

An Awareness Guide

Tropical Cyclones & Inland Flooding



U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Eastern Region Headquarters, Bohemia, N.Y.

Produced at
Southeast River Forecast Center,
Peachtree City, Ga.
July 2001



Tropical Cyclones Inland Flooding

The official hurricane season is June 1 through November 30 each year. One of the most damaging effects of a tropical cyclone is inland freshwater flooding. For the past 30 years, inland flooding has claimed more than half of all U.S. deaths associated with tropical cyclones or their remnants.

June 1 to November 30 is the official hurricane season. During each season, an average of ten tropical storms will develop in the Atlantic Basin, of which six will become hurricanes. Many of these will remain over the ocean and not affect any landmass. However, about five hurricanes strike the United States coastline every three years. Of these five, two will be major hurricanes (category 3 or greater on the Saffir Simpson Hurricane Scale). All five storms will move inland to begin a decaying process, producing torrential rains, flooding, and flash flooding many miles from their impact points on the coast.

In addition to wind, tornadoes, and storm surge flooding, a fourth tropical cyclone-associated menace exists -- *inland freshwater flooding*. Tropical cyclones can have life-threatening effects hundreds of miles inland. The public should be aware of and alert for the heavy rains, lightning, and the floods and flash floods these disturbances can bring.

Between 1970 and 1999, freshwater floods claimed about 59% of the 600 U.S. deaths associated with tropical cyclones or their remnants. Many of these deaths occurred after a tropical cyclone moved inland and weakened from its landfall intensity. These losses extend a century-long trend in the movement of the location of tropical cyclone-related casualties. Fatality centers occurred primarily at sea through the 1700s, migrated to the shoreline and coastal zone through the mid 1900s, and then to areas well inland during the past 50 years.

The eastern portion of the United States has had a long and destructive association with floods caused by dying hurricanes and tropical depressions. Page two shows the paths of some of the 20th century's more infamous events. All have made an impact on a region or locality and contributed to the flood records, local legend, and lore.

What is a Tropical Cyclone?



A tropical cyclone is a warm-core, non-frontal low pressure system that develops over tropical or subtropical waters and has a definite organized surface circulation. Tropical cyclones are classified as follows:

• Tropical Depressions

A tropical cyclone in which the maximum sustained surface wind speed is 38 mph (33 knots or 62 km/hr) or less.

• Tropical Storm

A tropical cyclone in which the maximum sustained surface wind speed ranges from 39 mph (34 knots or 63 km/hr) to 73 mph (63 knots or 118 km/hr).

• Hurricane

A tropical cyclone in which the maximum sustained surface wind speed is 74 mph (64 knots or 119 km/hr) or more.

