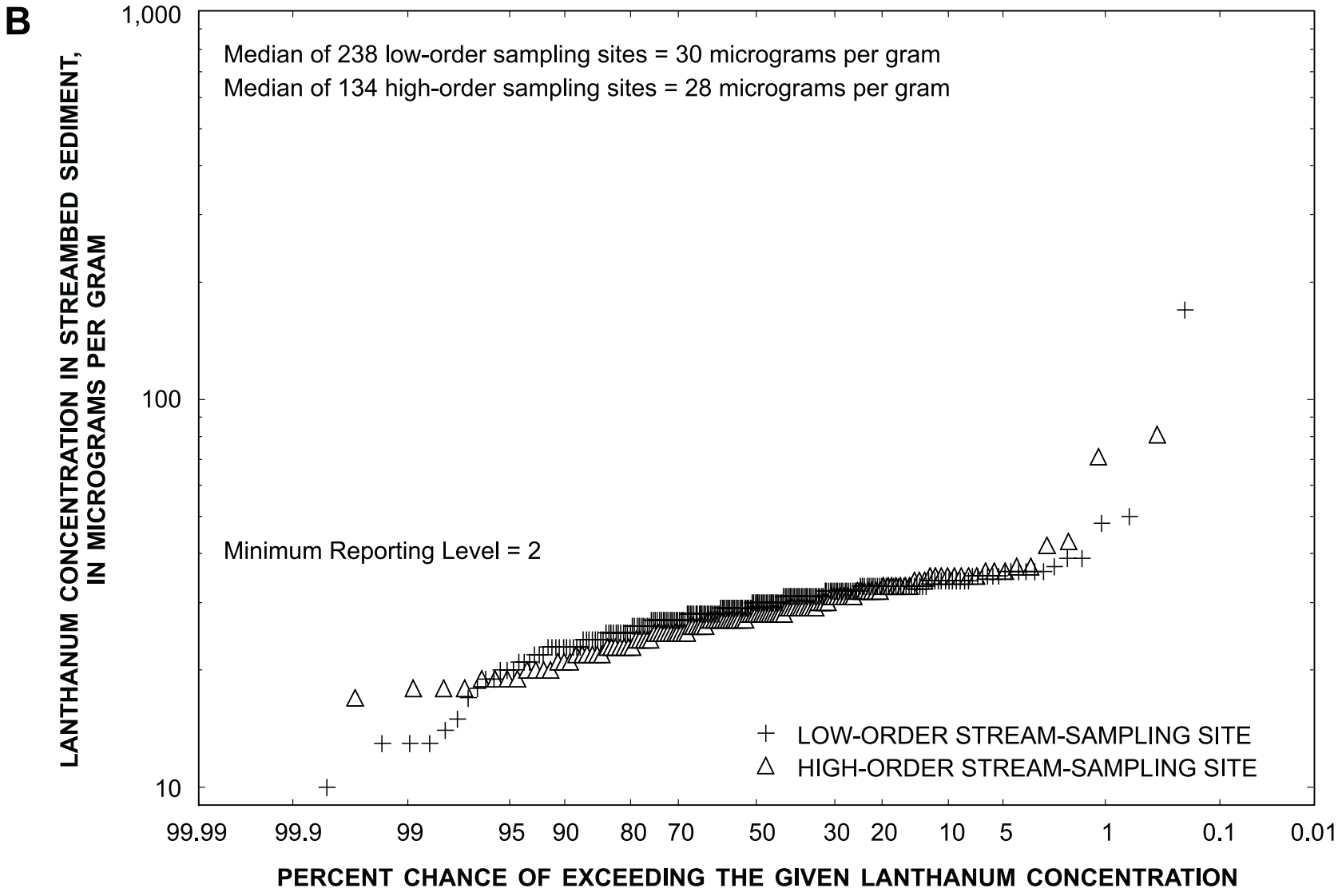
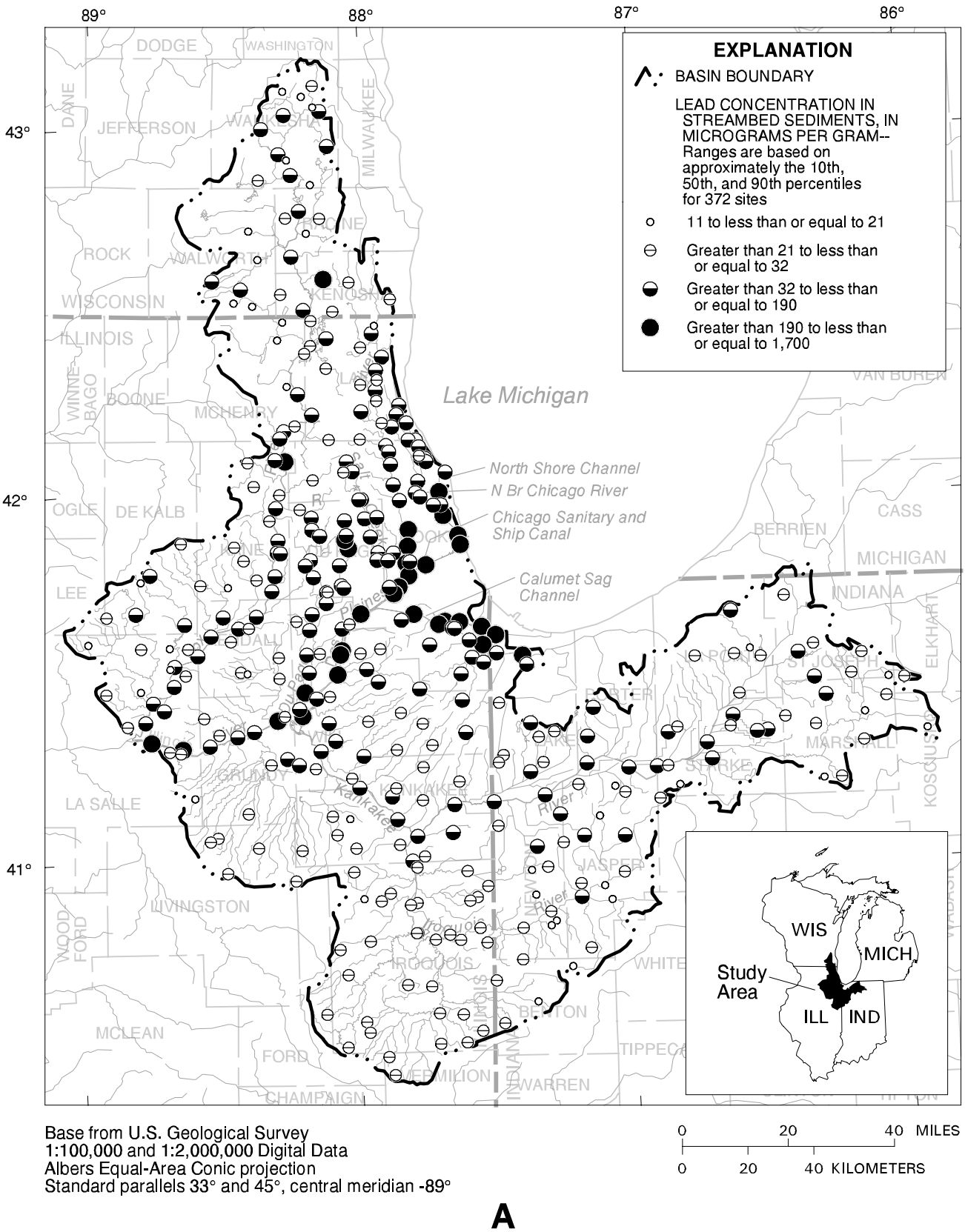


Figure 19. Lanthanum concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 20. Lead concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

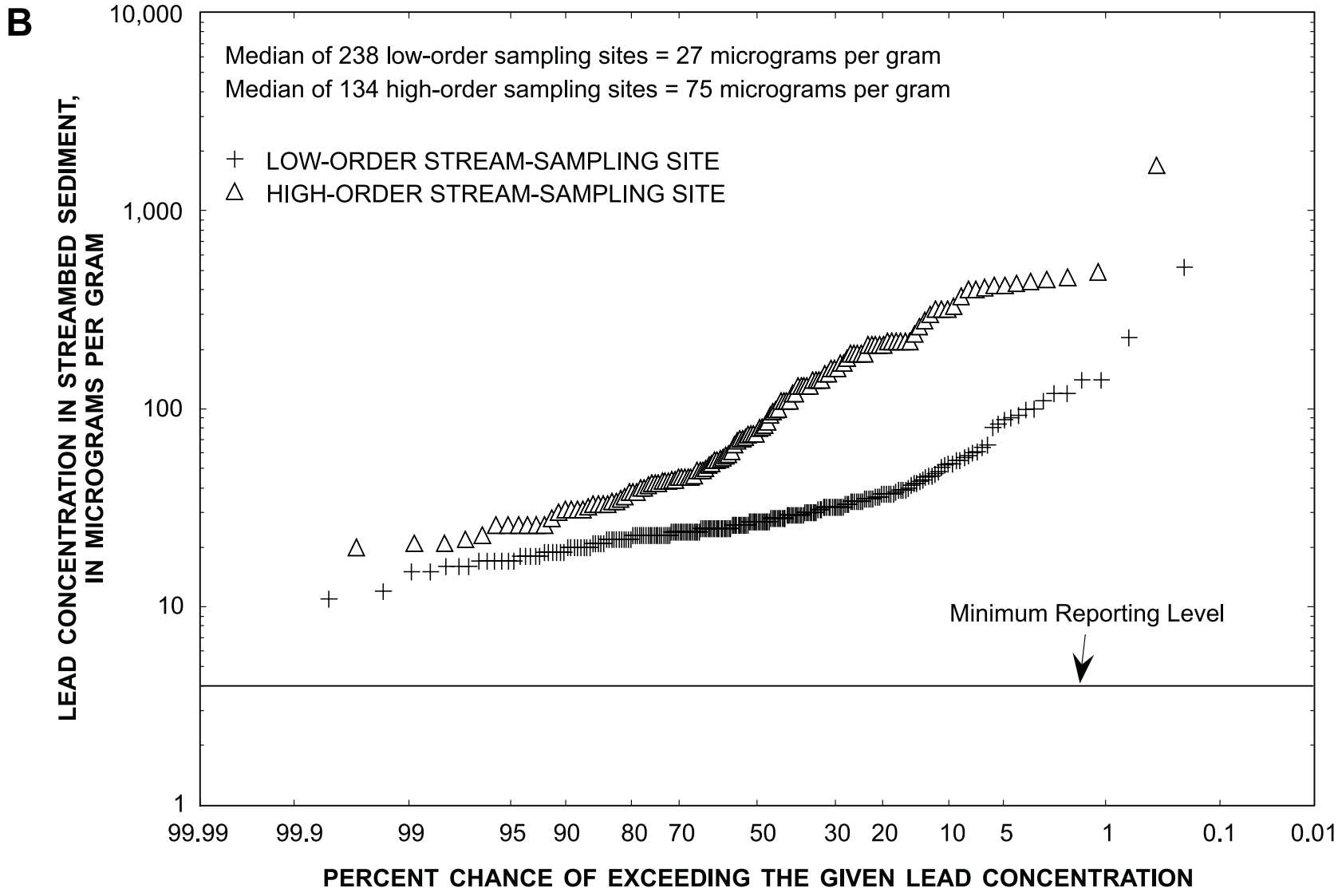
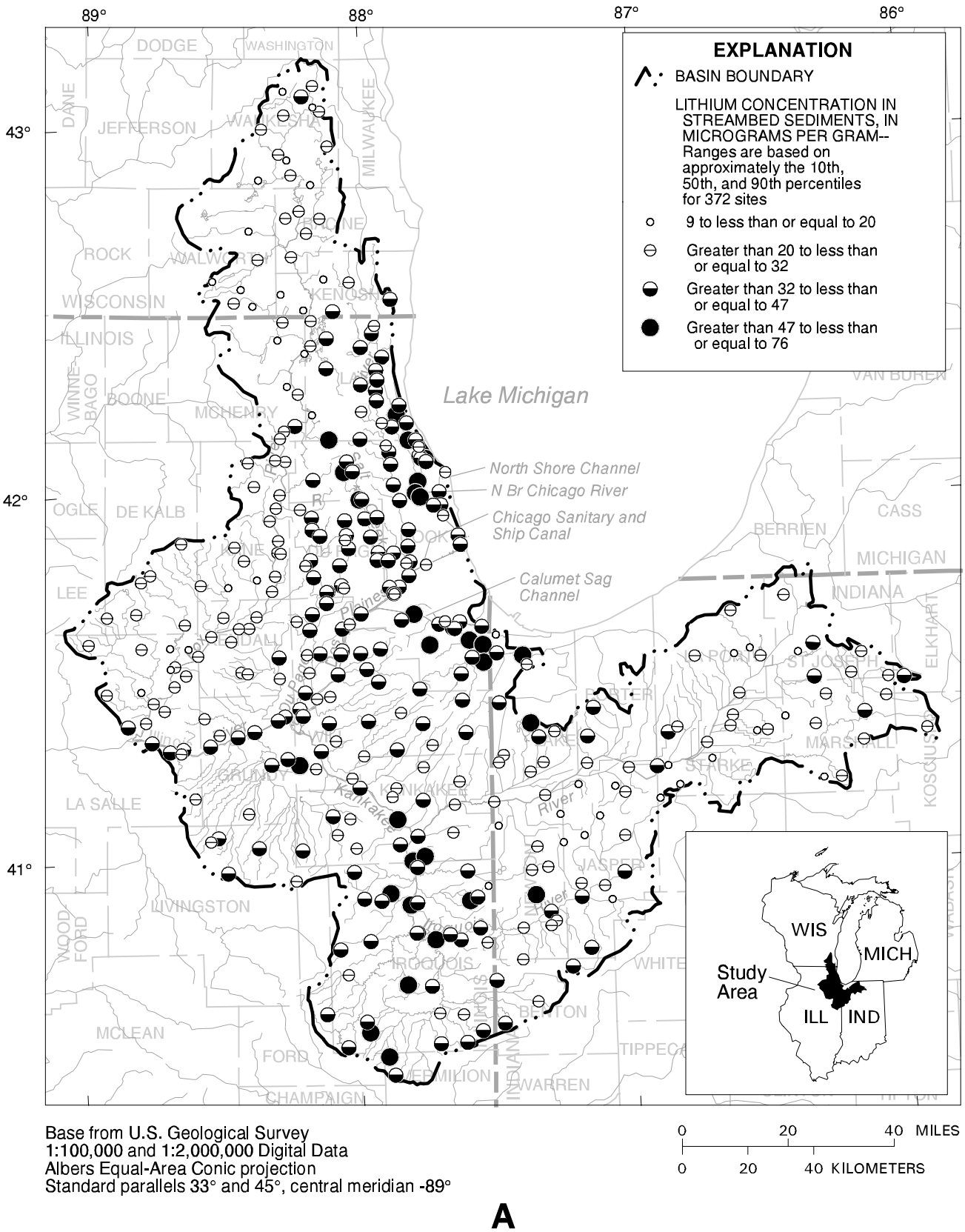


Figure 20. Lead concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 21. Lithium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

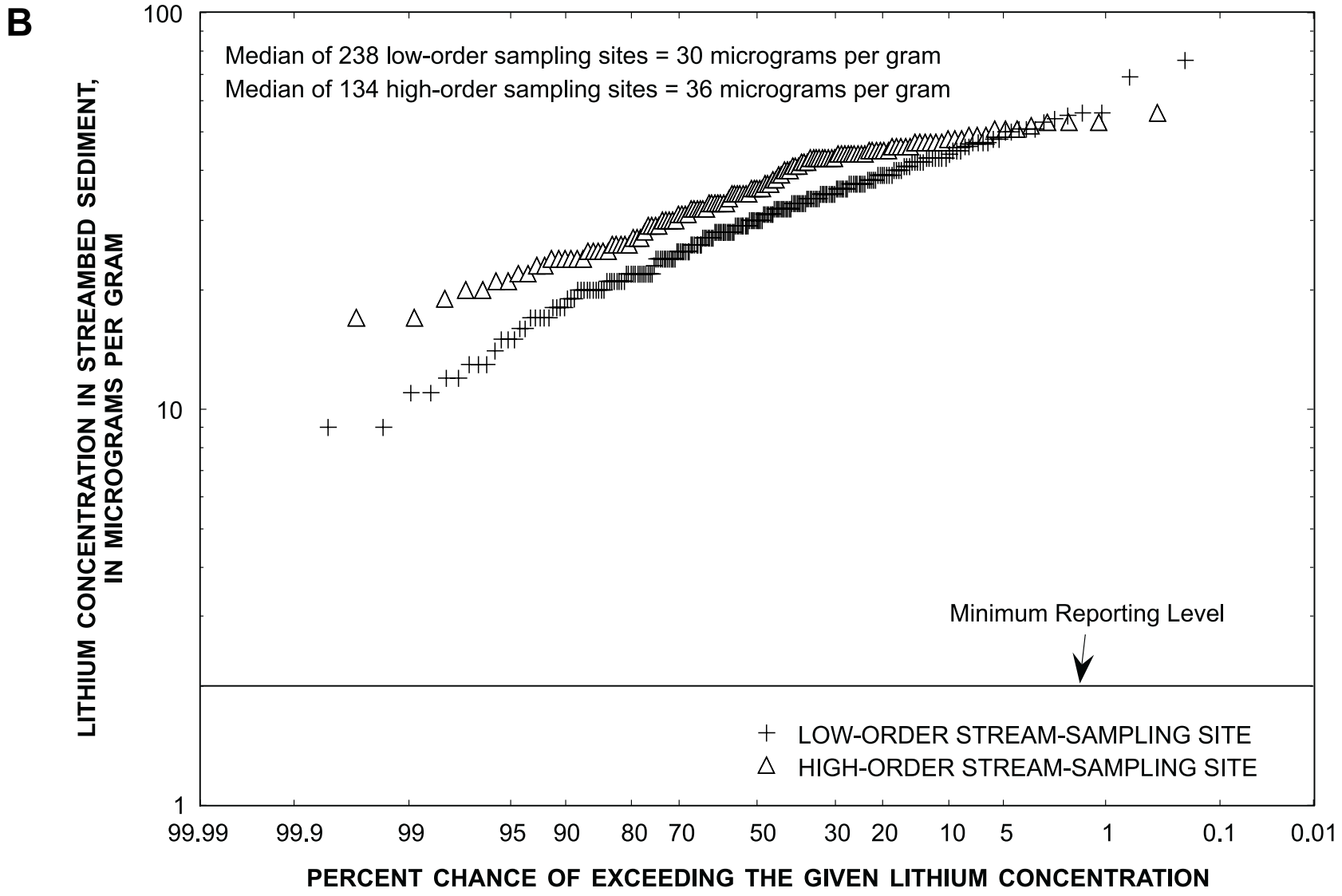


Figure 21. Lithium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

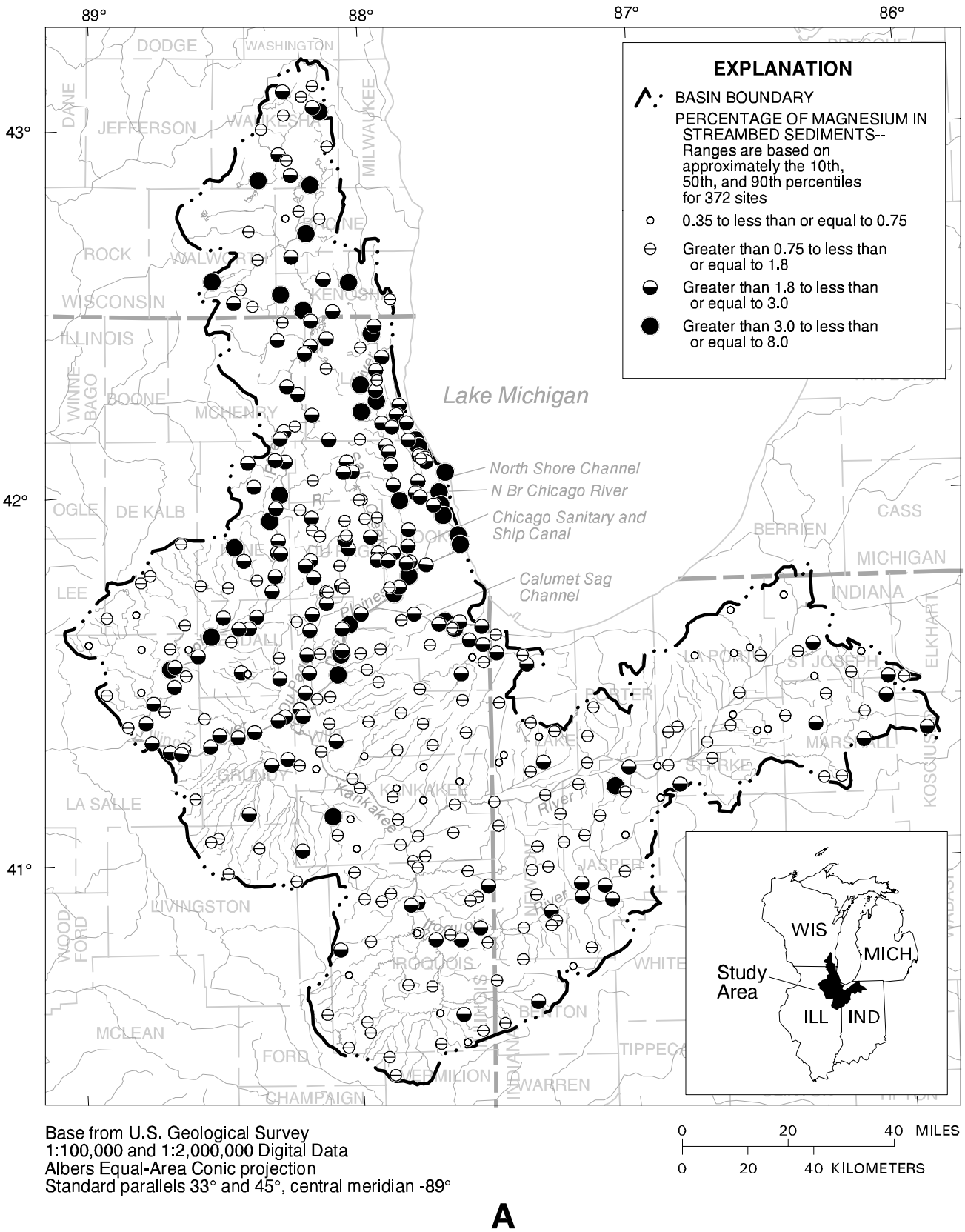


Figure 22. Percentage of magnesium in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

