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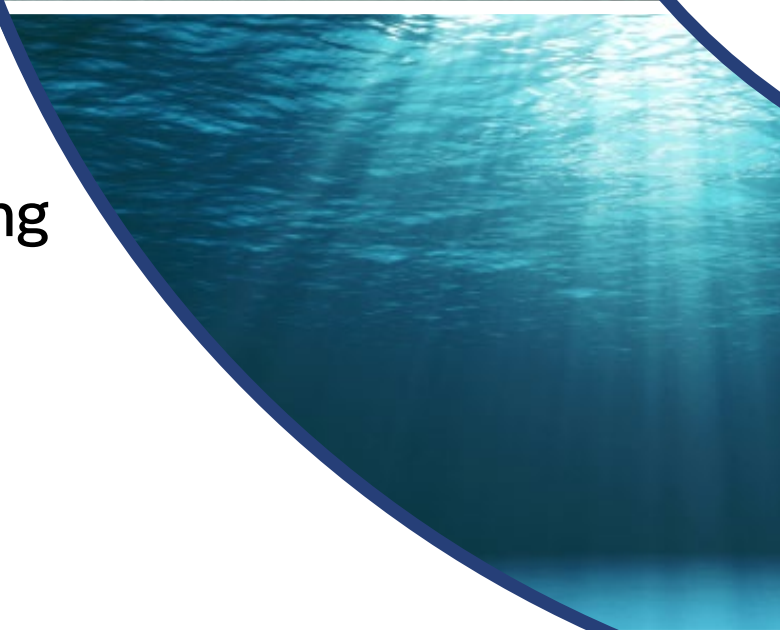


National Water Model (NWM) Tutorial

A 101 Guide to Understanding and Using the NWM

Introduction: What is the NWM?

The National Water Prediction Service (NWPS) is the National Oceanic and Atmospheric Administration's (NOAA) online, map-based platform that provides access to a wide range of water data, including river forecasts, streamflow observations, precipitation, and flood maps. It can be found at https://water.noaa.gov.

One of the main sources of data shown in the NWPS is the National Water Model (NWM). The NWM is a hydrological model that simulates hydrological conditions over the continental United States, South-Central Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands, on both gauged and ungauged rivers. Behind the scenes, the model runs in several configurations to support different uses. These include retrospective simulations for the past 40 years, as well as near–real–time estimates of current conditions and future forecasts since 2016, the year the NWM became operational.

Important Note: The NWM serves as a valuable supplemental resource when seeking data and tools to support flood forecasting and improve understanding of hydrological conditions, particularly streamflow and flood risk. While powerful, it is subject to uncertainty due to the limitations of input data. The NWM output also provides supplemental guidance to the National Weather Service (NWS) forecasters and should not be considered an official NWS river forecast. Always refer to official NWS alerts and guidance from local authorities for real-time decision-making and emergency response. For more detailed information about the NWPS, NWM, or related resources, contact your nearest National Weather Forecast Office.

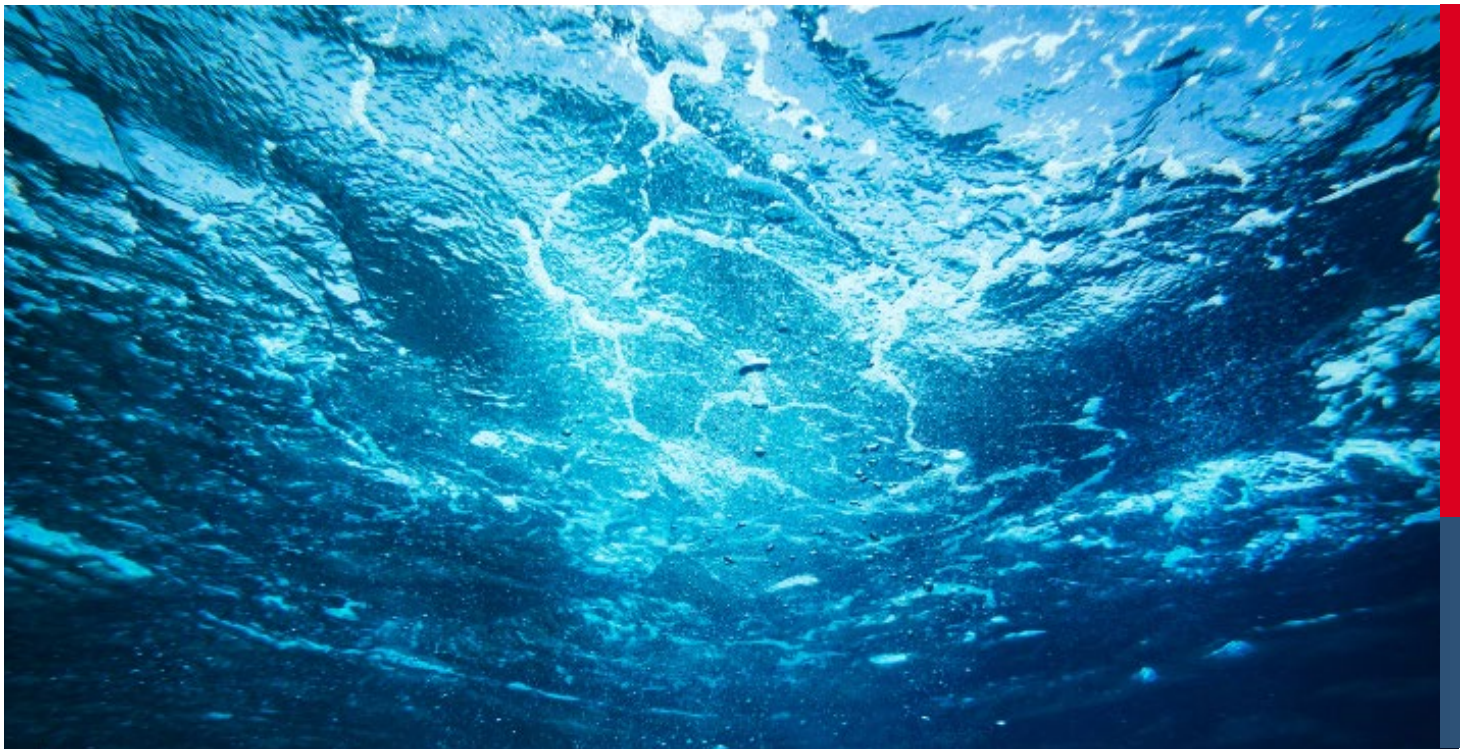
What Types of Information are Available from the NWM?

What data does the NWM use to make its simulations?

- NOAA and NWS Weather Data: Including precipitation, temperature, and other meteorological inputs
- USGS Gauge Readings: Observed river and stream conditions from a network of monitoring stations
- Land Surface Models: Models that use and combine soil moisture, runoff, and snowmelt data

What predictions can the model make?

- Return Intervals: Estimates of how frequently specific hydrological events (like a 1-in-25-year flood) are likely to occur
- Maximum High Flow Magnitudes: The highest streamflow values forecasted or recorded for a specific river
- Stage Exceedance Probabilities: The probability (expressed as a decimal or percentage) that a certain river stage will be equaled or exceeded within a given time frame
- Retrospective Data: 40-year retrospective data on streamflow and water levels showing how rivers have behaved over time
- Streamflow Forecasts: Estimates of how much water will be in rivers and streams (measured in cubic feet per second) based on forecasted precipitation
- River Stage Heights: How high the water will rise (measured in feet)
- Flood Inundation Mapping (FIM): Visual maps showing where flooding is likely to occur at different water levels. These maps are typically generated using the Height Above Nearest Drainage (HAND) method, which uses terrain elevation data to estimate how far water will spread from nearby streams.



What Questions Can the NWM Help Me Answer?

