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Appendix A: HAND and Synthetic Rating Curve References 69
Introduction

This handbook describes a suite of visualization services developed by the NOAA/NWS Office of Water Prediction (OWP) at the National Water Center (NWC). These dynamic services leverage forecasts from the NWS River Forecast Centers (RFCs) and the National Water Model (NWM). Included in the handbook is a brief description of the service and a summary of the methodology used to derive each visualization service; an Appendix is included to further describe methods for estimating inundation extent using the Height Above Nearest Drainage (HAND) method. Updates to existing services are documented in tables at the onset of each section.

Services leverage GIS technology and are made available through the NWC’s Enterprise GIS.
General Release Updates
For this release, the following general updates have been implemented:

- None

Specific updates for individual services can be found in the summary tables at the beginning of each configuration section.
## Reference Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWS Regions</td>
<td>Depicts the boundaries of the National Weather Service (NWS) Regions.</td>
<td>None</td>
</tr>
<tr>
<td>RFC Regions</td>
<td>Depicts the boundaries of the NWS River Forecast Centers (RFC).</td>
<td>None</td>
</tr>
<tr>
<td>WFO Domains</td>
<td>Depicts the domains of the NWS Weather Forecast Offices (WFO).</td>
<td>None</td>
</tr>
<tr>
<td>NWM Flowlines</td>
<td>Depicts the flowlines in the National Water Model (v2.0).</td>
<td>None</td>
</tr>
<tr>
<td>NWM Hawaii Flowlines</td>
<td>Depicts the flowlines in the National Water Model (v2.0) for the state of Hawaii.</td>
<td>None</td>
</tr>
<tr>
<td>NWM Waterbodies</td>
<td>Depicts the waterbodies in the National Water Model (v2.0).</td>
<td>None</td>
</tr>
<tr>
<td>U.S. Cities</td>
<td>Depicts U.S. cities.</td>
<td>None</td>
</tr>
<tr>
<td>U.S. County Boundaries</td>
<td>Depicts the boundaries of U.S. counties.</td>
<td>None</td>
</tr>
<tr>
<td>U.S. State Boundaries</td>
<td>Depicts the boundaries of U.S. states and territories.</td>
<td>None</td>
</tr>
<tr>
<td>U.S. Urban Areas</td>
<td>Depicts the extent of U.S. urban areas.</td>
<td>None</td>
</tr>
<tr>
<td>R&amp;R FIM Catchment Boundaries</td>
<td>Depicts catchment boundaries for FIM v2.X main stem (MS) configuration applied to R&amp;R streamflow forecasts.</td>
<td>New</td>
</tr>
</tbody>
</table>
NWS Regions

Description
Depicts the boundaries of the National Weather Service regions.

Source of data: https://www.weather.gov/gis/AWIPSShapefiles

Update Frequency
Static

Methodology
N/A
**RFC Regions**

**Description**
Depicts the boundaries of the NWS River Forecast Centers.

Source of data:  [https://www.weather.gov/gis/AWIPSShapefiles](https://www.weather.gov/gis/AWIPSShapefiles)

**Update Frequency**
Static

**Methodology**
N/A
WFO Domains

Description
Depicts the domains of the NWS Weather Forecast Offices.

Source of data: https://www.weather.gov/gis/AWIPSShapefiles

Update Frequency
Static

Methodology
N/A
**Description**
Depicts the flowlines in the National Water Model (v2.0).

Source of data: [https://water.noaa.gov](https://water.noaa.gov)

**Update Frequency**
Static

**Methodology**
N/A
**Description**
Depicts the flowlines in the National Water Model (v2.0) for the state of Hawaii.

Source of data: [https://water.noaa.gov](https://water.noaa.gov)

**Update Frequency**
Static

**Methodology**
N/A
**NWM Waterbodies**

*Description*
Depicts the waterbodies in the National Water Model (v2.0).

Source of data: [https://water.noaa.gov](https://water.noaa.gov)

*Update Frequency*
Static

*Methodology*
N/A
**U.S. Cities**

*Description*
Depicts U.S. cities.

*Source of data:*
https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservice.html

*Update Frequency*
Static

*Methodology*
N/A
**Description**
Depicts the boundaries of U.S. counties.

Source of data:  
[https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservice.html](https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservice.html)

**Update Frequency**
Static

**Methodology**
N/A
U.S. State Boundaries

Description
Depicts the boundaries of U.S. states and territories.

Source of data:
https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservice.html

Update Frequency
Static

Methodology
N/A
**Description**
Depicts the extent of U.S. urban areas.

