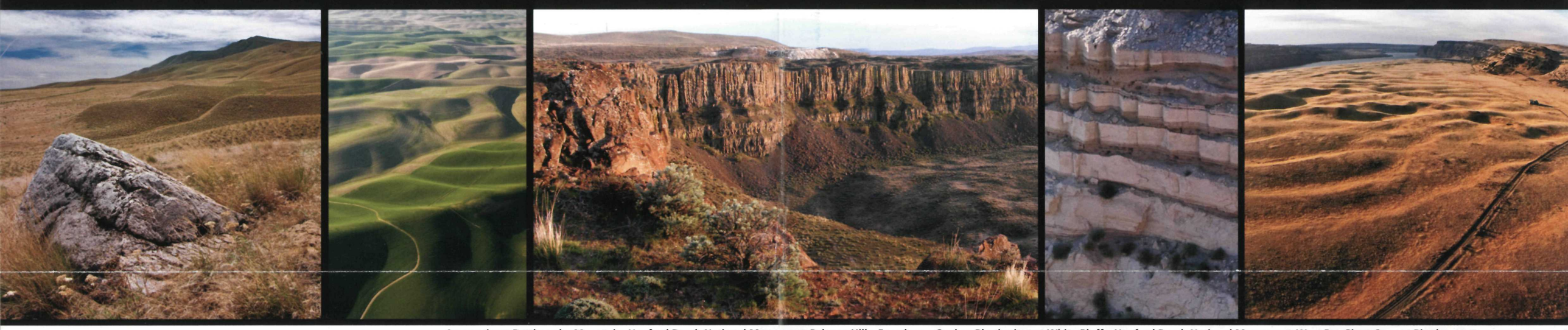
Ice Age Floods

Ice Age Floods National Geologic Trail
Montana / Idaho / Washington / Oregon

National Park Service
U.S. Department of the Interior



An erratic on Rattlesnake Mountain, Hanford Reach National Monument; Palouse Hills; Frenchman Coulee; Rhythmites at White Bluffs, Hanford Reach National Monument; West Bar Giant Current Ripples © BRUCE BJORNSTAD

Floods of Change

Imagine the greatest floods on earth crashing across and sculpting the lands of the northwestern United States. This incredible true story is recorded in rock and sediment. You can explore the geologic clues and landscapes made by the Ice Age Floods at sites along the Ice Age Floods National Geologic Trail.

At the end of the last Ice Age, about 18,000 to 15,000 years ago, an ice dam blocked the Clark Fork River in what is now northern Idaho. Water rose 2,000 feet (610 m) behind the dam and stretched eastward 200 miles (322 km), creating Glacial Lake Missoula. Eventually, the ice dam weakened, burst, and released as much as 500 cubic miles (2,084 km³) of water—about the volume of Lake Ontario and Lake Erie combined—in just two days. A wall of water hundreds of feet high thundered downstream at 65 miles per hour (105 km/hour) with 10 times more water than all the world's rivers today. This massive flood of water, ice, and debris shook the ground as it raced westward over 16,000 square miles (41,440 km²) in present-day Montana, Idaho, Washington, and Oregon. Over thousands of years, an ice dam repeatedly formed and burst, causing dozens of floods.

Today, widespread reminders of these Ice Age Floods dot the landscape: gigantic basalt coulees, enormous dry falls, large boulders moved hundreds of miles, high water lines, and huge current ripples. These outstanding examples of cataclysmic flood geology, exceptional scenery, and places for scientific research are all part of the Ice Age Floods National Geologic Trail.

Solving the Mystery

The story of the Ice Age Floods took nearly 50 years to piece together. During the 1920s–40s geologists debated the origin of eastern Washington's Channeled Scabland where eroded volcanic basalt surrounds braided channels and coulees. Most geologists believed that the Channeled Scabland was made by slow erosion by glaciers and streams. Geologic evidence that didn't fit with this idea led geologist J Harlen Bretz to hypothesize that the Channeled Scabland was formed by cataclysmic floods. Initially ridiculed, Bretz's hypothesis was validated when new technologies like satellite photography provided supporting evidence. By the 1970s it was universally accepted that the scoured landscape of the northwestern United States was the result of the Ice Age Floods.