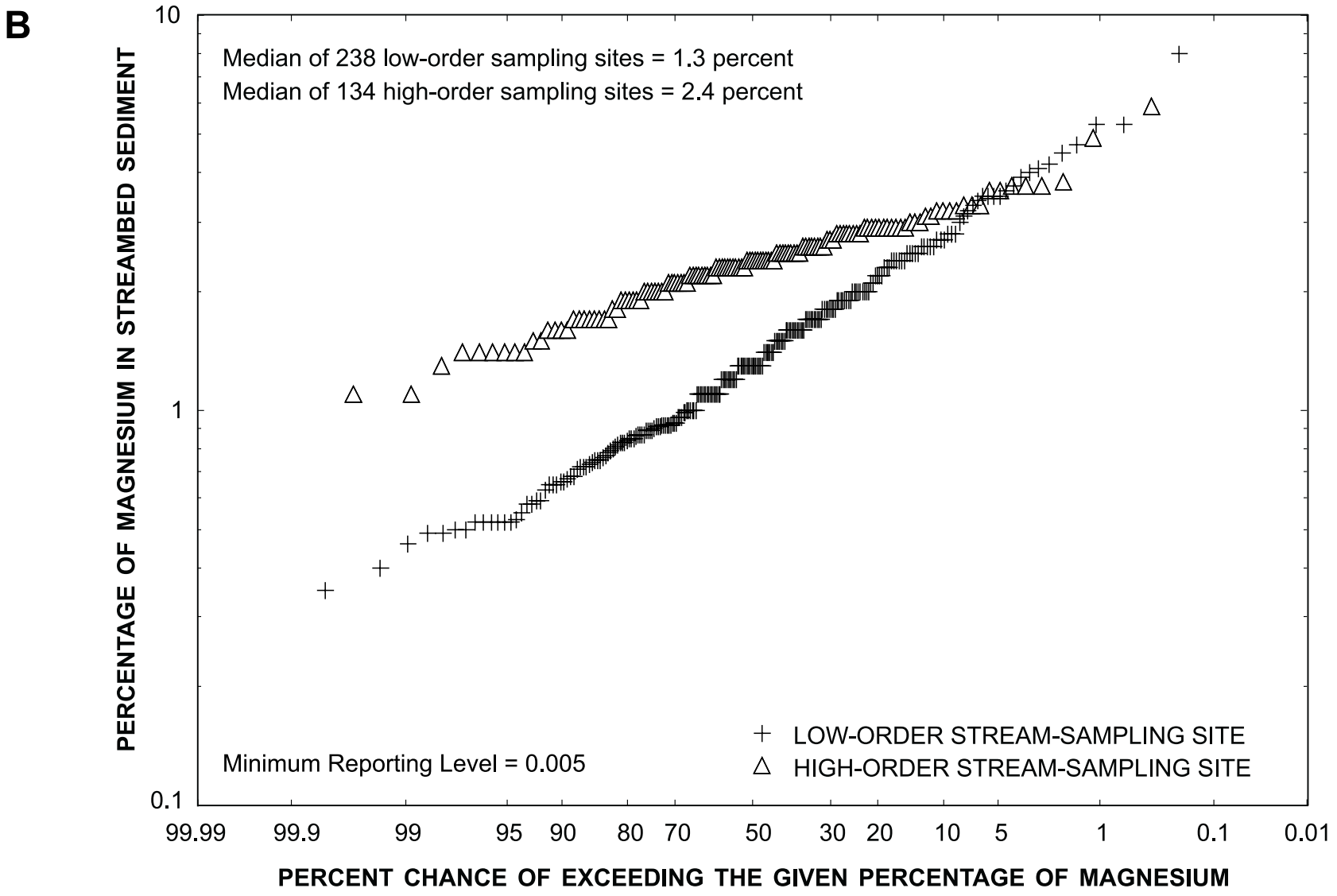
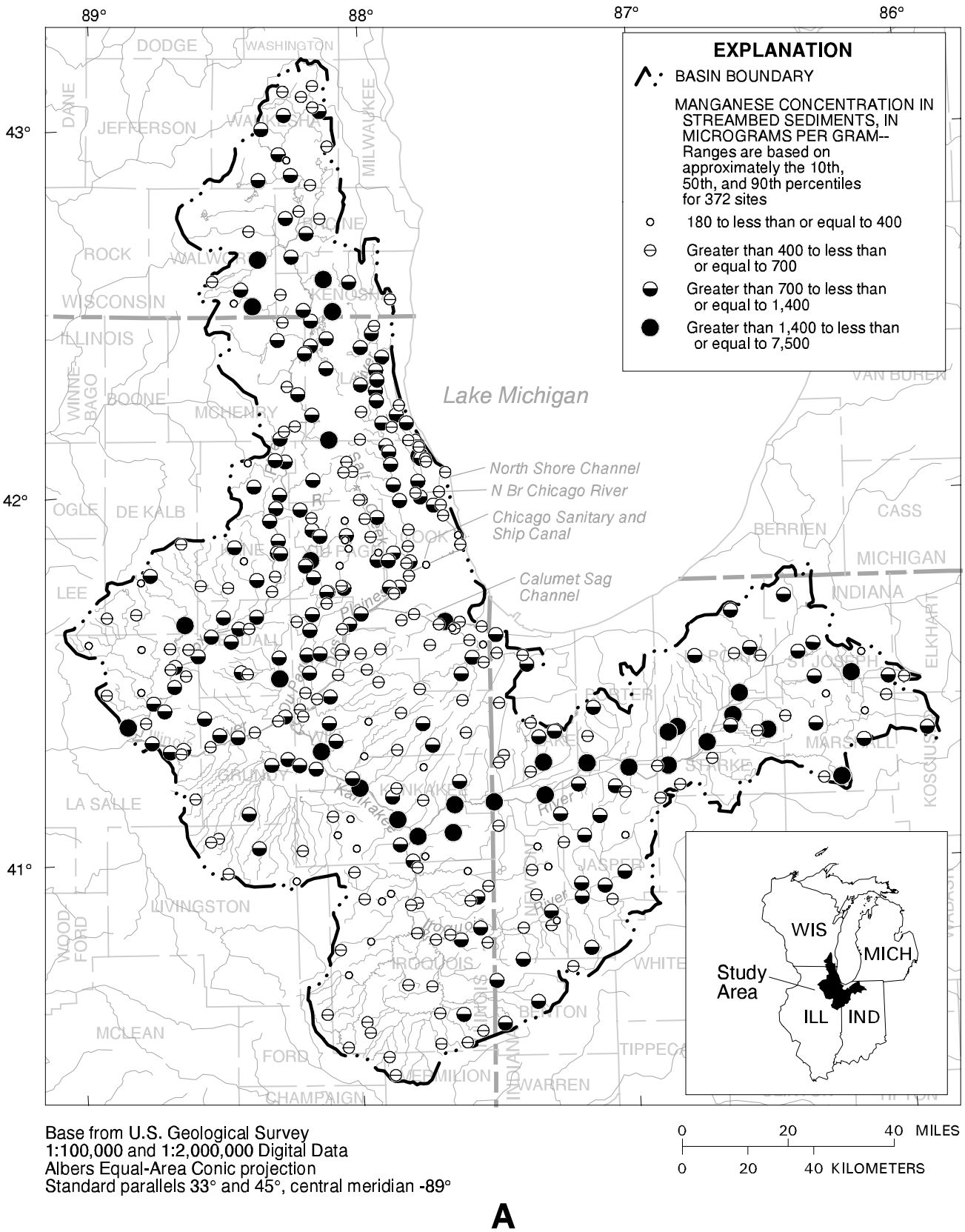


Figure 22. Percentage of magnesium in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 23. Manganese concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

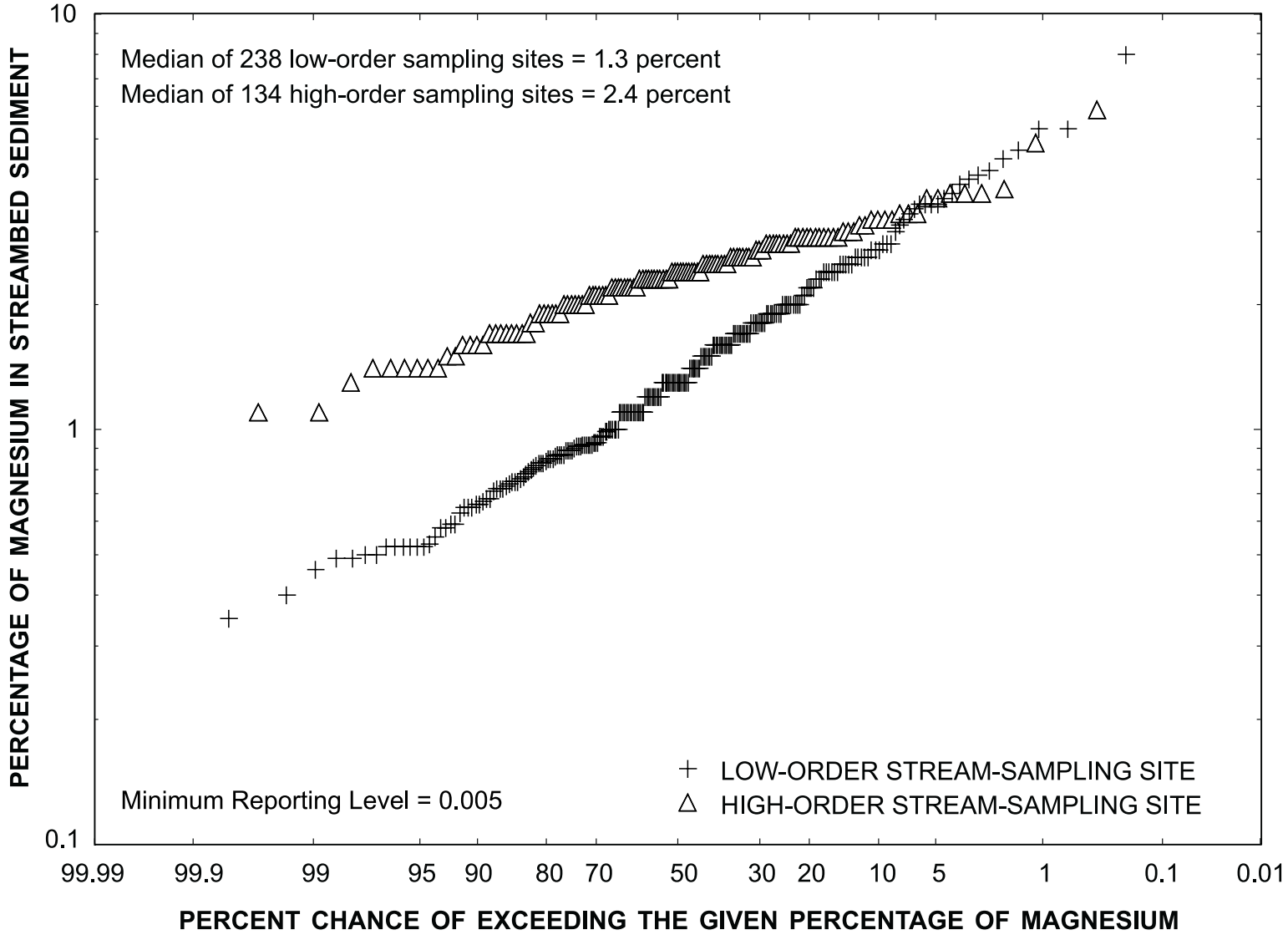


Figure 23. Manganese concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

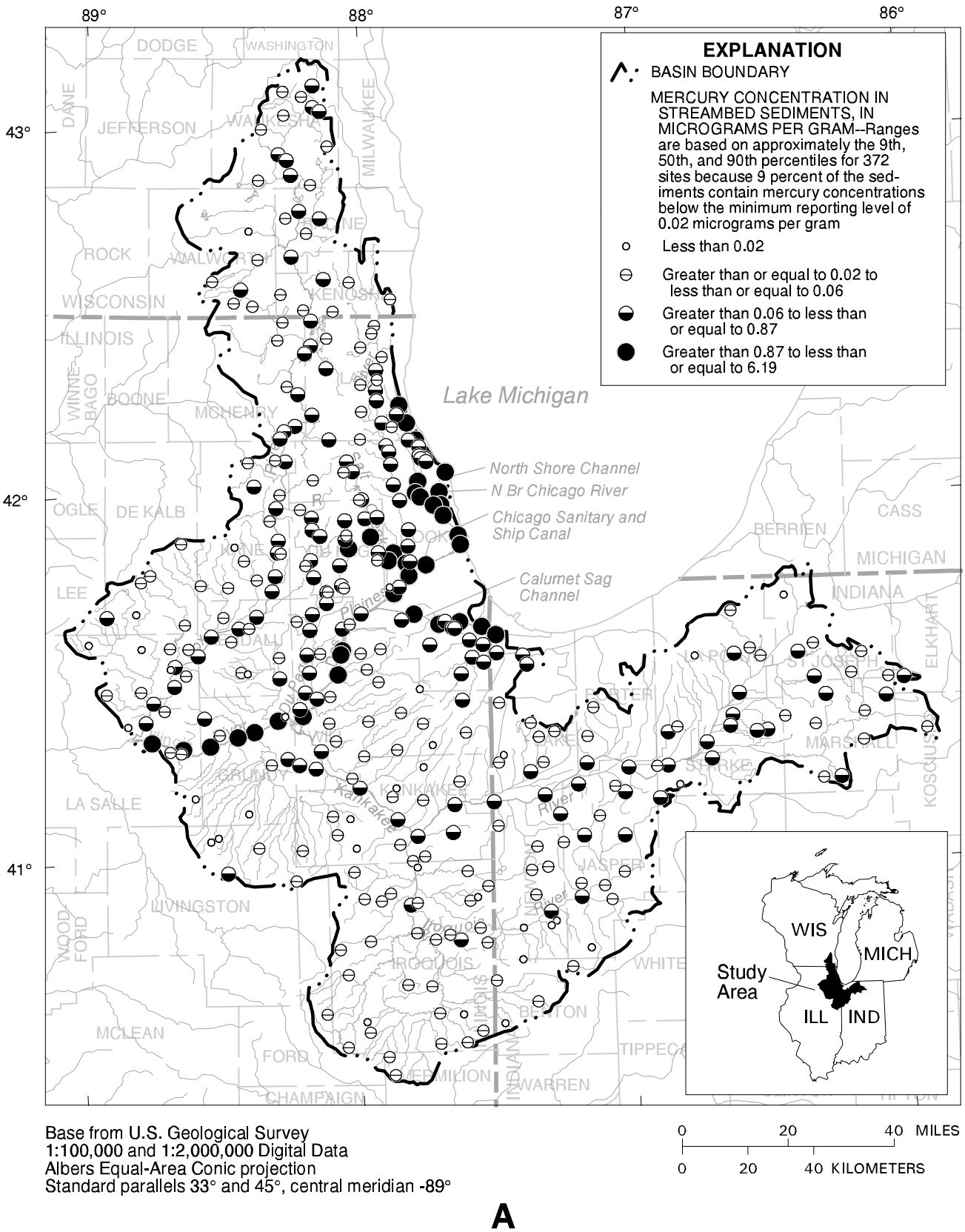


Figure 24. Mercury concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

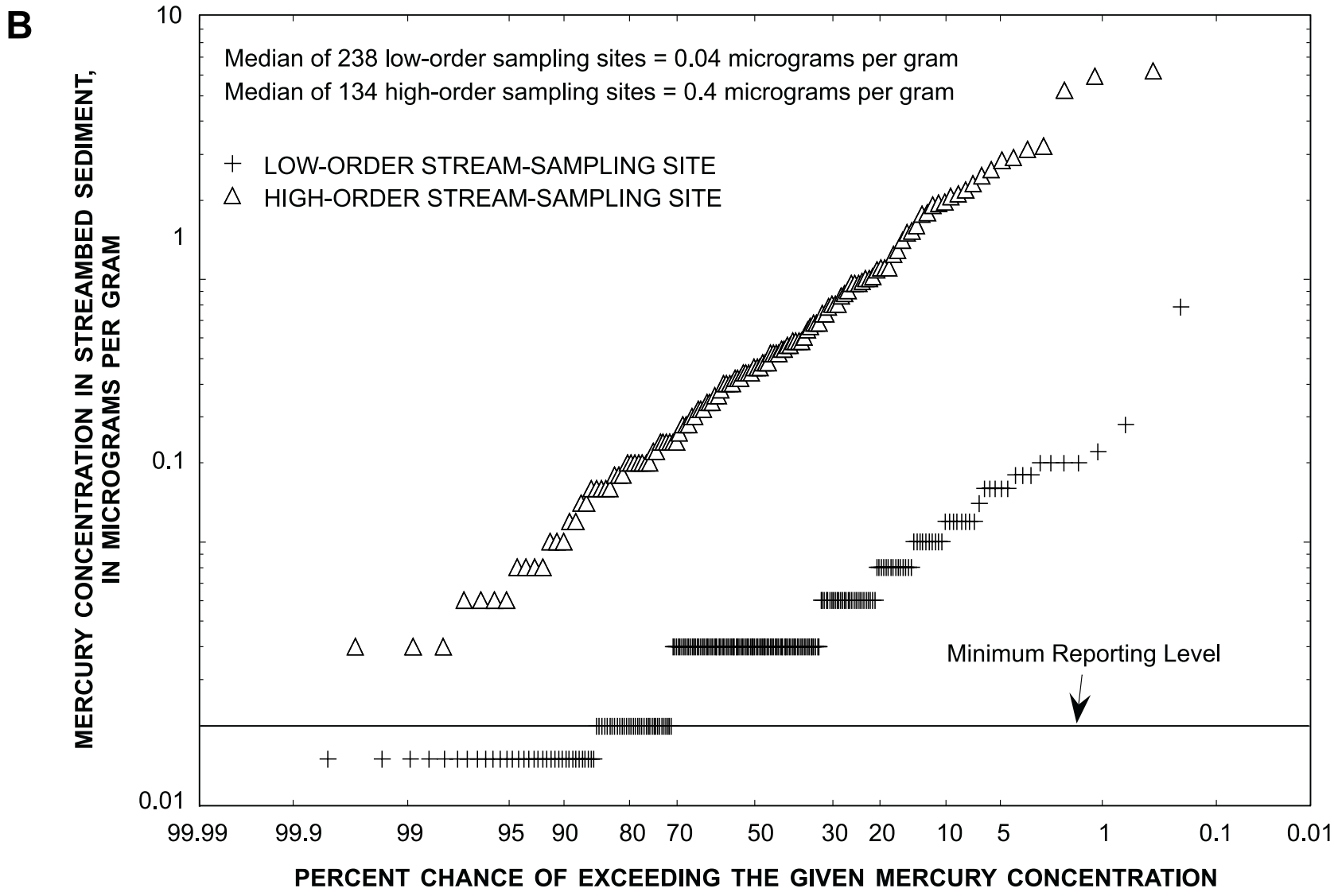
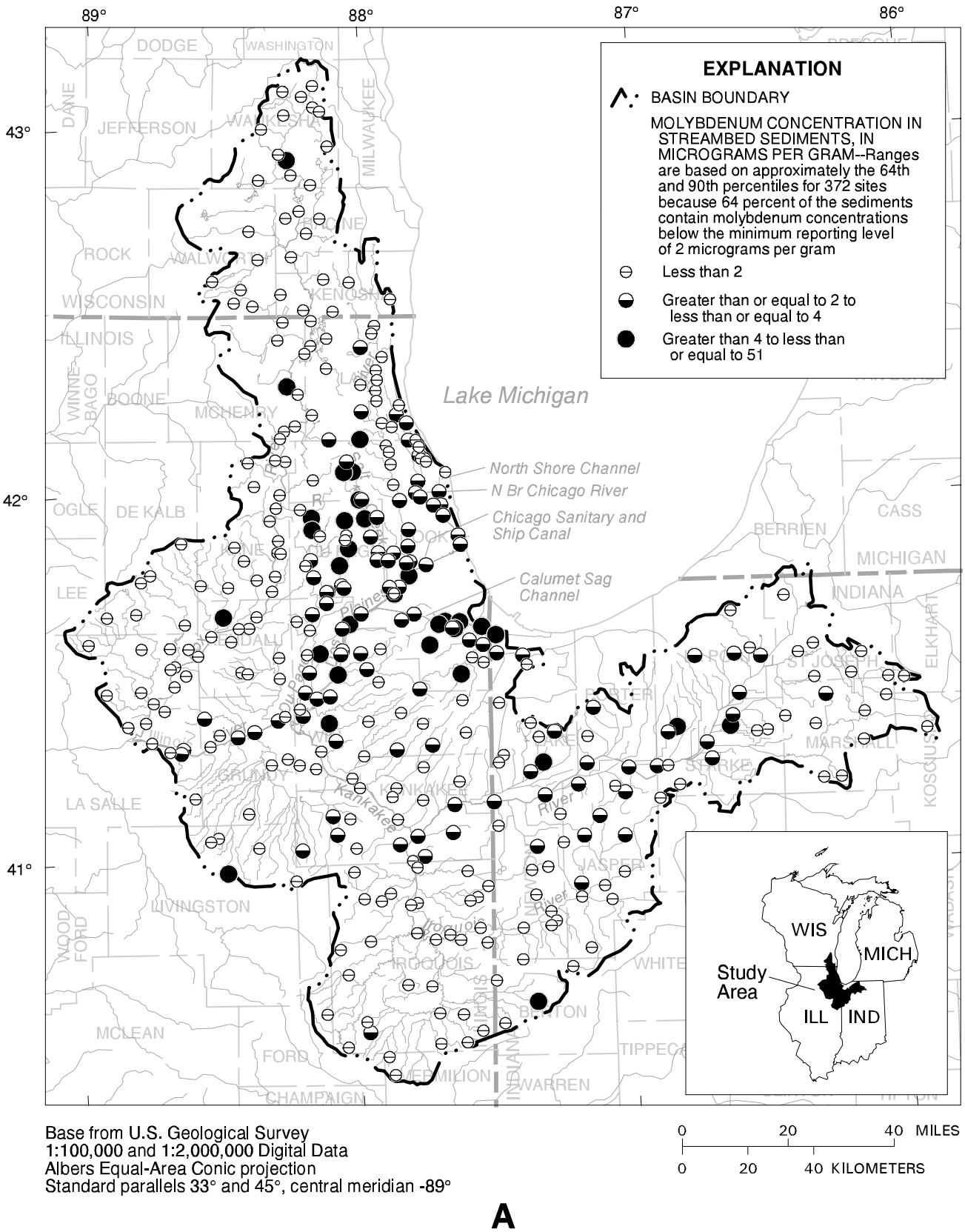


