How does water move in the Great Lakes basin?

You are familiar with the water cycle. The sun heats the surface of the earth, water evaporates, water vapor rises in the atmosphere cools and condenses, precipitation falls and then water flows in the streams, rivers, lakes and oceans. In this activity you will find out how water moves in the Great Lakes system.

OBJECTIVES

When you complete this activity you will be able to
- Locate and identify the Great Lakes on a map.
- Identify the connecting waters.
- Define water basin.
- Begin an analysis of the flow of water.

PROCEDURE

1. A basin is the area that a lake or river drains. Look at the direction that the rivers flow on your map and draw the basin lines around the Great Lakes so that all rivers that drain into the lakes are enclosed and any river that does not drain into the Great Lakes is outside of the basin. Each lake basin should be outlined in a different color.

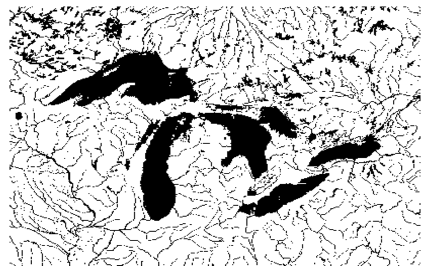
2. Compare your map with that of other students and resolve any differences you detect. Discuss the great differences in watershed sizes. Does the biggest watershed determine the biggest lake? What other factors may be involved in lake size?

3. Locate the following and label them on your map.

   Lakes: Erie, Georgian Bay, Huron, Michigan, Nipigon, Ontario, St. Clair, Superior.

   Rivers and Connections: Mackinac, Niagara, St. Lawrence, St. Marys, Detroit.

4. If you did not know which way the water flowed through the lakes, what information would you need to find your answer?



Authors

Richard Meyer and Rosanne W. Fortner

Earth Systems Understandings

This activity focuses on ESU's 3 and 4 (scientific process and interacting subsystems).

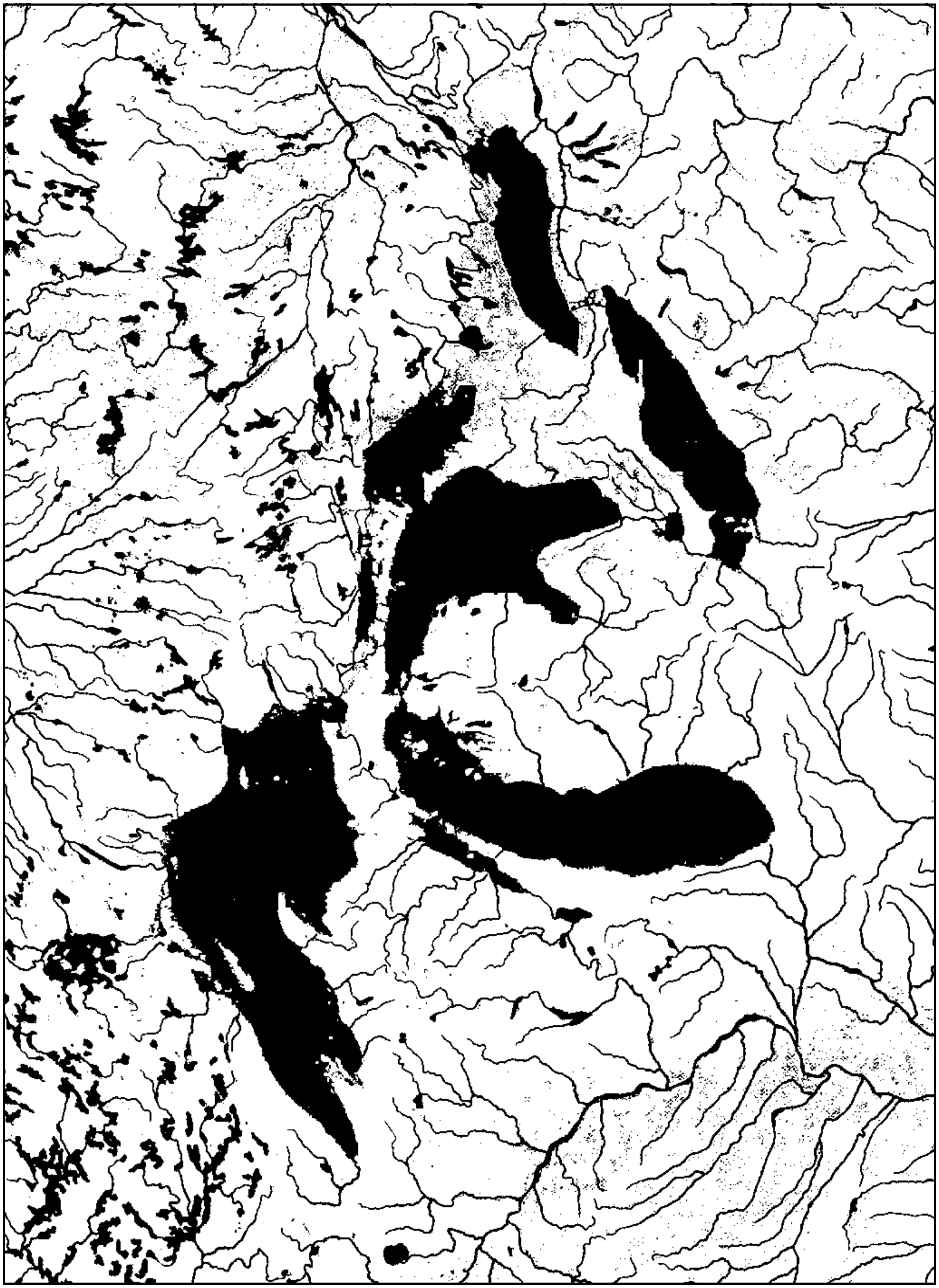
Materials

- Copies of the Map of the Great Lakes area. (One per student.)
- Colored pencils or markers.
- Copies of activity data charts.
- Paper, rulers and other supplies for student chart / diagram making.
- Atlas or Maps of Great Lakes area.

Teacher Notes

You might want to follow this activity with the activity *Out One Lake and In Another - How long does it take water to flow through the Great Lakes?*

Jigsaw: Students could work in expert groups, each group assigned a different lake to focus on and then return to base groups to put together an over all map and to share what they found significant about their lake.



Rivers of the Great Lakes Region

Modified from "Water," a map produced by the National Geographic Society, 1993

5. Examine Table 1 about the Great Lakes water system and choose some part of the data set that you find significant, develop a chart, diagram or some other meaningful way to display the chosen data. (Table 2 provides you with some background information about the Great Lakes. You may want to use it to help analyze Table 1.)

6. Share your chart, diagram or display with the class demonstrating how/why the data were significant to you.

Teacher Note

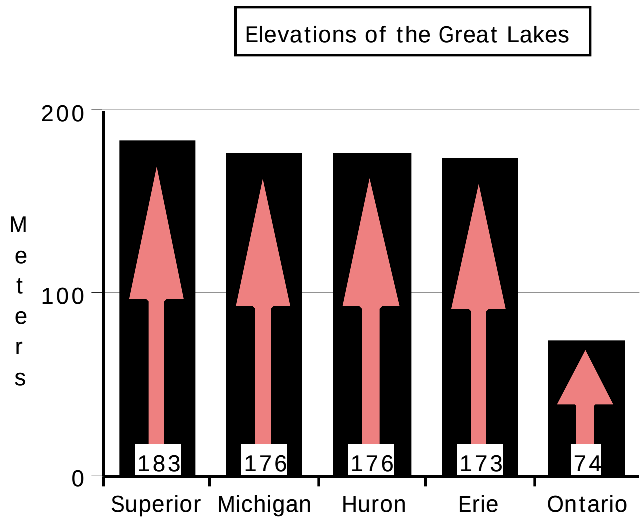
4. Elevation of lakes is the most logical.
5. Students may find that some of the numbers do not add up. (Input does not always equal output.) Have them hypothesize possible explanations (groundwater inflow and outflow, numbers rounded off, human use, etc.). The hypotheses could be used for further exploration.

