How Does Stratification Affect Water Quality?

Some lakes have water quality problems related to the layering of the lake's waters, which occurs in the summer months. Because of its shallowness, Lake Erie is such a lake. During the summer, the warm surface layer of water does not mix with the colder bottom layer of water. If a lot of algae has grown in the lake, decay of the dead algae on the lake bottom may use up all of the oxygen in the cold bottom water layer. When there is no oxygen in the bottom waters, the water is said to be *anoxic*. Fish and other animals cannot live in these anoxic waters. In the fall, the surface water cools and mixes with the bottom water, resupplying the bottom water with oxygen needed for life.

OBJECTIVES

When you complete the activity you will be able to:

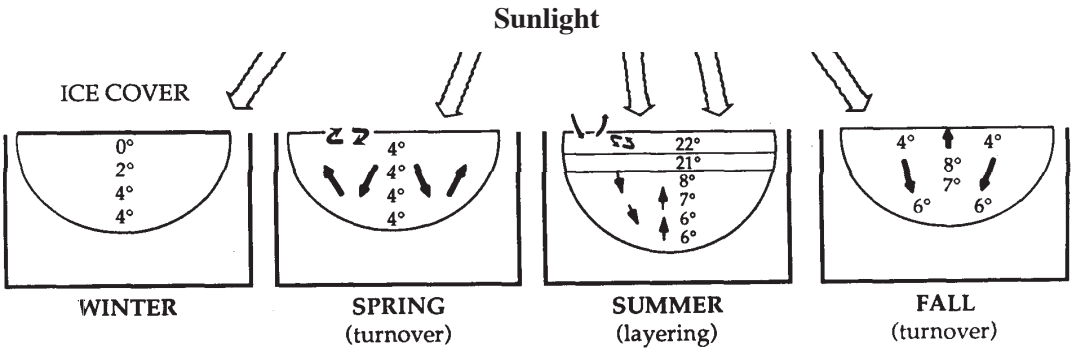
- Describe how stratification of lake waters influences water quality.
- Explain how phosphorus affects oxygen levels in lakes.

PROCEDURE

A. Look at the diagrams of Lake Erie on your worksheet (Figure1). The shaded area on each diagram shows the part of the Lake that was anoxic that year. These parts of the Lake contained no oxygen in the water.

   1. In which year do you think the Lake had the largest anoxic area? In which year does the Lake seem to have had the smallest anoxic area?

B. On the anoxia diagrams (Figures 2-6), use the string and ruler method to measure the perimeter of the anoxic part of the Lake in 1930. Stretch the string all the way around the perimeter (outer edge) of the shaded anoxic part. Then stretch the string along the ruler to measure its length in cm. The length of the string is equal to the perimeter of the anoxic part of the Lake. You may want to tape the string in place at your starting point or mark your starting point with your pencil.



Source

Modified from OEAGLS EP - 28 "Lake Layers: Stratification" by Chris Brothers, David A. Culver, and Rosanne W. Fortner.

Earth Systems Understandings

This activity focuses on Earth Systems Understandings 3 and 4 (scientific process and interacting subsystems).

Materials

- Worksheet and diagrams of anoxic areas in Lake Erie.
- Ruler.
- String.

Answers

1. The Lake had the largest anoxic area in 1973. The smallest anoxic area occurred in 1930.

2. What was the perimeter of the anoxic section in 1930 (Figure 2)?

C. Repeat step 2 for the diagrams of the Lake in 1964, 1973, 1976, and 1982 (Figures 3-6). Enter the perimeter of the anoxic part of the Lake for each year in the chart on your work sheet.

D. Using the steps for finding the area of a circle from its circumference, find the area of the anoxic section of the Lake from its perimeter. The formula you should use is $A = C^2/4$.

Although the anoxic section is not a perfect circle in shape, we will use this method to estimate the area of the anoxic part of the Lake from the perimeter you measured. Enter the area of the anoxic part of the Lake for each year in the chart on your worksheet.

3. In which year did the Lake have the largest anoxic area? In which year did it have the smallest anoxic area? How do these results compare to your earlier predictions?

E. Look at the map of Lake Erie divided into its three geographic basins (Figure 7), the Eastern, Central, and Western basins. Match the basins on this map with your map of the Lake showing anoxic areas.

4. In which Basin of the Lake are the anoxic areas found?

5. Looking at the map of Lake Erie divided into basins, what is the average depth in each of the three Basins?

Usually only lakes that are deeper than 40 feet or 12 meters stratify into temperature layers during the summer.