Figure 24. Mercury concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 25. Molybdenum concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

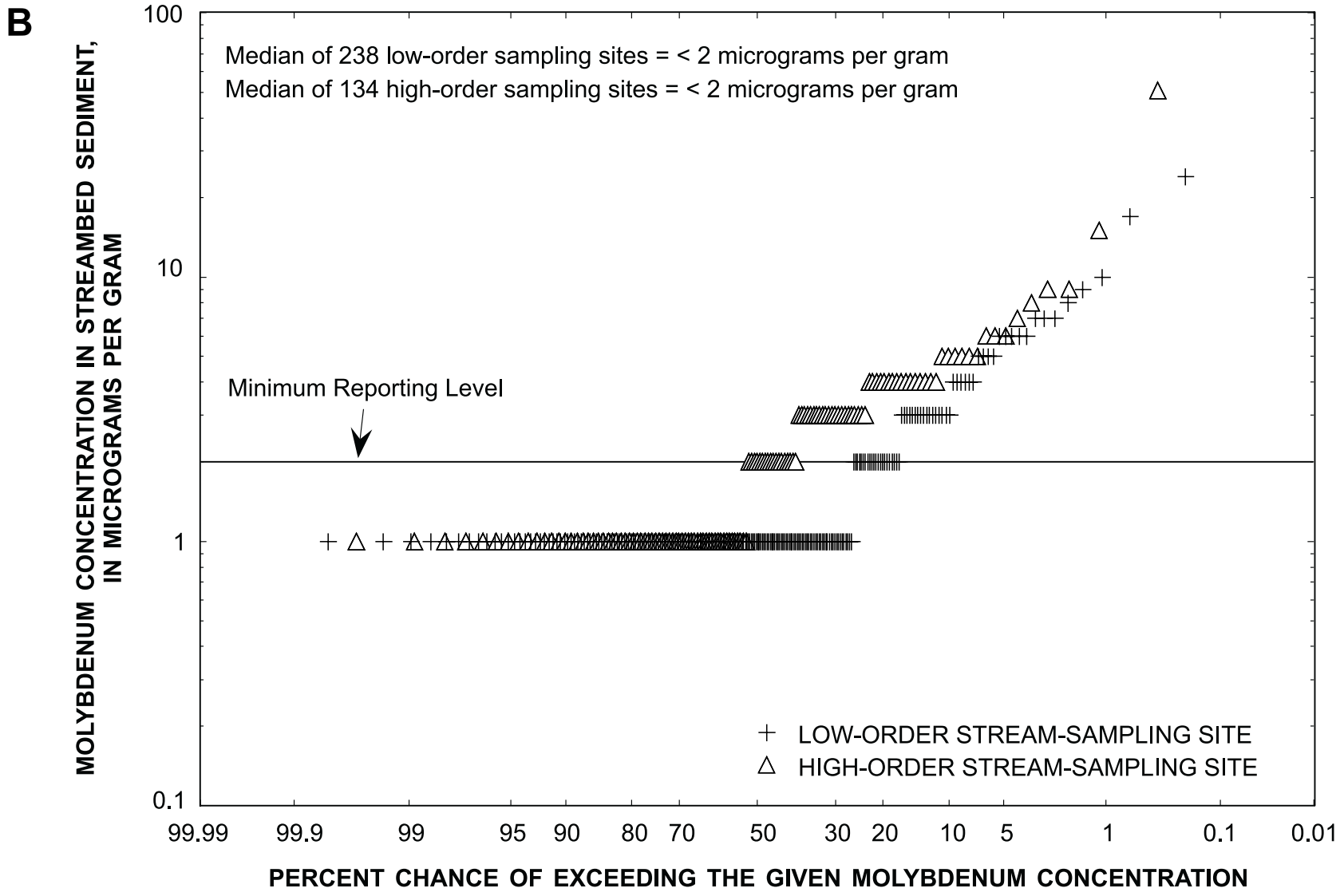


Figure 25. Molybdenum concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

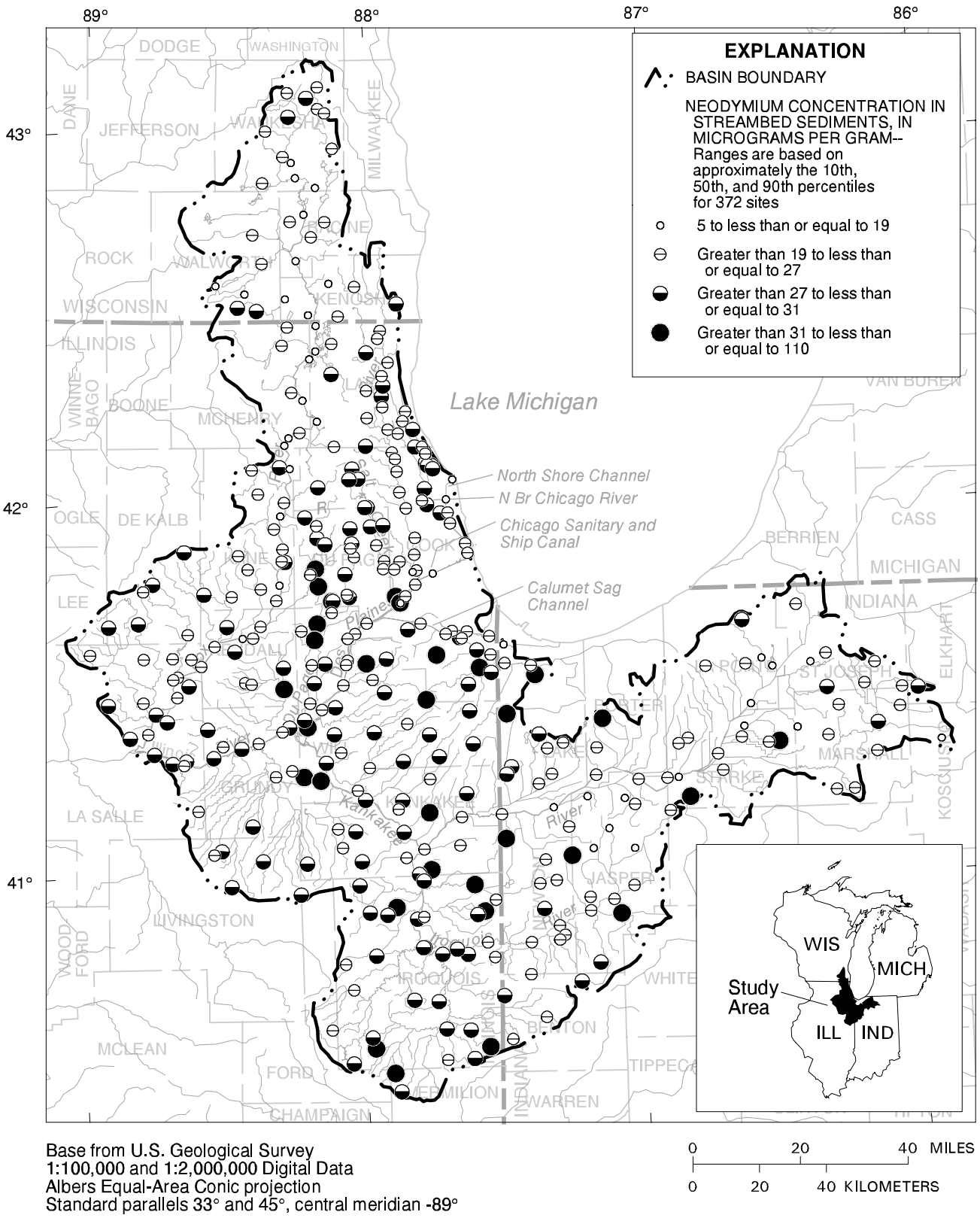


Figure 26. Neodymium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

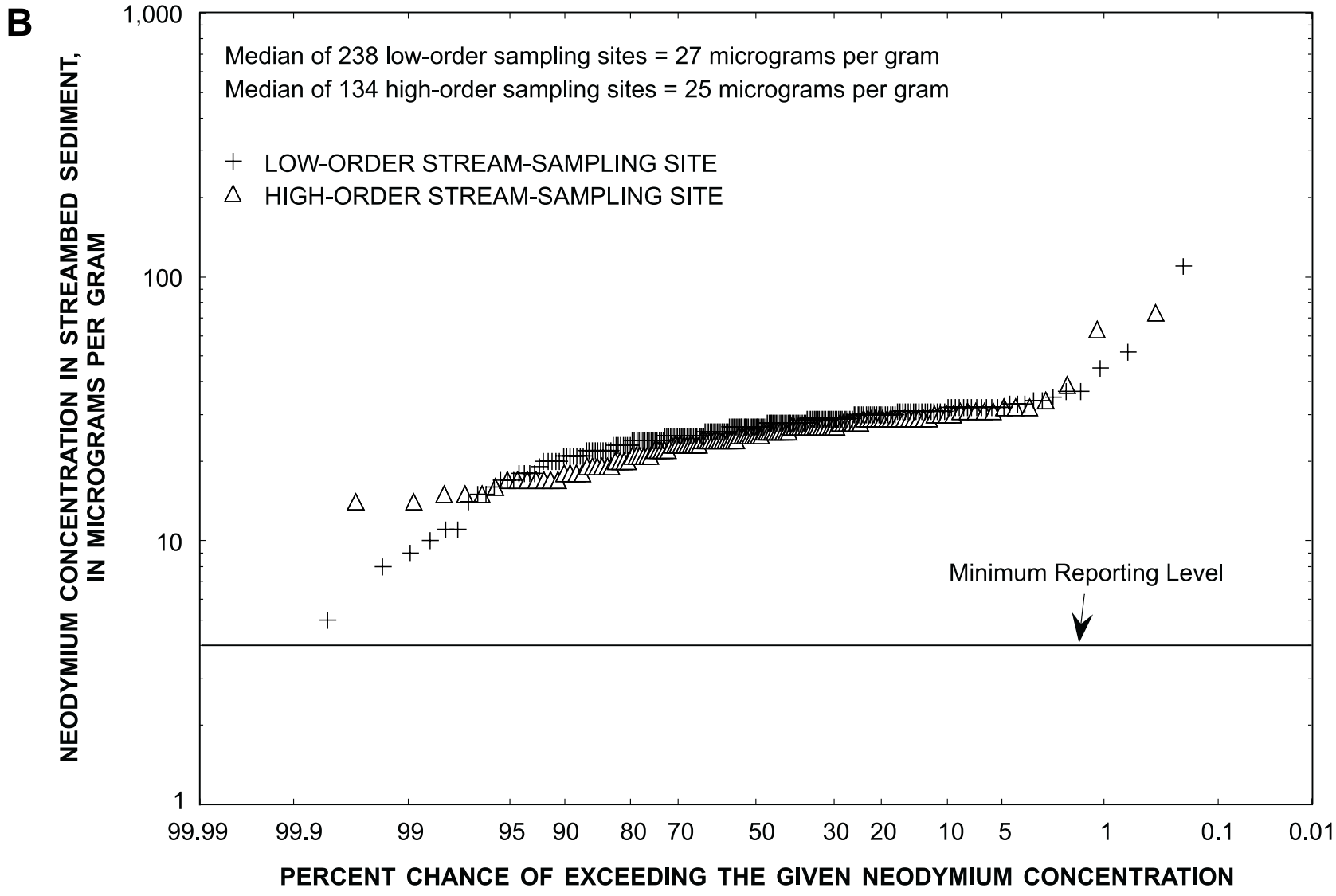
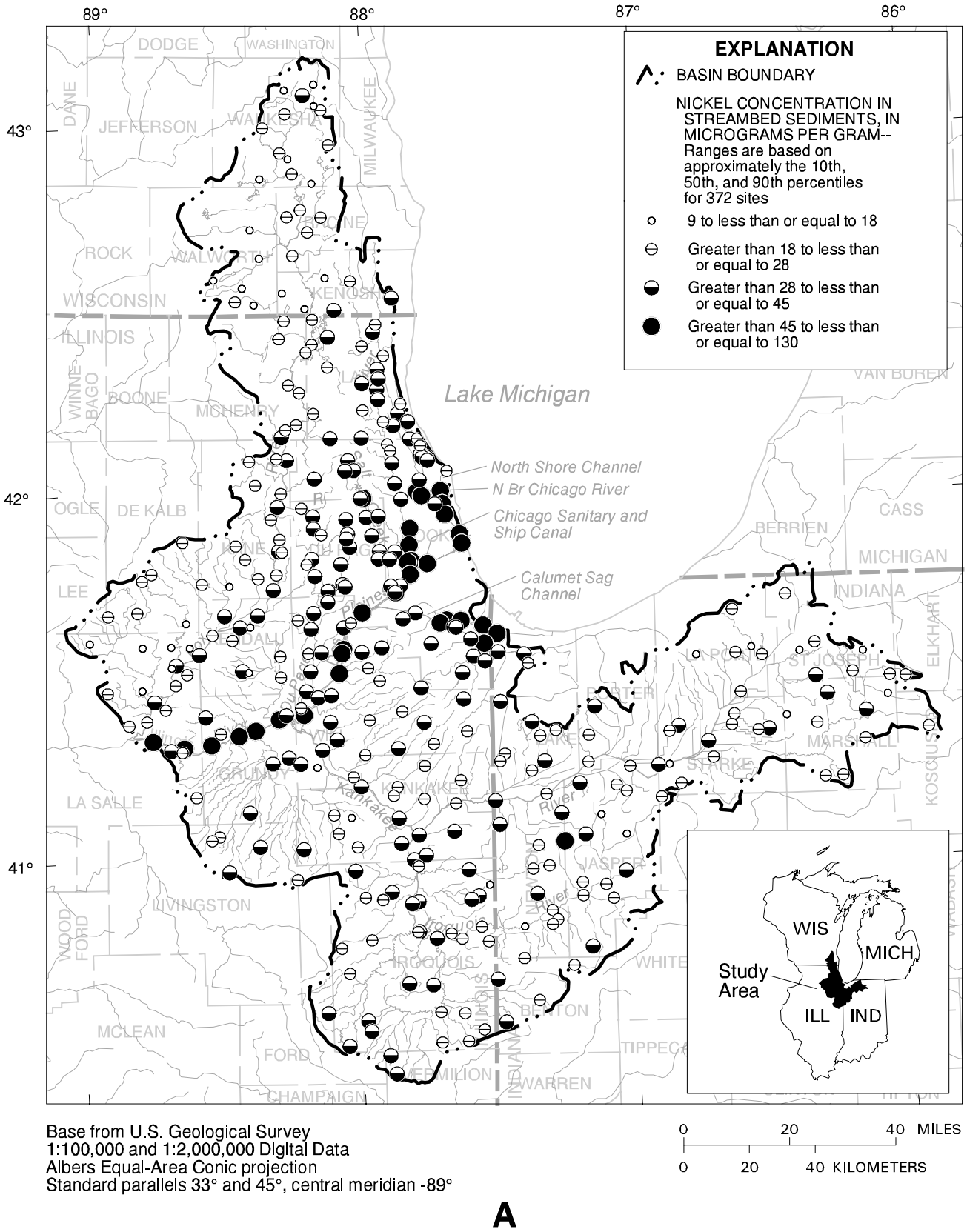


Figure 26. Neodymium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 27. Nickel concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

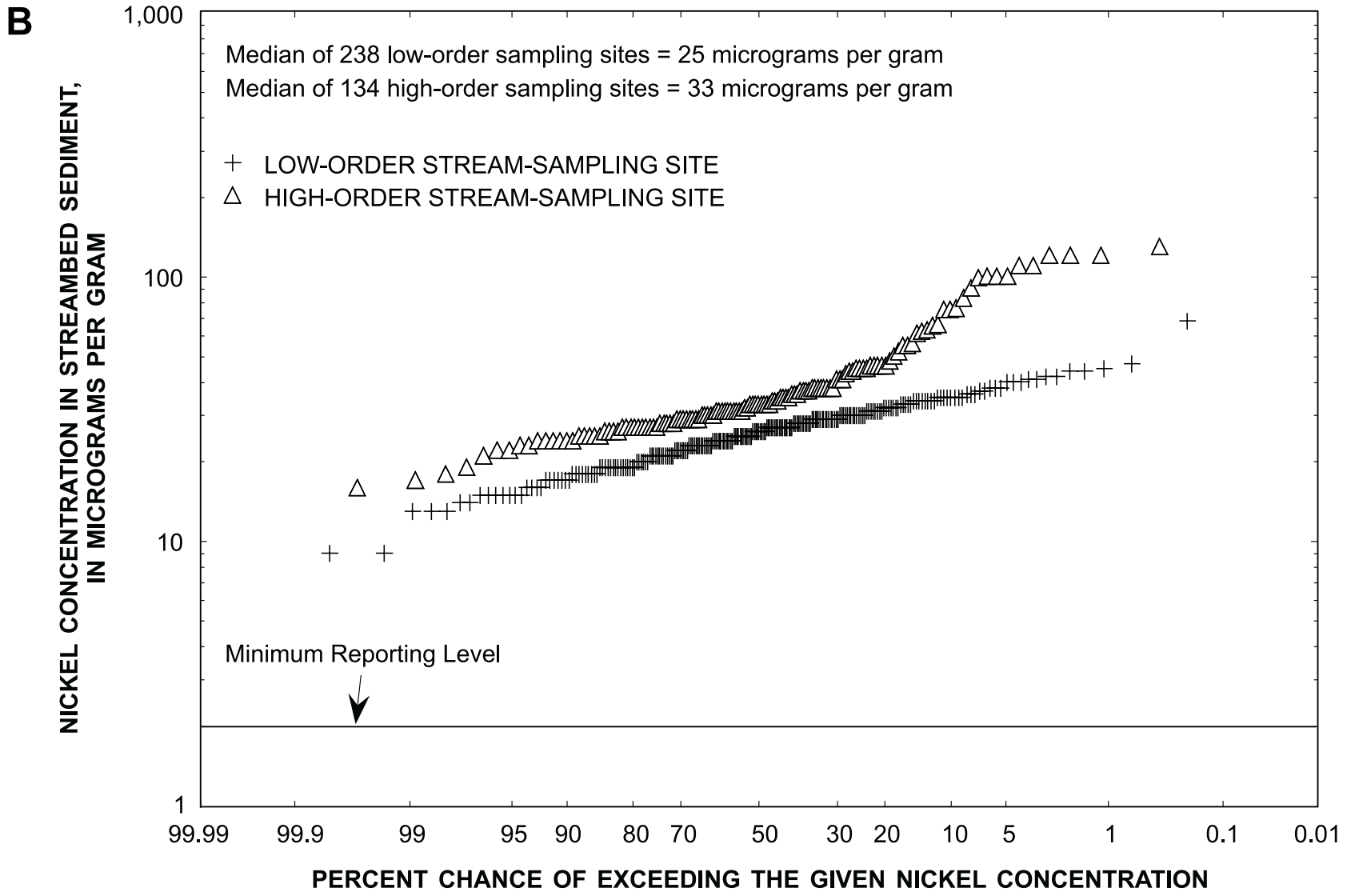
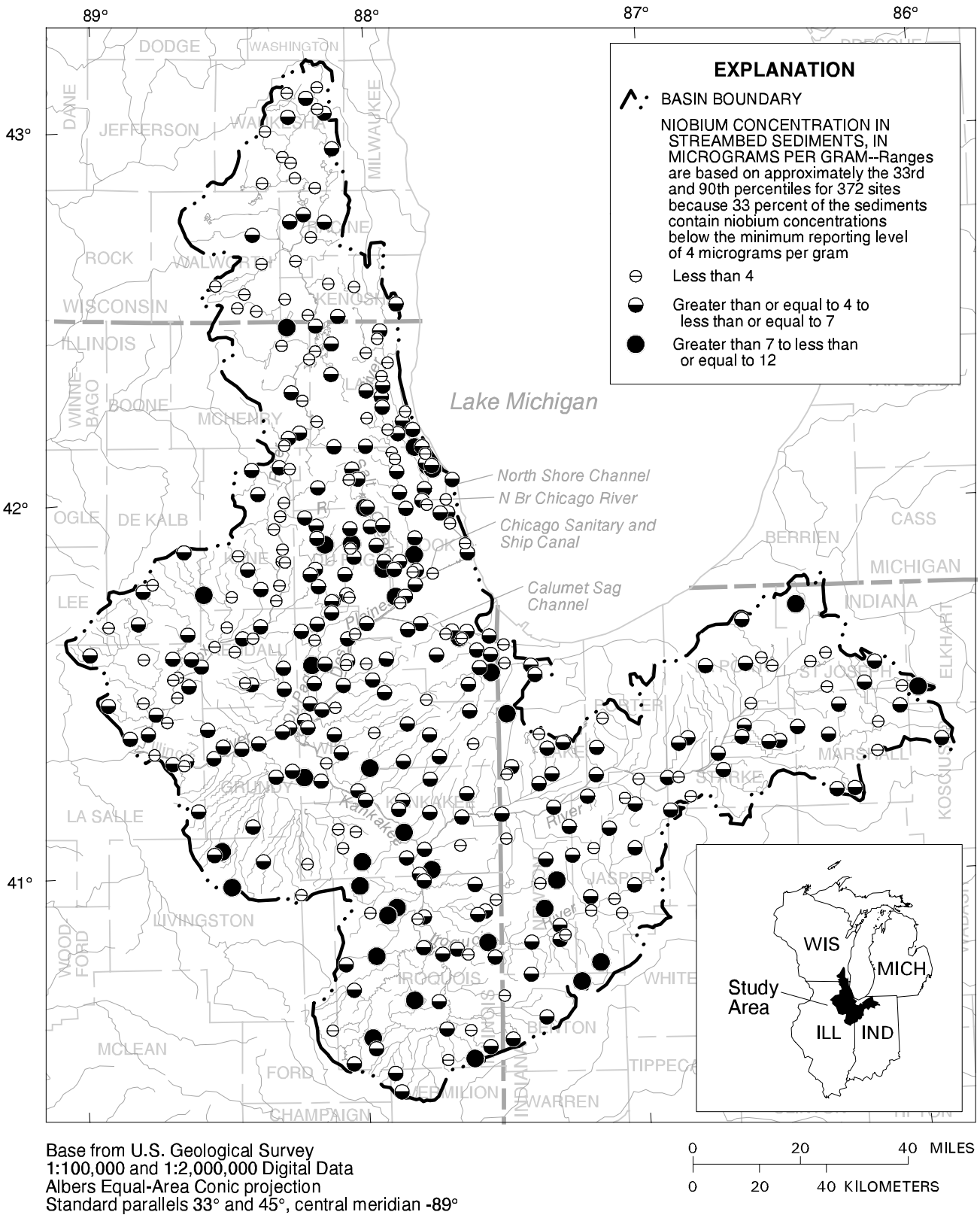