The Great Lakes Water System (Figures are in thousands of cubic meters per second)	Runoff into lake	Precipitation into lake	Inflow from upstream lake	Evaporation from lake	Outflow
Lake Superior	1.4	2.1	0.2	1.4	2.2
Lake Michigan	1.0	1.5	----	1.2	1.6
Lake Huron	1.4	1.5	3.7	1.2	5.3
Lake Erie	0.7	0.7	5.3	0.7	6.0
Lake Ontario	0.9	0.5	5.8	0.4	7.1

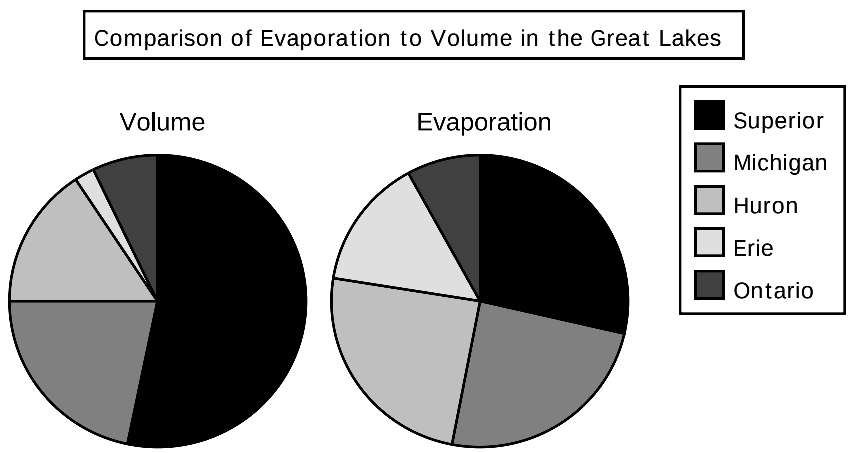
Table 1 - The Great Lakes Water System

Physical Data	Superior	Michigan	Huron	Erie	Ontario
Elevation (meters)	**183**	**176**	**176**	**173**	**74**
Length (kilometers)	**563**	**494**	**332**	**388**	**311**
Breadth (kilometers)	**257**	**190**	**245**	**92**	**85**
Avg. Depth (meters)	**147**	**85**	**59**	**19**	**86**
Max. Depth (meters)	**406**	**282**	**229**	**64**	**244**
Volume (km3)	**12,100**	**4,920**	**3,540**	**484**	**1,640**
Surface Area (km2)	**82,100**	**57,800**	**59,600**	**25,700**	**18,960**
Drainage Area (km2)	**127,700**	**118,000**	**134,100**	**78,000**	**64,030**
Total (km2)	**209,800**	**175,800**	**193,700**	**103,700**	**82,990**
Shoreline (km)	**4,385**	**2,633**	**6,157**	**1,402**	**1,146**
Retention (years)	**191**	**99**	**22**	**2.6**	**6**
Population 1980/81	**738,540**	**13,970,900**	**2,372,119**	**12,968,606**	**6,642,175**
1990/91	**607,121**	**10,057,026**	**2,694,154**	**11,682,169**	**8,150,895**

Table 2 - Physical Data of the Great Lakes (Data for Table 1 and 2 from: The Great Lakes - An Environmental Atlas and Resource Book, 1987 and 1995, US EPA & Environment Canada)



Example 1 of student data comparison for #5. Completed using ClarisWorks spreadsheet and entering the data from Table 2



The volume of Lake Superior is over 50% of the total Great Lakes volume compared to the evaporation where it is much less in comparison to the other lakes. Lake Erie on the other hand has a very small volume compared to the other lakes but a high evaporation rate. Why?

Example 2 of student data comparison for #5. Completed using ClarisWorks spreadsheet and entering the data to be compared from Table 1 and Table 2.

Going with the Flow

A Classroom Activity for *Ducks In The Flow - Where Did They Go?*

Summary:

Students use a simple model to discover that air moving over water causes the surface of the water to move horizontally. In writing and in a discussion, students relate this concept to surface currents in the ocean and the Great Lakes.

Student Learning Outcomes:

Students will be able to

- Relate the motion of surface currents (cause) to the motion of objects floating in the ocean and Great Lakes (effect)
- Relate the transfer of energy from wind moving across water (cause) to the horizontal movement of water (effect)
- Use the term "surface current" to explain horizontal movement of surface water caused by wind
- Explain that surface currents affect surface water, not deep water

Standards:

Ocean Literacy Essential Principles and Fundamental Concepts

- The Earth has one big ocean with many features.

National Science Education Standards

- (K-4) Position and motion of objects
- (5-8) Structure of the earth system
- (5-8) Motions and forces
- (5-8) Abilities necessary to do scientific inquiry

Grade Level: 3-5

Materials: (teams of 2-3 students)

- 5-6 quart clear plastic shoebox (1 per team)
- Water (to fill shoeboxes approximately ¾ full)
- Black construction paper (I per team)
- Bendable straws (1 per student)
- Paper towels (for clean up)
- Newspaper (to cover table/desk)
- *Going with the Flow Data Sheets 1-3* – (1 per student)
- For *Activity 1: Aluminum foil* (Each team crumples 20 one-inch squares into 10 loose balls that will float and 10 tight balls that will sink.)
- For *Activity 2: Rheoscopic fluid* (Dilute 150 ml of rheoscopic fluid in 3 L of water per team; the diluted fluid can be reused.)

Purchase Note: You can purchase rheoscopic (convection) fluid from many online vendors for approximately $10/L:

- Arbor Scientific - www.arborsco.com (# P8-5000)
- Carolina Biological - www.carolina.com (# GEO8450)
- Educational Innovations - www.teachersource.com (# RH-100)
- Fisher Scientific - www.fishersci.com (# S4520 or S4521)

Time: 1-2 class periods (45 minutes each)

For more information, please visit:
www.windows.ucar.edu/ocean_education.html

Activity 1 – Directions and Procedure

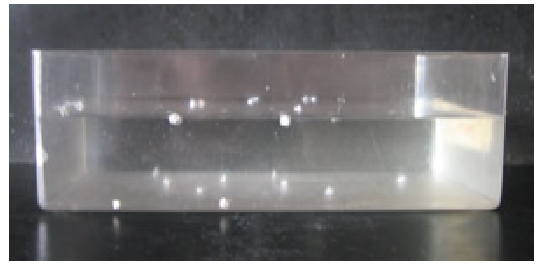


Figure 1: Some of the aluminum balls should sink and some should float.

1. ***Build the model***:

- Fill the ocean basin (shoe box) ¾ full with ocean water (water).
- Add the aluminum balls.
- Make sure that some sink to the bottom (deep water) and some float (surface water) – (Figure 1).
- Place the black paper under the model to improve visibility.

2. Relate the model to reality: Lead the class to complete the following graphic organizer and/or analogy notation on the board or overhead, prior to beginning the activity.

Graphic Organizer:

MODEL	REALITY (students answer)
Box	Ocean Basin or Great Lake basin
Water	Ocean or Great Lakes water
Air moving through the straw	Constant wind
Floating aluminum balls	Objects floating with the surface current or surface water molecules
Sunk aluminum balls	Objects deep in the ocean or deep water molecules

Analogy Notation:

Box : Lake Michigan Basin :: Air moving through straw : ______________

Answer: Constant wind

Box : Lake Michigan Basin :: Floating aluminum balls : ______________

Answer: Objects floating in the ocean or Great Lake or surface water molecules

Box : Lake Michigan Basin :: Sunk aluminum balls : ______________

Answer: Objects deep in the ocean or Great Lake/deep water molecules

Box : Lake Michigan Basin:: water : ________________

Answer: Ocean or Great Lakes Water

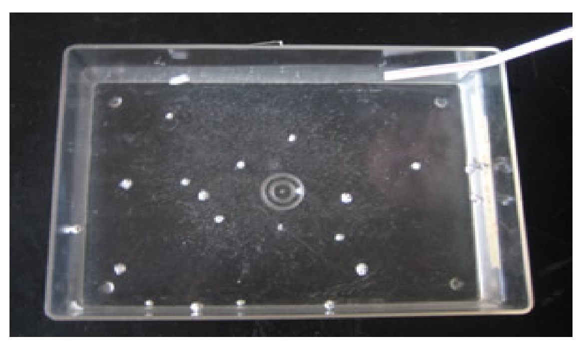


Figure 2: Straw placement while blowing.

3. ***Simulate wind***:

- The water begins still.
- Students place the shorter section of the bendable straws parallel to the surface of the water.
- One student in the team blows through the straw to simulate wind. Students blow horizontally (not down into the water) with the tip of the straw near the surface of the water and near the edge of the basin (shoe box) (Figure 2). The wind (blowing air) should be just hard enough to make ripples. With younger students, demonstrate the proper technique before beginning. The student creates wind in the same direction for 30 seconds.

Content Notes:

This models wind blowing across ocean water. The wind causes both little waves (ripples) and *surface currents. This activity simulates how wind makes surface water move by transferring energy to the water.*

The major ocean currents move in large cyclic patterns. This activity is not a good model for explaining that circulating pattern. The major ocean circulation occurs primarily because of the Coriolis Effect, which will be explained in the Ocean in Motion *activity.*

4. ***Observe the Motion***:

- The student not simulating the wind draws what s/he observes on *Data Sheet – Activity 1, Page 1* (Windy Observation boxes). S/he uses arrows to describe the motion and direction of the aluminum balls and wind (blown air).
- The student should differentiate between observations of floating balls and sunken balls.