• Extratropical

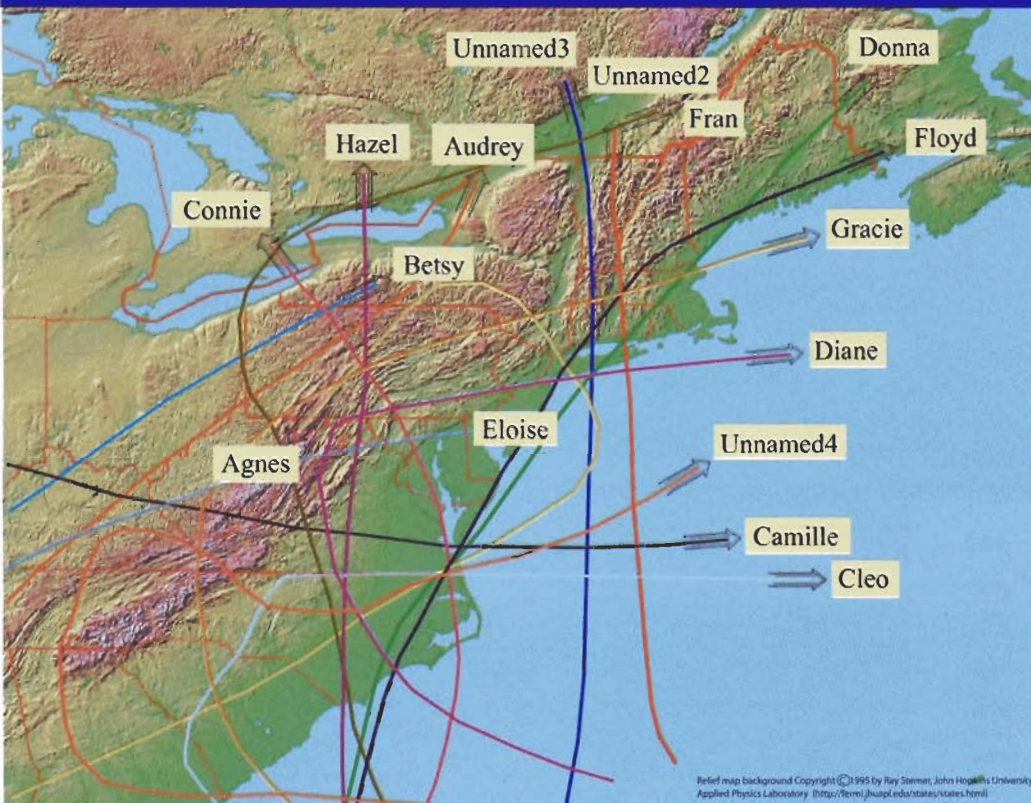
A term used in advisories and tropical summaries to indicate the cyclone has lost its "tropical" characteristics. The term implies both a northerly movement of the system and a change in its primary source of energy from the ocean to temperature contrasts between warm and cold air masses.



Major Flood-Producing Tropical Cyclones

The eastern portion of the country has had a long and destructive relationship with floods caused by dying hurricanes and tropical depressions.

Storm Tracks



Relief map background Copyright ©1995 by Ray Steiner, Johns Hopkins University Applied Physics Laboratory (<http://fermi.jhuapl.edu/states/states.html>)

Name	Date	Year	Category	Deaths*	Damages \$	Damages \$1999	Landing Location
Unnamed1	Sept. 12-17	1903	1	57	9 mil	18.7 mil	Central coastal NJ
Unnamed2	Oct. 31-Nov 4	1927	TS**	85	40 mil	383 mil	Long Island, NY-coastal CT
Unnamed3	Sept. 10-28	1938	3	100	37 mil	437 mil	Long Island, NY-coastal CT
Unnamed4	Aug. 5-15	1940	3	40	30 mil	357 mil	SC-GA coastal border
Carol	Aug 25-31	1954	?	60	461 mil	2.85 bil	Long Island, NY-coastal CT
Hazel	Oct. 5-18	1954	4	95	252 mil	1.56 bil	SC-NC coastal border
Connie	Aug. 3-14	1955	3	25			NC-VA coastal border
Diane	Aug. 7-21	1955	1	200	500 mil	3.11 bil	Southern NC coast
Audrey	June 25-28	1957	4	390	150 mil	889 mil	TX-LA coastal border
Gracie	Sept. 20-Oct. 2	1959	3	22			Southern SC coast
Donna	Aug. 29-Sept. 13	1960	4	50	387 mil	2.18 bil	Coastal FL, NC, & Long Island
Cleo	Aug. 20-Sept. 5	1964	2		128.5 mil	691 mil	Southeast FL coast
Betsy	Aug. 26-Sept. 12	1965	3	75			Tip of FL-Southeast LA
Camille	Aug. 5-22	1969	5	113	116 mil	527 mil	Bay St. Louis, MS
Agnes	June 14-22	1972	1	122	3.2 bil	12.76 bil	FL panhandle
Eloise	Sept. 13-27	1975	3		490 mil	1.52 bil	Western FL panhandle
Gloria	Sept 16-Oct. 1	1985	3	13	900 mil	1.39 bil	Central coastal Long Island, NY
Bob	Aug. 15-28	1991	2	1	1.5 bil	1.83 bil	MA-RI coastal border
Fran	Aug. 28-Sept. 8	1996	3	26	3.2 bil	3.40 bil	NC coast nr Cape Fear
Alberto	July 3-7	1996	TS**	22	750 mil	797 mil	Near Destin, FL
Floyd	Sept. 7-17	1999	4	56	4.5-6 bil	4.5-6 bil	Extreme Eastern NC coast

* deaths from freshwater flooding
 ** Tropical Storm

Factors Affecting Inland Flooding

Storm Speed – The slower the system moves, the more time for the rains to fall over a location.