Source of data:  
https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservic...html

**Update Frequency**
Static

**Methodology**
N/A
Replace and Route FIM Catchment Boundaries

Description
Catchments for the main stem FIM v2.X based on v1.3 Height Above the Nearest Drainage (HAND) grids.

Update Frequency
Static

Methodology
N/A
# AHPS and RFC Visualization Services

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHPS Maximum Stage Forecast</td>
<td>Depicts AHPS gauges with forecasts at or above &quot;action&quot; stage. Circles represent gauges where stages are changing by less than +/- 5% over the entire forecast period. Upward-pointing triangles represent gauges where a greater than 5% increase in stage is expected sometime during the forecast. If stage increases greater than 5% are not expected, downward-pointing triangles represent gauges where a greater than 5% decrease in stage is expected sometime during the forecast. Gauges are colored by their maximum forecast flood category.</td>
<td>● Updated Description</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● New Trend Algorithm (see description)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● New Fields</td>
</tr>
<tr>
<td></td>
<td></td>
<td>○ Altitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td>○ Altitude Datum</td>
</tr>
<tr>
<td>RFC Replace &amp; Route 5-Day Maximum Streamflow Forecast</td>
<td>Depicts maximum streamflow over the next 5 days derived from the official RFC forecasts routed through the National Water Model (v2.0) stream network downstream of AHPS gauges (Replace &amp; Route). Maximum streamflows are available downstream of AHPS gauges whose forecasts reach action status or greater.</td>
<td>● None</td>
</tr>
<tr>
<td>RFC Replace &amp; Route 5-Day Maximum Inundation Extent Forecast</td>
<td>Depicts expected maximum inundation extent derived from the official RFC forecasts routed through the National Water Model (v2.0) stream network downstream of AHPS gauges (Replace &amp; Route). Shown are areas expected to be inundated at some point over the next 5 days.</td>
<td>● None</td>
</tr>
<tr>
<td></td>
<td><strong>Note:</strong> Inundation extent is only viewable to users in the NWC FIM Services group on the NWC Portal.</td>
<td></td>
</tr>
</tbody>
</table>
**AHPS Maximum Stage Forecast**

**Description**
Depicts AHPS gauges with forecasts at or above "action" stage. Circles represent gauges where stages are changing by less than +/- 5% over the entire forecast period. Upward-pointing triangles represent gauges where a greater than 5% increase in stage is expected sometime during the forecast. If stage increases greater than 5% are not expected, downward-pointing triangles represent gauges where a greater than 5% decrease in stage is expected sometime during the forecast. Gauges are colored by their maximum forecast flood category.

**Update Frequency**
Once every 15 minutes.

**Methodology**
HML products transmitted through the SBN are ingested into a database and then queried through an API. Forecast time series are then analyzed to detect changes in flood stage.
**Description**
Depicts maximum streamflow over the next 5 days derived from the official RFC forecasts routed through the National Water Model (NWM) (v2.0) stream network downstream of AHPS gauges (Replace & Route). Maximum streamflows are available downstream of AHPS gauges whose forecasts reach action status or greater.

**Update Frequency**
Once per hour.

**Methodology**
HML products transmitted through the SBN are ingested into a database and then queried. Forecast streamflow time series are assimilated into the NWM (v2.0) channel routing module and then routed through river segments downstream (Replace & Route). The NWM Analysis and Assimilation configuration provides the initial streamflow conditions for Replace & Route.
RFC Replace & Route 5-Day Maximum Inundation Extent Forecast

**Description**
Depicts expected maximum inundation extent derived from the official RFC forecasts routed through the National Water Model (NWM) (v2.0) stream network downstream of AHPS gauges (Replace & Route). Shown are areas expected to be inundated at some point over the next 5 days. Inundation extents are derived using the Height Above the Nearest Drainage (HAND) method; stage heights are interpolated from routed discharges using synthetic rating curves, interpolated stage heights are rounded up to the nearest foot, and corresponding pre-computed inundation extent polygons are displayed.

*Note: Inundation extent is only viewable to users in the NWC FIM Services group on the NWC Portal.*

**Update Frequency**
Once per hour.

**Methodology**
HML products transmitted through the SBN are ingested into a database and then queried. Forecast streamflow time series are assimilated into the NWM (v2.0) channel routing module and then routed through river segments
downstream (Replace & Route). The NWM (v2.0) Analysis and Assimilation configuration provides the initial streamflow conditions for Replace & Route.