Content Note: *The surface currents affect the floating balls but not the sunken balls; similarly, ocean surface currents do not affect deep water.*

5. Students switch roles. The second wind maker blows in the same direction and at the same intensity as the first wind maker. The second observer records his/her observations on his/her copy of *Data Sheet – Activity 1, Page 1* (Windy Observation boxes). Repeat until everyone has a turn at both roles.

6. ***Simulate Calm and Observe the Motion***:

- Students stop blowing and wait 5 seconds to simulate a brief calm (ocean wind stops blowing for a short interval).
- Students draw observations on *Data Sheet – Activity 1, Page 2* (Calm Observation Boxes).

Content Note: *This models short lulls in winds. The water does not immediately stop moving, because the wind transfers energy to the water. The water continues moving until the energy is dissipated as heat or transferred to the side of the basin (shoe box).*

7. ***Relate the model to reality***:

- Guide students to connect their observations of the model to the motion of water in the ocean and wind blowing over the ocean and to the *Ducks in the Flow – Where Did They Go?* storybook. The aluminum balls model objects floating in the ocean, such as the ducky in the storybook. The questions on *Data Sheet – Activity 1, Page 3* guide this discussion.

Key Points:
1) Wind makes surface water of the ocean (and Great Lakes) move.
2) Wind transfers energy to the water. When the wind stops for a brief amount of time, the currents continue to flow, because the water still has energy.
3) Objects floating in the ocean (or Great Lakes) will move with the currents. The ducky in the Ducks in the Flow, Where Did They Go? *storybook traveled, because it floated in surface currents.*
4) Surface currents affect the surface water; deep water does not move with the currents.

Activity 2 – Directions and Procedure

Content Note: *Children may think that the aluminum balls in Activity 1 moved only because the wind blew on the balls, as with the motion of a sailboat. Though not completely untrue, this focuses attention on wind power, not surface currents. In this second activity, children more directly visualize currents using rheoscopic fluid, as opposed to indirectly inferring currents using floating objects.*

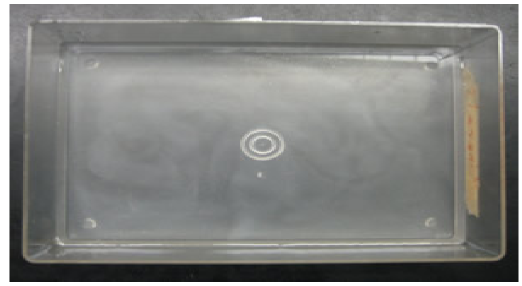


Figure 3: Water with Rheoscopic fluid before the "wind" is applied.

1. ***Build the model***:
- Fill the basin (shoe box) ¾ full with ocean water (diluted rheoscopic fluid) (Figure 3).
- Place the black paper under the model to improve visibility.

2. ***Relate the model to reality:*** Lead the class to complete the following graphic organizer and/or analogy notation on the board or overhead, prior to beginning the activity.

Graphic Organizer:

MODEL	REALITY (students answer)
Water with Rheoscopic fluid	Ocean or Great Lakes water
Box	Ocean Basin or Great Lake basin
Air moving through the straw	Constant wind

Analogy Notation:

For Beginners - Box : Lake Michigan Basin :: Water with Rheoscopic fluid : _______________

Answer: Ocean or Great Lakes Water

For Advanced Students - Box : Air moving through straw :: Lake Michigan Basin : _______________

Answer: Constant wind

3. ***Simulate wind***:
- The water begins still.
- Students place the shorter section of the bendable straws parallel to the surface of the water.
- One student in the team blows through the straw to simulate wind. Students blow horizontally (not down into the water) with the tip of the straw near the surface of the water and near the edge of the basin (shoe box) (Figure 4). The wind (blowing air) should be just hard enough to make ripples. With younger students, demonstrate the proper technique before beginning. The student creates wind in the same direction for 30 seconds.

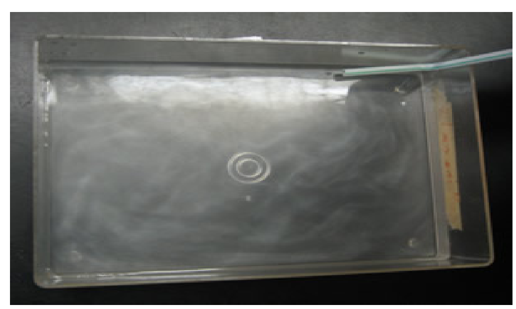


Figure 4: Water 10 seconds after "wind" begins to blow.

Content Notes: *This models wind blowing across ocean water. The ripples are not currents – they are little waves. This activity simulates how wind makes surface water move by transferring energy to the water.*

4. ***Observe the Motion***:

- The student not simulating the wind draws what s/he observes on *Data Sheet – Activity 2, Page 1* (Windy Observation boxes).
- S/he uses arrows to describe the motion and direction of the aluminum balls and wind (blown air).

5. Students switch roles. The second wind maker blows in the same direction and at the same intensity as the first wind maker. The second observer records his/her observations on his/her copy of *Data Sheet – Activity 2, Page 1* (Windy Observation boxes). Repeat until everyone has a turn at both roles.

6. ***Simulate Calm and Observe the Motion***:

- Students stop blowing and wait 5 seconds to simulate a brief calm (*ocean wind stops blowing for a short interval*).
- Students draw observations on *Data Sheet – Activity 2, Page 2* (Calm Observation Boxes).

7. ***Relate the model to reality***:

- Guide students to connect their observations of the model to the motion of water in the ocean and wind blowing over the ocean and to the *Ducks in the Flow – Where Did They Go?* storybook. The questions on *Data Sheet – Activity 2, Page 3* guide this discussion.

  Key points:
  1) Wind makes surface water in the ocean (and Great Lakes) move.
  2) Wind transfers energy to the water. When the wind stops for a brief amount of time, the currents continue to flow, because the water still has energy.
  3) Objects floating in the ocean (or Great Lakes) will move with the currents. The ducky in the Ducks in the Flow, Where Did They Go? *storybook traveled, because it floated in surface currents.*

Scientifically Accepted Explanation

In the classroom model, air blows over the surface water causing the water to move, pushing along more water, and setting up a miniature surface current. When wind blows over the ocean, the wind pushes the water and the water moves.

Some wind blows almost all the time. For example, the "Trade Winds" blow constantly over ocean water near Hawaii, and the "Westerlies" blow constantly over water off the west coast of the United States and Canada. These winds have been blowing in the same direction and fairly constantly for centuries. These constant winds push large, constant surface currents. Like the winds, surface currents are ancient and reliable.

In the model, the children stop blowing to simulate calm. Even if constant winds, like the Trade Winds, slow temporarily, the major ocean surface currents continue to move during these lulls, as in the model. Similarly, the direction of surface winds may temporarily change due to a storm. Nonetheless, the overall average direction and strength of the winds remains very constant, so the large surface currents in the oceans are very consistent.

Sometimes, wind blows and then stops, like a passing breeze or storm; it is inconsistent. Less constant winds can also cause small, short-lived surface currents. For example, if a child is fishing in a lake using a fishing float, and a breeze is blowing across the lake, the breeze may cause a temporary surface current that pushes the fishing float toward shore.

Surface currents are different from waves. Waves may cause floating objects (like the fishing float) to move up and down and back and forth, but the object will not ever progress in any one direction. The fishing float in this example will "bob" in the waves, but it will not be pushed to shore.

In the model, the aluminum balls move with the surrounding water – the water pushes the balls. The aluminum balls model objects such as the toy duck in *Ducks in the Flow – Where Did They Go?* Scientists track surface currents using special floating buoys called "drifters". In the storybook, the toy ducks and other plastic animals that were lost overboard in a shipwreck served as accidental drifters and were also tracked by scientists to map surface currents.

In the classroom activity, the surface water moves while the deeper water remains still. Surface currents do not extend to the deeper parts of the ocean. In the classroom model, "deep" refers to a few centimeters. In the ocean, "deep" refers to over a hundred meters (in some places more than 200 m!), depending on the location and season. In the classroom activity, the surface currents did not move in a straight line because they bounced off the sides of the container. In the ocean, surface currents also bounce off the sides of the ocean basins. However, the large-scale swirling of surface currents all around the ocean is caused by the Coriolis Effect (see the *Ocean in Motion* activity).