6. Which of the three basins in Lake Erie will stratify in the summer?

7. Does the Western Basin stratify during the summer? Why or why not? Will it become anoxic?

Answers

2. The perimeter of the anoxic section is approximately 3.6 cm.

3. The Lake had the largest anoxic area in 1973. The smallest anoxic area occurred in 1930.

4. Anoxic areas are found in the Central Basin. The small black dots in the Western Basin are islands, not anoxic areas.

5. Average depth of the Lake in the Eastern Basin is 80 feet (24 meters), the Central Basin, 60 feet (18 meters), and the Western Basin, 24 feet (7 meters).

6. The Eastern and Central Basin will stratify.

7. The Western Basin does not become anoxic because it does not stratify. It is shallow enough that oxygen is continually mixed and supplied to all depths of the Lake by wind and wave action.

Although the Eastern Basin stratifies during the summer, it does not become anoxic. This is because it is so deep. Deep waters are cold, while shallow waters are warm. Cold water can hold much more oxygen then warm water can.

The supply of oxygen in the cold waters of the Eastern Basin at the beginning of the summer is high. Oxygen at the bottom of the Lake is used throughout the summer by animals living there and in the decay of dead algae. Stratification of the lake's waters prevents more oxygen from reaching the bottom water. Even so, the oxygen supply in the Eastern Basin does not get used up during the summer, because the supply was very high at the beginning of the summer.

8. Is the Central Basin deeper or shallower than the Eastern Basin? Which of the two basins will have warmer bottom waters? Which of the two basins will have less oxygen in its bottom waters at the beginning of the summer? Which of the two basins will most likely become anoxic?

9. What might happen to fish and other animals living in the Central Basin when it becomes anoxic?

The farm fertilizers and the laundry detergents we use both contain a chemical called phosphorus. When fertilizers from farms or sewage containing detergents flows into a lake, phosphorus enters the lake as well. Phosphorus is a nutrient needed by all plants, including algae, to grow. When a large amount of phosphorus enters a lake, it may cause algae to grow and grow very rapidly. The result may be too much algae. The algae may use up the oxygen in the water, both through its own growth and as it decays. See Figure 8.

10. What happens to the lake when growth and decay of algae uses up all the oxygen?

People started putting phosphorus into detergents in the late 1950s. Before that, phosphorus was not used in detergents.

11. Explain the large anoxic areas that occurred in Lake Erie during the 1970s. How can you explain the smaller anoxic areas that occurred in 1930 and 1960?

Answers

8. The Central Basin is shallower than the Eastern one, its bottom waters are warmer, and they contain less oxygen at the beginning of the summer. Thus, the Central Basin is more likely to become anoxic.

9. Fish and other animals cannot live in anoxic waters. They may die from suffocation or they may move to areas of the Lake that still contain oxygen. There may be a change in the kinds of fish living in the Lake from species needing cold, high oxygen waters (trout and whitefish) to fish that can survive in warmer waters with less oxygen (carp).

10. The lake becomes anoxic.

11. Large anoxic areas in the 1970s probably resulted from large amounts of phosphorus from laundry detergents entering the Lake. The smaller anoxic areas in 1930 occurred before phosphates came into use. Although phosphates were being used by 1960, not as much phosphorus had entered the Lake by 1960 as had by the 1970s.

Answers

12. Such laws, called phosphorus bans or limits, were passed to reduce the amount of phosphorus entering the Lakes. It was hoped that by reducing the amount of phosphorus entering the Lakes, algae growth and anoxic areas could also be reduced.

13. Reducing the amount of phosphorus entering the Lake has contributed to a reduction in algae growth in the Lake. With less algae growth, smaller areas of the Lake became anoxic during the 1980s.

14. As less phosphorus enters Lake Erie, anoxic areas of the Lake should decrease in size. However, phosphorus will still be entering Lake Erie from farm runoff and other sources.

Note: In more recent years, data on anoxia have been collected differently, and equivalent diagrams cannot be constructed. There is evidence of smaller anoxic areas in the 1990s.

Online Resources

Use GLIN of GLIMR and search for nutrient information.
GLIN: http://www.great-lakes.net
GLIMR: http://www.cciw.ca/glimr/intro.html

In 1978, laws were passed by many states located in the Great Lakes Basin to limit the amount of phosphorus that could be used in detergents.