Forecast streamflows from Replace & Route are converted to forecast stages using synthetic rating curves derived from reach-averaged channel properties. Reach-averaged channel properties are derived from 10-meter elevation data. Forecast stages are then converted to forecast inundation extents using a 10-meter relative elevation grid derived using the HAND method.
NWM Visualization Services

This section outlines the suite of visualization services driven by the National Water Model (NWM). The NWM provides estimates of current and forecast hydrologic conditions (including streamflow) across the U.S. via several model configurations: Analysis and Assimilation (current conditions), Short-Range Forecast (18-hours), Medium-Range Forecast (10-days) and Long-Range Forecast (30-days); see Figure 1 below. For more information about the NWM, visit https://water.noaa.gov.

Figure 1: NWM configurations.
## Current Conditions: Analysis and Assimilation Configuration

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWM Streamflow Analysis - Hawaii</td>
<td>Depicts the streamflow output from the operational National Water Model (v2.0) analysis and assimilation for the state of Hawaii.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM High Flow Magnitude Analysis</td>
<td>Depicts high flow magnitudes derived from the operational National Water Model (v2.0) analysis and assimilation. Shown are reached with flow at or above bankfull. Reaches are colored by the annual exceedance probability of their current flow.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM High Flow Magnitude Analysis - Hawaii</td>
<td>Depicts high flow magnitudes derived from the operational National Water Model (v2.0) analysis and assimilation configuration for the state of Hawaii. Shown are reached with flow at or above bankfull. Reaches are colored by the annual exceedance probability of their current flow.</td>
<td>● Scale Dependent Rendering&lt;br&gt;● Updated Field Alias&lt;br&gt;○ Max Annual Exceed Prob (%) -&gt; Annual Exceed Prob (%)&lt;br&gt;● Updated Legend Category&lt;br&gt;○ Not Available -&gt; Insufficient Data</td>
</tr>
<tr>
<td>NWM Inundation Extent Analysis</td>
<td>Depicts inundation extent derived from the operational National Water Model (v2.0) analysis and assimilation.&lt;br&gt;&lt;br&gt;Note: Inundation extent is only viewable to users in the NWC FIM Services group on the NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.</td>
<td>● None</td>
</tr>
<tr>
<td>Past 72-Hour Accumulated Precipitation Analysis</td>
<td>Depicts accumulated precipitation totals over the past 72 hours derived from the MRMS forcing for the operational National Water Model (v2.0) analysis and assimilation.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM Snow Depth Analysis</td>
<td>Depicts the snow depth output from the operational National Water Model (v2.0) analysis and assimilation.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM Snow Water Equivalent Analysis</td>
<td>Depicts the snow water equivalent output from the operational National Water Model (v2.0) analysis and assimilation.</td>
<td>● None</td>
</tr>
<tr>
<td><strong>NWM Past 28-Day Low Flow Analysis</strong></td>
<td>Depicts low flow anomalies derived from the operational National Water Model (v2.0) analysis and assimilation. Anomalies are based on 28-day average streamflow percentiles for each reach for the current calendar day.</td>
<td>• None</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td><strong>NWM Low Soil Moisture Anomaly Analysis</strong></td>
<td>Depicts low soil moisture anomalies derived from the latest operational National Water Model (v2.0) output. Values represent soil saturation anomaly categories for the averaged 0 - 100 cm soil layer. Anomalies are based on the current operational forecast compared against the 15-day average low soil moisture percentiles centered around the current calendar day.</td>
<td>• None</td>
</tr>
<tr>
<td><strong>NWM Past 24 Hour Snow Melt</strong></td>
<td>Depicts snow melt over the past 24 hours derived from the operational National Water Model (v2.0) analysis and assimilation.</td>
<td>• None</td>
</tr>
<tr>
<td><strong>NWM Past 72 Hour Snow Water Equivalent Change</strong></td>
<td>Depicts snow water equivalent changes over the past 24, 48, and 72 hours derived from the operational National Water Model (v2.0) analysis and assimilation.</td>
<td>• None</td>
</tr>
</tbody>
</table>
**Description**
Depicts the streamflow output from the operational National Water Model (NWM) (v2.0) analysis and assimilation for the state of Hawaii.

**Update Frequency**
Once per hour.

**Methodology**
Raw NWM (v2.0) output is displayed.
**Description**
Depicts high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) analysis and assimilation. Shown are reaches with flow at or above bankfull. Reaches are colored by the annual exceedance probability (AEP) of their current flow. Bankfull flows and AEPs were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once per hour.