More Advanced Explanation

When wind blows over water, wind transfers kinetic energy to water molecules. The water molecules then transfer kinetic energy to the water molecules in front and just below them, setting up the ocean-wide surface currents. This kinetic energy is the reason why the surface current in the model does not stop immediately, even when the "wind" is calm. It takes a few minutes for the energy to dissipate into heat energy or be transferred to the sides of the "basin". The aluminum balls, floating plastic duckies, and drifter buoys move in currents because water molecules push against these objects.

The direction of the constant winds over the ocean (Westerlies, Easterlies, or Trade Winds) varies with latitude and depends on the Coriolis Effect. In the Northern hemisphere, the Trade Winds found at the latitude of Hawaii tend to blow south and are curved to the right, or west, due to the Coriolis Effect. The Northern “Westerlies” that affect most of North America tend to blow North and curve to the right, or east. The result of these winds can be seen in the surface current patterns in the ocean.

Connection to the Great Lakes

Surface currents are affected by the direction of the prevailing winds and Coriolis Effect, but they are also affected by the land masses that the moving water bumps into. This is particularly obvious in inland seas like the Great Lakes. Because the Great Lakes are smaller than the ocean, surface currents hit land sooner. Therefore, though Great Lakes’ surface currents resemble the swirls of the ocean surface currents, the patterns are more complicated. Surface currents in the Great Lakes change slightly on a daily, weekly, and monthly basis. Scientists take the average of these motions to discover the general trends in surface currents, which can be very useful for knowing where the surface currents may carry things like nutrients (chemicals that plants and algae need).

Connection to Social Studies

Surface currents have been used since ancient times to speed travelers across the sea, helping ancient Indonesians voyage to Madagascar and speeding the Vikings to Greenland. Did you know that Benjamin Franklin was one of the first to chart the Gulf Stream of the Atlantic Ocean? Mr. Franklin made eight round-trip voyages between North America and Europe.

Activity Extensions

- Imagine a place, where another shipwreck may occur and more plastic duckies may fall into the sea. Using a map of major surface currents in the ocean (gyres), predict possible places where the duckies may land. As a class, research the culture of other children in these imagined ducky landing sites.

- Listen to the song, “Wreck of the Edmund Fitzgerald” by Gordon Lightfoot. Research the location of this shipwreck that occurred in the Great Lakes. Predict where objects from this shipwreck may have moved, based on maps of Great Lakes’ surface currents. In what portion of the lakes would floating objects move faster? Slower?

- Use an encyclopedia to look up the Great Barrier Reef, Australia, and clownfish. If a clownfish managed to find his way into a surface current near the Great Barrier Reef, north of Brisbane, Australia, where might that clownfish end up?

Resources

Surface Currents and Winds in the Ocean

- UCAR's Windows to the Universe "Currents of the Ocean" - http://www.windows.ucar.edu/tour/link=/earth/Water/ocean_currents.html&edu=elem
- Museum of Science "Oceans in Motion" - http://www.mos.org/oceans/motion/currents.html
- NASA's "Ocean Motion and Surface Currents" (currents diagram) - oceanmotion.org/html/background/wind-driven-surface.htm
- NASA's "Ocean Motion" (winds diagram) - oceanmotion.org/html/background/equatorial-currents.htm

The Great Lakes

- Missouri Botanical Garden's "What's it like where you live?" - http://www.mbgnet.net/fresh/lakes/index.htm
- EPA's "Visualizing the Great Lakes" - http://www.epa.gov/glnpo/image/
- GLERL's Mean Circulation in the Great Lakes - www.glerl.noaa.gov/data/char/circ/mean/mean-circ.html

Photographs of Drifter Buoys

- NOAA's "The Global Drifter Program" - www.aoml.noaa.gov/phod/dac/gdp_drifter.html

Social Studies Connections

- "The Gulf Stream" (history) - http://fermi.jhuapl.edu/student/phillips/index.html
- Benjamin Franklin and Surface Currents, PBS Benjamin Franklin Weather Wise - www.pbs.org/benfranklin/l3_inquiring_weather.html
- TERC's "Study of Place (Franklin's map) - http://studyofplace.terc.edu/Activities/Activity.cfm?ActivityId=7&ActivityItemId=79
- Ancient Navigation and Surface Currents NOVA Online "Secret's of Ancient Navigation" - www.pbs.org/wgbh/nova/longitude/secrets.html
- Historical Shipwrecks in the Great Lakes Thunder Bay National Marine Sanctuary – http://thunderbay.noaa.gov/welcome.html
- Gordon Lightfoot: "Wreck of the Edmund Fitzgerald" – Song Lyrics - http://gordonlightfoot.com/wreckoftheedmundfitzgerald.shtml

This activity was developed by Laura Eidietis, Sandra Rutherford, Margaret Coffman, and Marianne Curtis. Parts of the activity were modified from the following sources:

- Tolman, Marvin N. *How are Ocean Currents Affected by Wind? Hands-on Earth science activities for grades K-6*, Second Edition, pp. 120-1, John Wiley & Sons/Jossey-Bass A. Wiley, San Francisco, 2006.
- VanCleave, Janice P., "Movers" in *Janice VanCleave's Earth Science for Every Kid*, pp.198-9, John Wiley & Sons, Inc., New York, 1991.

Illustrations by Lisa Gardiner
Graphic Design by Becca Hatheway

Going with the Flow

Name: ______________________________

Data Sheet - Activity 1, Page 1
(Aluminum Balls Activity)

Directions: Draw and describe what you observe. Imagine that you are looking down into the ocean basin from above.

KEY

Direction of movement

Floating balls

Sunken balls

Windy Observation

Balls in surface water (floating)

____

____

____

____

____

Balls in deep water (sunken)

____

____

____

____

____

Going with the Flow

Name: ___________________________

Data Sheet - Activity 1, Page 2
(Aluminum Balls Activity)

Directions: Draw and describe what you observe. Imagine that you are looking down into the ocean basin from above.

KEY

→ Direction of movement

○ Floating balls

△ Sunken balls

Calm Observation

Balls in surface water (floating)

____

____

____

____

____

Balls in deep water (sunken)

____

____

____

____

____

Going with the Flow

Name: ___________________________

Data Sheet - Activity 1, Page 3
(Aluminum Balls Activity)

What did you observe?

Compare the motion of the balls at the top of the water and at the bottom of the water.

____

____

____

____

What do you think?

Can wind cause currents on the bottom of the ocean?

(Circle One) YES NO Maybe

I think this because…

____

____

____

____

What did you observe?

Compare the motion of the balls when the wind was blowing and when the wind was not blowing.

____

____

____

____

Going with the Flow

Name: ____________________________

Data Sheet - Activity 2, Page 1
(Aluminum Balls Activity)

Directions: Draw and describe what you observe.

KEY

Motion of water

Windy Observation

From Above

____

____

____

____

____

From Side

____

____

____

____

____

Going with the Flow
Data Sheet - Activity 2, Page 2
(Aluminum Balls Activity)

Name: ______________________________

Directions: Draw and describe what you observe.

KEY

Motion of water

Calm Observation

From Above

____

____

____

____

____

From Side

____

____

____

____

____

Going with the Flow

Name: ________________________

Data Sheet - Activity 3
(Rheoscopic Fluid Activity)

What did you observe?

Compare the motion of the fluid when the wind was blowing to the motion of the fluid when the wind was not blowing.

____

____

____

____

What do you think?

If the wind stopped blowing for a <u>short time</u>, would the ocean currents stop?

(Circle One) YES NO Maybe

I think this because…

____

____

____

____

What do you think?

In *Ducks in the Flow - Where Did They Go?*, what caused the duck to travel so far?

____

____

____

I think this because…

____

____

____

Making Great (Lakes) Connections

OBJECTIVES

After participating in this activity, learners will be able to:

- identify the Great Lakes and the bodies of water that connect specific Great Lakes with each other and with the Atlantic Ocean
- describe the three-dimensional geography of the Great Lakes, including elevations
- describe why locks are needed, and how a lock system works

ACTIVITY SUMMARY

Groups of learners work on a single Great Lake and connecting waterway and then come together as a class to construct a simple three-dimensional model of the Great Lakes. Individual groups also present their Great Lake and connecting waterway information.

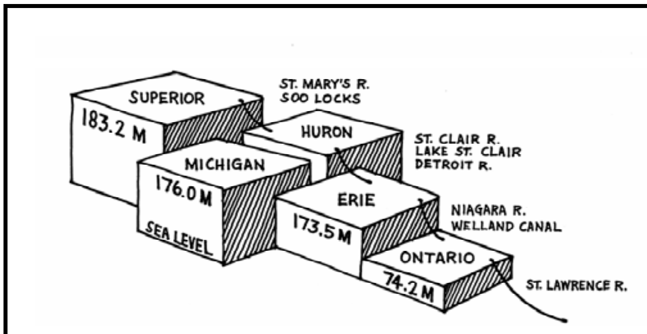
BACKGROUND

The surface of Lake Superior is about 600 feet (184 meters) above sea level. To allow ships to go from the Atlantic Ocean (0 feet elevation) to the Great Lakes and back for international trade, the United States and Canada have constructed a series of locks, channels, and canals that raise and lower ships to the level of the lakes, rivers, and ocean (Diagram 1).