12. Why do you think laws banning phosphorus in detergents were passed?

The amount of phosphorus entering Lake Erie has been reduced nearly 60 percent in the past twenty years.

13. Relate this information to the fact that the size of anoxic areas in the Lake seems to have decreased since 1976?

In January of 1990, the State of Ohio joined other Great Lakes states that have reduced phosphorus in detergents.

14. Predict the size of the anoxic area of Lake Erie in the 1990s if phosphorus continues to be reduced in the Lake.

Extension

1. Nutrients in the Great Lakes are addressed by activities in both the "Environmental Issues" and the " Life in the Great Lakes" ES-EAGLS collections. The activities relate to eutrophication and water quality in the Great Lakes. Students investigate the impact of nutrients in a lake by observing algae growth in samples of lake water and plot the amounts of nutrients reaching a lake following a storm to learn about the role of wetlands in improving water quality.

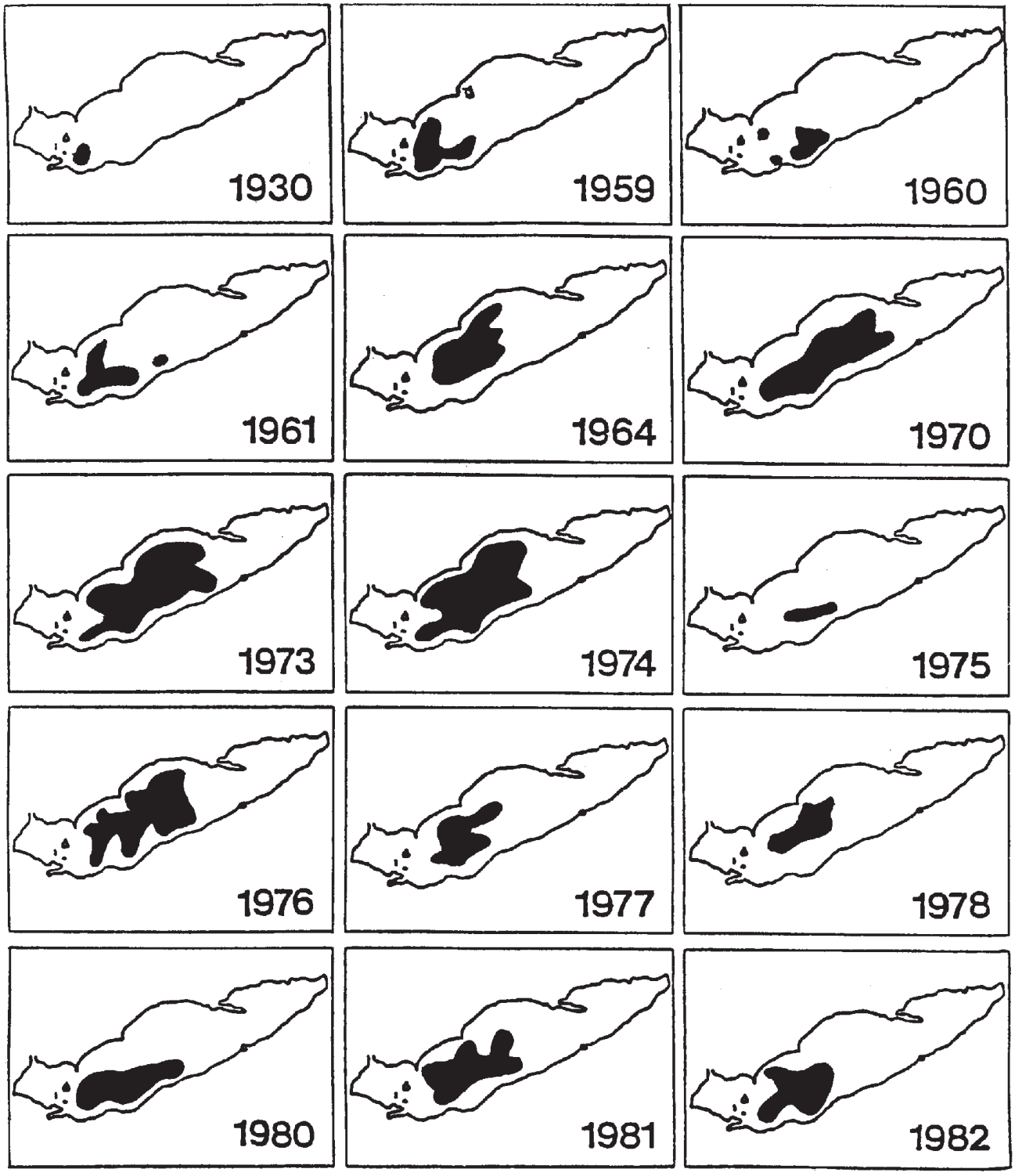
2. Have students check the phosphorus content of the detergents their families use. Most brands include this information in the list of ingredients. Which detergents contain the most and the least amounts of phosphorus? How important is this in the students' minds? Can one family make a difference?