**Methodology**
AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). NWM streamflow values are compared to these AEPs and classified accordingly. “Bankfull” conditions are approximated by the 67% AEP.
**NWM High Flow Magnitude Analysis - Hawaii**

**Description**
Depicts high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) analysis and assimilation configuration for the state of Hawaii. Shown are reaches with flow at or above bankfull. Reaches are colored by the annual exceedance probability (AEP) of their current flow. Bankfull flows and AEPs were derived from USGS regression equations found at [https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf](https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf).

**Update Frequency**
Once per hour.

**Methodology**
Bankfull flows and AEPs were derived from USGS regression equations found at [https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf](https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf). Streamflow values are then compared to AEPs and classified accordingly. “Bankfull” conditions are approximated by the 67% AEP.
**NWM Inundation Extent Analysis**

**Description**
Depicts inundation extent derived from the operational National Water Model (NWM) (v2.0) analysis and assimilation. Inundation extents are derived using the Height Above the Nearest Drainage (HAND) method; stage heights are interpolated from NWM (v2.0) discharges using synthetic rating curves, interpolated stage heights are rounded up to the nearest foot, and corresponding pre-computed inundation extent polygons are displayed.

*Note: Inundation extent is only viewable to users in the NWC FIM Services group on NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.*

**Update Frequency**
Once per hour.

**Methodology**
NWM streamflows are converted to stages using synthetic rating curves derived from reach-averaged channel properties. Reach-averaged channel properties are derived from 10-meter elevation data. Stages are then
converted to inundation extents using a 10-meter relative elevation grid derived using the HAND method. “Bankfull” conditions are approximated by the 67% AEP. AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). For more information on HAND and synthetic rating curves, see the references listed in Appendix A.
Past 72-Hour Accumulated Precipitation Analysis

Description
Depicts accumulated precipitation totals over the past 72 hours derived from the MRMS forcing for the operational National Water Model (NWM) (v2.0) analysis and assimilation. Data for each interval can be seen by using a filter to select the name of the desired layer.

Update Frequency
Once per hour.

Methodology
Hourly precipitation from the NWM (v2.0) analysis and assimilation configuration is accumulated over past intervals: 1 hour, 3 hours, 6 hours, 12 hours, 24 hours, 48 hours, and 72 hours. NWM (v2.0) analysis and assimilation precipitation is derived from a HRRR/RAP/MRMS/MPE blend.
**NWM Snow Depth Analysis**

**Description**
Depicts the snow depth output from the operational National Water Model (NWM) (v2.0) analysis and assimilation.

**Update Frequency**
Once per hour.

**Methodology**
Raw NWM (v2.0) output is displayed.
NWM Snow Water Equivalent Analysis

**Description**
Depicts the snow water equivalent output from the operational National Water Model (NWM) (v2.0) analysis and assimilation.

**Update Frequency**
Once per hour.

**Methodology**
Raw NWM (v2.0) output is displayed.
NWM Past 28-Day Low Flow Analysis

**Description**
Depicts low flow anomalies derived from the operational National Water Model (NWM) (v2.0) analysis and assimilation. Anomalies are based on 28-day average streamflow percentiles for each reach for the current calendar day. Streamflow percentiles were derived from 28-day streamflow averages for each reach for each calendar day using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once per day.

**Methodology**
Low flows are based on 28-day average streamflow percentiles for each reach for the current calendar day. For example, reaches shown in red, the Drought (< 2nd) category, have a 28-day streamflow average below their 2nd streamflow percentile for this time of year. Streamflow percentiles were derived from 28-day streamflow averages for each reach for each calendar day using a 25-year retrospective analysis of the NWM (v2.0).
**NWM Low Soil Moisture Anomaly Analysis**

**Description**
Depicts low soil moisture anomalies derived from the operational National Water Model (NWM) (v2.0) analysis and assimilation. Values represent soil saturation anomalies for the 0 - 100cm soil layer. Anomalies are based on 15-day average soil saturation percentiles for each reach centered around the current calendar day. Percentiles were derived from 15-day soil saturation averages for each reach for each calendar day using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once per day.

**Methodology**
Soil moisture percentiles were created at a 1km-resolution from a 15-day average centered around the day of the year using a 25-year retrospective analysis of the NWM (v2.0).
NWM Past 24 Hour Snow Melt

**Description**
Depicts snow melt over the past 24 hours derived from the operational National Water Model (v2.0) analysis and assimilation.

**Update Frequency**
Once per day.

**Methodology**
Compares snow water equivalent values from 24 hours in the past to current conditions. A decrease in snow water equivalent directly corresponds to an equal amount of snow melt in the past 24 hours.
NWM Past 72 Hour Snow Water Equivalent Change

**Description**
Depicts snow water equivalent changes over the past 24, 48, and 72 hours derived from the operational National Water Model (v2.0) analysis and assimilation. Data for each interval can be seen by using a filter to select the name of the desired layer.