For extreme changes in levels between the Great Lakes, lock systems were developed to raise and lower ships. To lower a ship which is in a lock, water is drained out of the lock. No pumps are needed until the operation is reversed, and a ship needs to be raised.

Until the early 1800s, transportation between the lakes and ocean was very difficult. In 1825, the Erie Canal opened, more directly connecting Lakes Ontario and Erie with the Atlantic Ocean via the Hudson River and port of New York. In 1829, the Welland Ship Canal was constructed between Lakes Ontario and Erie to provide a shipping channel around Niagara Falls. (This canal was improved and enlarged several times from 1833 to 1919.) In 1855, the St. Mary's Falls Ship Canal (popularly known as the Soo Locks) connecting Lake Superior and Lake

DIAGRAM 1



Huron was enlarged to accommodate large lake-going vessels. Around the late 1800s to early 1900s, a 27-foot-deep navigation canal was dredged through Lake St. Clair from the St. Clair River Delta to the head of the Detroit River. The St. Lawrence Seaway was completed in 1959, opening the Great Lakes to medium sized, international, ocean-going vessels (Diagram 1).

Because of this navigation system, 80 percent of the world's cargo ships can now sail as far west as Lake Superior. Almost 200 million tons of international and interlake cargo are transported through the Great Lakes and St. Lawrence River and Seaway each year. Today, the main commodities shipped on the Great Lakes are iron ore, coal, limestone, and grain.

Not all changes as a result of the navigation system are positive. Opening the Great Lakes system to ships and navigation also opened the system to the invasion of exotic species. The arrival and impacts of exotic species created changes in the Great Lakes ecosystem, and many of these changes were negative. Increased industrial growth and development also led to environmental degradation, pollution, and loss of wetlands.

MATERIALS

- shapes of each of the Great Lakes to scale and made of reusable and markable material (example: laminated poster board with a foam core)
- washable markers (dependent on materials used)
- string
- tape
- materials to support the lake cutouts at various levels (books, Styrofoam® blocks)
- a different Great Lakes card for each group
- a different Connecting Waterways card for each group
- Michigan Sea Grant Extension Bulletins (maps) for the learners to use as reference materials

PROCEDURE

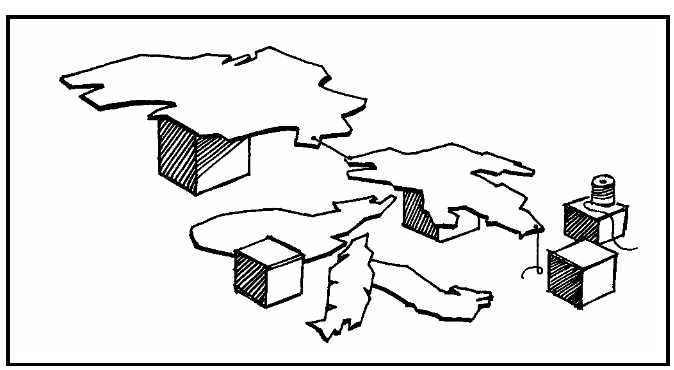
Day One

1) Introduce learners to the Great Lakes. Explain to them that they will be doing group projects that will be brought together as a class project to form the entire Great Lakes system.
2) Divide the class into six groups. Give each group a lake shape. (Count Lake St. Clair for the sixth group.) Pass out markers. Pass out one Great Lakes card and one Connecting Waterways card to each group.
3) Allow time for the learners to use reference materials (Michigan Sea Grant Extension Bulletins, maps, books), learn more about their lake, and mark information on their lake shapes.

Day Two

4) Have learners place their lake shapes into the proper geographical position and elevation. Pass out one string to each group (Diagram 2).
5) Discuss how boats move. Explain the concept of locks.
6) Assign each group a connecting waterway to research and put into place. (Provide connecting channel/

DIAGRAM 2



waterway card with various questions.)

7) Put blocks into place.
8) Have the learners present their lake and connecting channel as a group. Each learner in the group can identify and explain two places on the map, and answer one connecting channel question.

ASSESSMENT/EVALUATION

- Have learners complete the "Connecting Channels Quiz."
- Give the learners a blank map of the Great Lakes basin and have them label all the Great Lakes and their connecting channels. (Or have the learners draw their own map.)

SOURCE

Modified by Jim Lubner, University of Wisconsin Sea Grant Institute; Nancy Link, St. Joan of Arc School, Michigan; and Kimberly Tanton, Detroit Edison, Michigan. Background material adapted from *The Life of the Lakes: A Guide to the Great Lakes Fishery* and "How do ships get from one lake to another?" in *Earth Systems—Education Activities for Great Lakes Schools: Great Lakes Shipping.*

ADAPTATIONS

- Have the groups switch cards and do the activity again.
- Visit the Detroit or St. Clair River to observe freighters. Try to determine what kind of cargo they are carrying. Do upstream ships travel faster that those traveling downstream? From what countries or states do the ships come?
- Continue the lesson with information on trade and/or settlement patterns on the Great Lakes.

COMPUTER EXTENSIONS

Great Lakes Education Program: **http://www.msue.msu.edu/seagrant/**

The Great Lakes: An Environmental Atlas and Resource Book: **http://www.epa.gov/glnpo/atlas/intro.html**

U.S. Coast Guard Station St. Clair Shores, Michigan web site: **http://www.dot.gov/dotinfo/uscg/d9/stclair.html**

Great Lakes shipping schedules: **http://www.oakland.edu/boatnerd/**

ADDITIONAL RESOURCES

Local Contacts

Local Navigation/locks office

Navy Sea Cadet Program—*Pride of Michigan,* docked on the Clinton River

U.S. Coast Guard Station—St. Clair Shores

U.S. Coast Guard Auxiliary—Algonac

Teaching Materials and References

Michigan Sea Grant. Obtain these publications from MSU Bulletin Office, 10B Agriculture Hall, MSU, East Lansing, MI 48824 **(http://ceenet.msue.msu/edu/bulletin)**

Lake Superior (Bulletin E-1866)
Lake Michigan (Bulletin E-1867)
Lake Huron (Bulletin E-1868)
Lake Erie (Bulletin E-1869)
Lake Ontario (Bulletin E-1870)

Clary, James. 1985. "Ladies of the Lakes." *Michigan Natural Resources Magazine.*

Dann, S. L. 1994. *The Life of the Lakes: A Guide to the Great Lakes Fishery.* MICHU-SG-93-401, pp. 24–32. East Lansing, MI: Michigan Sea Grant College Program.

Edsall, T. A. and J. E. Gannon. 1991. *A Profile of Lake St. Clair.* MICHU-SG-91-701. Ann Arbor, MI: Michigan Sea Grant College Program.

Holling, Holling Clancy. 1941. *Paddle-to-the-Sea.* Boston, MA: Houghton Mifflin Co.

International Joint Commission. 1995. *The Great Lakes: An Environmental Atlas and Resource Book.* EPA-905-B-95-001. Chicago, IL: Environmental Protection Agency.

Ohio Sea Grant. 1997. "How do ships get from one lake to another?" *Earth Systems—Activities for Great Lakes Schools: Great Lakes Shipping.* EP-084, pp. 33–37. Columbus, OH: Ohio Sea Grant Publications.

TEACHER MEMOS

Subjects: Social Studies, Science.

Michigan Standards: ss6, ss7, ss8, ss19, s1, s12, s13.

Skills: Description, Gathering Data, Interpretation, Investigation, Large Group, Listening, Mapping, Modeling, Reporting, Small Group.

Timing: Pre-cruise.

Charting the GLEP Course: Complete this activity before “Invader Species of the Great Lakes.”

Conceptual Framework Reference: IA1, IA2, IB1, ID1, ID2, IIB2, IIB3, IIIB2, IIIC1, IVC1.

Duration: Two Days. Day 1 = 30 minutes–1 hour; Day 2 = 1 hour.

Setting: Classroom.

Connecting Channels Quiz

LEARNER'S WORKSHEET

Name ______________________________

Answers to the following questions are names of the main rivers, canals, and lakes that connect the Great Lakes together.