Orography – Lifting of the warm, moist tropical air over geographical barriers such as hills and mountains. Also, the gradual increase in elevation as the system moves inland amplifies and intensifies the rain.

Interaction with other weather features -- Agnes (1972) fused with another storm system, producing floods in the northeast

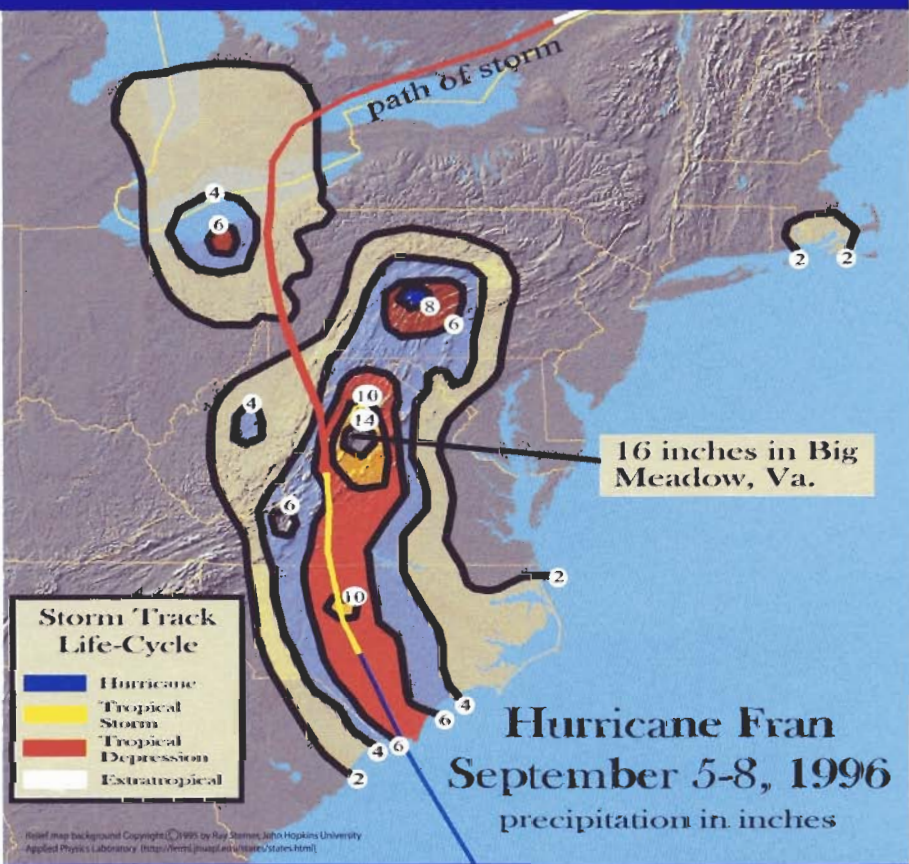
United States which caused 122 deaths and \$3.2 billion (\$12.8 billion in 1999 dollars) in damages.

Antecedent conditions – The wetness or dryness of the soil, the existing capacity of the streams and rivers, ponds and lakes, and reservoirs. Connie (1955) dropped 10 inches of rain on parts of Pennsylvania, New York, and New England. Less than a week later, Diane dropped 12-15 inches of rain on the saturated ground and nearly full rivers, resulting in 299 deaths.

Each tropical cyclone possesses its own flood-producing personality as it interacts with our lives. Four main factors influence the destructive nature of each storm system. These factors vary greatly from storm to storm, month to month, and location to location.



Storm Total Precipitation



The Saffir-Simpson Hurricane Scale is no indicator of the potential for heavy rain and inland flooding. A tropical storm could produce more rainfall than a category 5 hurricane.