The NWM is a valuable supplemental tool for understanding streamflow and water conditions in your area of interest. The model can help answer questions such as:

- Is my region forecasted to flood? (Section 2-3, 5)
- What does the streamflow near my home look like? (Section 2-3)
- What kinds of flood conditions could put my area at risk of flooding? (Section 2-3)
- How high, and how quickly, is the river expected to rise? (Section 2-3)
- What does streamflow look like on ungauged rivers and streams? (Section 3)
- How can I explore NWM-based estimates of streamflow in my area from past years? (Section 4)
- How vulnerable is it across different scenarios? (Section 5)

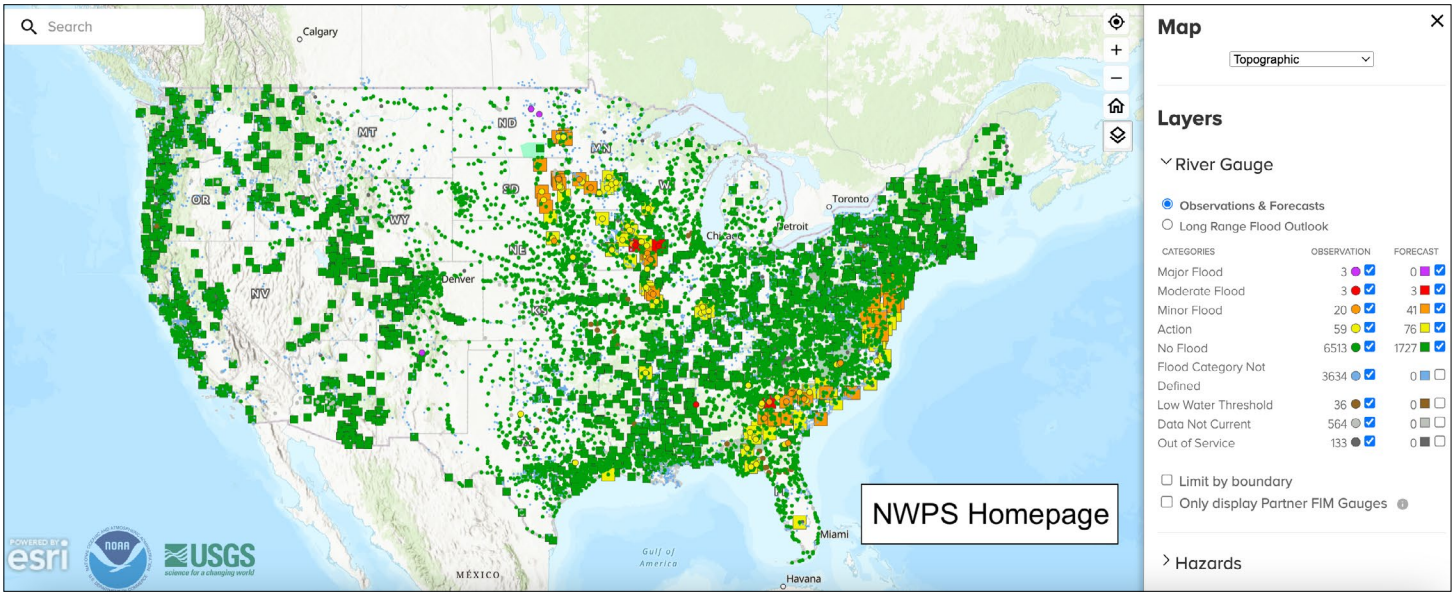
Step-by-Step: How to Evaluate Flood Risks Using the NWPS Website, NWM Data & FIM Services

This tutorial provides a step-by-step guide to: (1) navigate the NWPS website and find basic information on streamflow and flood risk; (2) access NWM near–real–time data and future forecasts and understand how to use and interpret this information; (3) access NWM historical & retrospective datasets; and (4) explore potential flood impacts using Flood Inundation Mapping (FIM) services.

This first section of the guide **(Steps 1 and 2)** will help orient you to the NWPS homepage and walk through its core functions. You will learn how to: search for local streamflow information on gauged rivers, and view near–real-time (latest analysis) and forecasted flood risk alerts with predictions of what infrastructure could be impacted.

Section 1: Understanding the NWPS Website

1. **Access the NWPS homepage:** Open your browser and navigate to the National Water Prediction Service (NWPS) homepage: https://water.noaa.gov/

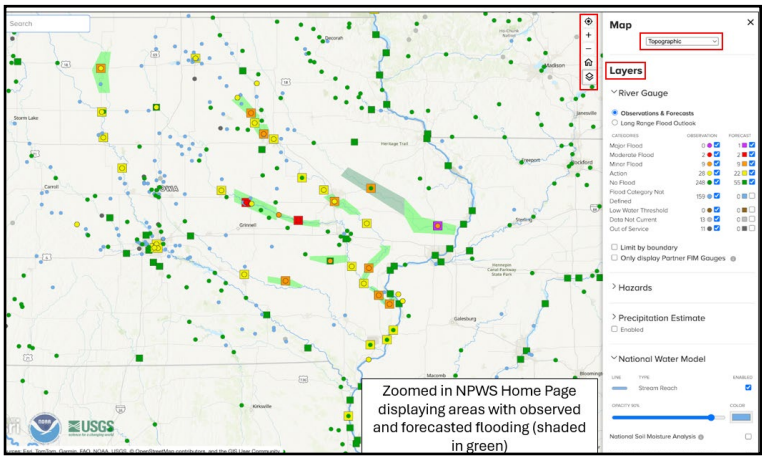


2. **Understand the map view:** You'll arrive at an interactive map of the U.S. showing thousands of colored circles, squares and shaded areas.

Squares: Forecast points that provide future projections.

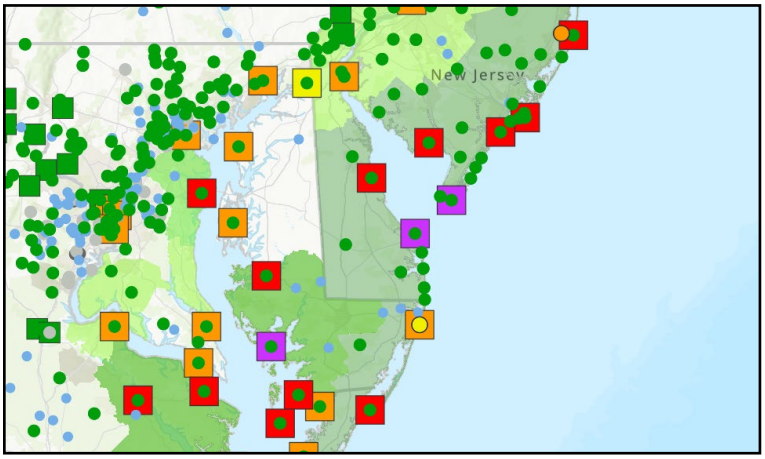
Circles: Observation-only gauges that show past or current conditions (using USGS real-time data).

Shaded Areas: Active flood watches or warnings, often corresponding to squares and circles with forecasted and observed flooding.



Colors: Indicate streamflow conditions

- Purple = Major Flooding
- Red = Moderate Flooding
- Orange = Minor Flooding
- Yellow = Action Stage
- Green = Normal Flow
- Other colors indicate areas where data is not available or low water thresholds.



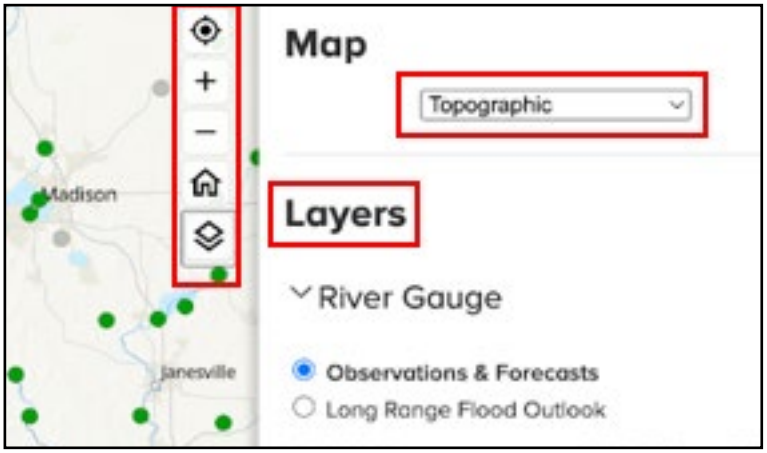
Map Controls (top-right of the map):

a. The ⊙ button centers the map on your current location (if location services are enabled on your device).

b. The + and − buttons allow you to zoom in and outrespectively.