I am the link between Lake Ontario and the Atlantic Ocean. ____________________

I am a river between Lake Erie and Lake Ontario. ____________________

Ships get around Niagara Falls by using me. ____________________

I am the most downstream link between Lakes Huron and Erie. ____________________

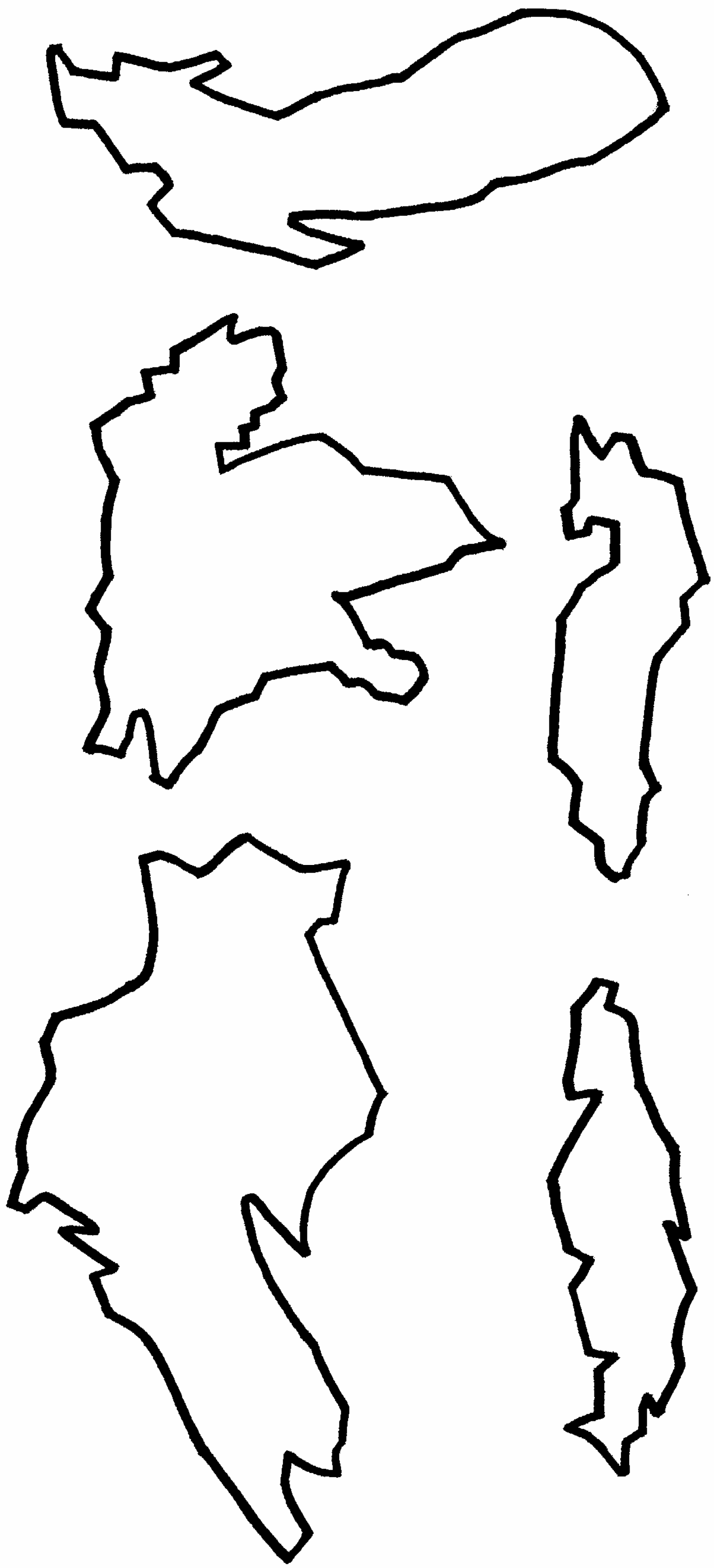
I am the middle link between Lakes Huron and Erie. ____________________

I am the most upstream link between Lake Huron and Lake Erie. ____________________

I am the river between Lake Superior and Lake Huron. ____________________

I am the lock system between Lake Superior and Lake Huron. ____________________

I am the straits between Lake Michigan and Lake Huron. ____________________



COPY MASTER

GREAT LAKES CARDS

Lake Superior

Locate these items or places on Lake Superior and write them on your lake shape.

1) Duluth, Minnesota
2) Marquette, Michigan
3) Thunder Bay Area of Concern
4) Superior, Wisconsin
5) Isle Royale National Park, Michigan
6) United States/Canadian border
7) Keewenaw Peninsula, Michigan
8) Whitefish Bay
9) St. Mary's River
10) Soo Locks

Use Extension Bulletin E-1866

Lake Michigan

Locate these items or places on Lake Michigan and write them on your lake shape.

1) Milwaukee, Wisconsin
2) Chicago, Illinois
3) Straits of Mackinac
4) Traverse Bay, Michigan
5) Escanaba, Michigan
6) Green Bay Area of Concern
7) Gary, Indiana
8) Door Peninsula
9) Manistee National Forest
10) Sleeping Bear Dunes National Lakeshore

Lake Huron

Locate these items or places on Lake Huron and write them on your lake shape.

1) Mackinac Island, Michigan
2) Georgian Bay, Ontario, Canada
3) United States/Canadian border
4) Saginaw River—Bay Area of Concern
5) Port Huron, Michigan
6) St. Mary's River and Soo Locks
7) Manitoulin Island, Ontario, Canada
8) Huron National Forest, Michigan
9) Au Sable River, Michigan
10) St. Clair River

Use Extension Bulletin E-1868

Lake Erie

Locate these items or places on Lake Erie and write them on your lake shape.

1) Toledo, Ohio
2) Detroit, Michigan
3) Windsor, Canada
4) Erie, Pennsylvania
5) Buffalo, New York
6) Detroit River Area of Concern
7) Long Point, Provincial Park, Canada
8) Niagara Falls, Ontario, Canada
9) Welland Canal
10) United States/Canadian border

Use Extension Bulletin E-1869

Lake Ontario

Locate these items or places on Lake Ontario and write them on your lake shape.

1) Rochester, New York
2) St. Lawrence River
3) Toronto Harbour Area of Concern
4) Welland Canal
5) Niagara Falls, New York
6) Bay of Quinte
7) St. Lawrence Islands (National Park)
8) Canoe Picnic Point, New York State Park
9) United States/Canadian border
10) New York State (Erie) Barge Canal

Lake St. Clair

Locate these items or places on Lake St. Clair and write them on your lake shape.

1) Clinton River
2) Metropolitan Beach, Michigan
3) Mt. Clemens, Michigan
4) Anchor Bay
5) Navigation Channel
6) St. Clair River Area of Concern
7) Peach Island, Provincial Park, Canada
8) Detroit River
9) Algonac, Michigan State Park
10) United States/Canadian border

Use *A Profile of Lake St. Clair* MICHU-SG-91-701

CONNECTING WATERWAYS CARDS

CONNECTING WATERWAYS

St. Lawrence Seaway

Research this Great Lakes connecting waterway and answer the following questions.

1) What two large bodies of water does the St. Lawrence Seaway connect?
2) At what sea levels/elevations are these two bodies of water? Which body of water is higher?
3) Why was it necessary to build the St. Lawrence Seaway?
4) What economic products do ships carry between states, Canada, and countries around the world?
5) Do you think exotic species came into the Great Lakes through the St. Lawrence Seaway? How?

CONNECTING WATERWAYS

Welland Canal and Niagara River

Research these Great Lakes connecting waterways and answer the following questions.

1) What two large bodies of water do these two waterways connect?
2) At what sea levels/elevations are these two bodies of water? Which body of water is higher?
3) What are the differences between the Welland Canal and the Niagara River?
4) Why was it necessary to build the Welland Canal?
5) How does the canal work for ships, and how does the lock system work?

CONNECTING WATERWAYS

Detroit River and Lake St. Clair Navigation Channel

Research these Great Lakes connecting waterways and answer the following questions.

1) What two large bodies of water does the Detroit River connect?
2) At what sea levels are these two bodies of water? Which body of water is higher?
3) What is the St. Clair Navigation Channel used for?
4) Why was it necessary to build the St. Clair Navigation Channel?
5) Why do you think the large cities of Windsor and Detroit developed along the Detroit River?

CONNECTING WATERWAYS

St. Clair River and Lake St. Clair Navigation Channel

Research these Great Lakes connecting waterways and answer the following questions.

1) What two large bodies of water does the St. Clair River connect?
2) At what sea levels are these two bodies of water? Which body of water is higher?
3) What is the St. Clair Navigation Channel used for?
4) Why was it necessary to build the St. Clair Navigation Channel?
5) How do you think the non-native zebra mussel was introduced into Lake St. Clair?

CONNECTING WATERWAYS

St. Mary's River and Soo Locks

Research this Great Lakes connecting waterway and answer the following questions.