Figure 27. Nickel concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 28. Niobium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

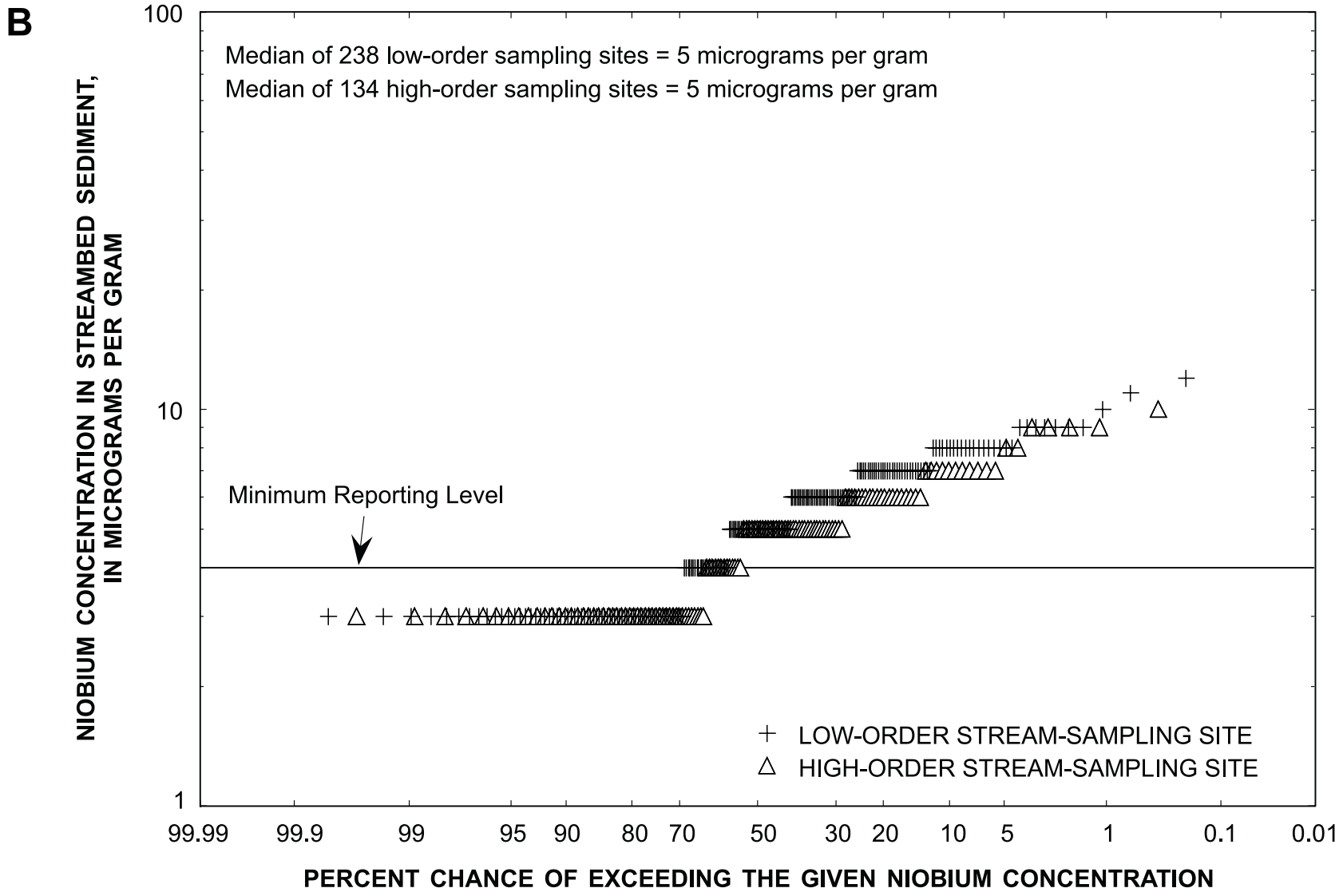


Figure 28. Niobium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

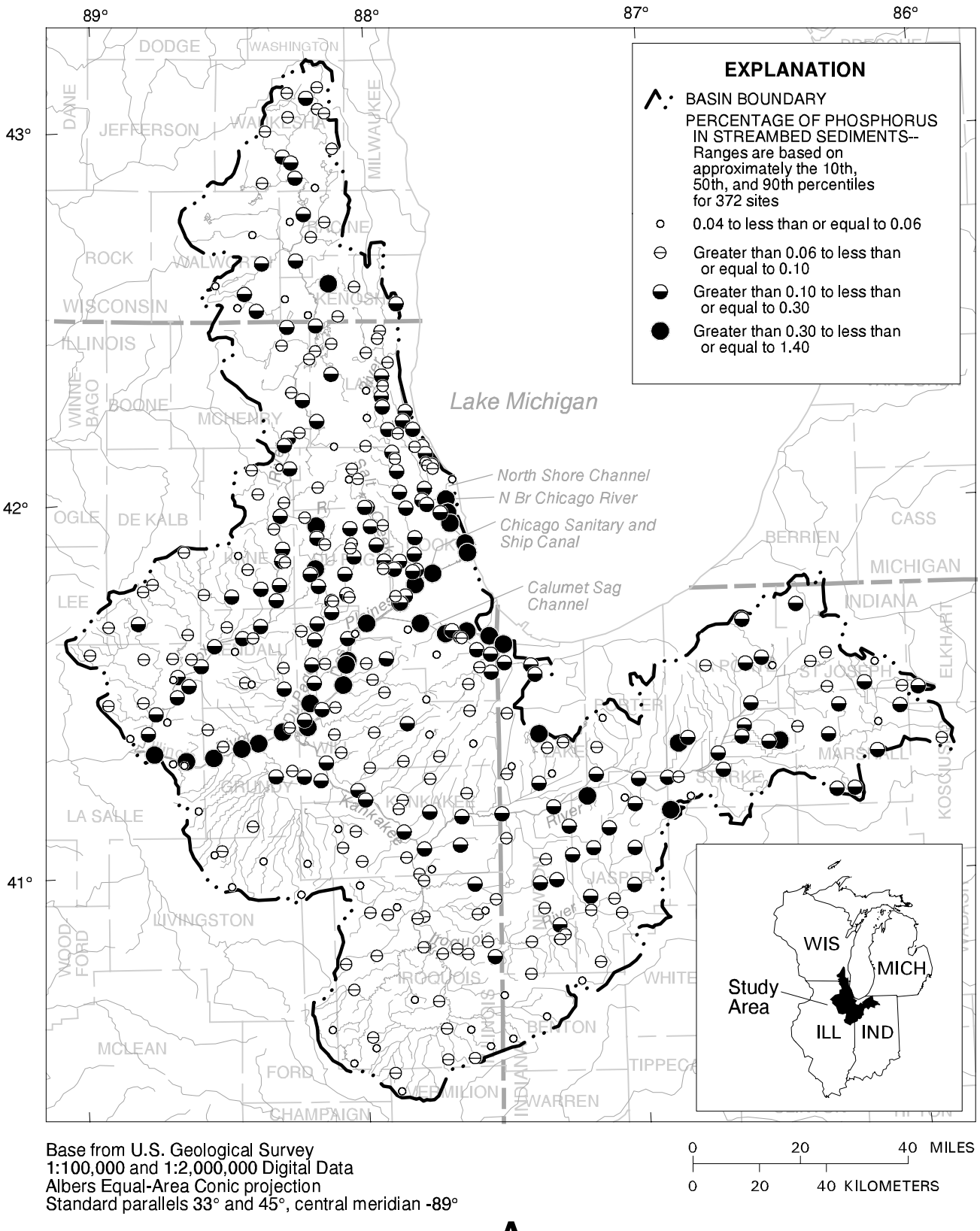


Figure 29. Percentage of phosphorus in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

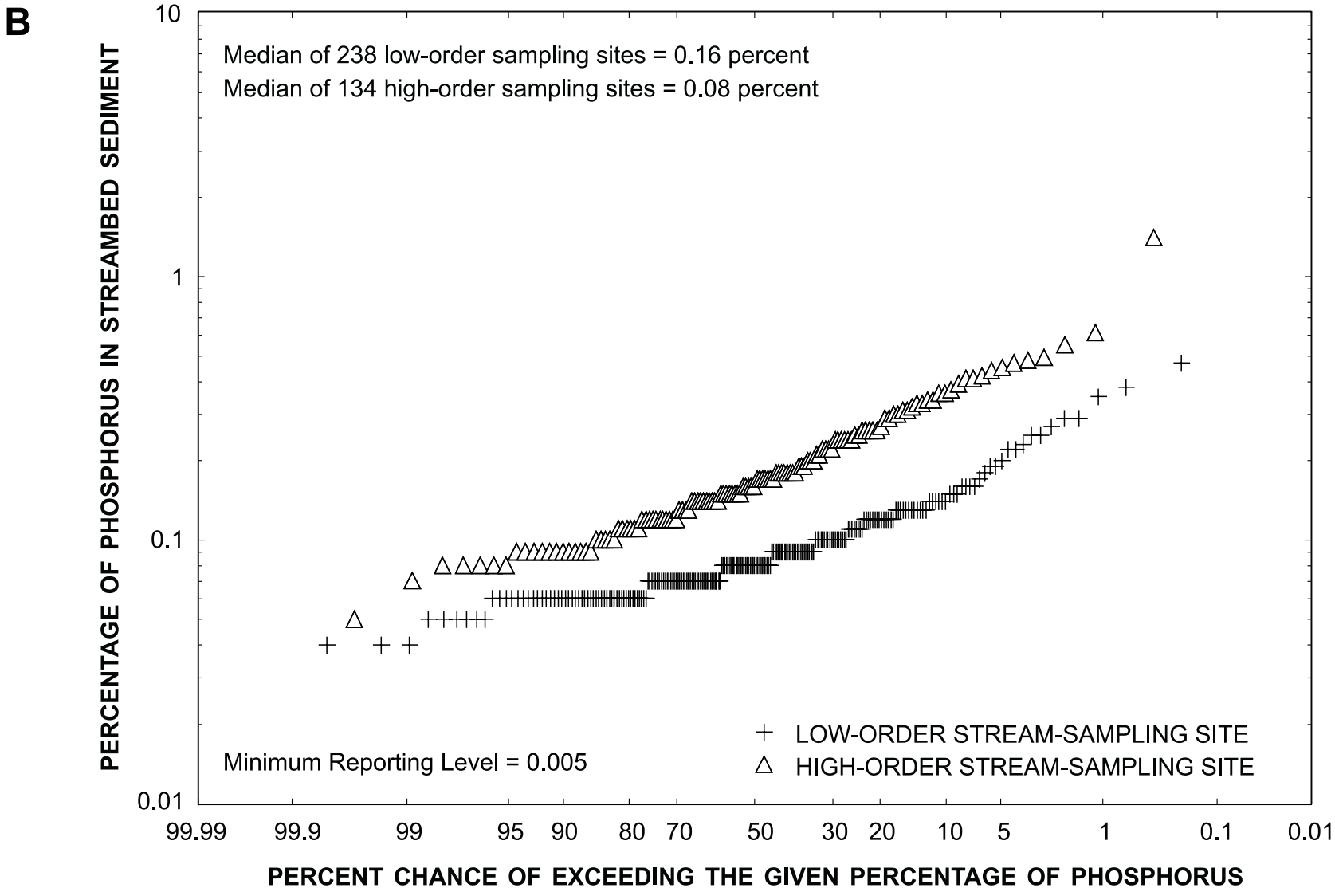
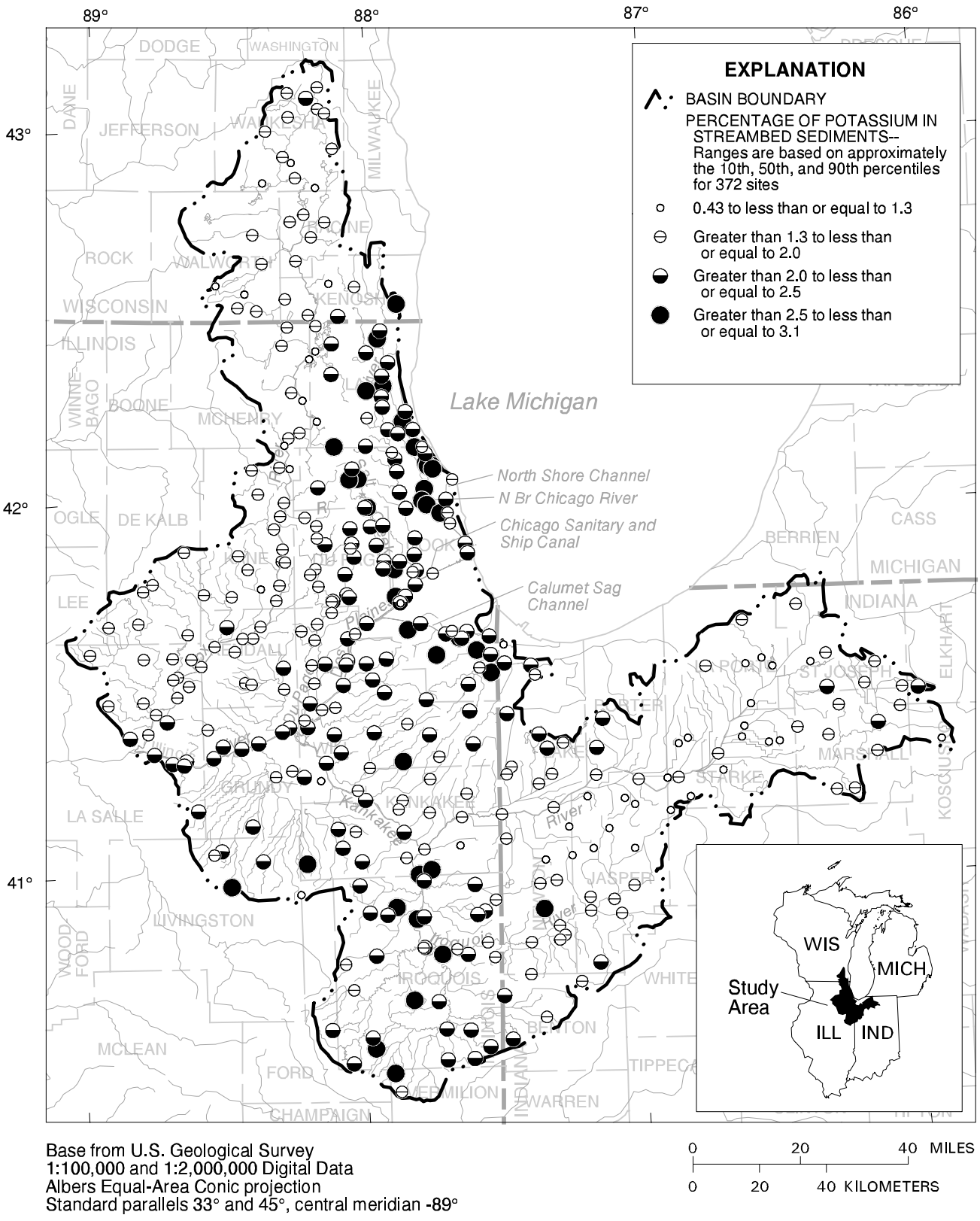


Figure 29. Percentage of phosphorus in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 30. Percentage of potassium in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

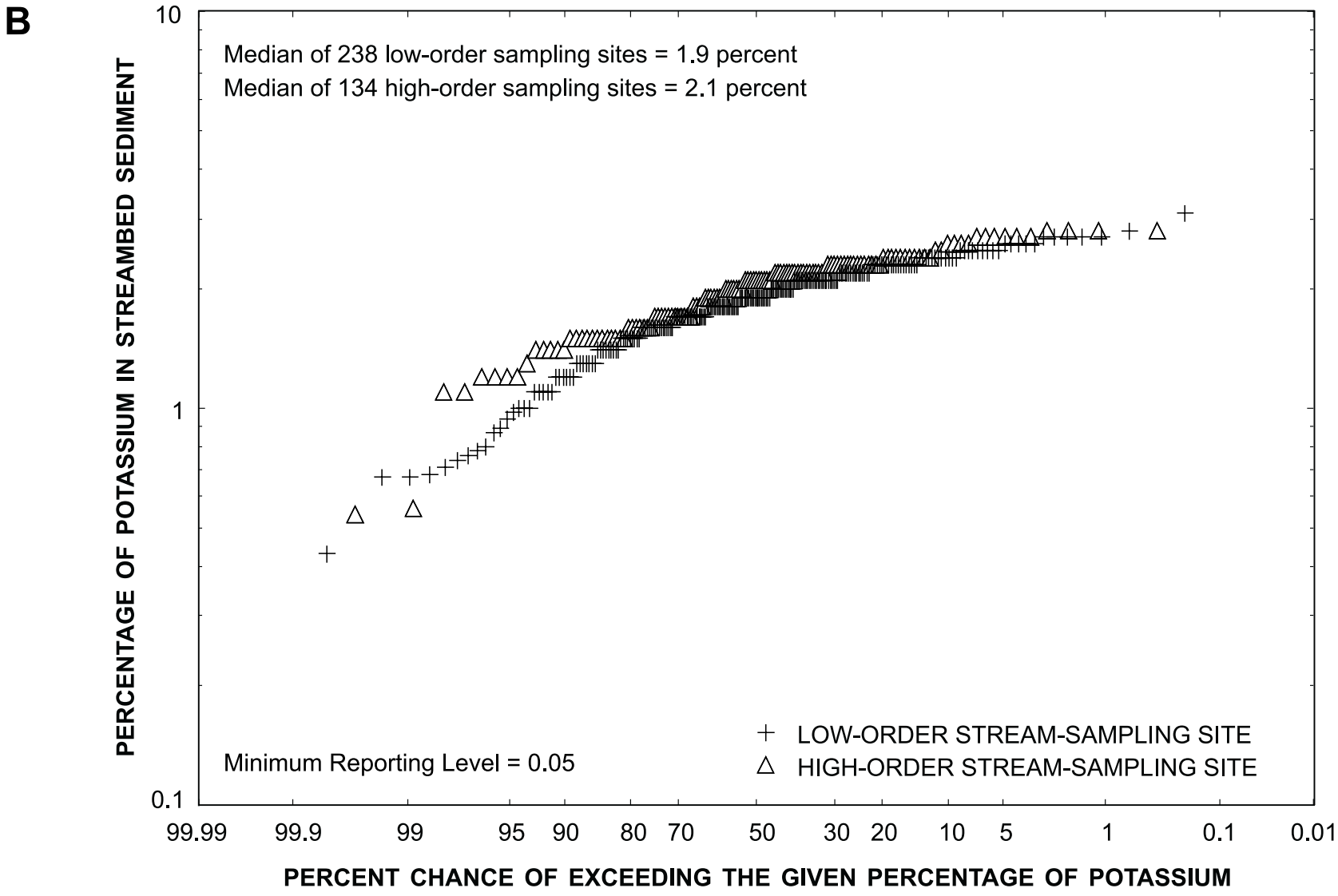


Figure 30. Percentage of potassium in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