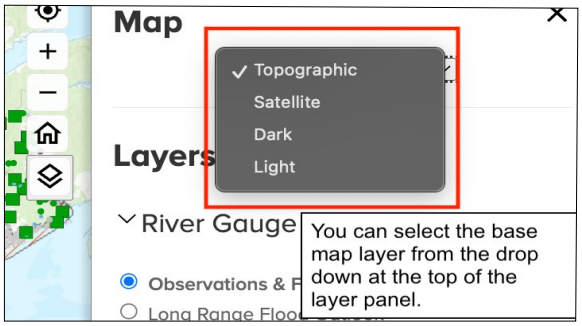
c. The ⌂ button resets the map display to the default.

d. The ◈ button opens and closes the layers panel.



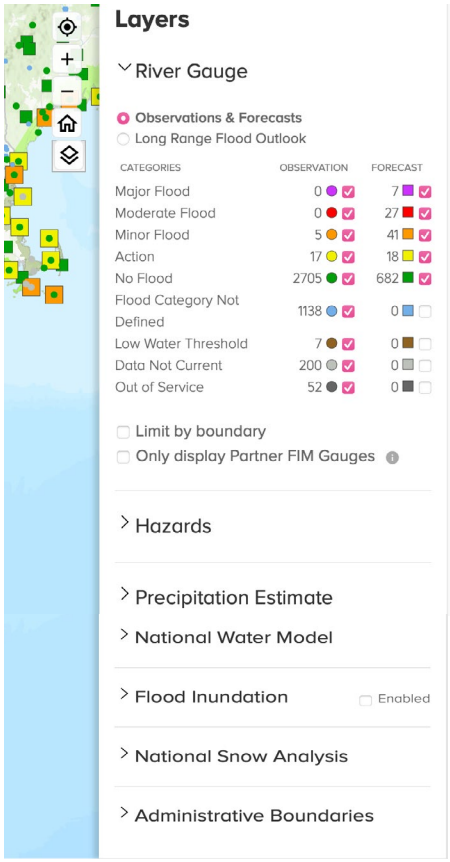
3. **Set your geography and terrain:** On the right, choose a base map to display your preferred landscape. By default, the 'Topographic' layer shows terrain, watersheds, and infrastructure, helping you see how water flow by elevation. See other base map options in the dropdown menu, including:

   a. **Satellite:** Uses satellite imagery and can be useful for identifying landmarks, including large water bodies.
   b. **Light:** Simple base map with high contrast and can be useful for to keep the information clear and share NWPS maps with others.
   c. **Dark:** Same as above – simple base map with high contrast.



4. **Add specific data layers:** You can add layers to visualize different information. The default 'River Gauge' layer shows color-coded observations and forecasts. You can also enable additional layers:

   a. **Long-Range Flood Outlook:** Shows rivers with a minor, moderate, or severe flood risk over the next 3 months. By default, it shows rivers with at least a 50% chance of exceeding flood thresholds, but this percentage can be adjusted.
   b. **Limit by Boundary:** Focus results within a specific watershed, county, or custom boundary. Displays only the gauges visible in your current zoom level.
   c. **Only Display Partner FIM Gauges:** Displays gauges in areas with Flood Inundation Mapping available.



Additional Layers on NWPS Website:

   a. Hazards (not covered in this tutorial)
   b. Precipitation Estimate (not covered in this tutorial)
   c. National Water Model (see Step 3)
   d. Flood Inundation (see Step 5)
   e. National Snow Analysis (not covered in this tutorial)
   f. Administrative Boundaries (not covered in this tutorial)

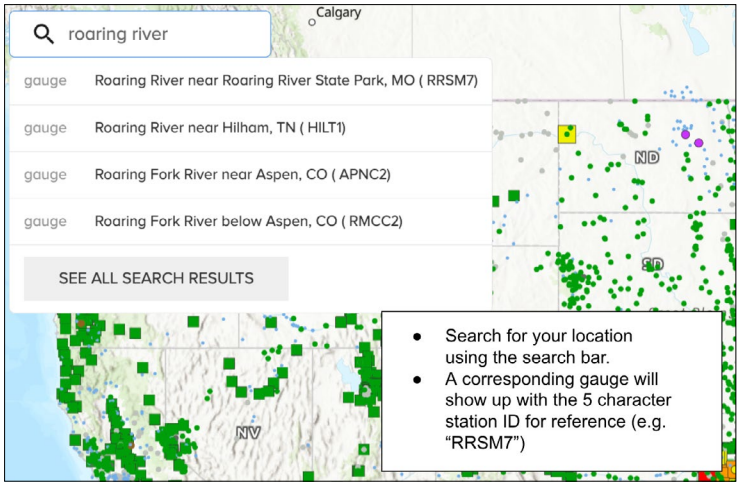
   For more information on the layers not covered in this tutorial (c-e above), please refer to NOAA User's Guide.

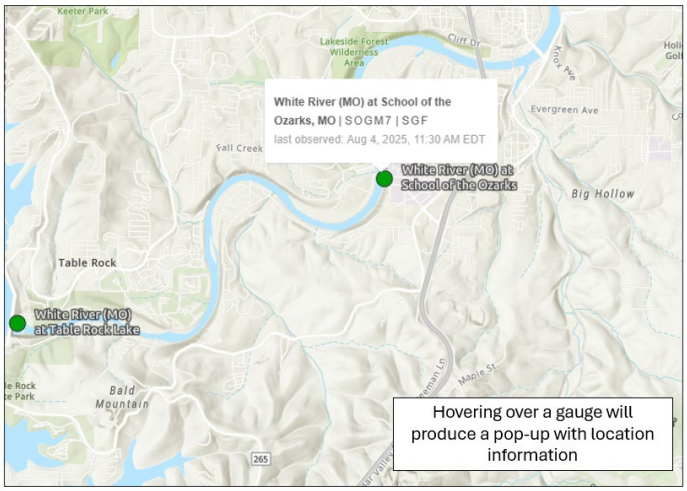
5. **Share and save view:** The NWPS map URL (https://water.noaa.gov/map/) automatically saves your settings (layers, zoom level, and selected gauge), so you can bookmark or share with others.

Section 2: Using the NWPS to Access Gauged River Data

To check current and forecasted streamflow conditions from an official gauged point:

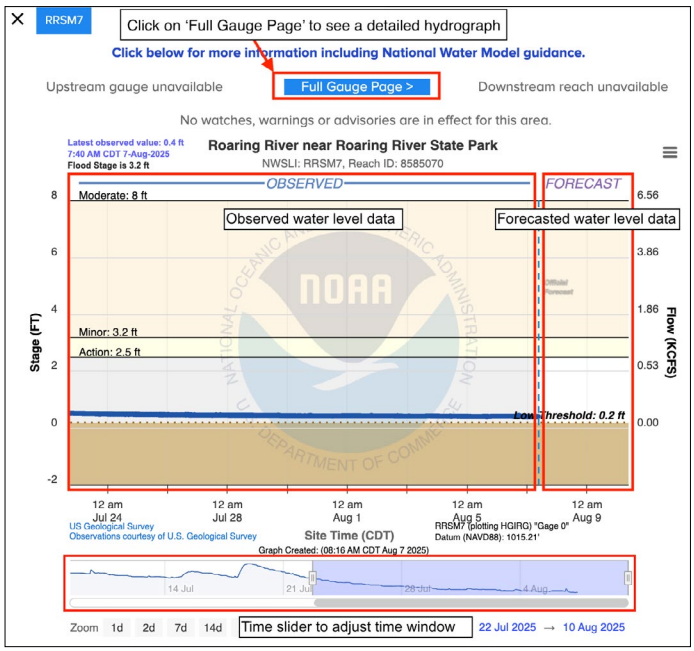
1. **Find a Gauge:**
   a. Enter your location in the search bar (at the top left of water.noaa.gov homepage)
   b. Click on a square or circle near your area of interest: When hovering over a square or circle, which represent river gauges with available streamflow data, a pop-up with location information will be appear. After you click on one of these, you can preview current and forecasted streamflow data.