3. Have students do research on the farming practices used in their area. What is no-till agriculture? Are any farmers using it? What are the advantages and disadvantages of no-till? Students could interview farmers or county Soil and Water Conservation District staff to find out.

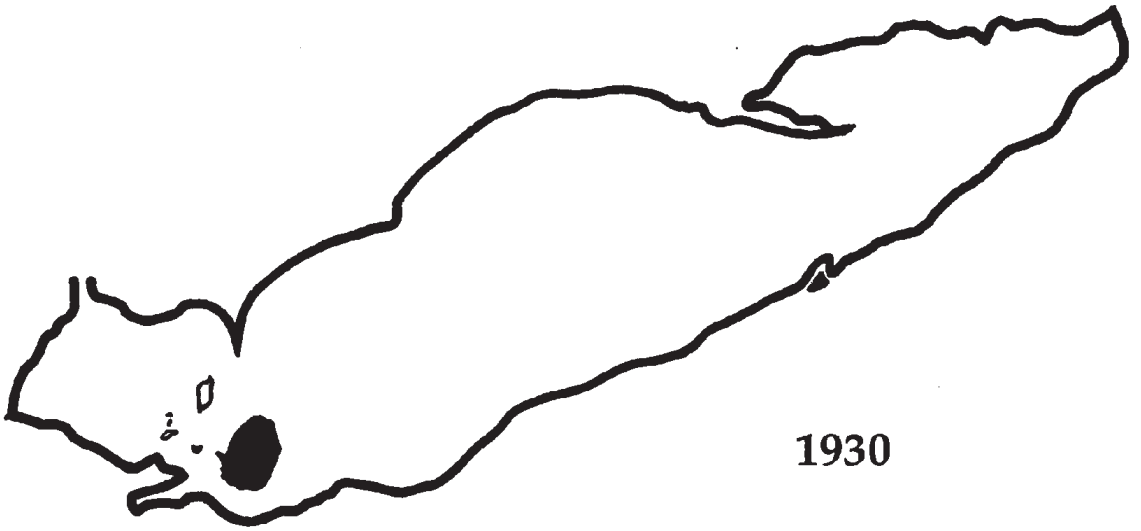
Reference

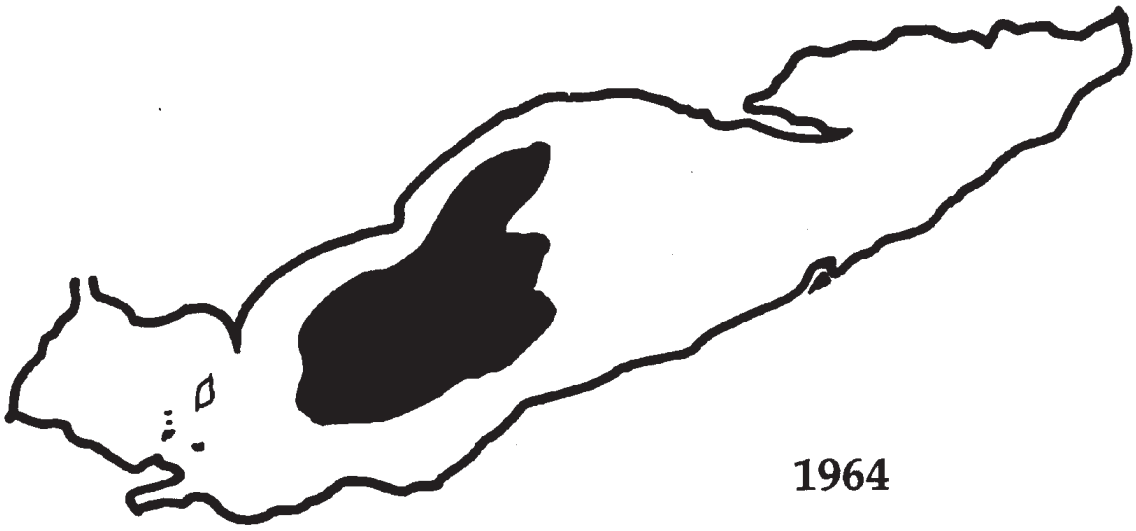
Herdendorf, Charles E. "Recovering from Phosphorus Enrichment." *The Great Lake Erie*. 1993. Rosanne W. Fortner and Victor J. Mayer, editors. Ohio Sea Grant, Columbus, OH.