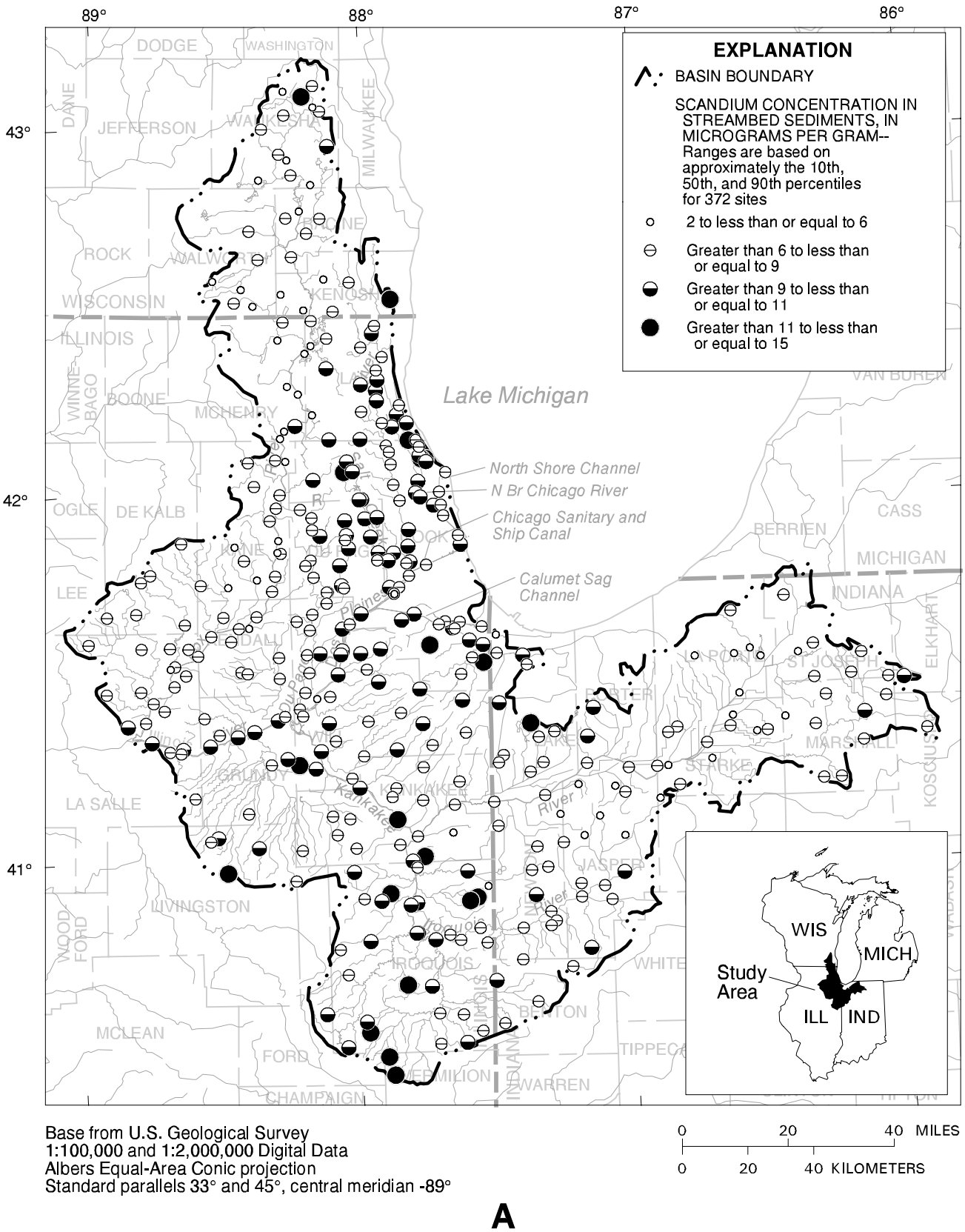


Figure 31. Scandium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

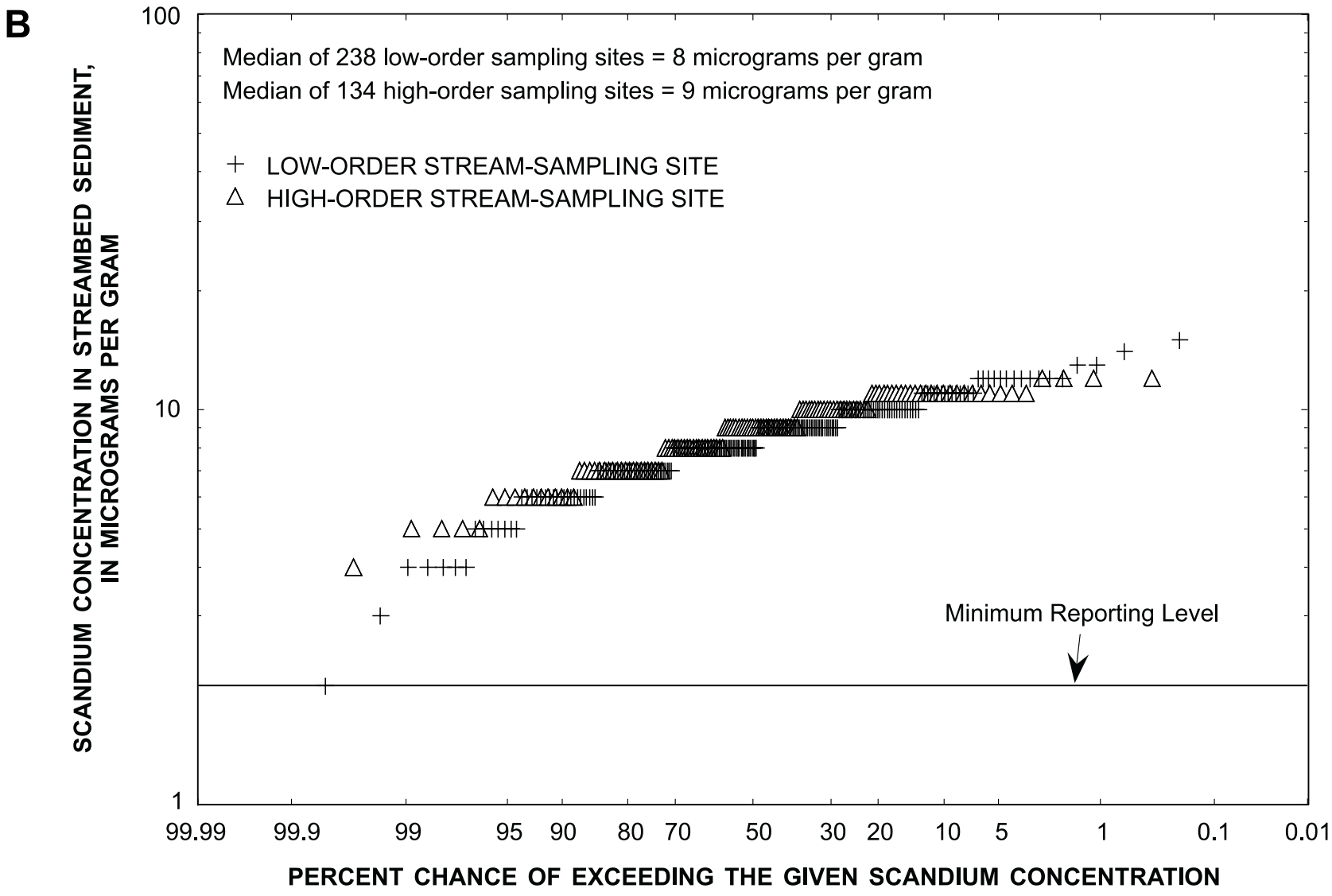
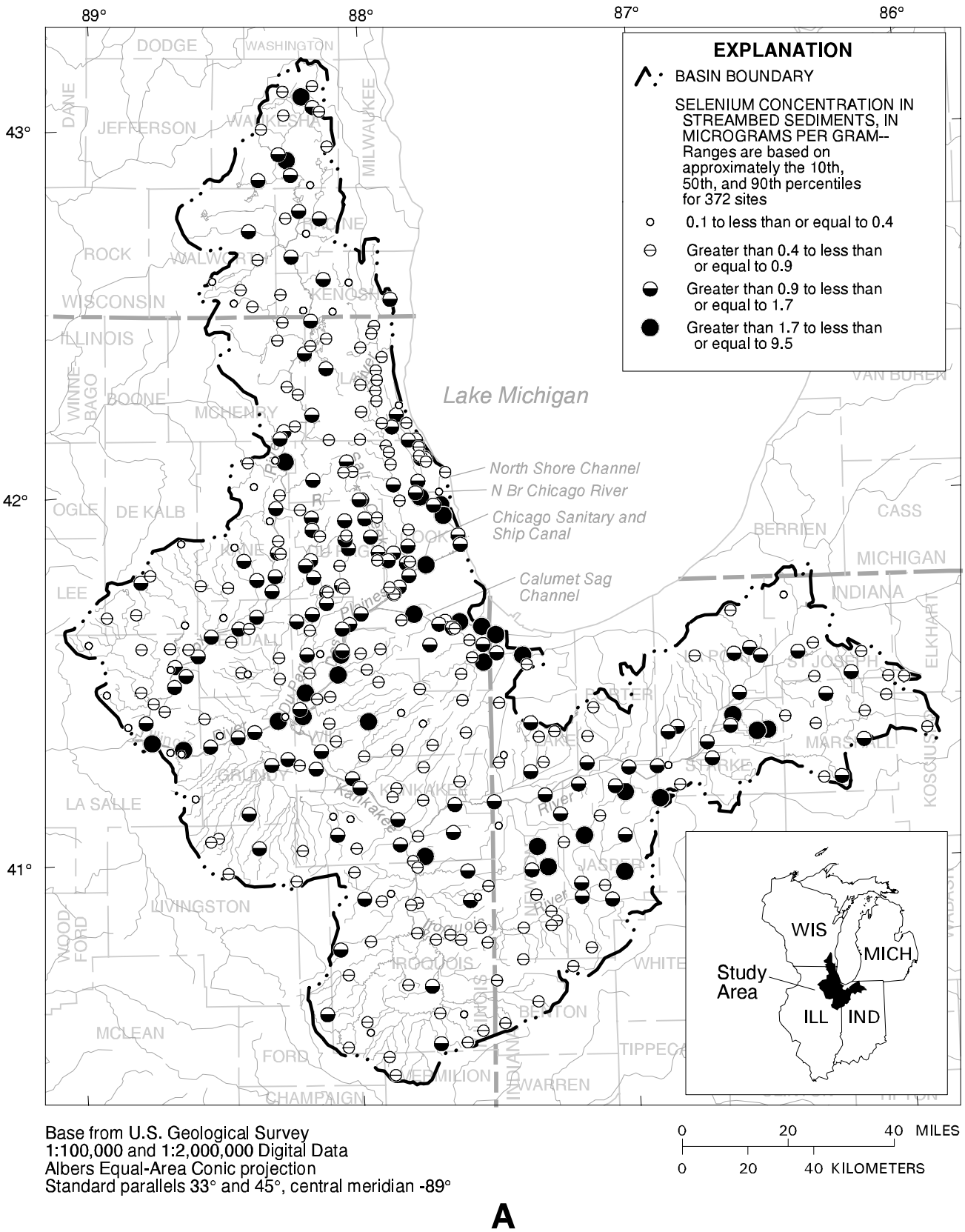


Figure 31. Scandium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 32. Selenium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

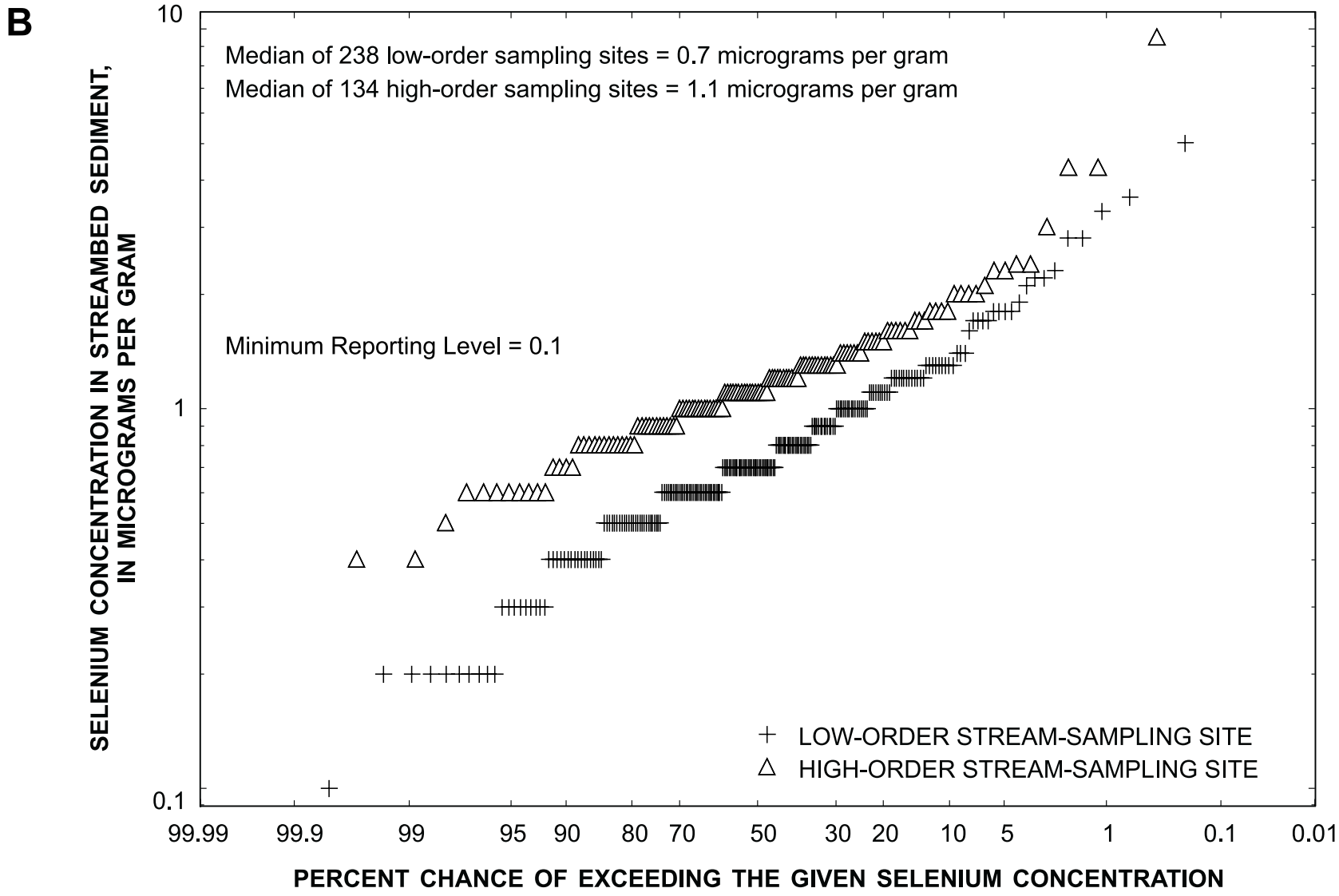


Figure 32. Selenium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

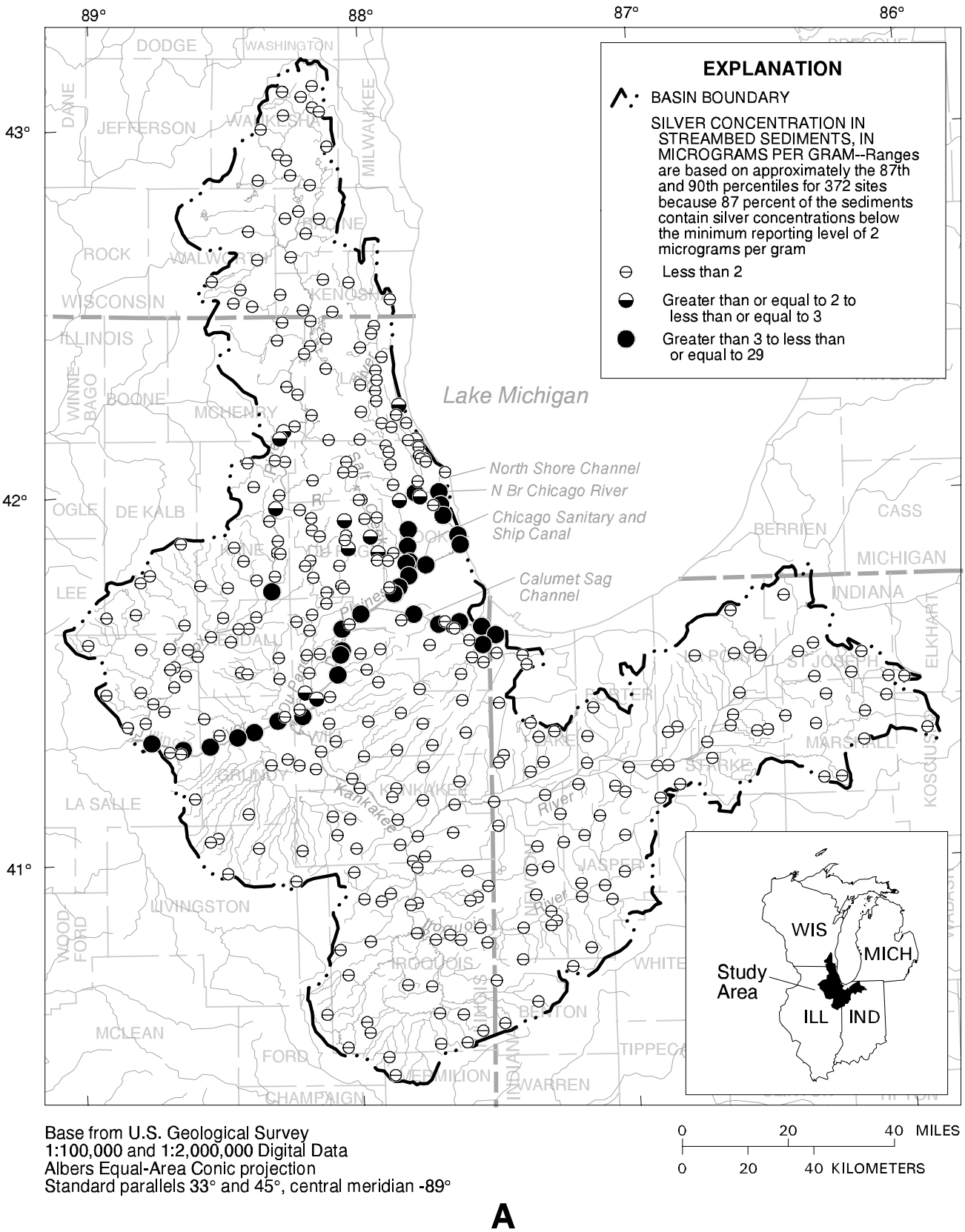


Figure 33. Silver concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

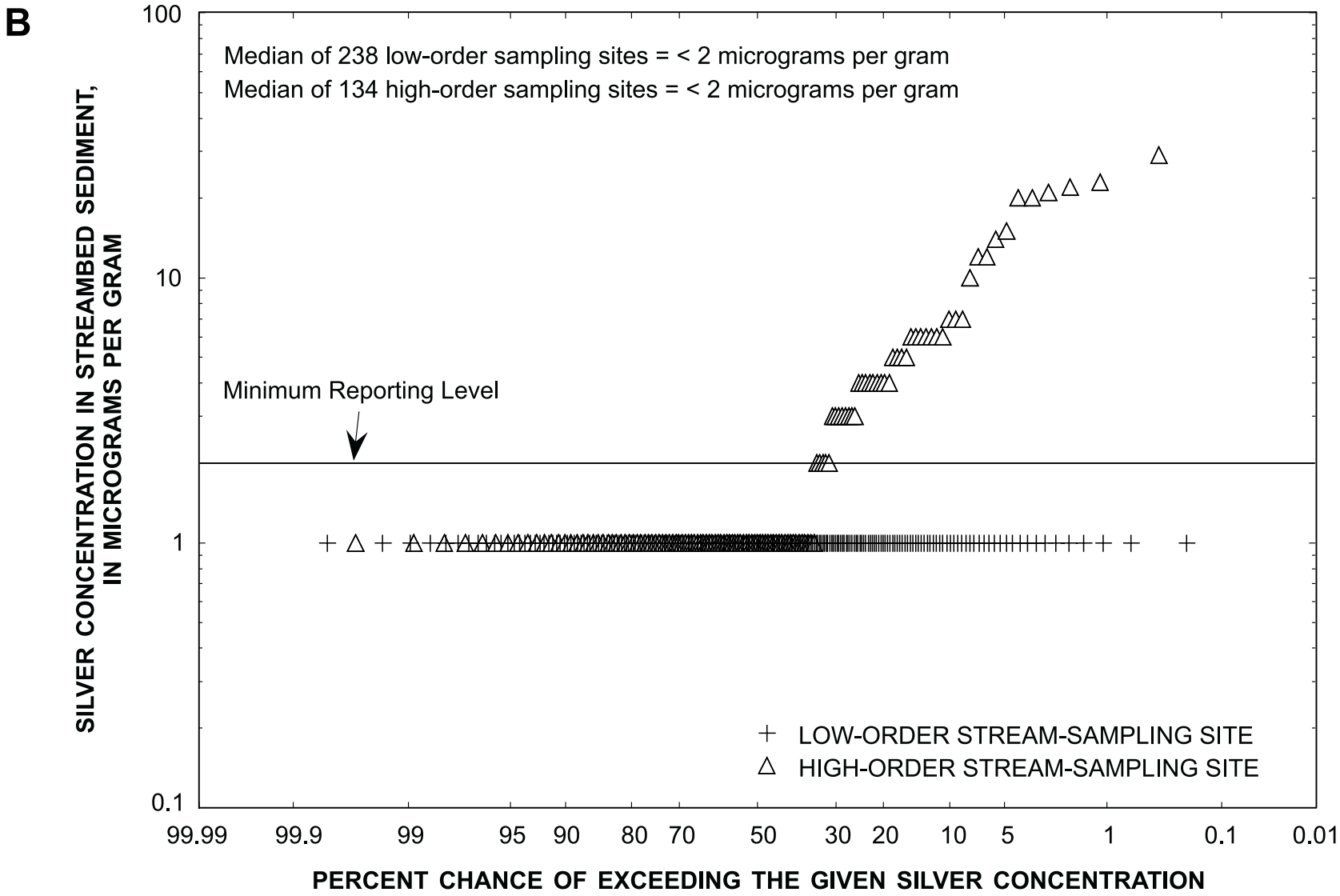


Figure 33. Silver concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

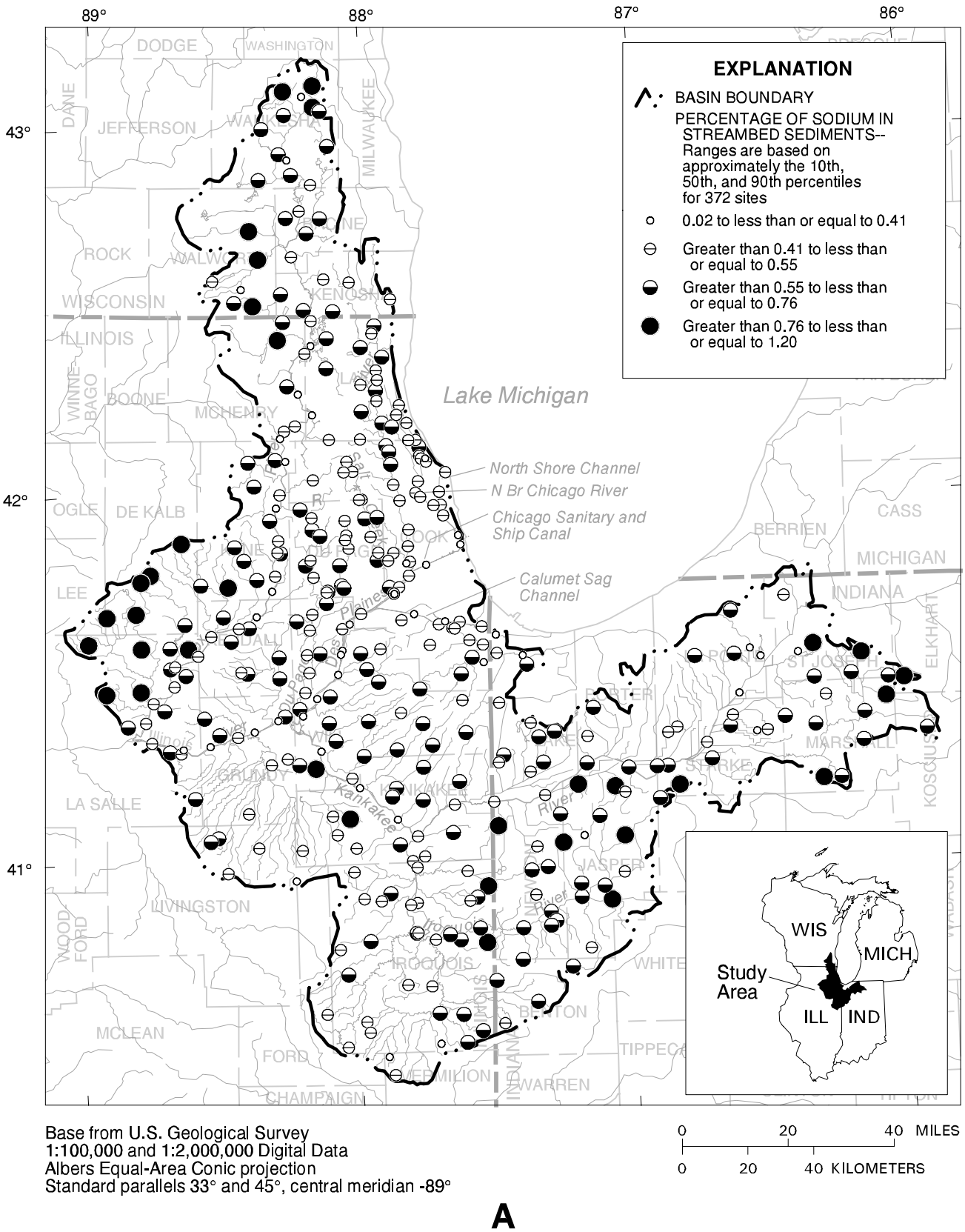


Figure 34. Percentage of sodium in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