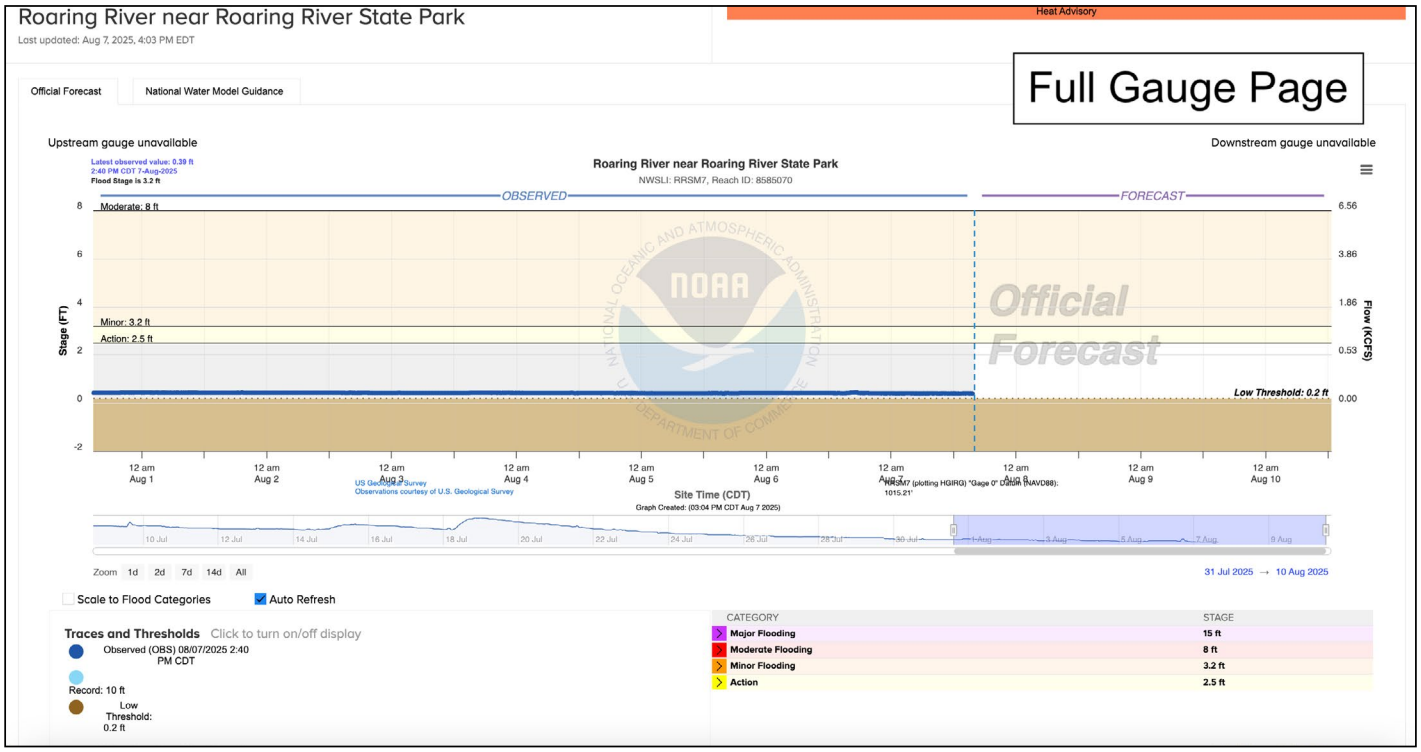


2. **Interpreting the Hydrograph:** Once you click a circle or square, you will see a hydrograph page. The default view shows official, real-time data from USGS of gauged streams across the US. On the hydrograph you will find the following information:

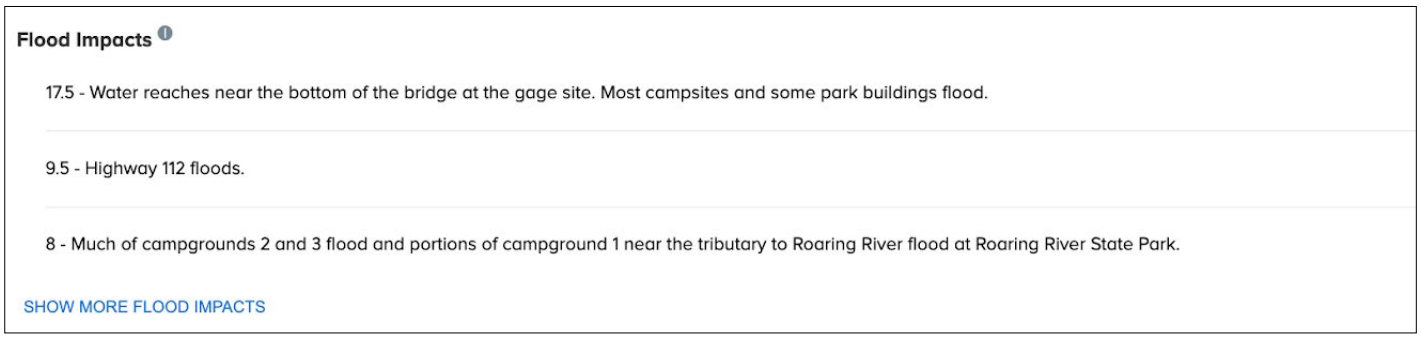
   a. **Left side**: Observed water level data (past stage height in ft)
   b. **Right side**: Forecasted water level data (stage height in ft) of what the model predicts will happen in the next few days
   c. **Bottom**: A time slider to adjust the time window you'd like displayed for water level data
   d. **Flood Categories**: The shaded colors on the hydrograph correspond to Flood Thresholds from No Action (no color), Action (yellow), Minor (orange), Moderate (red), and Major (purple). For rivers experiencing unusually low streamflow, the graph may show the Low Threshold (brown). These flood categories are calibrated differently for each river based on streamflow.



e. Click "**Full Gauge Page**" at the top of the preview page to see a detailed hydrograph and flood impact information.



3. **View Flood Impact Statements** (if available):
   a. Flood impact statements will be shown below the hydrograph on the full gauge page when flooding impacts infrastructure. For example:

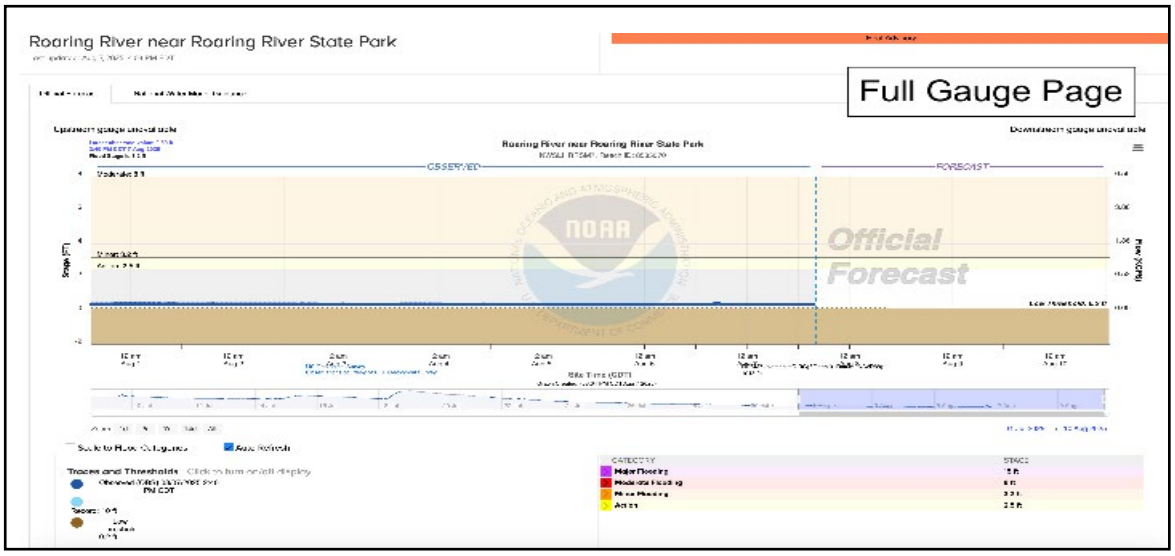


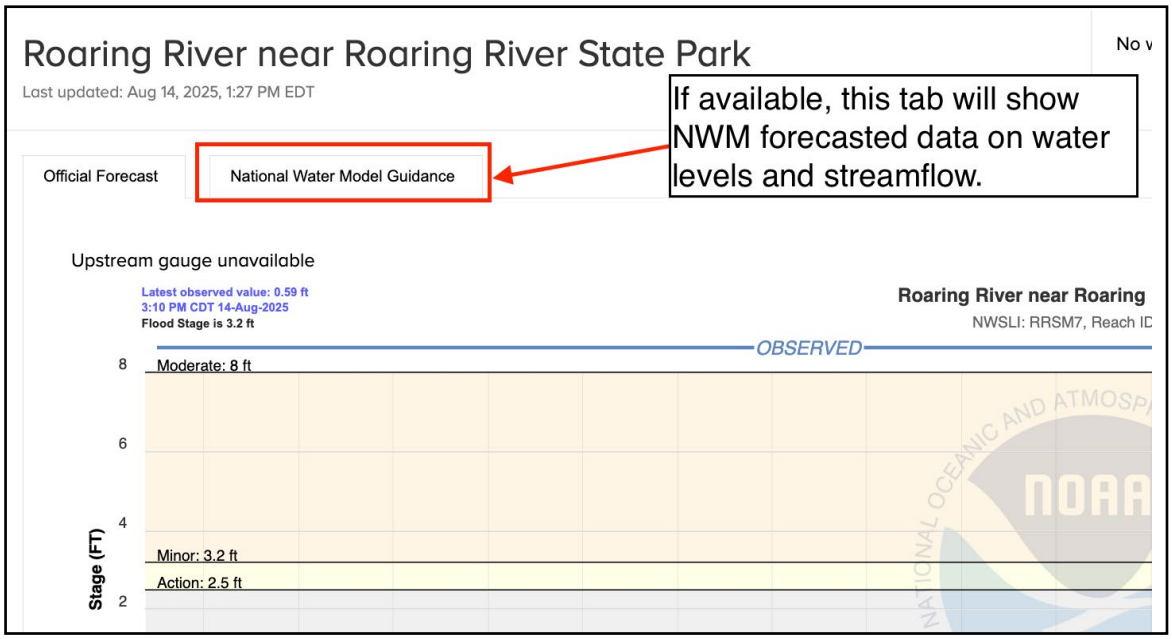
Note: If you see streamflow on the hydrograph reach the "action" flood category, you may want to view the National Weather Service's Alerts Page and select your region to view more detailed hazard information from your local Weather Forecast Office.

Section 3: Accessing the NWM within the NWPS website

While NWPS defaults to showing USGS gauge data, which provides real-time, observed measurements of water levels and flow, you can also view simulated streamflow and water-level forecasts from the NWM – even for ungauged rivers. These streamflow forecasts may be useful for assessing streamflow patterns and flood risk, particularly where there are no other sources of information available. This section **(Step 3)** describes the two ways to access NWM datasets within NWPS:

1. **Option 1: View NWM Forecasts from a Gauge Page**
   a. After clicking "Full Gauge page" (see steps above, image for reference below), you will see the detailed hydrohraph. Underneath your region's name you will see a “National Water Model Guidance.” Click this tab to view the NWM datasets. You will then be able to review modeled streamflow and water level predictions for that reach.

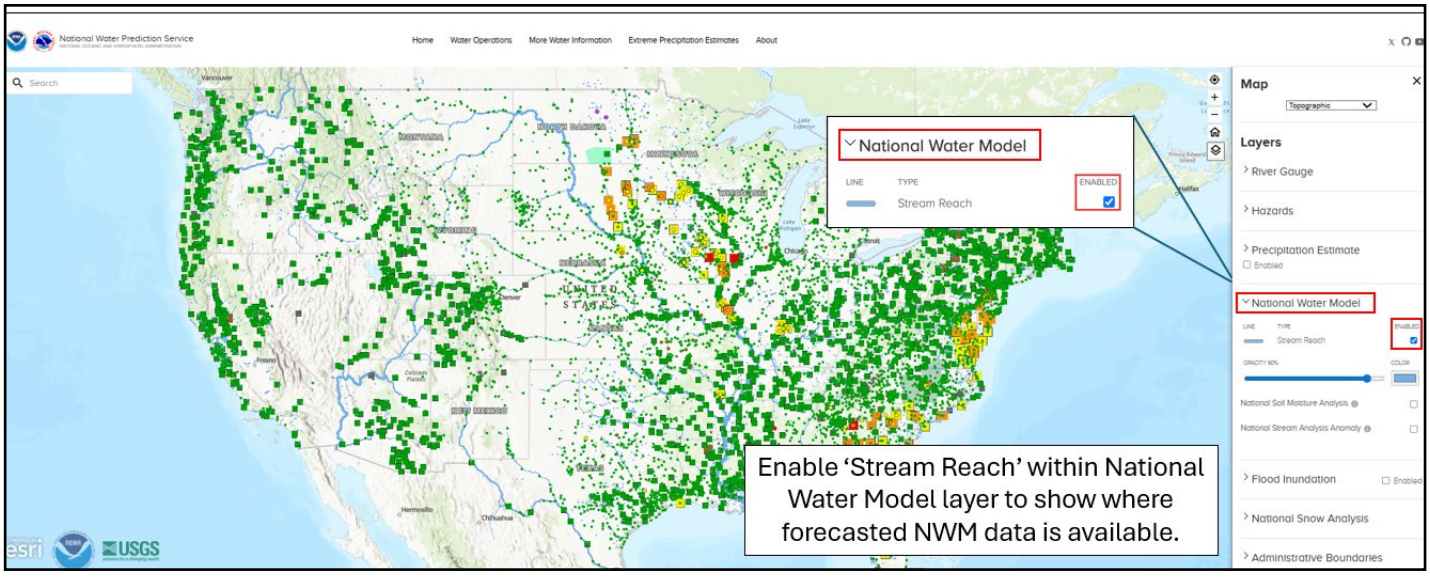




2. Option 2: Enable the NWM Layer from the NWPS Map

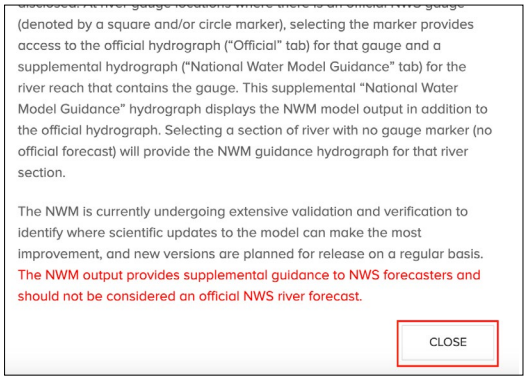
a. On the main map (http://water.noaa.gov), open the Layer Panel.