J Harlan Bretz
© JULIAN GOLDSMITH

Joseph Pardee
USGS

J Harlen Bretz, 1882-1981
A high school teacher turned geology professor, J Harlen Bretz was fascinated with the glacial geology of the Puget Sound. He became an expert on the features of stream and glacial erosion and began field research in the Channeled Scabland of eastern Washington in 1922. Challenging common beliefs, Bretz believed that the Channeled Scabland was formed not by ordinary stream erosion but by cataclysmic floods. What eluded him, though, was the source of the floods.

Joseph Pardee, 1871-1960
Joseph Pardee, a geologist with the US Geological Survey, proposed a source for Bretz's catastrophic floods. As he studied the Channeled Scabland and the intermountain basins of Montana in 1910, he found high water marks near Missoula, Montana—evidence of a large glacial lake. Later, in the Camas Prairie of northwestern Montana, he discovered giant ripple marks of sediment made by powerful currents flowing over the bottom of ancient Glacial Lake Missoula. Like Bretz, Pardee's discoveries played a key role in understanding the story of the Ice Age Floods.

The work of these and present-day scientists show us that the gradual processes shaping our Earth can be punctuated by sudden, cataclysmic events, and that such events are possible in our lifetimes!

The magnitude of the erosive changes wrought by these glacial streams is nothing short of amazing. —J Harlen Bretz, 1923

Lasting Impressions

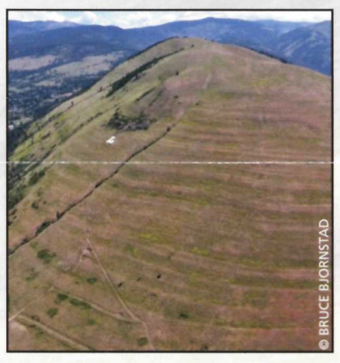
As the Ice Age Floods swept across the landscape from Montana to the Pacific Ocean, they eroded massive amounts of rock and debris from the land and deposited them farther down the flood route. Along the national geologic trail, deeply eroded coulees, scoured water gaps, remnant waterfalls, and basalt cliffs lead to gravel bars, giant ripple marks, and large boulders. These clues from the past guide your passage through geologic space and time.

As you learn about 13 flood features here, find them on the map side of this brochure marked by numbered stars.

ICE AGE FLOODS
NATIONAL GEOLOGIC TRAIL

1. Lake Missoula Strandlines

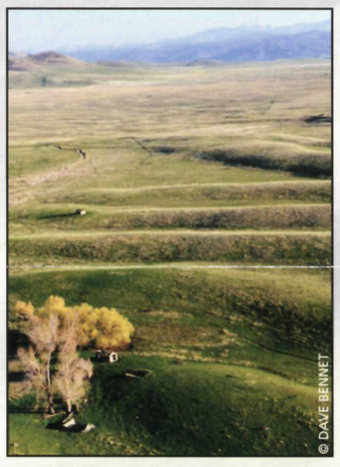
Imagine you are standing on the edge of Glacial Lake Missoula 15,000 years ago. You can hear lapping waves cutting benches known as "strandlines" into the shoreline. Today, you can see these huge strandlines on hills surrounding Missoula, Montana, marking changes in lake level over time. On Mount Sentinel, marked with an "M", and Mount Jumbo, marked with an "L", the strandlines are seen as horizontal lines in the vegetation or highlighted by snow in the winter. Public hiking trails switchback through the strandlines on Mount Sentinel and Mount Jumbo.



© BRUCE BJORNSTAD

2. Camas Prairie Ripples

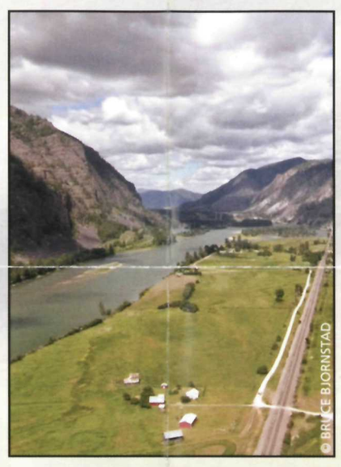
Water alters everything it touches. Floodwaters deposited giant gravel bars in the Camas Prairie Basin of present-day western Montana. Similar in shape to small ripple marks on a sandy beach, these gravel bars are up to 30 feet (9.1 m) tall. Formed by deep, raging floodwaters as the lake drained, they remind us of the sheer power of the Ice Age Floods. Observe the Camas Prairie Ripples by driving Montana Highway 382 south over Markle Pass.