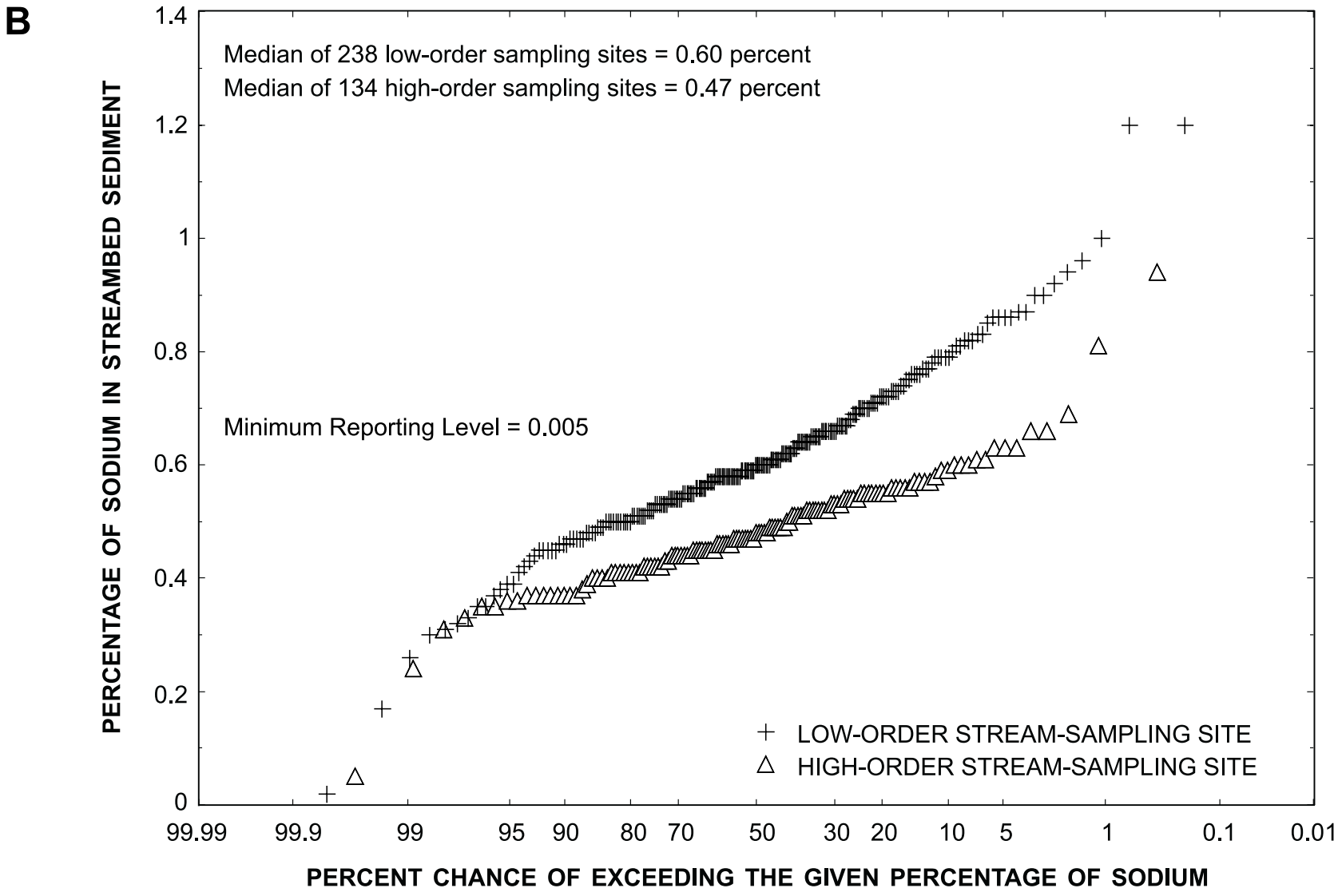


Figure 34. Percentage of sodium in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

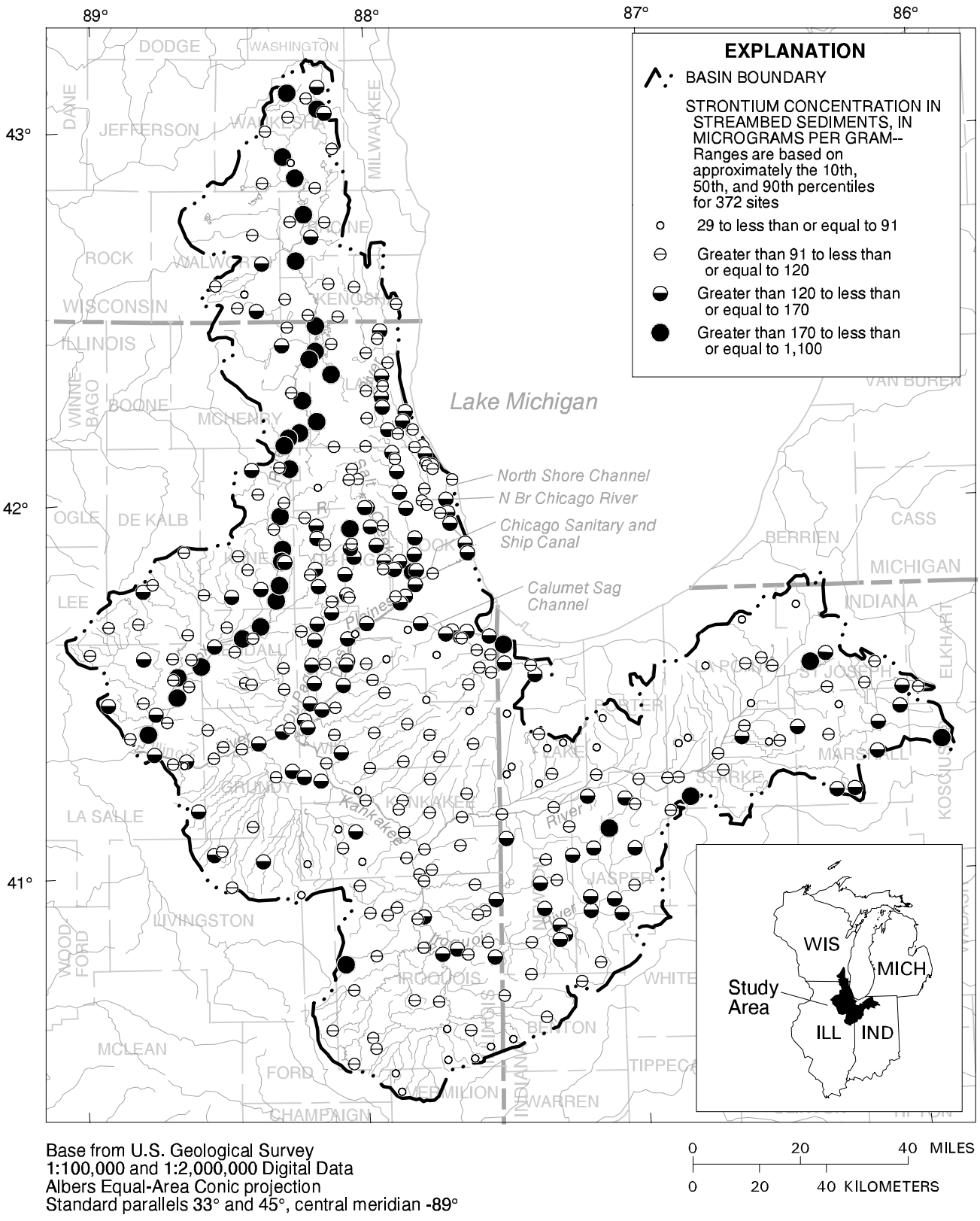


Figure 35. Strontium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

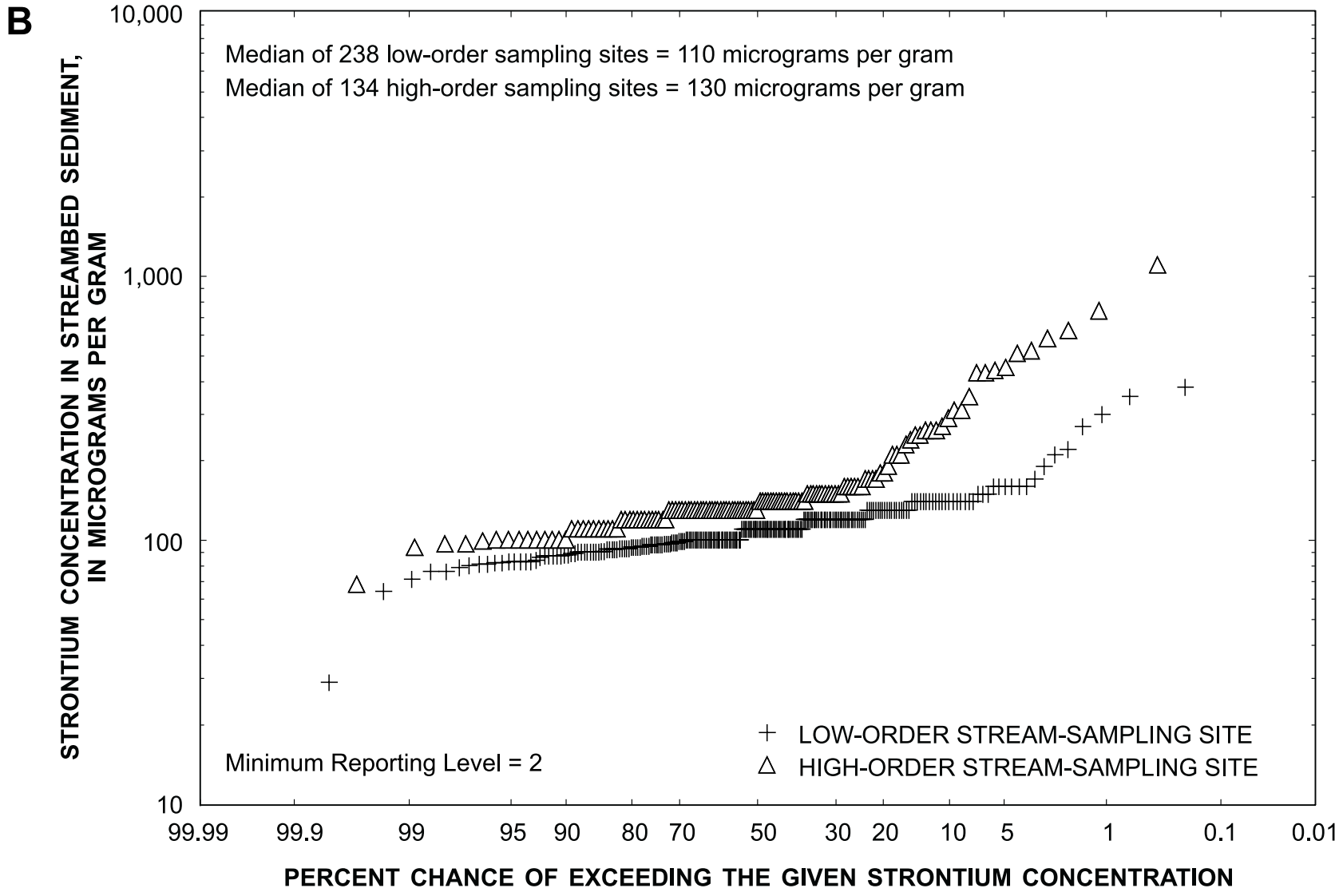
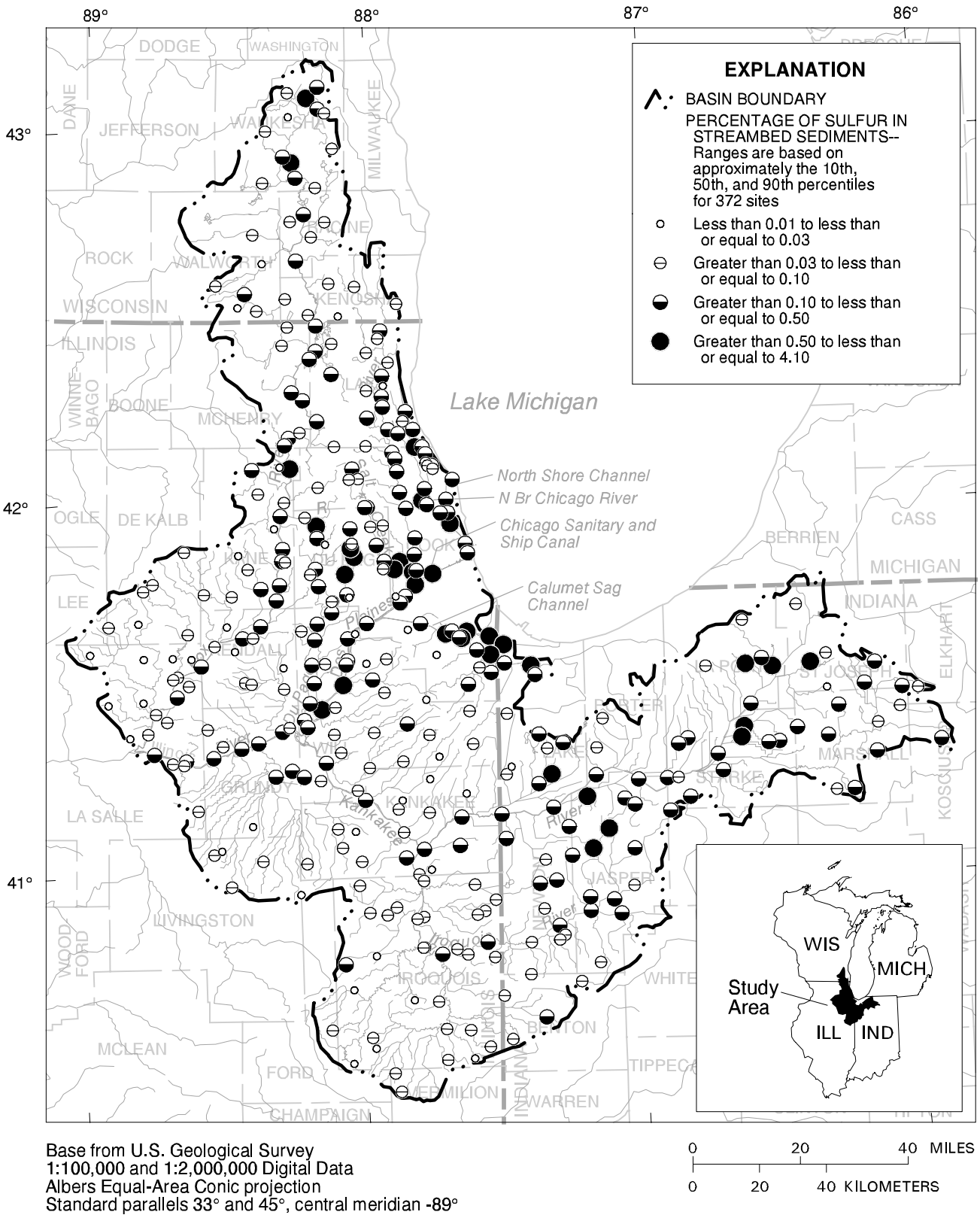


Figure 35. Strontium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 36. Percentage of sulfur in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

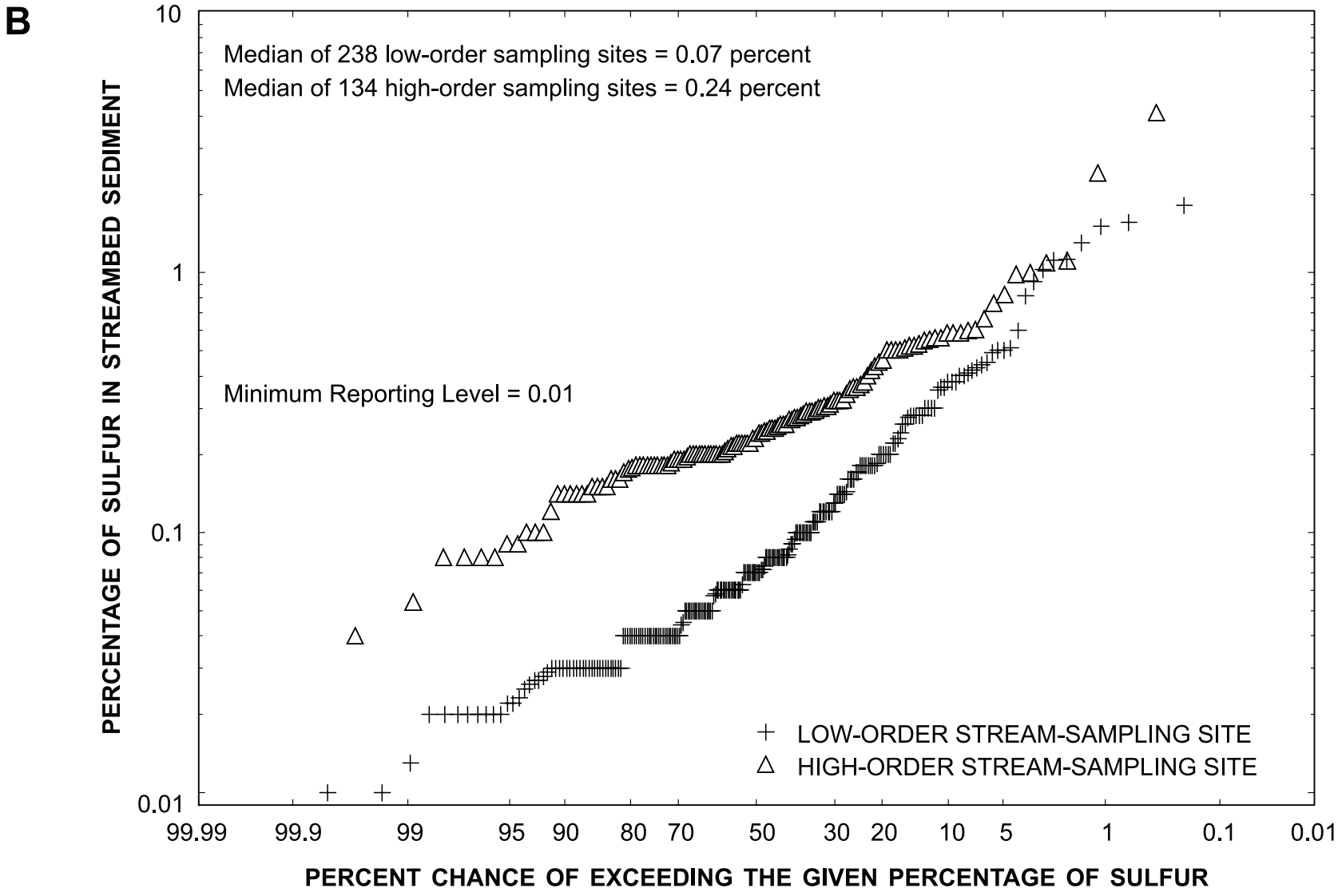
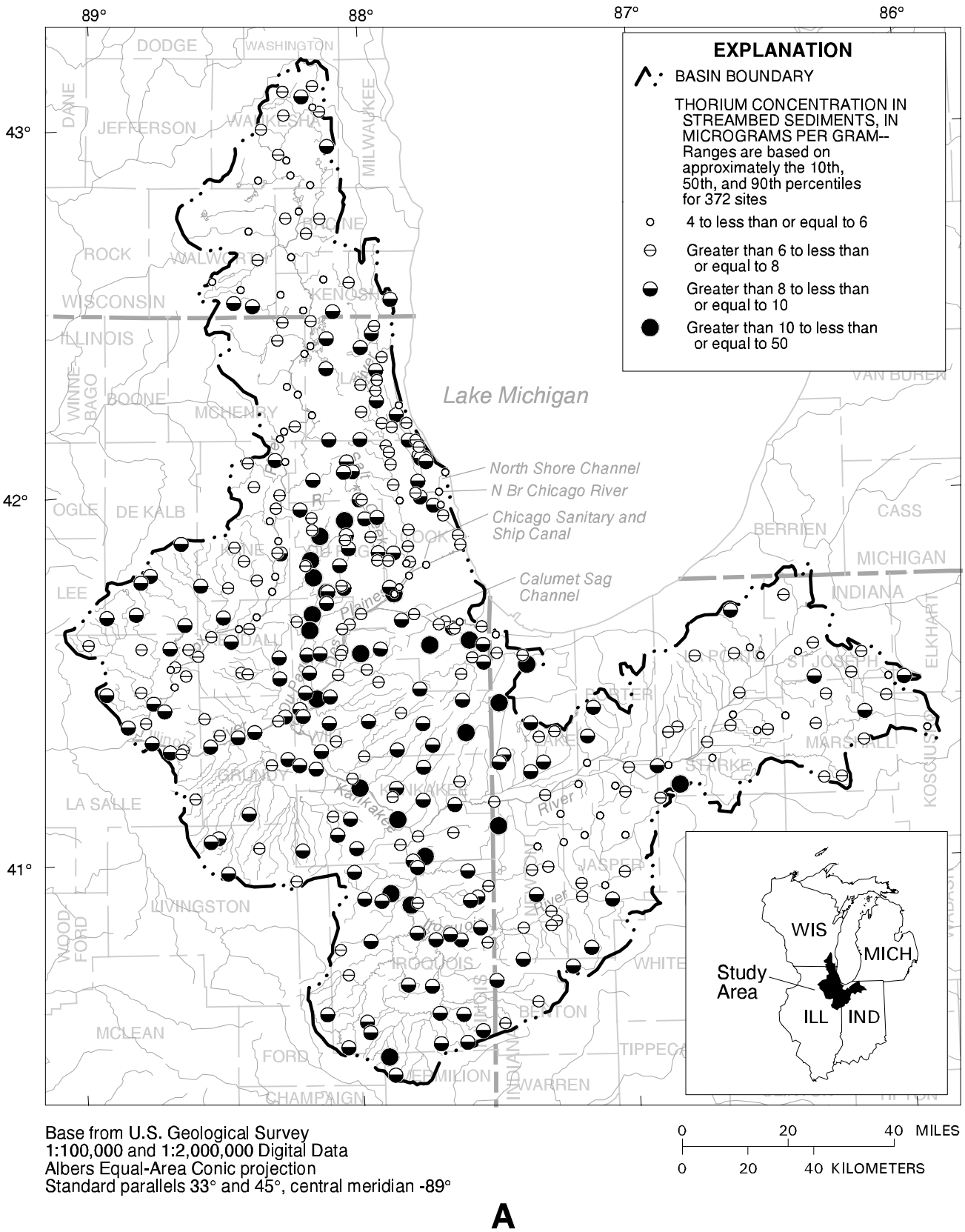