**Update Frequency**
Once per hour.

**Methodology**
Compares current snow water equivalent values to snow water equivalent values from 24, 48, and 72 hours in the past.
# Short-Range Forecast

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWM 18-Hour Bankfull Arrival Time Forecast</td>
<td>Depicts expected bankfull arrival times derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull within the next 18 hours. Reaches are colored by the time at which they are expected to be at bankfull.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM 18-Hour High Flow Magnitude Forecast</td>
<td>Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 3, 5, and 10 days. Reaches are colored by the annual exceedance probability of their maximum forecast flow over the next 3, 5, and 10 days.</td>
<td>● None</td>
</tr>
</tbody>
</table>
| NWM 60-Hour High Flow Magnitude Forecast - Hawaii | Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) short-range forecast for the state of Hawaii. Shown are reaches that are expected to have flow at or above bankfull over the next 60 hours. Reaches are colored by the annual exceedance probability of their maximum forecast flow over the next 60 hours. | ● Scale Dependent Rendering  
● Updated Legend Category  
○ Not Available -> Insufficient Data |
| NWM 18-Hour Maximum Inundation Extent Forecast    | Depicts expected maximum inundation extent derived from the operational National Water Model (NWM) (v2.0) short-range forecast.  

*Note: Inundation extent is only viewable to users in the NWC FIM Services group on the NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.* | ● None                                       |
<p>| NWM 18-Hour Streamflow Rate of Change Forecast   | Depicts expected change in discharge derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Change is computed between the current streamflow and that expected over the next 18 hours at 3-hourly intervals, and is only displayed for reaches that are expected to have flow at or above bankfull over the next 18 hours. | ● None                                       |
| NWM 18-Hour Peak Flow                            | Depicts expected peak flow arrival times derived from the operational National Water Model (NWM) | ● None                                       |</p>
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>New/Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival Time Forecast</td>
<td>(v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 18 hours. Reaches are colored by the time at which they are expected to be at their maximum flow within the forecast period.</td>
<td></td>
</tr>
<tr>
<td>NWM 12-Hour Bankfull Probability Forecast</td>
<td>Depicts above-bankfull probabilities derived from a time-lag of the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull within the next 12 hours, using the last 7 NWM (v2.0) short-range forecasts. Reaches are colored by the probability that they will meet or exceed bankfull within the next 12 hours.</td>
<td>None</td>
</tr>
<tr>
<td>18-Hour Accumulated Precipitation Forecast</td>
<td>Depicts expected accumulated precipitation totals over the next 18 hours derived from the HRRR forcing for the operational National Water Model (v2.0) short-range forecast.</td>
<td>None</td>
</tr>
<tr>
<td>NWM 18-Hour Rapid Onset Flooding</td>
<td>Depicts the potential for rapid onset flooding derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches with a forecast flow increase of 100% or greater in an hour, and which are expected to be at above bankfull within 6 hours of that increase. Also shown are HUC10 polygons symbolized by the percentage of NWM features in each that are expected to meet previously mentioned criteria.</td>
<td>New</td>
</tr>
<tr>
<td>NWM 60-Hour Accumulated Precipitation Forecast - Hawaii</td>
<td>Depicts expected accumulated precipitation totals over the next 60 hours derived from the NAM-Nest forcing for the operational National Water Model (v2.0) short-range forecast for Hawaii. Data for each interval can be seen by using a filter to select the name of the desired layer.</td>
<td>New</td>
</tr>
</tbody>
</table>
NWM 18-Hour Bankfull Arrival Time Forecast

**Description**
Depicts expected bankfull arrival times derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull within the next 18 hours. Reaches are colored by the time at which they are expected to be at bankfull. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once every hour.

**Methodology**
The arrival time is calculated by comparing the forecast streamflow for each lead time to the estimated “bankfull” condition. The time at which forecast streamflow first exceeds the “bankfull” condition is considered the arrival time. “Bankfull” conditions are approximated by the 67% annual exceedance probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0).
NWM 18-Hour Maximum High Flow Magnitude Forecast

**Description**
Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 3, 5, and 10 days. Reaches are colored by the annual exceedance probability (AEP) of their maximum forecast flow over the next 3, 5, and 10 days. Bankfull flows and AEPs were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once per hour.