Secondary rainfall maximums can occur well inland during the decay of a tropical cyclone, making flooding a *major threat*.

As long as a system maintains its tropical identity and characteristics, it has the potential for producing heavy rains and flooding.

The heaviest rains are not necessarily located or focused directly along the track of the tropical cyclone.

Remember

Flooding Takes Many Forms

Flash Flood

Flash floods occur within a few minutes or hours of excessive rainfall or a dam or levee failure. Flash floods can roll boulders, tear out trees, destroy buildings and bridges, and scour out new channels. Rapidly-rising water can reach heights of 30 feet or more. Furthermore, flash flood-producing rains can also trigger catastrophic mudslides. You may not always have a warning of these sudden and deadly floods.



Most flood deaths are due to *flash floods*. Nearly half of all flash flood fatalities are automobile-related. Two feet of water will carry away most automobiles.

River Flood



Flooding along rivers is a natural and inevitable part of life. Some floods occur seasonally when winter or spring rains, coupled with melting snows, fill river basins with too much water too quickly. Torrential rains from decaying hurricanes or tropical systems can also produce major or record river flooding.

Urban Flood

As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization increases runoff two to six times over what would occur on natural terrain. During periods of urban flooding, streets can become swift-moving rivers, while basements can become death traps as they fill with water.



Flash & Urban Flooding -- short events which occur within 6 hours of heaviest rain

River Flooding -- a longer event which may last a week or more

Before the Flood

Know your elevation above flood stage and your flood risk. Do your local streams or rivers flood easily? If so, be prepared to move to a safe place quickly. Know your evacuation routes.

Keep your automobile fueled. If electric power is cut off, gas stations may not be able to operate pumps for several days.

Store drinking water in clean bathtubs and in various containers. Water service may be interrupted.

Keep a food supply that requires little cooking and no refrigeration. Again, electrical power may be interrupted.

Keep prescription drugs and first aid supplies on hand.

Keep a NOAA Weather Radio, a battery-powered commercial radio, emergency cooking equipment, and flashlights in working order.

Install check valves in building sewer traps to prevent floodwater from backing up into the drains in the home.

What YOU Can Do



Assemble a *disaster supplies kit* containing: first aid kit, canned food, can opener, bottled water, rubber boots, rubber gloves, NOAA Weather Radio, battery-powered commercial radio, flashlight, and extra batteries.

What Your Community Can Do

Assist hospitals and other operations, which are critically affected by power failure, by arranging for auxiliary power supplies.

River and rainfall readings are valuable to local emergency management agencies (EMA) and the National Weather Service (NWS) in assessing flood conditions and taking appropriate actions. Readings from these gages are vital in the decision-making process when action needs to be taken. Advanced warning provided by early detection is critical to saving lives. Automatic flood detection systems are valuable commercially for flood-prone communities.



Martin County Fairgrounds, Florida - FEMA, State of Florida, and private industry representatives work together to inform residents at a local housing fair that disaster mitigation help is available.

Photo by Ty Harrington/FEMA News Photo

Contact your local NWS or EMA office for more information on local flood warning systems.



Stay Informed

NOAA Weather Radio is the best means of receiving warnings from the National Weather Service

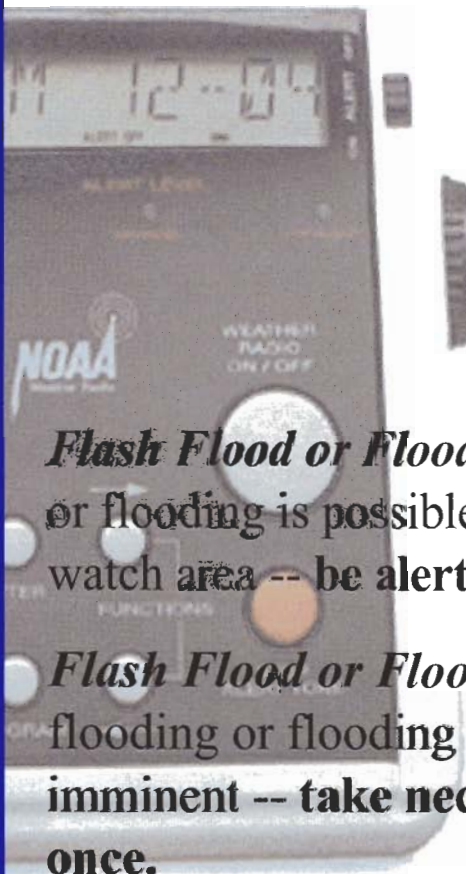
The National Weather Service continuously broadcasts updated weather warnings and forecasts on NOAA Weather Radio. These radios are sold in many stores, through mail-order, and on the internet. The average signal has a broadcast range of 40 miles and will depend on topography. The National Weather Service recommends purchasing a radio that has both a battery backup and a tone-alert feature which automatically alerts you when a watch or warning is issued.