Figure 36. Percentage of sulfur in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 37. Thorium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

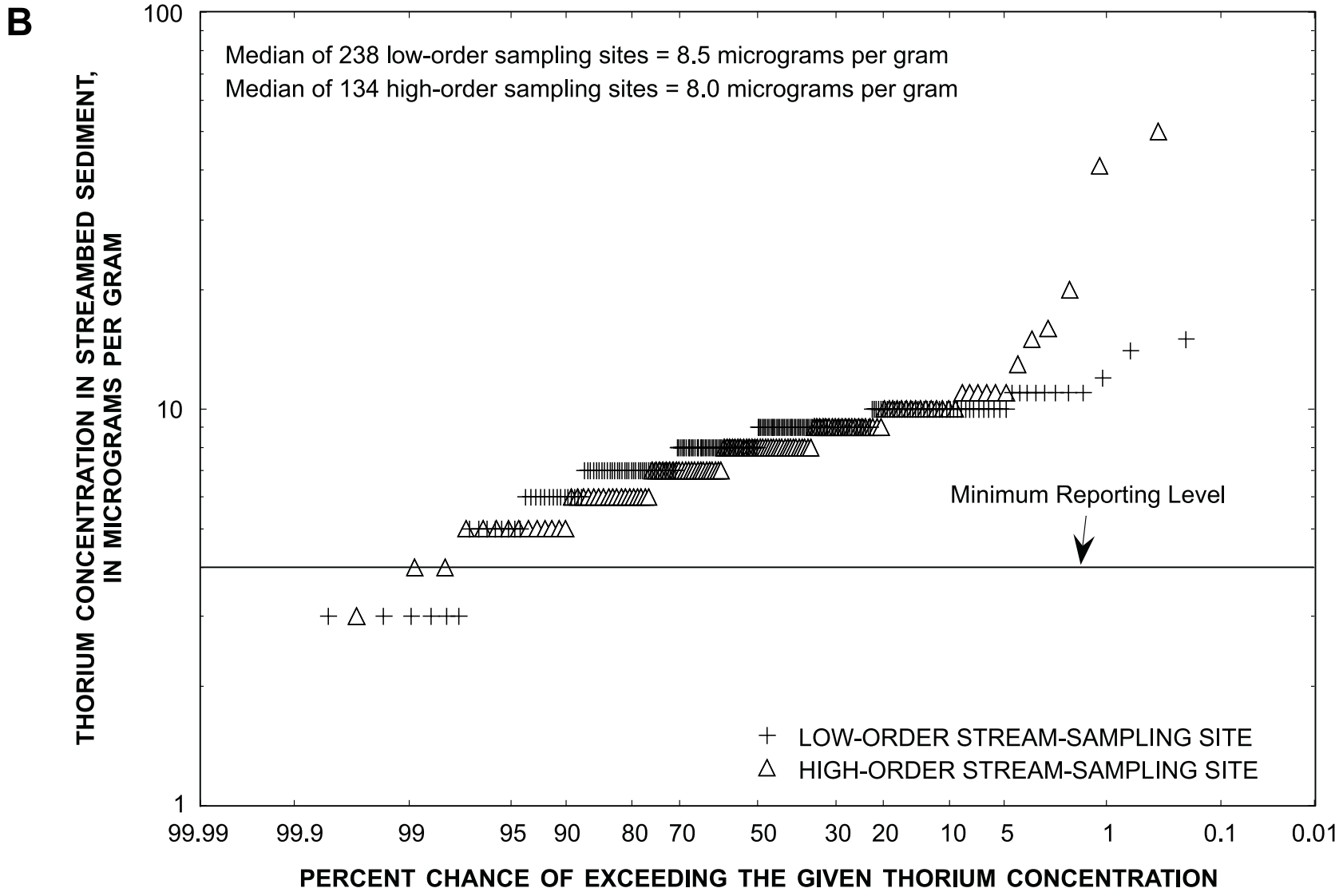
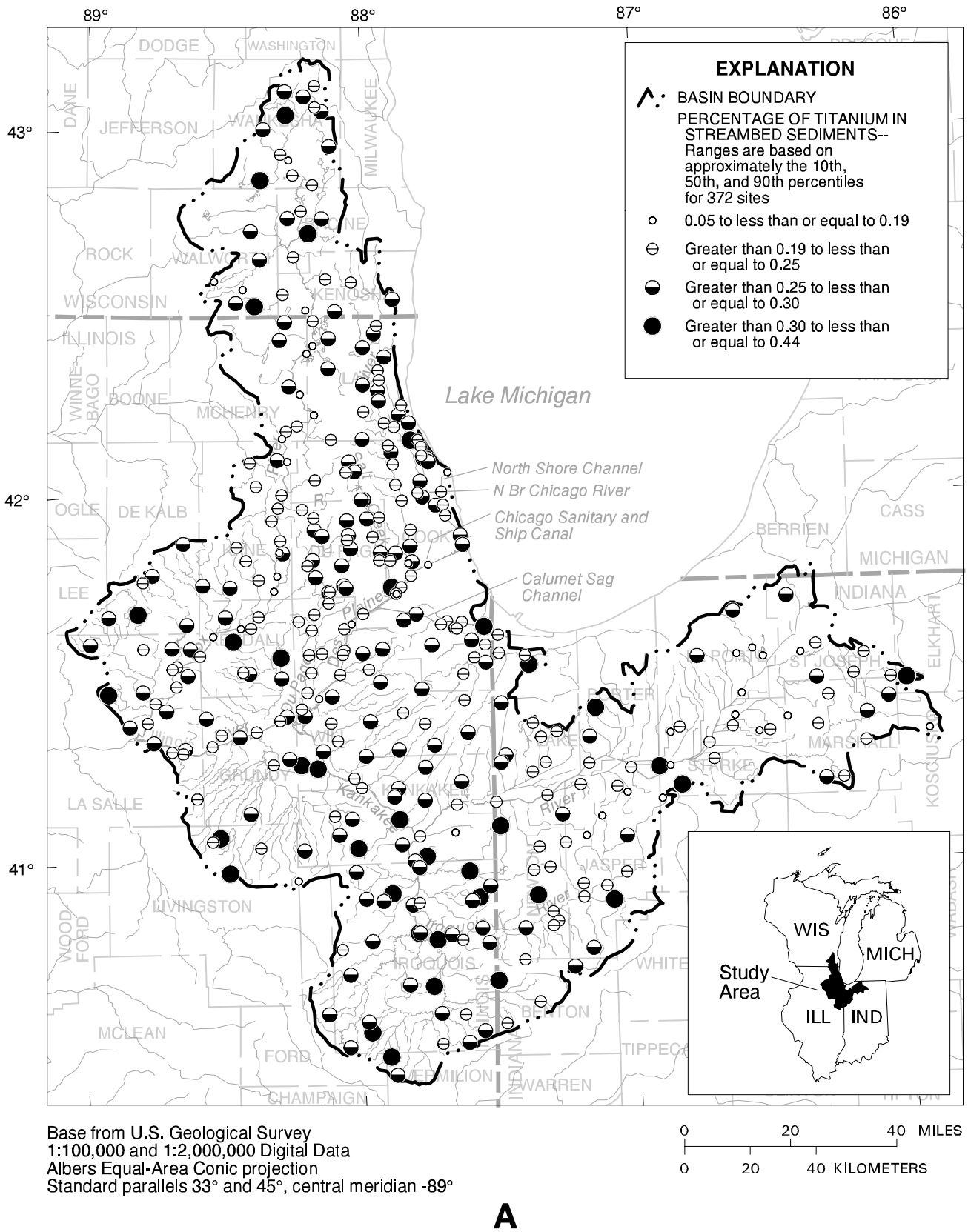


Figure 37. Thorium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 38. Percentage of titanium in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

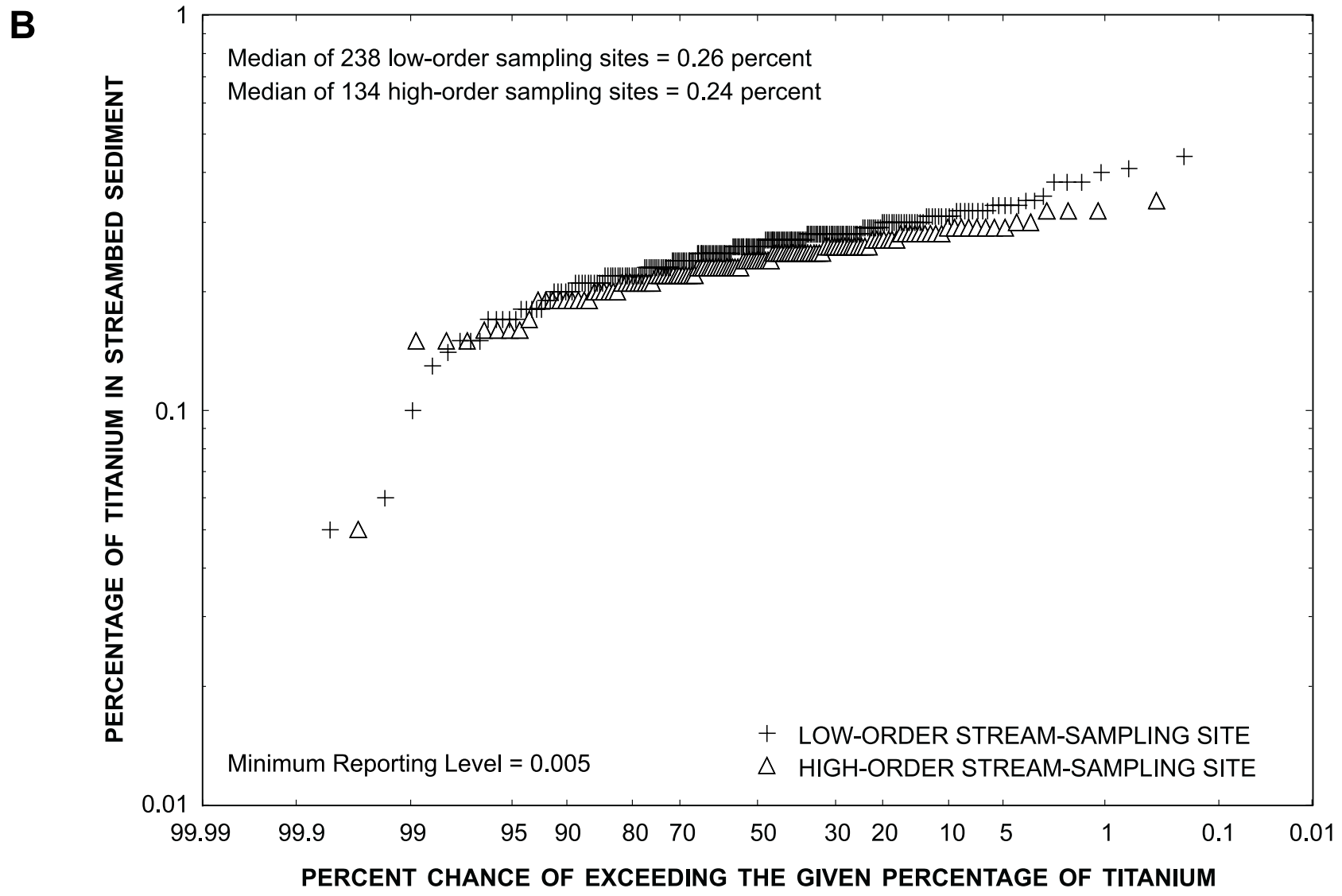


Figure 38. Percentage of titanium in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

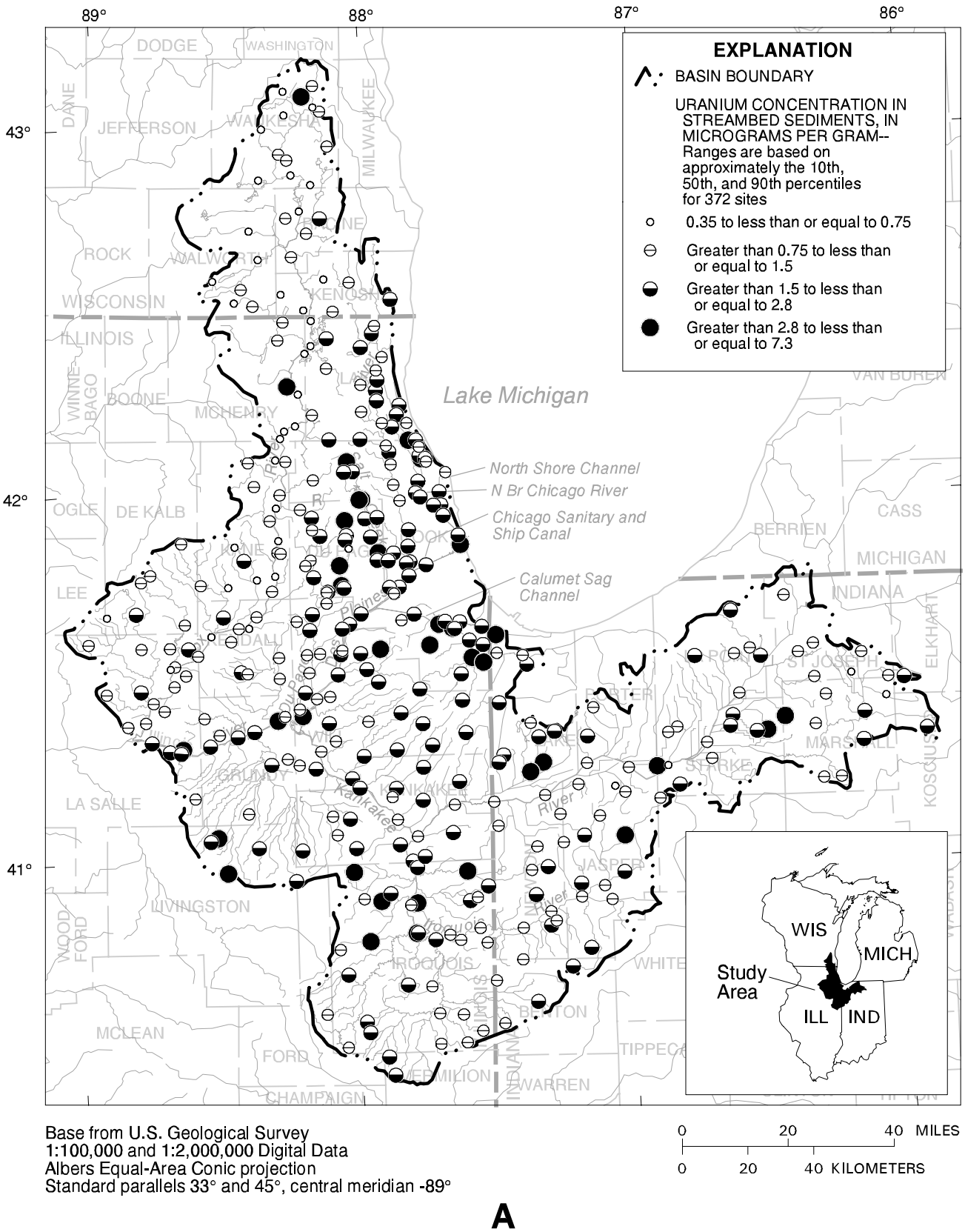


Figure 39. Uranium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

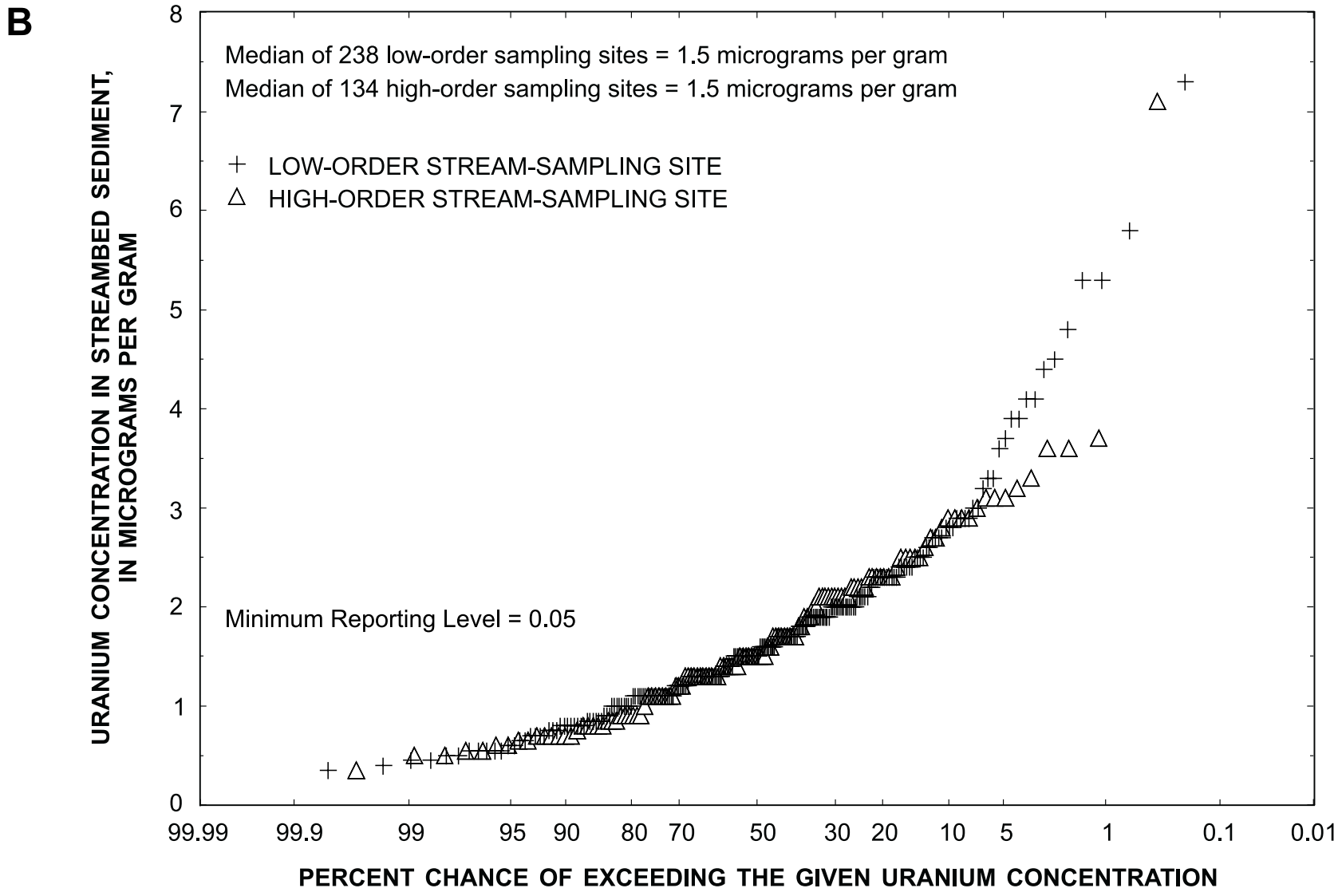
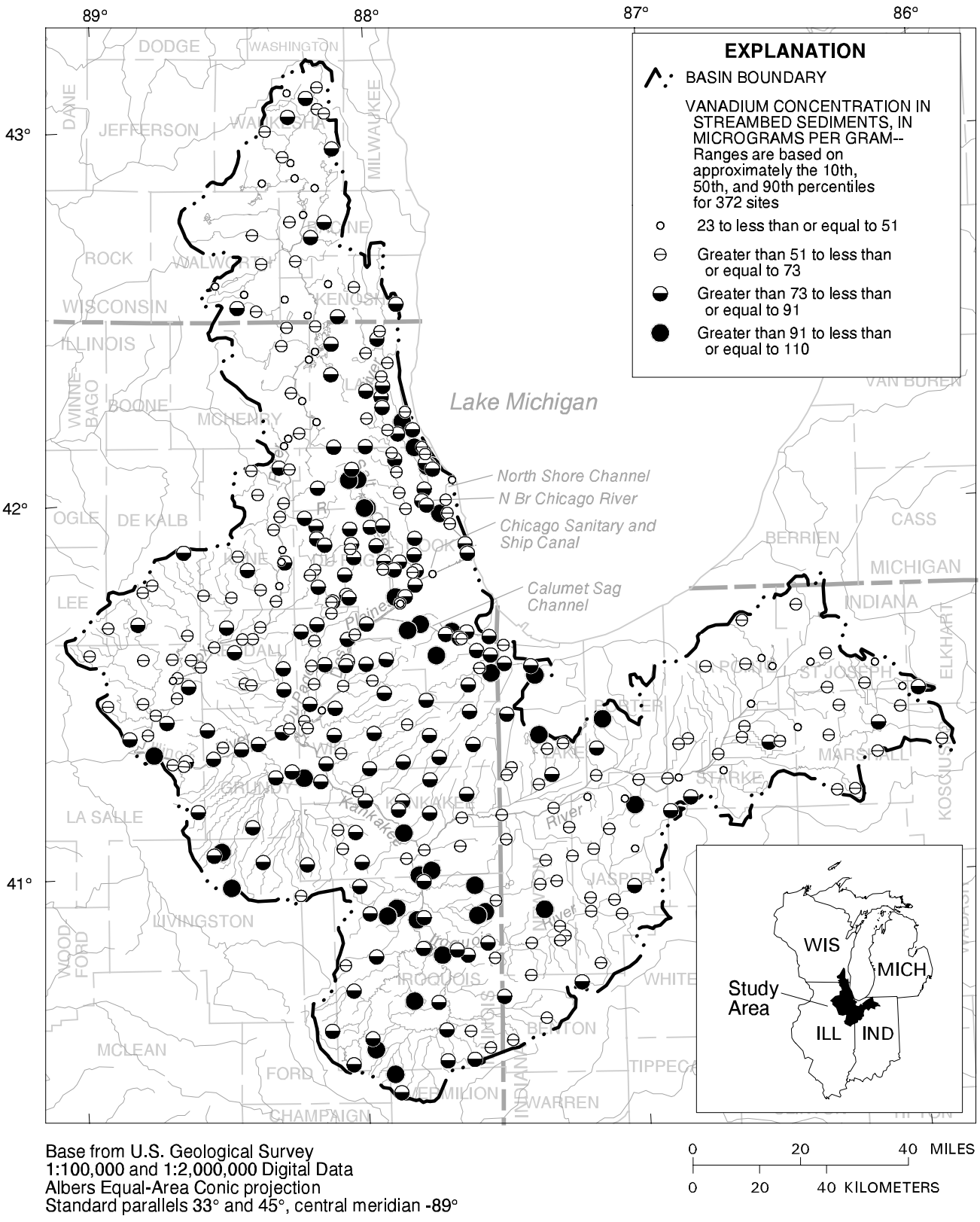


Figure 39. Uranium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.