1) What two large bodies of water does this waterway connect?
2) At what sea levels are these two bodies of water? Which body of water is higher?
3) Why do you think the St. Mary's River is an Area of Concern?
4) Why was it necessary to build the Soo Locks?
5) How does the lock system work for ships and barges?

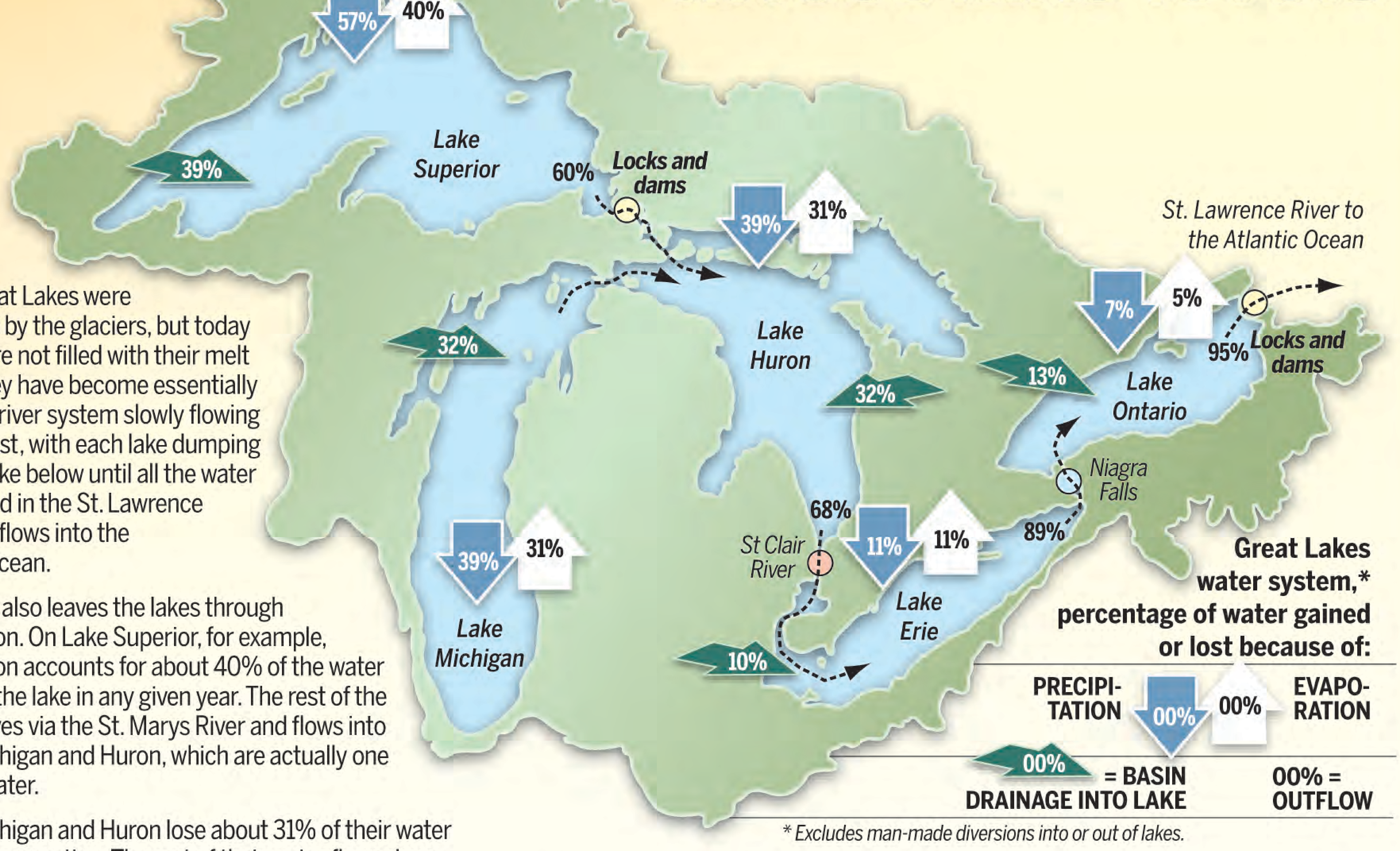
CONNECTING WATERWAYS

Straits of Mackinac

Research this Great Lakes connecting waterway and answer the following questions.

1) What two large bodies of water does this waterway connect?
2) At what sea levels are these two bodies of water? Which body of water is higher?
3) What famous bridge was built to connect the lower and upper parts of Michigan?
4) Why are canals, channels, or lock systems not necessary for ships and barges in the Straits of Mackinac?
5) What economic products do ships carry between states, Canada, and countries around the world?

How precipitation and evaporation affect lake levels



The Great Lakes were carved by the glaciers, but today they are not filled with their melt water. They have become essentially one giant river system slowly flowing west to east, with each lake dumping into the lake below until all the water is collected in the St. Lawrence River and flows into the Atlantic Ocean.

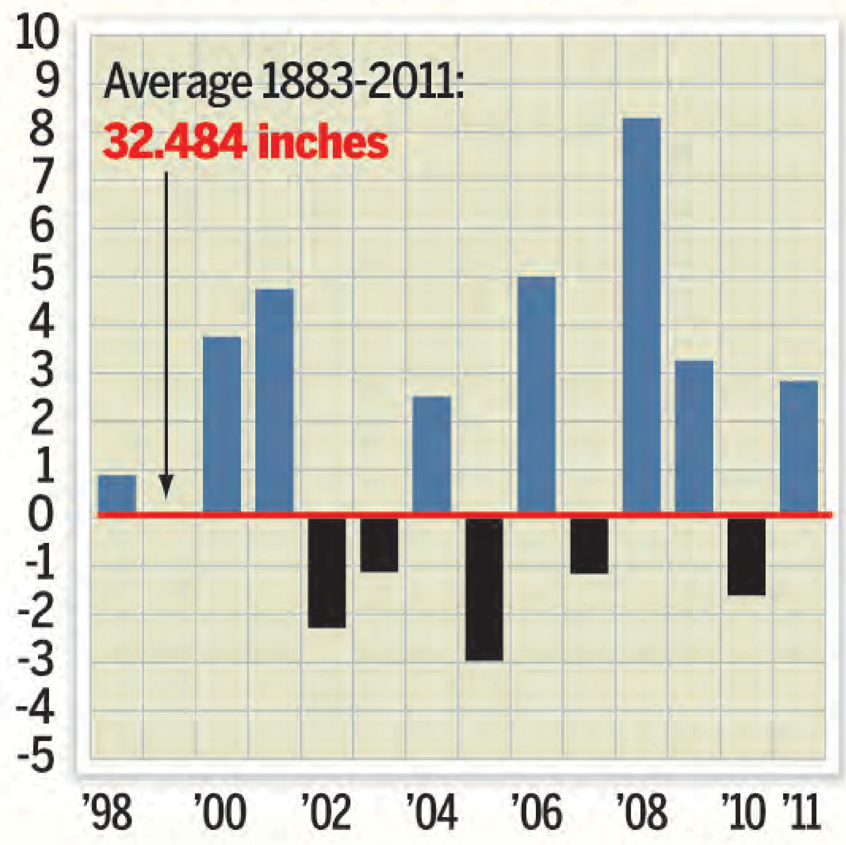
But water also leaves the lakes through evaporation. On Lake Superior, for example, evaporation accounts for about 40% of the water lost from the lake in any given year. The rest of the water leaves via the St. Marys River and flows into Lakes Michigan and Huron, which are actually one body of water.

Lakes Michigan and Huron lose about 31% of their water through evaporation. The rest of their water flows down the St. Clair River into Lake Erie and ultimately out to the Atlantic, though a sliver of it also leaves via the man-made Chicago Sanitary and Ship Canal and flows down to the Gulf of Mexico.