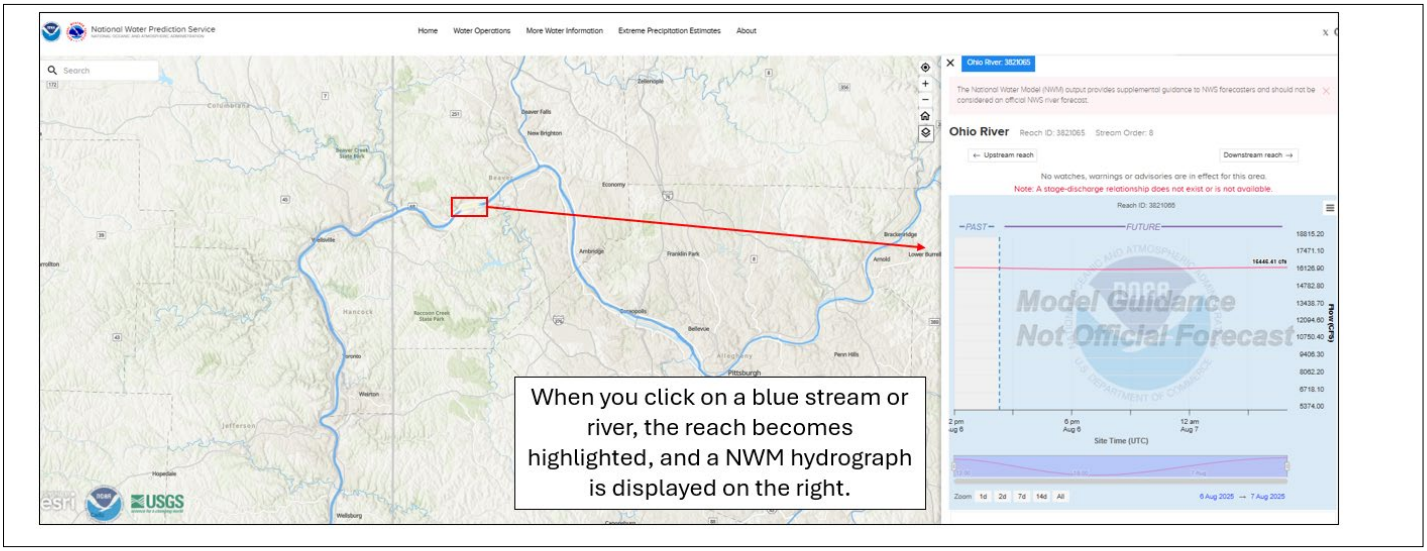
b. Enable the "National Water Model" layer by checking the box next to "Stream Reach."



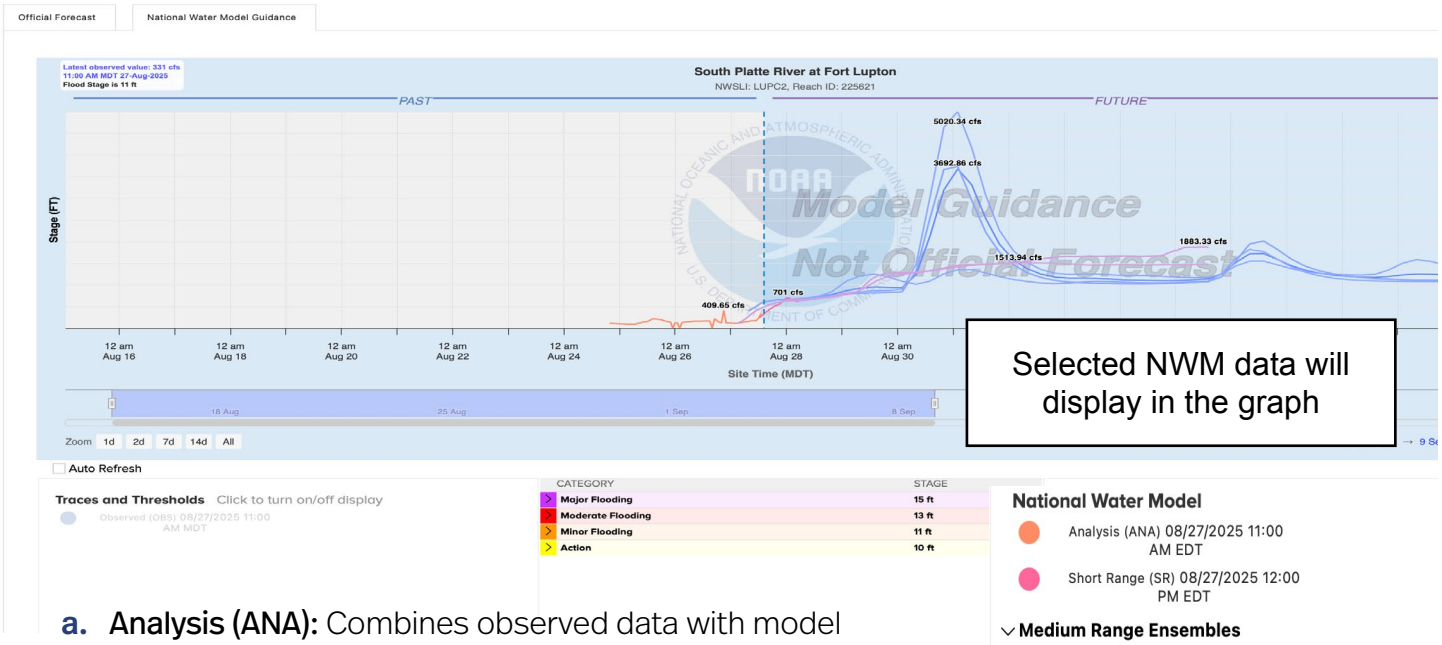
c. A pop-up providing more information about the NWM will show on the map, click "Close" to continue.

d. On the map, click on any blue stream segment to see NWM forecast data, even if there's no gauge. A side panel will display forecasted and historical streamflow, with options to change the time range (similar to the hydrograph page in Step 2).



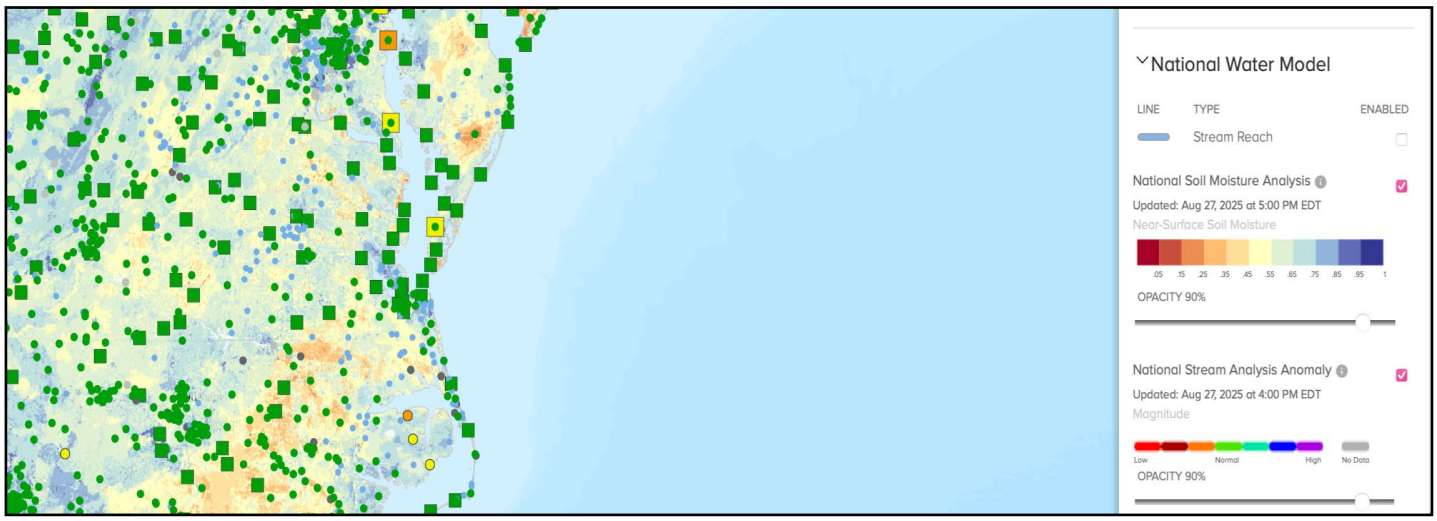


3. **Interpreting NWM Data on Hydrograph:** Whether you go through Option 1 or Option 2, you will land to the NWM hydrograph, where you will see different types of NWM data. The Analysis (ANA) and Short Range (SR) lines are displayed by default on the graph and appear as orange and pink lines, respectively. You can view data from the 'Medium Range Ensembles' and 'Long Range Ensembles' by selecting these options in the dropdown menu. When these data points are selected, they will appear as purple or blue lines on the graph. More information about each NWM data type is below:



a. **Analysis (ANA):** Combines observed data with model simulations to produce the best estimate of current conditions. It serves as a starting points for short-, medium-, and long-range forecasts. Analysis cover the past three days.
b. **Short Range (SR):** Shows modeled streamflow for the next 18 hours using data from weather models, with hourly streamflow output. These are deterministic values, meaning they represent a single best-estimate prediction rather than a range of possible outcomes.
c. **Medium Range Ensembles:** The forecast is based on six slightly different model runs to account for uncertainty, with each run producing its own forecast called an ensemble member. Streamflow values are shown hourly. Users can choose to view any of the six individual ensemble members, the average of all six (mean ensemble), or a 10-day ensemble forecast.
d. **Long Range Ensembles:** For long-range ensembles, the forecast is based on four model runs. Streamflow values are shown every six hours. Users can view any of the four individual ensemble members, each extending 30 days, or the mean ensemble.