The National Weather Service's internet data sources provide another means of receiving warnings and flood and storm information. The Weather.gov connection provides links to your local National Weather Service office for live computer data broadcasts via satellite, radio, and internet. The Hydrologic Information Center web site (<http://www.nws.noaa.gov/oh/hic/index.html>) provides updated national summaries of hydrologic conditions, forecasts, and outlooks.

Stay informed about the storm by listening to NOAA Weather Radio, commercial radio, or television for the latest flash flood/flood watches, warnings, and advisories

The rule for being safe in a flooding situation is simple: *Head for higher ground and stay away from flood waters!*

What To Listen For



Flood Potential Statement:

Forecasts indicate the possibility of flooding beyond 36 hours -- **be aware.**

Flash Flood or Flood Watch: Flash flooding or flooding is possible within the designated watch area -- **be alert.**

Flash Flood or Flood Warning: Flash flooding or flooding has been reported or is imminent -- **take necessary precautions at once.**



When a **Flash Flood Warning** is issued for your area, or the moment you realize that a flash flood is imminent, act quickly to save yourself.

You may have only seconds!



Remember:
It's better to be wet than dead!

When you receive a FLOOD WARNING:

- If advised to evacuate, do so *immediately*.
- Move to a safe area before access is cut off by rising water.
- Continue to monitor NOAA Weather Radio, television, or emergency broadcast stations for information.

Go to higher ground -- Climb to safety!

Get out of areas subject to flooding. These include dips, low spots, canyons, washes, etc.

Avoid already-flooded and high-velocity flow areas. Do not attempt to cross flowing streams.

If driving, be aware that the roadbed may not be intact under floodwaters. Turn around and go another way. **NEVER** drive through flooded roadways!

If the vehicle stalls, *leave it immediately and seek higher ground!* Rapidly rising water may engulf the vehicle and its occupants and sweep them away.

Be especially cautious at night, when it is harder to recognize flood dangers.

**MARK TRAIL CHAMPIONS
NOAA WEATHER RADIO-**
THE VOICE OF THE NATIONAL WEATHER SERVICE

NOAA WEATHER RADIO SHOULD BE AS COMMON IN HOMES AND PUBLIC PLACES AS SMOKE DETECTORS!



During the Flood

- Avoid areas subject to sudden flooding.
- If you come upon a flowing stream where water is above your ankles, **STOP!** Turn around and go another way.
- Do not attempt to drive over a flooded road. The depth of the water is not obvious. The roadbed may be washed out under the water and you could be stranded or trapped.
- Children should **NEVER** play around high water, storm drains, creeks or rivers.
- Do not go white-water boating or rafting. A flood changes the characteristics and behavior of a waterway.

If freshwater has come in contact with floodwater, throw it out.

Boil drinking water before using. Wells should be pumped out and the water tested for purity before drinking. If in doubt, call your local public health authority.

Seek necessary medical care at the nearest hospital. Food, clothing, shelter, and first aid are available from the Red Cross.

Do not visit disaster areas. Your presence might hamper rescue and other emergency operations.

Electrical equipment should be dried and checked before being returned to service.

Use flashlights, not lanterns, torches, or matches, to examine buildings. Flammables may be inside.

Report broken utility lines to appropriate authorities.



After the Flood