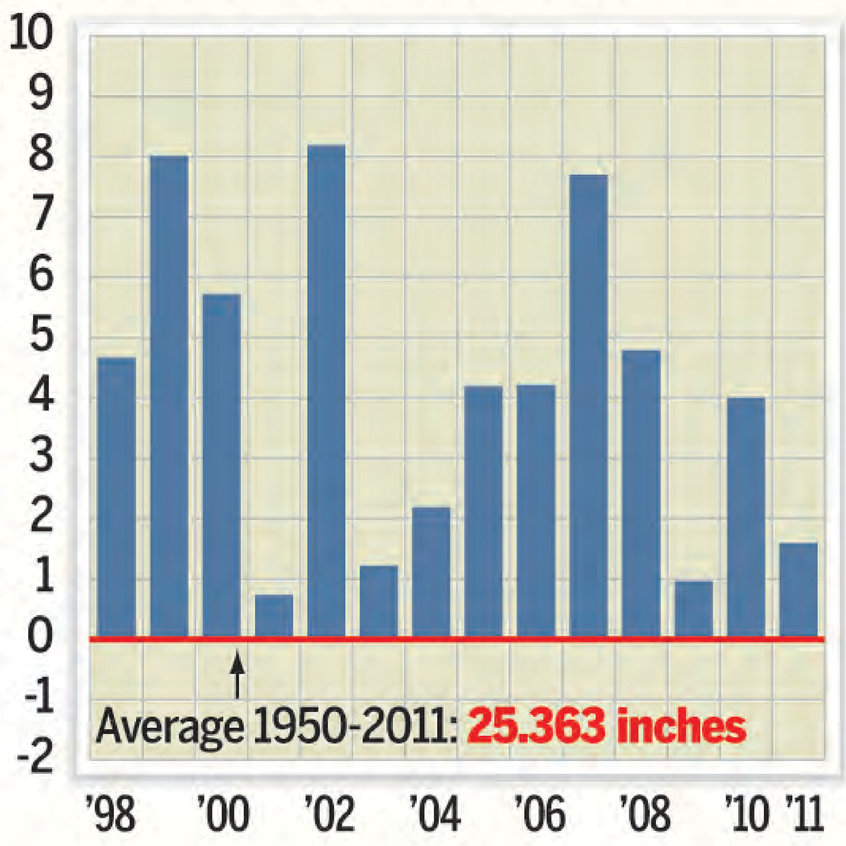
All these water losses are compensated for by precipitation, in the form of water that falls directly onto the lakes and from water that enters as runoff from surrounding land in the basin.

On Lake Superior, about 57% of its annual water budget comes from over-lake precipitation and 39% comes from runoff. On Lakes Michigan and Huron, about 39% of the annual water budget comes from over-lake precipitation and about 32% comes from runoff. The rest is whatever comes down the St. Marys River from Lake Superior.

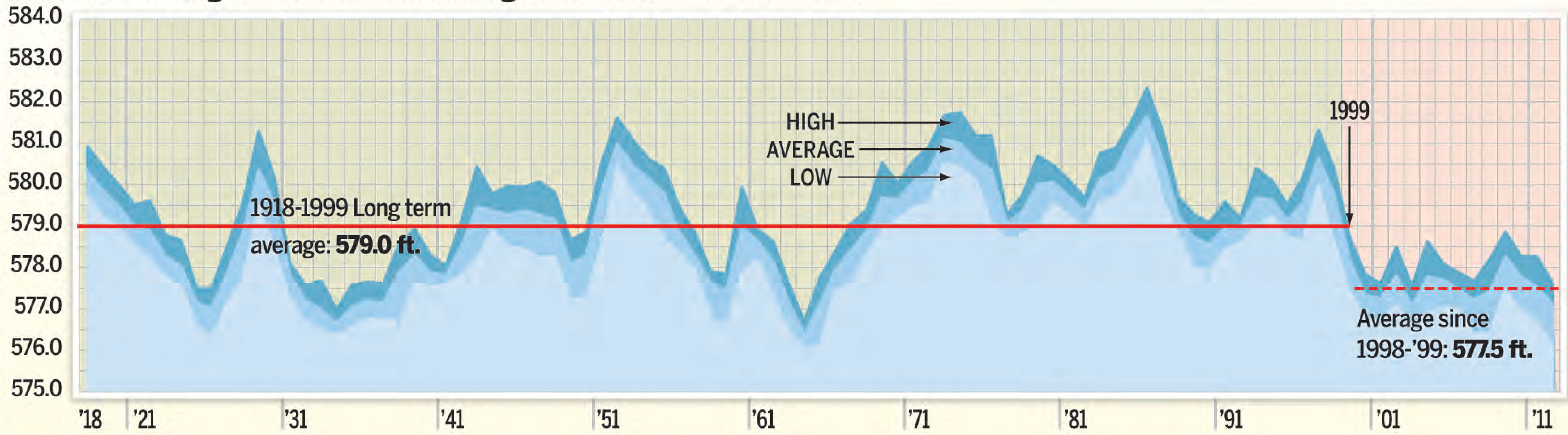
Lake Michigan-Huron annual deviation from average precipitation, in inches, 1998-2011



Lake Michigan-Huron annual deviation from average evaporation, in inches, 1998-2011



Lake Michigan-Huron annual average lake level, in feet, 1918-2012



All this means that the volume of water in the lakes at any given time is tied to these things – **precipitation** (over-lake rain and snow storms as well as runoff) and **inflows** from the lake above, minus **evaporation** and **outflows** to the ocean. This basic equation has kept Lakes Michigan and Huron remarkably stable. But now it appears something is amiss. Michigan and Huron have been below their long-term average for 14 years and counting, yet during this period they have received above-average precipitation.

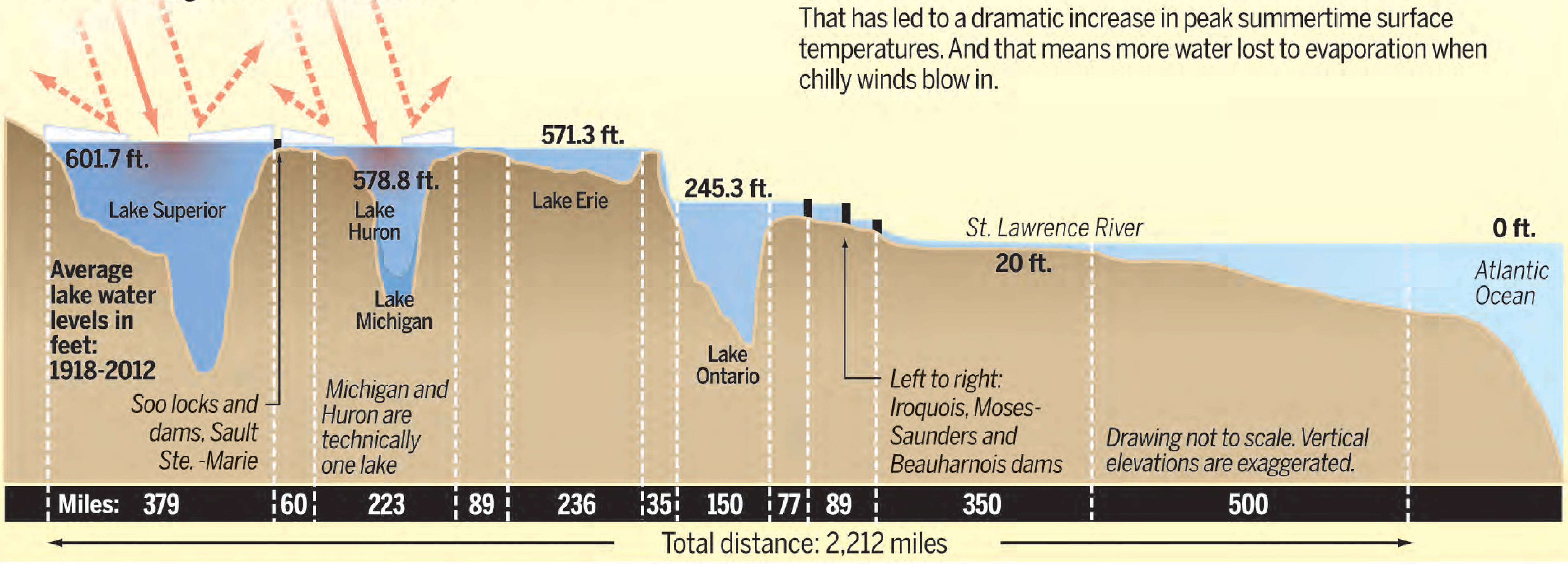
The problem appears to be tied to increased evaporation, and it starts with a recent increase in water temperatures. The summertime average surface temperature for Lake Michigan at one mid-lake buoy has increased 3.4 degrees since the late 1990s.

So how did the lake get so warm so fast?

Ice. Or, more specifically, lack of it. Air temperatures have a profound effect on the amount of ice that stretches across the upper part of the lakes. In the early 1970s, wintertime ice stretched over vast expanses of Lake Michigan, particularly in the north, but it has since shrunk by 63%. The same thing has happened on Lake Superior, which lost on average 76% of its ice coverage. Snow-covered ice bounces solar radiation back into the sky. Where there is no ice, the dark open waters begin sucking up sunlight – and heat – even in early spring.

This has caused a thermal cascade in the lakes. The cold-weather warming gives the lakes a jump start on their annual warming cycle.

That has led to a dramatic increase in peak summertime surface temperatures. And that means more water lost to evaporation when chilly winds blow in.



Source: U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration

Journal Sentinel