A

Figure 40. Vanadium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

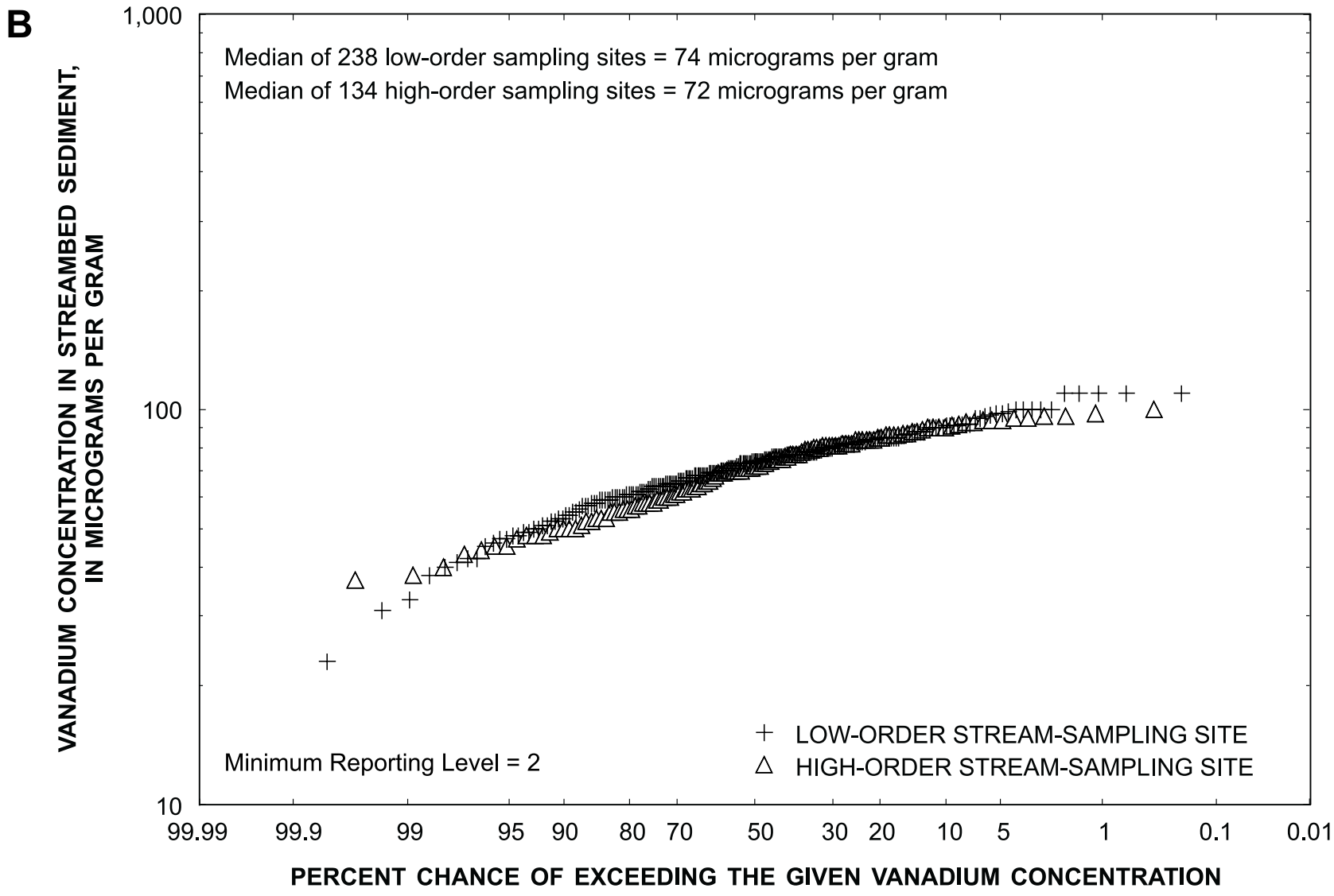


Figure 40. Vanadium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

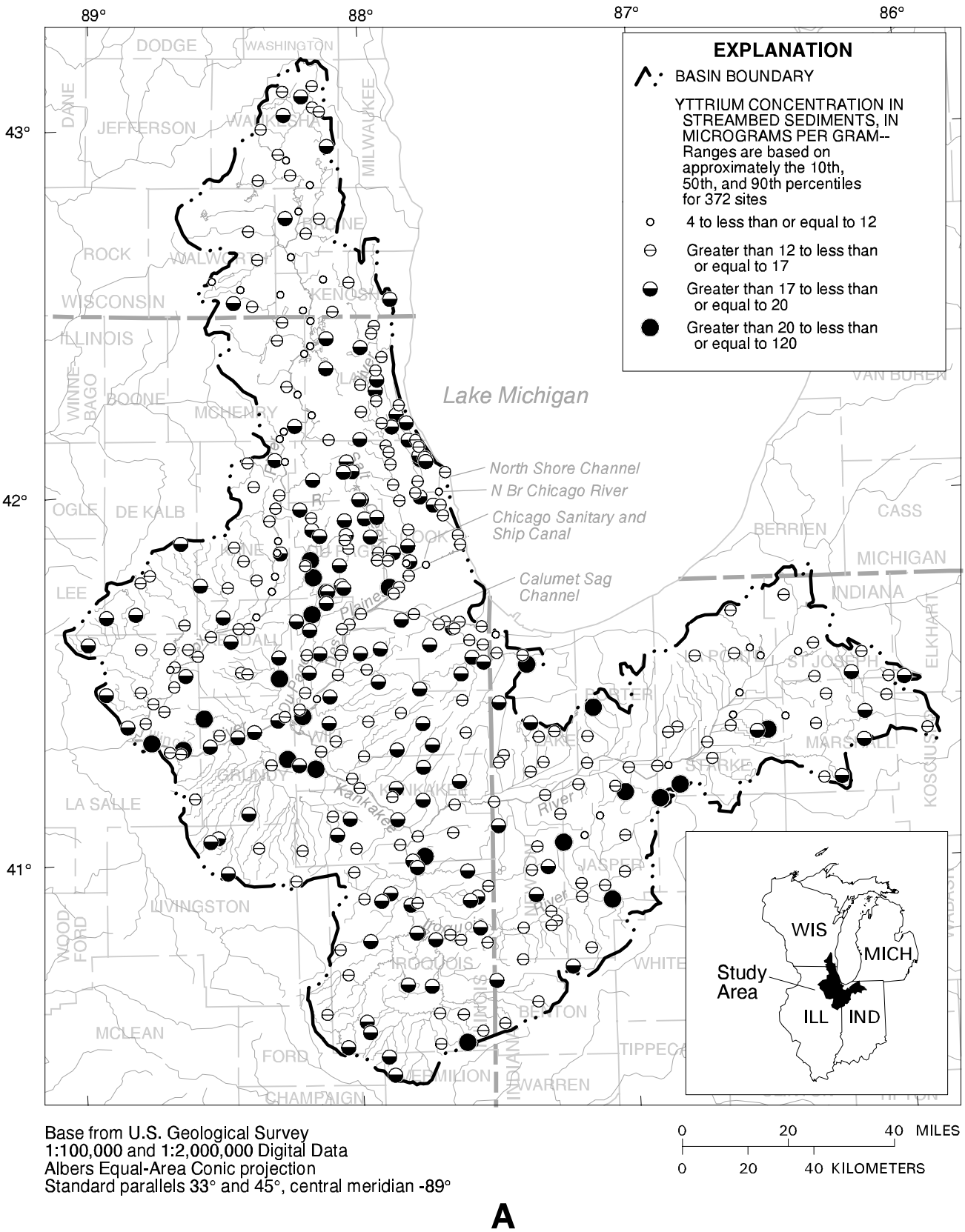


Figure 41. Yttrium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

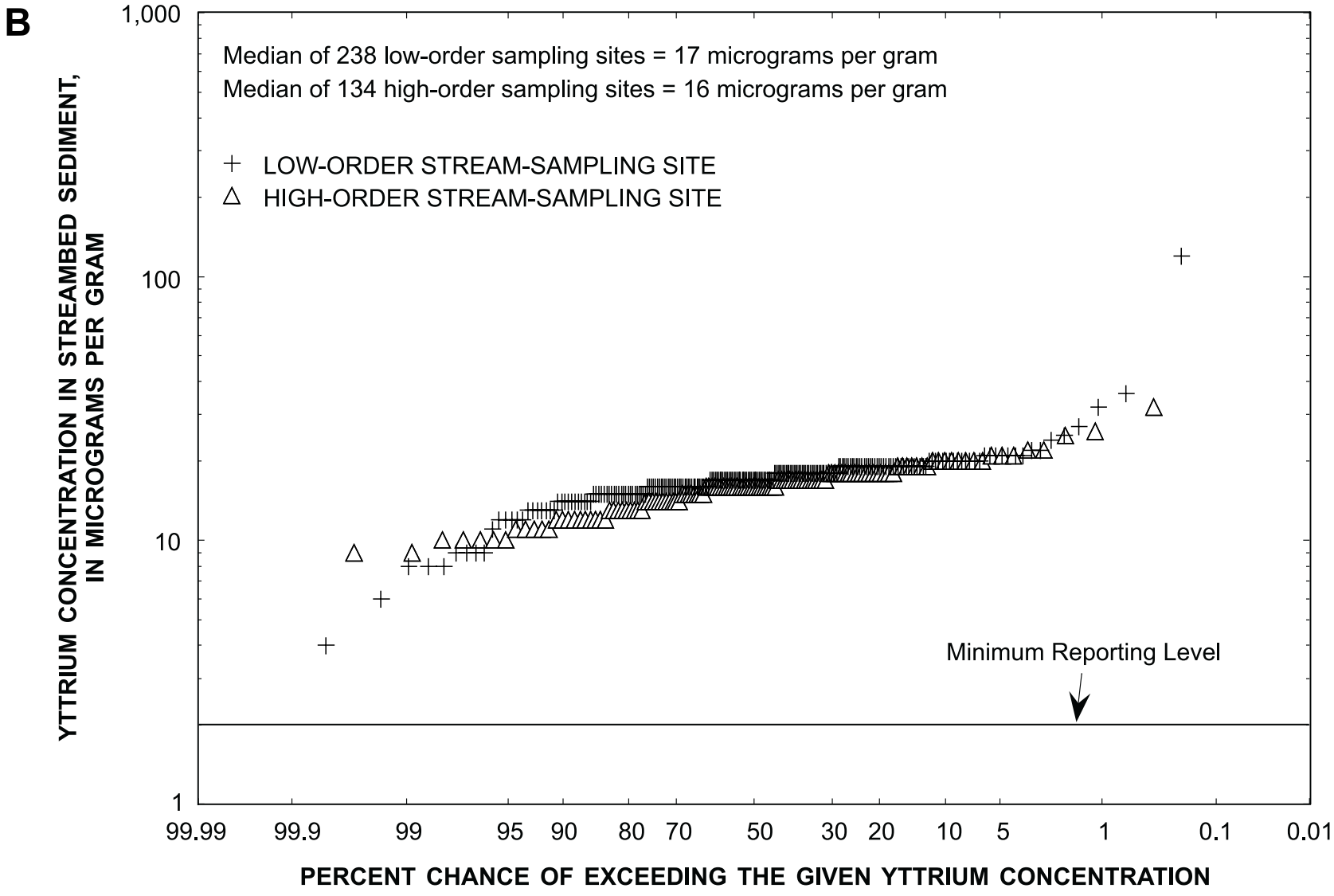


Figure 41. Yttrium concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

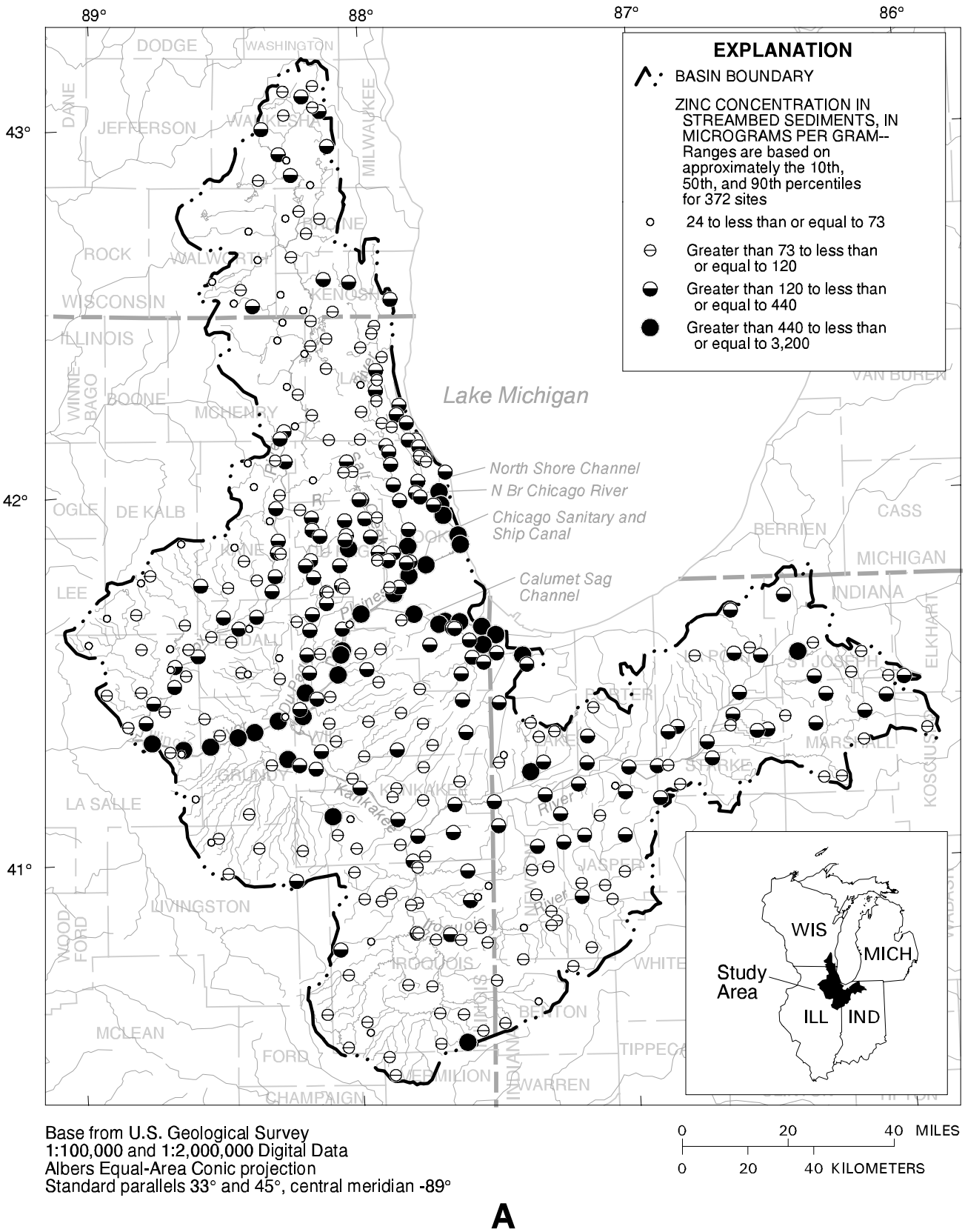


Figure 42. Zinc concentration in fine-grained streambed sediment in the upper Illinois River Basin: (A) map showing spatial distribution.

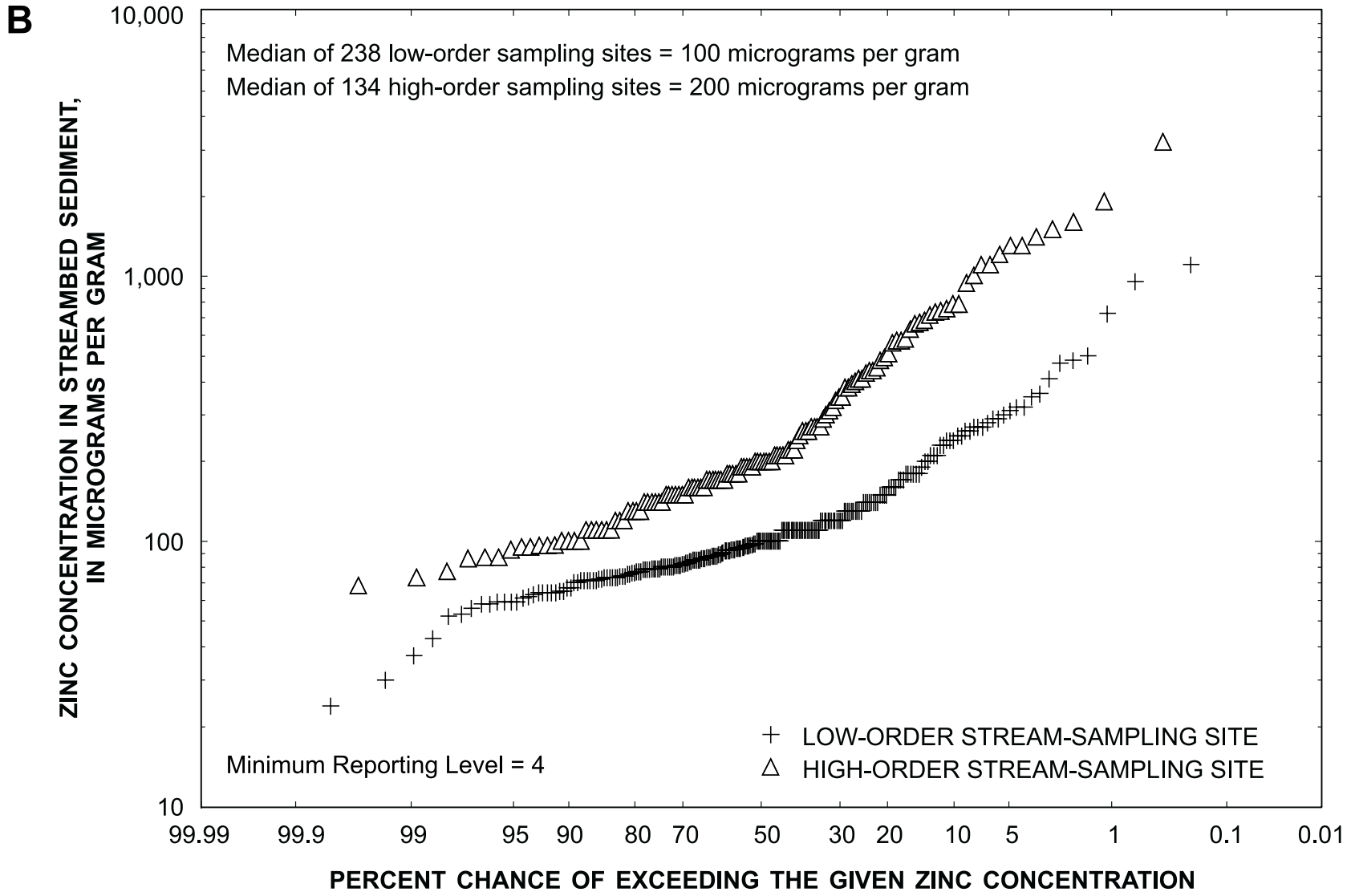


Figure 42. Zinc concentration in fine-grained streambed sediment in the upper Illinois River Basin: (B) exceedance probability plot.

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Fitzpatrick, Arnold, and Colman—SPATIAL DISTRIBUTION OF GEOCHEMICALS IN THE FINE FRACTION OF STREAMBED SEDIMENT, 1987—
U.S. Geological Survey Water-Resources Investigations Report 98–4109