4. **View Additional National Water Model Layers:** Other layers that can be enabled in the National Water Model are shown below. Enable these layers in the Layer Panel under the 'National Water Model.'
    a. **National Soil Moisture Analysis:** Shows soil saturation (%) in the top 40cm of soil (updated hourly).
    b. **National Stream Analysis Anomaly:** Highlights whether current streamflow is unusually high or low for the time of year.
        - Example: A river may appear as purple if it is flowing higher than average in mid-July compared

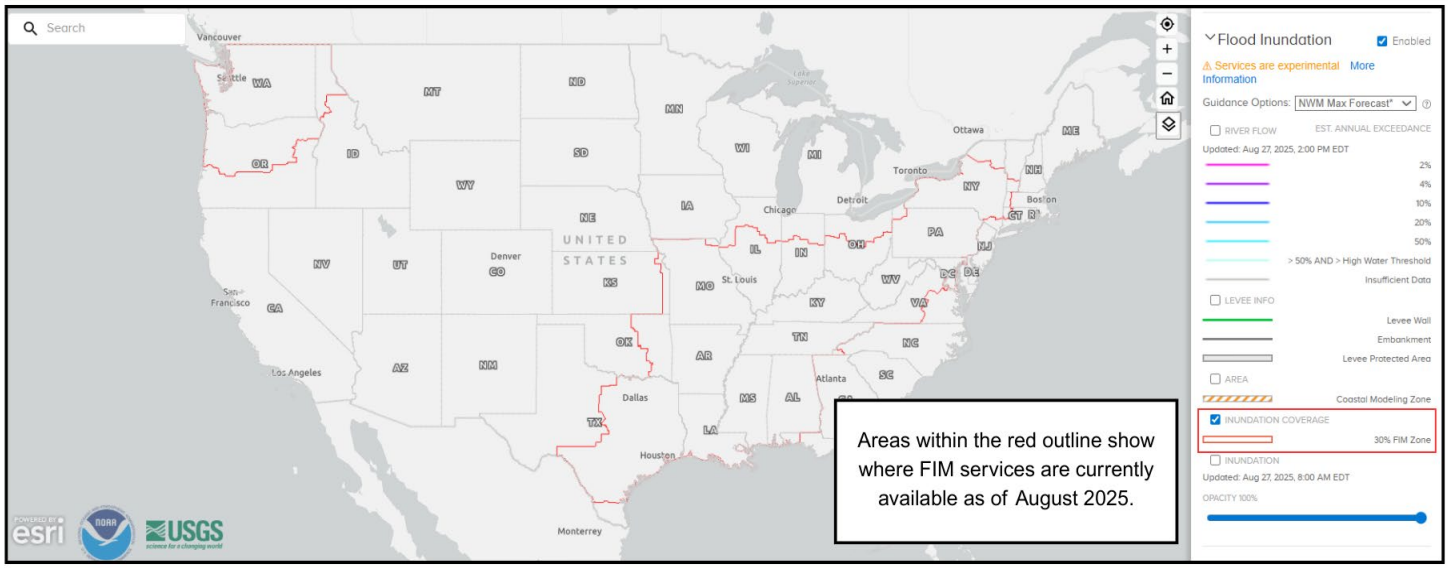


Section 4: Accessing NOAA NWM Retrospective Datasets

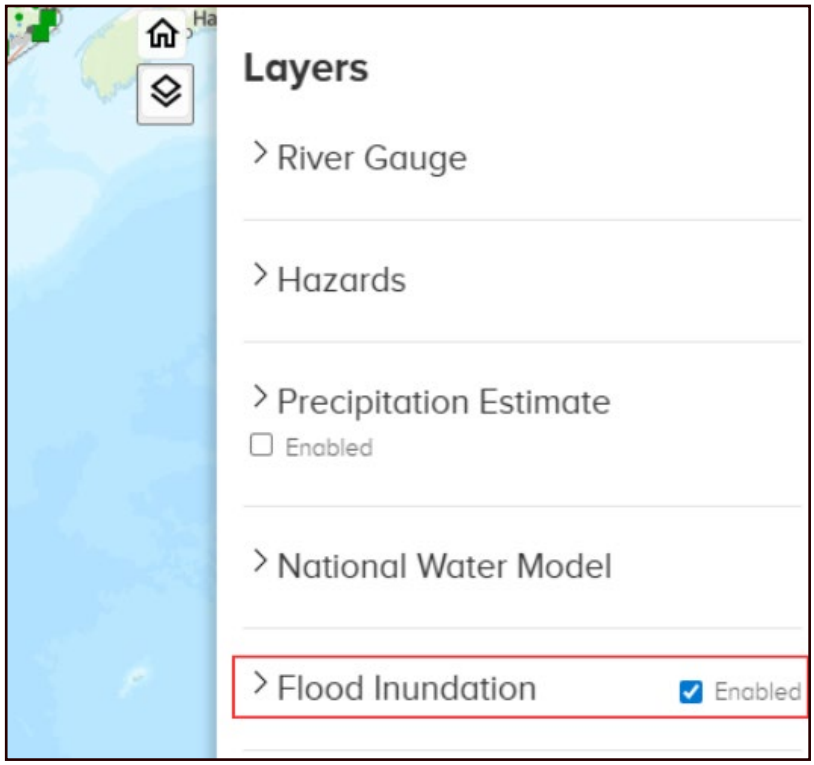
1. Accessing additional retrospective simulations from the NWM on streamflow, as well as other hydrological conditions from the past 40 years, requires some experience in data science and modeling. As these datasets use simulated data, not the near-real-time analysis for forecast data explained above, they have limited utility in evaluating the NWM forecast accuracy in past events. These simulations are typically used for assessing overall model performance, calibrating parameters, or supporting hydrologic research. Below is some guidance for how you might be able to access this information depending on your circumstances:
   a. **Contact Experts:** Reach out to NOAA officials within your local National Weather Forecast Office who might be able to help you access this information. Please visit: https://www.weather.gov/srh/nwsoffices to see NWS offices.
   b. **Tutorials:** Below are some tutorials on how to access the NWM retrospective dataset developed in Jupyter notebooks. They will walk you through how to access the National Water Model (version 3) retrospective, simulated data, particularly the streamflow data. Note: The following resources assume that users have basic to intermediate knowledge and skills working with cloud-native data, Python, relevant packages such as x-array, and experience using Jupyter Notebook.
      - Garousi-Nejad, I., A. M. Castronova, K. B. Raub (2024). Demonstration of the National Water Model's Applicability to Community Resilience Planning: Cincinnati Use Case, HydroShare, http://www.hydroshare.org/resource/0ef4366e7711478fa2637f5049b4881a
      - Garousi-Nejad, I., A. M. Castronova, K. B. Raub (2024). Demonstration of the National Water Model's Applicability to Community Resilience Planning: Minnesota Use Case, HydroShare, http://www.hydroshare.org/resource/3200bab682ec4c3287147cbe40e768ee
   c. **Datasets**: This is recommended for those who are proficient in hydrologic modeling and data analytics. To access NWM raw data please visit: https://registry.opendata.aws/nwm-archive/

Section 5: Flood Inundation Mapping (Experimental)

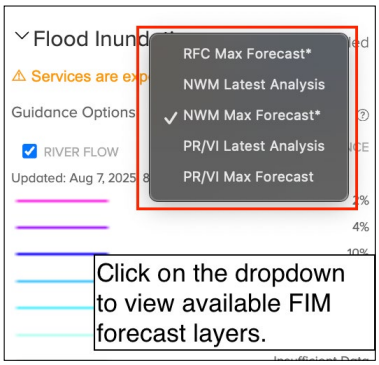
For certain locations, you can view flood inundation maps based on NWM forecasts. Flood Inundation Mapping (FIM) shows where flooding may occur if water exceeds certain levels. Currently, FIM services are considered experimental, and they cover parts of the Midwest and Southeast, including flood-prone river systems like the Ohio, Mississippi, and Tennessee Rivers, as well as some major urban centers (e.g., Houston, Atlanta, St.Louis) as of July 2025. Coverage also extends to parts of the Northeast, Washington, and Oregon. FIM is still under development and its network will be expanded through 2026.