© DAVE BENNETT

3. Eddy Narrows

West of the Camas Prairie Ripples is a flume-shaped section of canyon called the Eddy Narrows. Draining Glacial Lake Missoula waters accelerated through this canyon at 80 miles per hour (129 km/hour), scouring the valley walls down to bare bedrock to 1,000 feet (305 m) above the valley floor. On Montana Highway 200, between mileposts 59 and 60, stop at the KooKooSint Bighorn Sheep Viewing Interpretive Site to see these vertical canyon walls.



© BRUCE BJORNSTAD

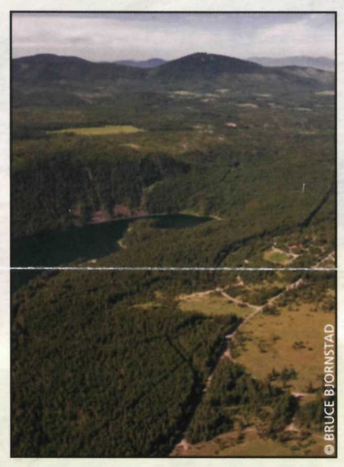
4. Glacial Dam at Green Monarch Ridge

Before torrents raged through Eddy Narrows, the flow of water was impeded by ice at the confluence of a tributary. As the Purcell Trench Ice Lobe of the continental ice sheet advanced south from Canada, it was stopped by the Green Monarch Ridge, building an ice dam 4,000 feet (1219 m) tall and nearly 40 miles (64 km) wide that blocked the Clark Fork River, thus filling Glacial Lake Missoula. View the Green Monarch Ridge and the Purcell Trench from a large pullout on Idaho State Route 200, about one mile (1.6 km) west of Hope, Idaho and 15 miles (24 km) east of Sandpoint, Idaho.

© BRUCE BJORNSTAD

5. Missoula Floods Outburst Plain

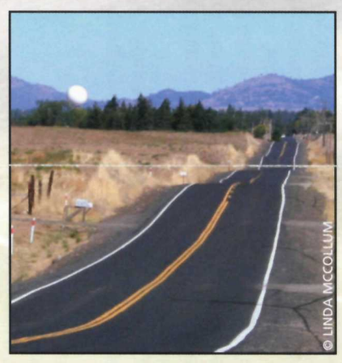
When the ice dam holding back Glacial Lake Missoula burst, water was not the only thing to rocket through the breach. Ice, boulders, and other debris were deposited in the Rathdrum Prairie by escaping floodwaters. Explore this and other flood remnants like debris-damned lakes, giant ice-rafted boulders called erratics, and huge gravel bars at Farragut State Park on the southern tip of Lake Pend Oreille, Idaho.



© BRUCE BJORNSTAD

6. Sunset Prairie Antidune Field

As floodwaters flowed west, they deposited over 15 square miles (39 km²) of unusually symmetrical, serpentine sand ridges that measure up to 15 feet (4.6 m) tall and are spaced about 100 feet (30 m) apart. The Sunset Prairie Antidunes are the result of shallow, high-flow floodwaters and are formed facing upstream. While parking is not available, drive through this antidune field—one of the largest on Earth—from a two-mile drive north on South Rambo Road off US Highway 2 a couple of miles west of Airway Heights, Washington.



© LINDA MCCOLLUM

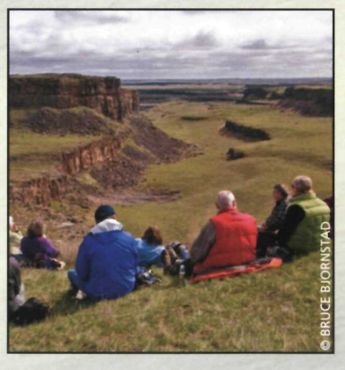
7. Dry Falls at Grand Coulee

Fifty miles (80 km) northwest of Sunset Prairie Antidune Field, the mighty Columbia River flows. At the end of the Ice Ages, a lobe of the continental ice sheet diverted the Columbia River south along the path of the Grand Coulee. Floodwaters hundreds of feet deep formed a huge waterfall. Recession of the waterfall's lip during each flood event carved a canyon 20 miles (32 km) upstream from the fall's original location at Soap Lake. A huge "dry waterfall" remains as an unmistakable clue of the floods' power. Four times larger than Niagara Falls, the Great Cataract Group was the largest waterfall known on earth at 3.5 miles (5.6 km) wide and 400 feet (122 m) tall. The western part of the cataract, Dry Falls, is one mile (1.6 km) wide. Imagine the roar of the ancient falls from the Dry Falls Visitor Center viewpoint off Washington State Route 17 between Coulee City and Sun Lakes-Dry Falls State Park.

© BRUCE BJORNSTAD

8. Drumheller Channels (NNL)

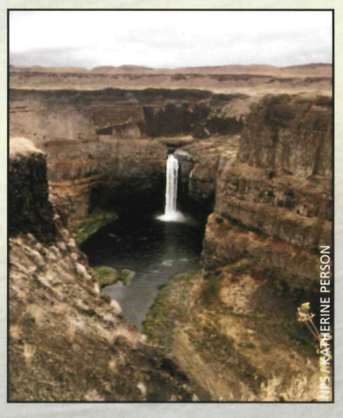
As floodwaters continued rushing south from Dry Falls, they left behind "butte-and-basin scabland"—a landscape marked by hundreds of buttes surrounded by a network of braided channels. Known as the Drumheller Channels, they were the largest outlet of floodwaters from the Quincy Basin. Water flowed at speeds of up to 65 miles per hour (105 km/hr), eroding the topsoil and underlying basalt to create the channels, basins, potholes, and buttes. View this prime example of Ice Age Floods erosion at the Drumheller Channels National Natural Landmark (NNL) viewpoint 9.1 miles (14.6 km) northwest of Othello, Washington along McManamon Road.



© BRUCE BJORNSTAD

9. Palouse Falls

To the east of Drumheller Channels, another flood path showcases an active waterfall. Palouse Falls was created when floodwaters rerouted the ancestral Palouse River from flowing into the Columbia River and into its current course towards the Snake River. The Palouse River drops 200 feet (61 m) over a sheer cliff into a roiling bowl, then zigzags six miles (9.7 km) through the 300-foot (91 m) coulee cliffs of the Palouse River Canyon before flowing into the Snake River. View Palouse Falls from viewpoints and hiking trails at Palouse Falls State Park, 2.3 miles (3.7 km) east of Washington State Route 261.



© KATHERINE PERSON

10. Wallula Gap (NNL)

All floodwaters crossing the Channeled Scabland funneled through a narrow two-mile-wide (3.2 km) gap in the Horse Heaven Hills called Wallula Gap. Like the neck of an hourglass, Wallula Gap restricted the flow of floodwaters along the Columbia River. As water, ice, and debris hit this constriction, it formed a hydraulic dam. Floodwaters backed up behind this dam creating Lake Lewis, an enormous temporary slack-water lake 900 feet (274 m) deep. See Wallula Gap by driving south on eastbound US 12 from Pasco, Washington. After crossing the Snake River, look for the gap across the Horse Heaven Hills to the south.

© BRUCE BJORNSTAD

11. Columbia River Gorge

Once free of Wallula Gap, the Ice Age Floods ripped through the Columbia River Gorge for 200 miles (322 km) to Crown Point, creating alien-looking hoodoos and scablands, massive landslides, and giant gravel bars. As the churning, muddy waters rampaged to the sea, they stripped the river valley of rock and debris, dug pits, and tore massive basalt columns from the bedrock. A drive along Oregon's Interstate 84 between Wallula Gap and Crown Point—or a more leisurely drive along Washington State Route 14 that parallels I-84 between Plymouth and Vancouver—highlights the aftermath of these cataclysmic floodwaters. Along I-84, the Vista House atop Crown Point provides a stunning panorama.

© KATHERINE PERSON

12. Lower Columbia

Each time Ice Age Floods surged beyond the confines of the Columbia River Gorge, they covered the lowlands of current-day Portland, Oregon and Vancouver, Washington, as well as Oregon's Willamette and surrounding valleys, with slack-water lakes up to 400 feet (122 m) deep. These slack-water lakes formed behind hydraulic dams at Ḳalama Gap, a constriction of the Columbia River where it flows through the Pacific Coast Range. Over 200 feet (61 m) of sediment were deposited and now underlie the fertile valley floor all along the flood paths from Portland to Eugene. Find panoramic views of the lower Columbia River—and nearby volcanoes that would have been islands during the Ice Age Floods—from James Woodhill Park atop Portland's Rocky Butte.

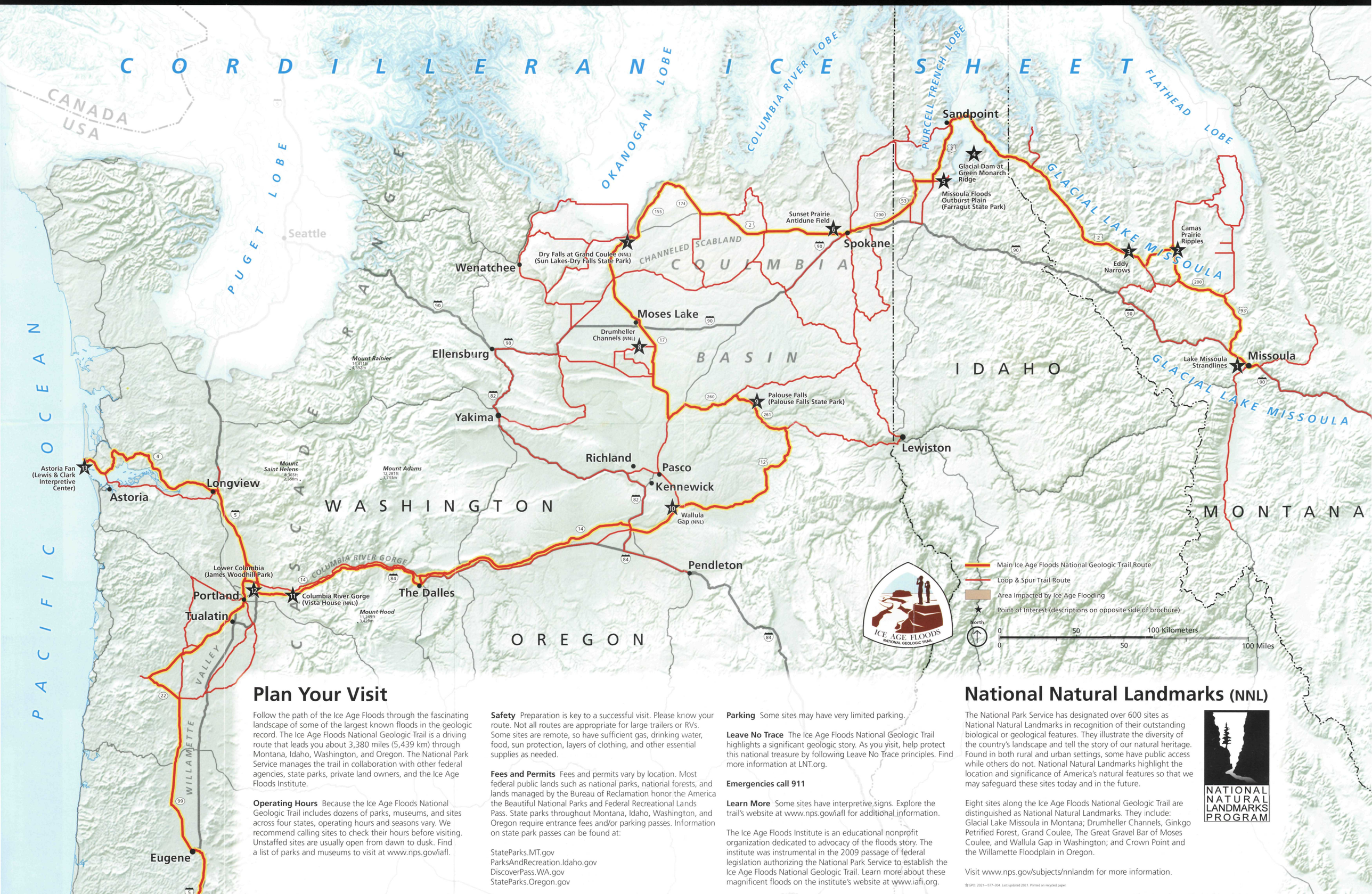
© BRUCE THOMPSON

13. Astoria Fan

Glacial floodwaters continued along the path of the Columbia River and out to sea. However, when the Ice Age Floods reached the exposed Astoria Canyon at the mouth of the Columbia River, sea level was about 300 feet (91 m) lower than it is today. The dense, sediment-laden floodwaters created powerful currents that cut deeper into the Astoria Submarine Canyon across the continental shelf. These currents deposited massive amounts of sediment hundreds of miles offshore across the Astoria Deep Sea Fan and as far south as the northern California border. Overlook the confluence of the Columbia River and the Pacific Ocean from Lewis and Clark Interpretive Center in Cape Disappointment State Park, Washington.

© AARON WEBSTER

Exploring The Ice Age Floods



Plan Your Visit

Follow the path of the Ice Age Floods through the fascinating landscape of some of the largest known floods in the geologic record. The Ice Age Floods National Geologic Trail is a driving route that leads you about 3,380 miles (5,439 km) through Montana, Idaho, Washington, and Oregon. The National Park Service manages the trail in collaboration with other federal agencies, state parks, private land owners, and the Ice Age Floods Institute.

Operating Hours Because the Ice Age Floods National Geologic Trail includes dozens of parks, museums, and sites across four states, operating hours and seasons vary. We recommend calling sites to check their hours before visiting. Unstaffed sites are usually open from dawn to dusk. Find a list of parks and museums to visit at www.nps.gov/iafl.

Safety Preparation is key to a successful visit. Please know your route. Not all routes are appropriate for large trailers or RVs. Some sites are remote, so have sufficient gas, drinking water, food, sun protection, layers of clothing, and other essential supplies as needed.

Fees and Permits Fees and permits vary by location. Most federal public lands such as national parks, national forests, and lands managed by the Bureau of Reclamation honor the America the Beautiful National Parks and Federal Recreational Lands Pass. State parks throughout Montana, Idaho, Washington, and Oregon require entrance fees and/or parking passes. Information on state park passes can be found at:

StateParks.MT.gov
ParksAndRecreation.Idaho.gov
DiscoverPass.WA.gov
StateParks.Oregon.gov

Parking Some sites may have very limited parking.

Leave No Trace The Ice Age Floods National Geologic Trail highlights a significant geologic story. As you visit, help protect this national treasure by following Leave No Trace principles. Find more information at LNT.org.

Emergencies call 911

Learn More Some sites have interpretive signs. Explore the trail's website at www.nps.gov/iafl for additional information.

The Ice Age Floods Institute is an educational nonprofit organization dedicated to advocacy of the floods story. The institute was instrumental in the 2009 passage of federal legislation authorizing the National Park Service to establish the Ice Age Floods National Geologic Trail. Learn more about these magnificent floods on the institute's website at www.iafi.org.

National Natural Landmarks (NNL)

The National Park Service has designated over 600 sites as National Natural Landmarks in recognition of their outstanding biological or geological features. They illustrate the diversity of the country's landscape and tell the story of our natural heritage. Found in both rural and urban settings, some have public access while others do not. National Natural Landmarks highlight the location and significance of America's natural features so that we may safeguard these sites today and in the future.

Eight sites along the Ice Age Floods National Geologic Trail are distinguished as National Natural Landmarks. They include: Glacial Lake Missoula in Montana; Drumheller Channels, Ginkgo Petrified Forest, Grand Coulee, The Great Gravel Bar of Moses Coulee, and Wallula Gap in Washington; and Crown Point and the Willamette Floodplain in Oregon.

NATIONAL NATURAL LANDMARKS PROGRAM

Visit www.nps.gov/subjects/nnlandm for more information.

☆GPO: 2021—577-304. Last updated 2021. Printed on recycled paper.