**Methodology**
AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Maximum streamflow values are compared to these AEPs and classified accordingly. “Bankfull” conditions are approximated by the 67% AEP.
NWM 60-Hour Maximum High Flow Magnitude Forecast - Hawaii

**Description**
Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) short-range forecast for the state of Hawaii. Shown are reaches that are expected to have flow at or above bankfull over the next 60 hours. Reaches are colored by the annual exceedance probability (AEP) of their maximum forecast flow over the next 60 hours. Bankfull flows and AEPs were derived from USGS regression equations found at [https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf](https://pubs.usgs.gov/sir/2010/5035/sir2010-5035_text.pdf).

**Update Frequency**
Once every 6 hours.

**Methodology**
values are compared to these AEPs and classified accordingly. “Bankfull” conditions are approximated by the 67% AEP.
NWM 18-Hour Maximum Inundation Extent Forecast

Description
Depicts expected maximum inundation extent derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Inundation extents are derived using the Height Above the Nearest Drainage (HAND) method; stage heights are interpolated from NWM (v2.0) discharges using synthetic rating curves, interpolated stage heights are rounded to the nearest foot, and corresponding pre-computed inundation extent polygons are displayed.

Note: Inundation extent is only viewable to users in the NWC FIM Services group on NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.

Update Frequency
Once per hour.

Methodology
NWM streamflows are converted to stages using synthetic rating curves derived from reach-averaged channel properties. Reach-averaged channel properties are derived from 10-meter elevation data. Stages are then
converted to inundation extents using a 10-meter relative elevation grid derived using the HAND method. “Bankfull” conditions are approximated by the 67% annual excess probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). For more information on HAND and synthetic rating curves, see the references listed in Appendix A.
NWM 18-Hour Streamflow Rate of Change Forecast

**Description**
Depicts expected change in discharge derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Change is computed between the current streamflow and that expected over the next 18 hours at 3-hourly intervals, and is only displayed for reaches that are expected to have flow at or above bankfull over the next 18 hours. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once per hour.

**Methodology**
Change is computed between the current streamflow and that expected in 3, 6, 9, 12, 15, and 18 hours, and is only displayed for reaches that are expected to have flow at or above “bankfull” at any time within the next 18 hours. “Bankfull” conditions are approximated by the 67% annual excess probability. AEPs were derived from a multi-decade reanalysis of the NWM (v2.0).
Description
Depicts expected peak flow arrival times derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 18 hours. Reaches are colored by the time at which they are expected to be at their maximum flow within the forecast period. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0). Updated hourly.

Update Frequency
Once every hour.

Methodology
Shown are reaches that are expected to have forecast streamflow at or above “bankfull” conditions within the next 18 hours. “Bankfull” conditions are approximated by the 67% annual excess probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Reaches are colored by the time at which they are expected to be at their maximum streamflow within the forecast period, even if it is not the first peak to occur.
**NWM 12-Hour Bankfull Probability Forecast**

**Description**
Depicts above-bankfull probabilities derived from a time-lag of the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches that are expected to have flow at or above bankfull within the next 12 hours, using the last 7 NWM (v2.0) short-range forecasts. Reaches are colored by the probability that they will meet or exceed bankfull within the next 12 hours. Probabilities are derived from the streamflow values for each reach over the past 7 NWM (v2.0) short-range forecasts, equally weighted. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once every other hour.

**Methodology**
Shown are reaches that are expected to have forecast streamflow at or above “bankfull” conditions within the next 12 hours. “Bankfull” conditions are approximated by the 67% annual excess probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Probabilities are computed for a 12-hour valid time range from the latest NWM (v2.0) short-range forecast reference time. For a particular reach, all forecast streamflow values from the past 7 NWM (v2.0) short-range forecasts for the
valid time range of interest are obtained and considered of equal weight. From these values, the number of times a reach was forecast to be at or above “bankfull” is used to compute bankfull probability over the 12-hour valid time range.
18-Hour Accumulated Precipitation Forecast

Description
Depicts expected accumulated precipitation totals over the next 18 hours derived from the HRRR forcing for the operational National Water Model (v2.0) short-range forecast. Data for each interval can be seen by using a filter to select the name of the desired layer.

Update Frequency
Once per hour.