Figure 1. Anoxia Diagrams of Lake Erie 1930 - 1982.

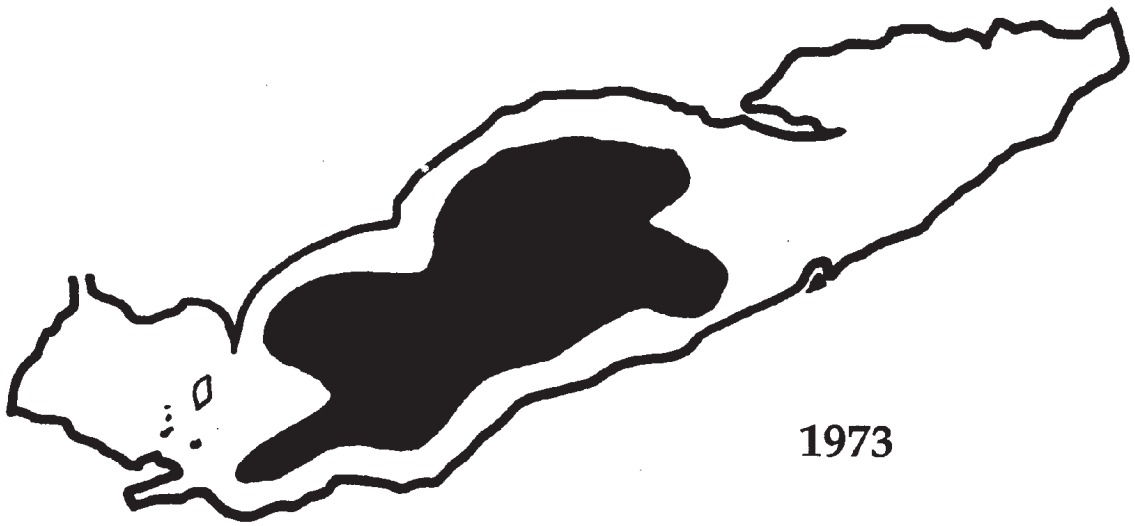


Figures 2 and 3. Anoxia Diagrams of Lake Erie.





Figures 4 and 5. Anoxia Diagrams of Lake Erie.



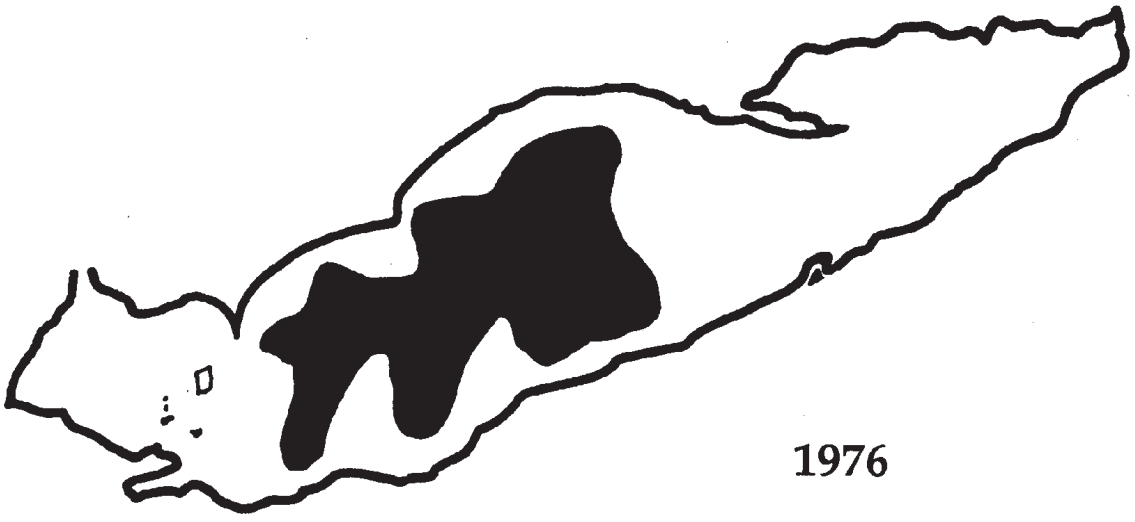


Figure 6. Anoxia Diagram of Lake Erie.

Figure 7. Three Basins of Lake Erie.

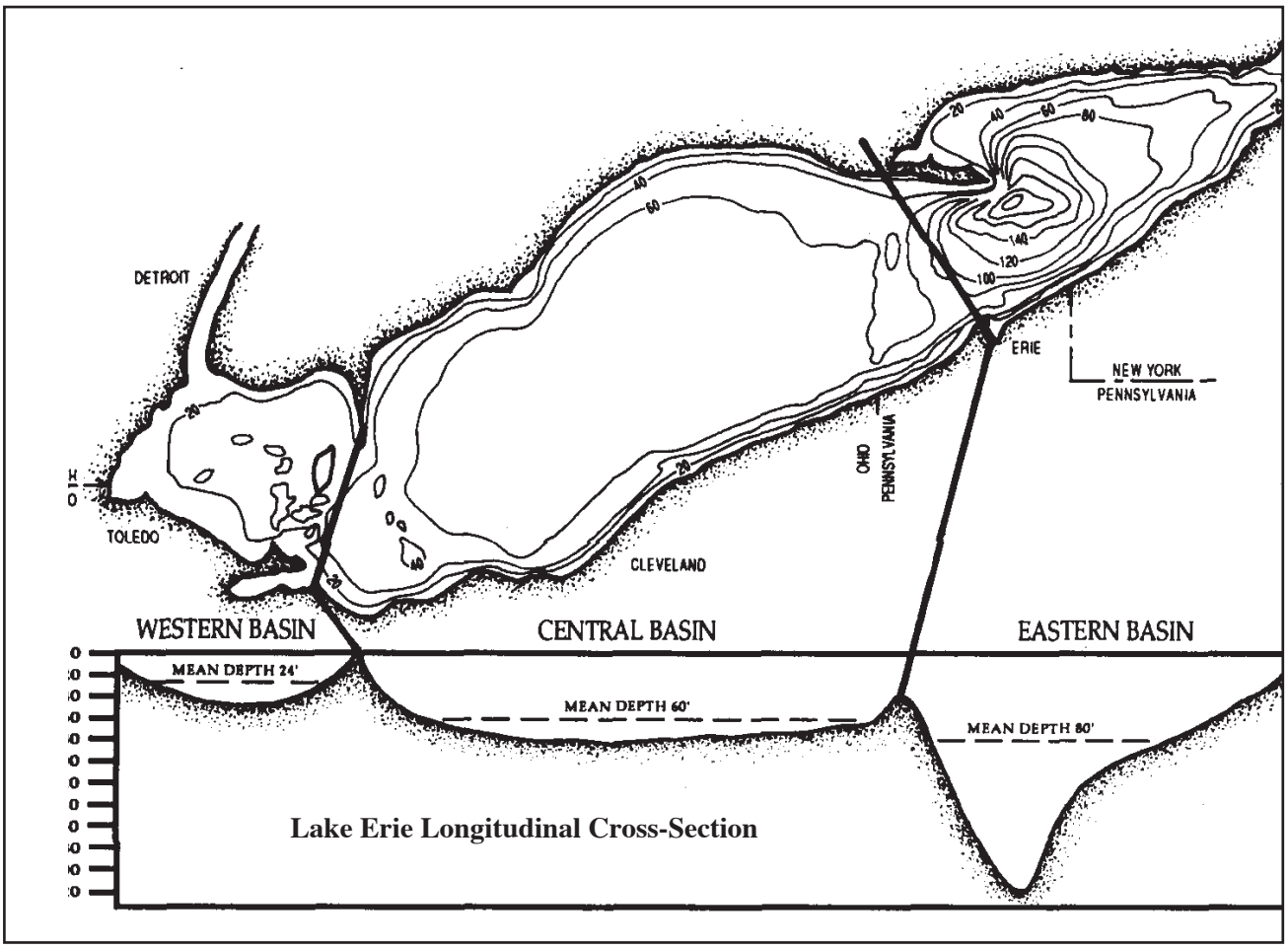


Figure 8. Cultural Eutrophication (Accelerated aging of lakes).