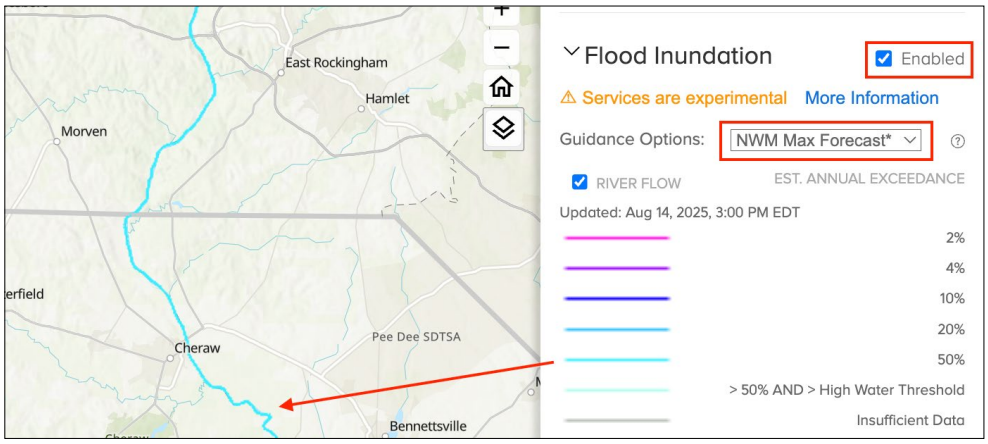


1. **To view flood inundation forecasts:** Enable the 'Flood Inundation' layer in the layer panel.



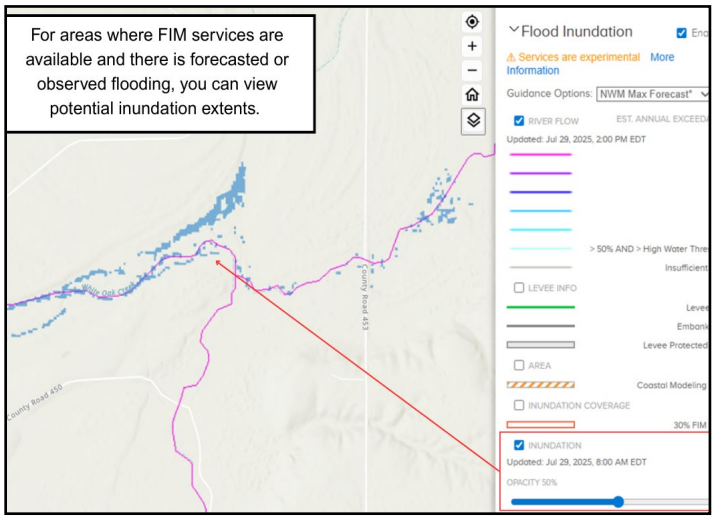
2. **Understand 'River Flow':** When ‘River Flow’ is enabled right below the Guidance Options, it displays only rivers that are currently experiencing streamflow at or above the thresholds associated with specific flood stages. River flow conditions are shown in different colors, with each color representing a specific threshold exceedance. There are several display options for 'River Flow.'
3. **Select display option:** A dropdown menu will appear when you click on 'Guidance Options.' By default, the display is set to “NWM Max Forecast,” which is the most useful option for checking whether an ungauged river is exceeding high streamflow thresholds. Alternatively, some people may prefer to leave the option set to ‘RFC Max Forecast’ for a snapshot of flooding on major gauged rivers throughout the country. Specific information on the utility of each layer is provided below.





a. **RFC Max Forecast:** This only displays inundated areas for rivers serviced by River Forecast Centers (RFC) when streamflow reaches the ‘Action’ stage. Streamflow levels are based on up to 5-day forecasts. On the Flood Inundation layer, streams are represented as having exceeded minor, moderate, or severe streamflow thresholds. Since the flood inundation layer is displayed on top of the rivers, you may want to adjust its opacity so that the river beneath remains visible. This will allow you to see the river’s color, which corresponds to its flood status as defined by the categories shown in the ‘River Flow’ section of this panel.
b. **NWM Max Forecast:** This layer is based on a 5-day weather forecast and displays rivers, including those both covered and not covered by RFCs, that exceed the high streamflow threshold. These thresholds vary regionally and are determined by the NWM's 40-year retrospective data. The values are presented as recurrence intervals. For example, 2% flood represents a 2% chance of a flood occurring every year over a 100-year period, which corresponds to a 1-in-50- year flood.
c. **NWM Latest Analysis:** This displays the simulated data from the analysis run that is updated hourly based on recent observations for rivers where streamflow has exceeded the high streamflow threshold. It is intended to provide a snapshot of the most recent modeled floods. The values are also represented as recurrence intervals.
d. **Others:** Remaining options cover the U.S Virgin Islands and Puerto Rico only.

4. **To view flood inundation extent:** Enable the ‘Inundation’ layer within ‘Flood Inundation’ to show flood inundation extents. When you zoom in to a river that is exceeding a threshold, you will be able to see the modeled extent of flood inundation represented by blue squares. You can also adjust the opacity of this layer using the slider.



5. **Additional Flood Inundation data:** Other layers you can enable within the Flood Inundation layer drop-down include:
   a. **Levee Info:** Displays locations and elevations of levees, embankments and protected areas that are within the National Levee Database.
   b. **Coastal Modeling Zone:** These are areas between 0m and 10m above sea level along the coast where inundation models should be viewed with caution as they do not account for coastal processes (e.g., storm surge).
   c. **Inundation Coverage:** These show areas that have Flood Inundation Mapping (FIM) coverage within a red line boundary. As of June 2025, FIM services currently provide partial national coverage (approximately 30% of the United States), with plans to continue expansion through 2025-2026.

Glossary of key terms

- **Action Stage:** The level of a rising stream at which communities need to take some type of mitigation action to prepare for flooding (determined by the NWS).
- **Crest:** The highest stage or level of a flood wave as it passes a certain point.
- **Cubic Feet per Second (CFS):** A unit measuring the volume of water flow per second. To learn more about what the standard streamflow in cfs would be for a specific river, please visit USGS WaterWatch website. WaterWatch provides statistical information on streamflow based on historical data in graphs and tables. The NWPS flood categories and corresponding streamflow values for rivers with gages is also a useful reference point.
- **Exceedance Probability:** The likelihood, expressed as a decimal (e.g., 0.01), that a streamflow or stage threshold is equaled or surpassed in a given time period.
- **HAND Method:** Stands for Height Above Nearest Drainage and is a model based on terrain analysis that estimates inundation using elevation and proximity to streams.
- **Hydrograph:** A graph displaying river levels over time, which is used for both real-time and historical comparisons.
- **Return Interval:** Also known as recurrence interval, is an indicator of how frequent a particular hydrological event occurs on average. For example, a 1-in-100 year flood has a 1% chance of occurring every year.
- **Stage Height:** The height of the water surface above a reference point, usually in feet.

Where can I learn more about the NWM or other NOAA resources?

- National Water Prediction Service
- User's Guide to the National Water Prediction Service (NWPS)
- Introducing the New National Water Prediction Service (NWPS)
- NWS National GIS Map Viewer
- NWS Products and Services
- NWS Flood Inundation Mapping Services
- Using the National Water Model within NWPS
- Reading the River Forecast, a recording of John Goff, Senior Service Hydrologist with NOAA/NWS in Burlington, VT hosted by Flood Ready Vermont