Methodology
Hourly forecast precipitation from the NWM (v2.0) short-range forecast configuration is accumulated over future intervals: hour 1, hour 2, hour 3, hours 4-6, hours 7-9, hours 10-12, hours 13-15, hours 16-18 and hours 1-18. NWM (v2.0) short-range forecast precipitation is derived from a HRRR/RAP blend.
NWM 18-Hour Rapid Onset Flooding

Description
Depicts the potential for rapid onset flooding derived from the operational National Water Model (NWM) (v2.0) short-range forecast. Shown are reaches with a forecast flow increase of 100% or greater in an hour, and which are expected to be at above bankfull within 6 hours of that increase. Also shown are HUC10 polygons symbolized by the percentage of NWM features in each that are expected to meet previously mentioned criteria. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

Update Frequency
Once per hour.

Methodology
Shown are reaches that are expected to have a forecast flow increase of 100% or greater in an hour, and which are expected to be at above bankfull
within 6 hours of that increase. “Bankfull” conditions are approximated by the 67% annual excess probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Reaches are colored in two ways. One sublayer colors reaches by the time at which they are expected to reach “Bankfull” conditions. Another sublayer colors reaches by the length of time between when the streamflow increases above bankfull and the streamflow decreases below bankfull. If the streamflow never decreases below bankfull within the forecast period, the length will be “ongoing”. HUC10s are also shown and colored based on the percentage of NWM features within that HUC that reach rapid onset flooding criteria.
NWM 60-Hour Accumulated Precipitation Forecast - Hawaii

**Description**
Depicts expected accumulated precipitation totals over the next 60 hours derived from the NAM-Nest forcing for the operational National Water Model (v2.0) short-range forecast for Hawaii. Data for each interval can be seen by using a filter to select the name of the desired layer.

**Update Frequency**
Once per hour.

**Methodology**
Hourly forecast precipitation from the NWM (v2.0) short-range forecast configuration is accumulated over future intervals: hours 1-3, hours 3-6, hours 6-9, hours 9-12, hours 12-24, hours 24-48, and hours 48-60. NWM (v2.0) short-range forecast precipitation is derived from a HRRR/RAP blend.
## Medium-Range Forecast

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
<th>Updates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWM 10-Day Bankfull Arrival Time Forecast</td>
<td>Depicts expected bankfull arrival times derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 10 days. Reaches are colored by the time at which they are expected to reach bankfull.</td>
<td>● None</td>
</tr>
<tr>
<td>NWM 10-Day High Flow Magnitude Forecast</td>
<td>Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 3, 5, and 10 days. Reaches are colored by the annual exceedance probability of their maximum forecast flow over the next 3, 5, and 10 days.</td>
<td>● None</td>
</tr>
</tbody>
</table>
| NWM 10-Day Maximum Inundation Extent Forecast | Depicts expected maximum inundation extent derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are areas that are expected to be inundated sometime over the next 3, 5, and 10 days.  

*Note: Inundation extent is only available to users in the NWC FIM Services group on NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.* | ● None                   |
| NWM 10-Day Peak Flow Arrival Time Forecast   | Depicts expected peak flow arrival times derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 10 days. Reaches are colored by the time at which they are expected to be at their maximum flow within the forecast period. | ● None                   |
| NWM 5-Day Bankfull Probability Forecast      | Depicts bankfull probabilities derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull on Day 1, Day 2, Day 3, and Days 4-5, using the 7 members of the NWM (v2.0) medium-range forecast. Reaches are colored by the percentage of ensemble members that forecast that the reach will meet or exceed bankfull. | ● Layer rename  
○ Day 4 - 5 to Days 4-5  
● Updated underlying algorithm to reflect probability of ensemble member agreement instead of percentage of time forecasted to be above bankfull |
| 10-Day Accumulated Precipitation Forecast | Depicts expected accumulated precipitation totals over the next 10 days derived from the GFS forcing for the operational National Water Model (v2.0) medium-range forecast. | • None |
| NWM 10-Day Snow Water Equivalent Change | Depicts expected snow water equivalent changes over the next 1, 3, 5, 7, and 10 days derived from the operational National Water Model (v2.0) medium-range forecast. | • None |
Description
Depicts expected bankfull arrival times derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 10 days. Reaches are colored by the time at which they are expected to reach bankfull. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

Update Frequency
Once every 6 hours.

Methodology
The arrival time is calculated by comparing the forecast streamflow for each lead time to the estimated “bankfull” condition. The time at which forecast streamflow first exceeds the “bankfull” condition is considered the arrival time. “Bankfull” conditions are approximated by the 67% annual exceedance probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0).
**Description**
Depicts expected high flow magnitudes derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 3, 5, and 10 days. Reaches are colored by the annual exceedance probability (AEP) of their maximum forecast flow over the next 3, 5, and 10 days. Bankfull flows and AEPs were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once every 6 hours.

**Methodology**
AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Maximum streamflow values over the forecast period are compared to these AEPs and classified accordingly. “Bankfull” conditions are approximated by the 67% AEP.
NWM 10-Day Maximum Inundation Extent Forecast

Description
Depicts expected maximum inundation extent derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are areas that are expected to be inundated sometime over the next 3, 5, and 10 days. Inundation extents are derived using the Height Above the Nearest Drainage (HAND) method; stage heights are interpolated from NWM (v2.0) discharges using synthetic rating curves, interpolated stage heights are rounded up to the nearest foot, and corresponding pre-computed inundation extent polygons are displayed.

Note: Inundation extent is only viewable to users in the NWC FIM Services group on NWC Portal, and only available over the Texas/WGRFC, SERFC, MARFC and NERFC domains.

Update Frequency
Once every 6 hours.

Methodology
NWM streamflows are converted to stages using synthetic rating curves derived from reach-averaged channel properties. Reach-averaged channel
properties are derived from 10-meter elevation data. Stages are then converted to inundation extents using a 10-meter relative elevation grid derived using the HAND method. “Bankfull” conditions are approximated by the 67% annual exceedance probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). For more information on HAND and synthetic rating curves, see the references listed in Appendix A.
**Description**
Depicts expected peak flow arrival times derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull over the next 10 days. Reaches are colored by the time at which they are expected to be at their maximum flow within the forecast period. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

**Update Frequency**
Once every 6 hours.

**Methodology**
Shown are reaches that are expected to have forecast streamflow at or above “bankfull” conditions within the next 10 days. “Bankfull” conditions are approximated by the 67% annual exceedance probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Reaches are colored by the time at which they are expected to be at their maximum streamflow within the forecast period, even if it is not the first peak to occur.
NWM 5-Day Bankfull Probability Forecast

Description
Depicts bankfull probabilities derived from the operational National Water Model (NWM) (v2.0) medium-range forecast. Shown are reaches that are expected to have flow at or above bankfull on Day 1, Day 2, Day 3, and Days 4-5, using the 7 members of the NWM (v2.0) medium-range forecast. Reaches are colored by the probability that they will meet or exceed bankfull on Day 1, Day 2, Day 3, and Days 4-5. Probabilities are computed as the % agreement across the 7 ensemble members that a given reach will be at or above bankfull at some point during the time period of interest, based on the NWM (v2.0) medium-range forecast. Bankfull flows were derived using a 25-year retrospective analysis of the NWM (v2.0).

Update Frequency
Once every 6 hours.

Methodology
Shown are reaches that are expected to have forecast streamflow at or above “bankfull” conditions on Day 1, Day 2, Day 3, and Days 4-5. “Bankfull” conditions are approximated by the 67% annual exceedance probability (AEP). AEPs were derived from a multi-decade reanalysis of the NWM (v2.0). Probabilities are computed for Day 1, Day 2, Day 3, and Days 4-5 valid time ranges from the latest NWM (v2.0) medium-range forecast reference time. For a particular reach, all forecast streamflow values from the 7 members of the latest NWM (v2.0) medium-range forecast for the valid time ranges of interest are obtained and considered of equal weight. From these values, the number of times a reach was forecast to be at or above “bankfull” during each of the valid time ranges is used to compute bankfull probabilities.
10-Day Accumulated Precipitation Forecast

Description
Depicts expected accumulated precipitation totals over the next 10 days derived from the GFS forcing for the operational National Water Model (v2.0) medium-range forecast. Data for each interval can be seen by using a filter to select the name of the desired layer.

Update Frequency
Once every 6 hours.

Methodology
Hourly forecast precipitation from the NWM (v2.0) medium-range forecast configuration is accumulated over future intervals: Hours 1-6, Hours 7-12, Hours 13-18, Hours 19-24, Day 1, Day 2, Day 3, Days 4-5, Days 6-7, Days 8-10, and Days 1-10. NWM (v2.0) medium-range forecast precipitation is derived from the GFS.
Description
Depicts expected snow water equivalent changes over the next 1, 3, 5, 7, and 10 days derived from the operational National Water Model (v2.0) medium-range forecast. Data for each interval can be seen by using a filter to select the name of the desired layer.

Update Frequency
Once every 6 hours.

Methodology
Compares current snow water equivalent values to snow water equivalent values from the 1, 3, 5, 7, and 10 day lead times of the medium-range forecast.
Appendix A: HAND and Synthetic Rating Curve

References

For more information on the Height Above the Nearest Drainage (HAND) method of inundation mapping and derivation of synthetic rating curves, please refer to the following publications:
