STRATEGIC PLAN
2021-2026

National Oceanic and Atmospheric Administration
National Weather Service
Office of Water Prediction

OWP | OFFICE OF WATER PREDICTION

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DIRECTOR'S MESSAGE

The National Weather Service (NWS) and its Office of Water Prediction (OWP) are dedicated to creating a Weather-Ready Nation; a society that is prepared for and responds to weather, water, and climate-dependent events. Over the last decade NWS has taken proactive steps to transform and innovate, including moving into a partner and customer-centric service delivery model. We are committed to being world leaders in providing weather, water, and climate impact-based decision support services (IDSS).

The OWP and the National Water Center (NWC) were established in 2015, but the organization's water mission dates back to the very origins of the NWS when in 1891 the newly created Weather Bureau became responsible for issuing flood warnings. I am proud of the progress that OWP and NWS have made over the last five years to advance our water forecasting capabilities and related decision support that better informs decisions related to water resources management and helps mitigate the impact of water-related disasters. Highlights of our advances are included below.

- ***Leveraged innovative hydrologic science and technology to improve services:***
  Collaborating with our partners, we made significant improvements in our ability to deliver flooding and drought forecast capabilities, improve preparedness for water-related disasters, and inform routine high-value water decisions at the local, state, and national levels. Additionally, the NWC, a world-class facility, is operational and serves as a catalyst to accelerate the transition of research into operations and is a Center of Excellence for addressing our nation's water challenges.

- ***Established an agile, collaborative, and transparent organization:***
  We built an organization that embraces technology and leverages tools that create a collaborative work environment, allowing us to thrive in any circumstance – including the COVID-19 virtual environment.

- ***Developed a world class workforce:***
  Our world class workforce is committed to using the best proven science and technology available to accomplish our mission. They are experts in their fields and are dedicated to collaborating across the NWS, National Oceanic and Atmospheric Administration (NOAA), and with our partners to realize a Weather-and-Water-Ready Nation.

Although we have made significant advancements, water challenges remain in the top three national and global risks. We must continue to invest and prioritize in strengthening the nation's water forecasting and warning services capabilities. This Strategic Plan outlines OWP's goals and objectives for the next six years (2021-2026). It will guide our priorities and investment decisions, and I look forward to collaboratively working with our dedicated NWS employees and partners to implement it successfully.

Dr. Thomas Graziano, *Director, Office of Water Prediction*
National Weather Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

EXECUTIVE SUMMARY

Water is essential for life and is inexorably linked to environmental protection, sustainable development, and international peace and security. Too much water, too little water, or poor water quality endangers life, property, communities, economies, and ecosystems. As a nation we are faced with many water challenges including flooding, drought, water availability, water quality, and climate change. Water challenges affect all economic sectors, from agriculture to utilities, and the impacts are escalating. Population growth and economic development, particularly in flood and drought prone regions, stress water supplies and increase vulnerabilities facing communities and businesses. In recent years, flooding disasters in the United States represented one of the costliest natural hazard events in terms of life and property loss.[1]

Additionally, the changing climate is intensifying the impacts to water availability and quality, further increasing the uncertainty facing the nation. The changing climate system necessitates new tools and the use of more physically-based water modeling and fully coupled earth system modeling approaches that leverage the rapid expansion of available data and technology. For the third consecutive year, The World Economic Forum Global Risk Report placed water crises in the top five highest impact, highest likelihood global risks, along with climate action failure, biodiversity loss, extreme weather events, and natural disasters.[2]

The National Weather Service's (NWS) Office of Water Prediction (OWP) is dedicated to addressing our water challenges and fulfilling the vision of a Weather-and-Water Ready Nation. Since the establishment of OWP in 2015, the nation's requirement for advanced water prediction capabilities has continued to grow. During the last five years the OWP has made advancements in many critical areas including science and technology innovations, advanced operational capabilities and decision support, organizational transparency and agility, and creating a world class workforce.

Hydrologic Science and Technology Innovations Leading to Improved Services

Relying on the latest hydrologic science and technology, we continue to focus on improving our water-related, impact-based decision support services (IDSS). Working closely with partners in the National Oceanic and Atmospheric Administration (NOAA), across the Federal Government, and academia we have made significant progress evolving the National Water Model (NWM), and developing a next-generation, NWM framework that will expand and accelerate community development to more rapidly improve model capability and forecast skill. The NWM provides water forecast guidance at unprecedented spatial and temporal detail, which compliments the river forecasts generated by NWS River Forecast Centers (RFCs). We have also made advances in our Community Hydrological Prediction System (CHPS) and our Hydrological Ensemble Forecast Services (HEFS), to ensure NWS field offices have the best operational tools available to meet our mission. In 2019, we successfully demonstrated a new flood inundation mapping (FIM) capability serving 25 million people residing in flood-vulnerable freshwater basins, expanded this demonstration to 115 million residents in the continental US in 2020, and are on a path toward operational implementation nationwide. The NWC is operational and, in collaboration with other Federal agencies and enterprise partners, is delivering a new generation of water information and services to the nation. The National Water Center is committed to providing state-of-the-science capabilities that promote service equity across the nation, improving forecasts and services for high-impact events that disproportionately affect vulnerable populations and previously underserved communities.

1 National Academies of Sciences, Engineering, and Medicine. 2019. Framing the Challenge of Urban Flooding in the United States. Washington, DC: The National Academies Press. https://www.nap.edu/catalog/25381/framing-the-challenge-of-urbanflooding-in-the-united-states

2 World Economic Forum. The Global Risks Report 2020. http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

Agile, Collaborative, and Transparent Organization

We built an organization that embraces collaboration, transparency, and technology that leverages cloud-based tools allowing us to adapt and thrive in challenging circumstances – including a rapid and seamless transition to a virtual environment in response to COVID-19. We established an efficient organizational model that includes service-based Division Directors, a Chief Scientist, and a focus on delivering the right capabilities within schedule and budget with a Chief of Programs and Director of our Portfolio Management Office. The OWP's comprehensive portfolio management framework and associated processes promote transparency, improve communication, enhance accountability, drive results, and maximize efficiency and return on investment.

World Class Workforce

We developed and recruited a world class workforce that is geographically distributed in Alabama, Maryland, and Minnesota. They are dedicated, motivated, and committed to the teamwork and collaboration necessary to realize our vision of a Weather-and-Water-Ready Nation and mission of protecting lives and property, and enhancing the national economy. The OWP is fully committed to creating a best-in-government workplace that is diverse and has a culture of inclusion.

Data shows that between 2004-2014 major United States flood events cost an average of $9 billion in direct damage and 71 lives annually. [1]

This OWP Strategic Plan 2021-2026 outlines the goals and objectives that the organization will accomplish in the next six years. We are committed to mitigating the nation's water risks by leveraging advances in observations and modeling, the rapid expansion of available data, and advancement of computer capabilities such as cloud, high-performing computing, artificial intelligence (AI), and machine learning (ML).

Leveraging the NWC, these mission-focused capabilities and services — which encompass floods, drought, low-flow risks, and information needs for routine and long-range water management and planning — are designed to:

- Improve national preparedness and response for water-related disasters through delivery of high-resolution flood forecast inundation maps and other associated services;
- Support integrated water resource management at the local, state, regional, tribal and national levels;
- Inform event-driven, high impact, and routine, high-value water decisions at the local, state, regional, tribal, and national levels;
- Address water information service needs that support and promote informed water stewardship; and
- Enhance the delivery of water-related decision support services through the NWS River Forecast Centers (RFCs), Regional Operations Centers (ROCs), and Weather Forecast Offices (WFOs).

OWP'S MISSION & VISION

Mission

Collaboratively research, develop and deliver timely and consistent, state-of-the-science national hydrologic analyses, forecast information, data, guidance, and equitable decision-support services to inform essential emergency management and water resources decisions across all time scales.

Vision

OWP envisions a Nation strengthened by equitable and actionable intelligence that informs water-related decisions, which enhance safety, resilience, security, and our economy.

ALIGNMENT WITH THE DEPARTMENT OF COMMERCE, NOAA, AND NWS PLANS

OWP Support of the Department of Commerce

The OWP directly supports the Department of Commerce's (DOC) goals and objectives outlined in the current Strategic Plan (2018 to 2022) to transform water prediction and related services. Table 1 outlines the Department's Strategic Objective 3.3, Reduce Extreme Weather Impacts, flood mitigation performance metrics and OWP's progress towards meeting these.

Table 1: Status of DOC's Water Performance Metrics

Department of Commerce Performance Metric	Status
NWS will improve decision support services by demonstrating a new flood inundation mapping capability serving 25 million people (i.e., 8 percent of the U.S. continental population) residing in flood-vulnerable freshwater basins. Complete by September 30, 2019	✓ Complete. OWP successfully demonstrated flood inundation mapping across Texas.
NWS will improve its flood related decision support services by expanding the demonstration of a new flood inundation mapping capability to at least an additional 10% of the U.S. continental population residing in flood-vulnerable freshwater basins. Complete by September 30, 2021	✓ Complete. OWP is on schedule to demonstrate this capability using NWM guidance and RFC forecasts, and NWS is expanding this demonstration to the majority of the continental U.S.

It is important to highlight that OWP plans to incrementally expand the demonstration and operational implementation of flood inundation mapping nationwide.

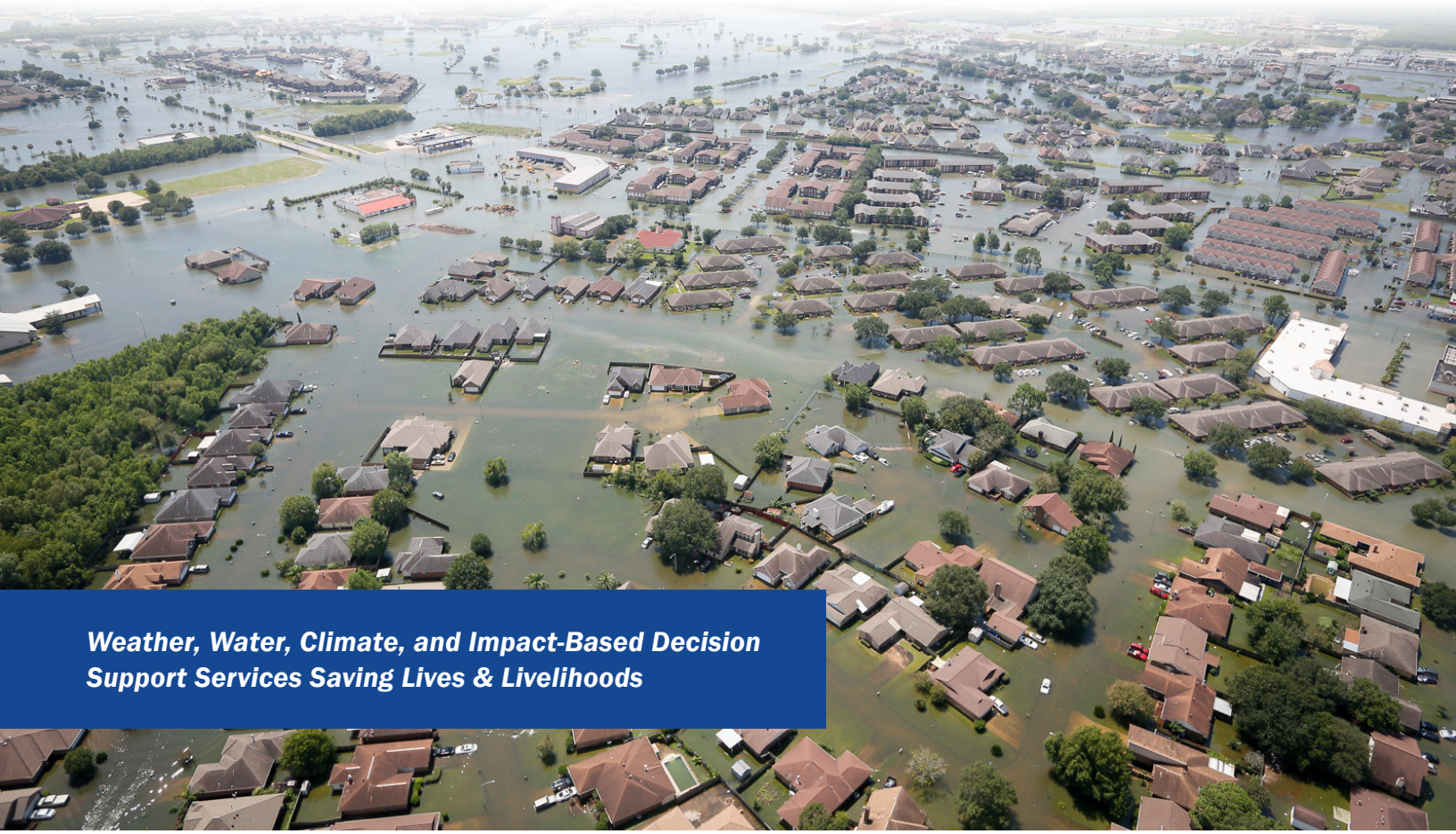
OWP Support of NOAA

Water is a common thread that runs through all NOAA line offices and mission areas, each of which serve stakeholders through a variety of field offices, laboratories, and national service outlets. The OWP leads the cross-line office NOAA Water Team, which facilitates coordination and collaboration of water-related activities across NOAA, and reports routinely to the NOAA's Weather, Water and Climate Board (WWCB). The NOAA Water Team is responsible for implementing the NOAA Water Initiative and Five-Year Plan, released in 2016. The overarching goal of the NOAA Water Initiative is to transform water resources prediction and information service delivery to better meet and support evolving societal needs. The initiative represents an unparalleled level of internal collaboration and integration, including a first ever cross-NOAA integrated Annual Operating Plan for water, to enhance the agency's capability to develop and deliver improved water information services.

OWP Support of NWS

With the NWC as the anchor, the entire OWP team works collaboratively to create a consistent and unified national hydrologic program with the Water Resource Service Branch (WRSB) of the NWS Analyze Forecast and Support Office (AFSO), the NWS Office of Central Processing (OCP), the Office of Dissemination (ODIS), the Office of Observations (OBS), the Office of Science Technology and Integration (OSTI), the NWS Regional Headquarters, the National Centers for Environmental Prediction (NCEP), the ROCs, RFCs, and WFOs. This integrated NWS team works across NOAA and with federal, state, local, tribal, academic, and private sector partners to respond to growing national needs for water prediction services to address growing national water resources challenges. This collaboration includes efforts to implement the organization's current Strategic Plan 2019-2022 Objective 1.8,[3] which calls on NWS to:

- Deliver actionable water resources information from national to street-level across all time scales
- Provide minutes-to-months river forecasts that quantify both atmospheric and hydrologic uncertainty
- Improve forecasts of total water in the coastal zone by linking terrestrial and coastal models in partnership with the National Ocean Service
- Deliver forecasts of flood inundation, which depict the areal extent and depth of floodwaters, and link this information to other geospatial information to inform life-saving decisions



Weather, Water, Climate, and Impact-Based Decision Support Services Saving Lives & Livelihoods

3 https://www.weather.gov/media/wrn/NWS_Weather-Ready-Nation_Strategic_Plan_2019-2022.pdf

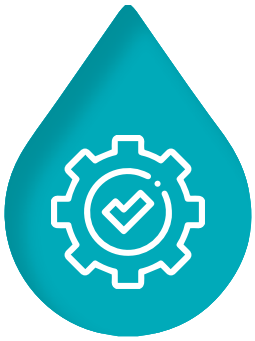
OWP STRATEGIC GOALS AND OBJECTIVES

The OWP is advancing the nation's water prediction capabilities and promoting service equity through excellence in operations, and the evolution and maturation of the National Water Model, the Community Hydrologic Prediction System (CHPS), real-time Flood Inundation Mapping, and the Hydrologic Ensemble Forecast Service (HEFS). The organization and its workforce are enhancing NWS' capabilities to deliver flooding and drought forecast services, improve preparedness for water-related disasters, and inform high-value water IDSS at the local, state, and national levels. Over the next six years, OWP will continue to deliver enhanced capabilities around the three goals described below.

Additionally, OWP is committed to excellence in information technology and remains engaged with the Federal, industry, and the academic communities to plan for and leverage the best available technologies, platforms, and services. This includes advances in High Performance Computing, Cloud Infrastructure, Big Data Management, Geographic Information Systems (GIS), Machine Learning (ML) and Artificial Intelligence (AI), and dissemination capabilities. The following sections provide the organization's detailed objectives that will be accomplished to meet each goal.

GOAL 1

Advance Water Prediction Capabilities



GOAL 2

Strengthen Operational Infrastructure

GOAL 3

Enable Collaboration and Organizational Excellence

GOAL 1

Advance Water Prediction Capabilities

Provide authoritative national capabilities for water modeling, analysis, prediction and mapping.

Modeling, Forecasting, and Mapping Objectives

1.1 Evolve the NWM nationally. Implement NWM version 3.0 with updates that include a domain expansion to Alaska (Cook Inlet and Copper River Basin), an improved runoff generation calculation, inland hydraulic routing, coastal hydraulics and coastal freshwater-estuary-ocean coupling (compound flooding), improved hydrofabric, improved channel representation, increased modularity, an enhanced reservoir module, and improved calibration.

1.2 Advance and accelerate community water resources modeling through the development and implementation of a Next Generation (NextGen) NWM, and couple the NWM with other NOAA modeling capabilities under the auspices of NOAA's Unified Forecast System (UFS). NWM NextGen includes the development of a common, flexible, standards-based software framework that facilitates collaboration, accelerates development, enables multi-model scientific evaluation, and promotes model interoperability of hydrologic, hydraulic, water quality, and coastal models using an open-source software development paradigm.

1.3 Conduct exploratory efforts for water quality prediction, including water temperature modeling, in partnership with the NOAA/National Marine Fisheries Service (NMFS) and other collaborators.

1.4 Leverage the NextGen NWM to deliver initial water quality prediction capabilities for water temperature, salinity, and turbidity to better inform decisions related to ecosystem, habitat, and species management and water supply; and an extended long range ensemble capability to address a full water year of prediction spanning low to high flow regimes, supporting drought to flood decision support services.

1.5 Advance the coupling of coastal and inland water models to provide routine, accurate, and actionable total water level forecasts for 120 million Americans living in the coastal zone, to enable accurate simulation of the additive impacts of freshwater and storm surge flooding.

1.6 Develop real-time flood inundation mapping, and implement nationwide to provide actionable, street-level information on the areal extent, depth, and infrastructure impacted by flood waters, needed by emergency managers to inform critical decisions that save lives and property, and support natural resources management in partnership with federal agencies to address the intersection of aquatic resources (wetlands) and events that connect streams and rivers to these wetlands.

Data, Analytics, and Analysis Objectives

1.7 Improve data assimilation to optimally integrate and leverage the best available water observation information, including advanced airborne observations from the partnered NWS/OWP and Office of Marine and Aviation Operations (OMAO) snow and soil moisture survey. Integrate the Snow Data Assimilation System (SNODAS) into the NWM NextGen framework.

1.8 Enhance techniques for evaluating NWS hydrologic modeling performance through the establishment of comprehensive evaluation tools and a set of defined routine evaluation methods that describe model performance, including the development and implementation of a comprehensive evaluation program strategy as part of a Water Resources Evaluation Service (WRES) that supports field operations.

1.9 Expand terrain and bathymetric analysis for more explicit specification of stream channel geometry and improved forecast accuracy, necessary to enhance streamflow prediction and comprehensive flood inundation mapping capabilities.

1.10 Enhance big data and geospatial analytics to integrate and process the large volume and broad spectrum of data generated by the NWM with other geospatial information to inform the increasingly challenging decisions faced by water resources stakeholders.

1.11 Improve precipitation frequency estimates, update and expand NOAA's precipitation frequency Atlas 14, and develop a methodology to address climate non-stationarity.

1.12 Develop machine learning/artificial intelligence-based simulation of reservoir processes to accurately account for reservoir operations and other water management activities, which have a significant impact on streamflow forecasts.

Integrated Earth System Context

Modern prediction of the weather-water-climate system requires an integrated earth system approach across multiple temporal and spatial scales. The progress of terrestrial hydrologic science and prediction is enhanced significantly through integration with atmosphere, cryosphere, and ocean and coastal processes. The water cycle itself is the natural connection point for the integration of these basic sciences. Recognizing this, OWP is working closely with its partners in NOAA and across the Federal Government toward an IHTM framework as part of NOAA's effort to advance its NWM. The NWM, in turn, will be coupled to other NOAA modeling capabilities under the auspices of NOAA's Unified Forecast System (UFS). The UFS numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. UFS is designed to support the weather enterprise and to be the source for NOAA's future operational numerical weather prediction applications.

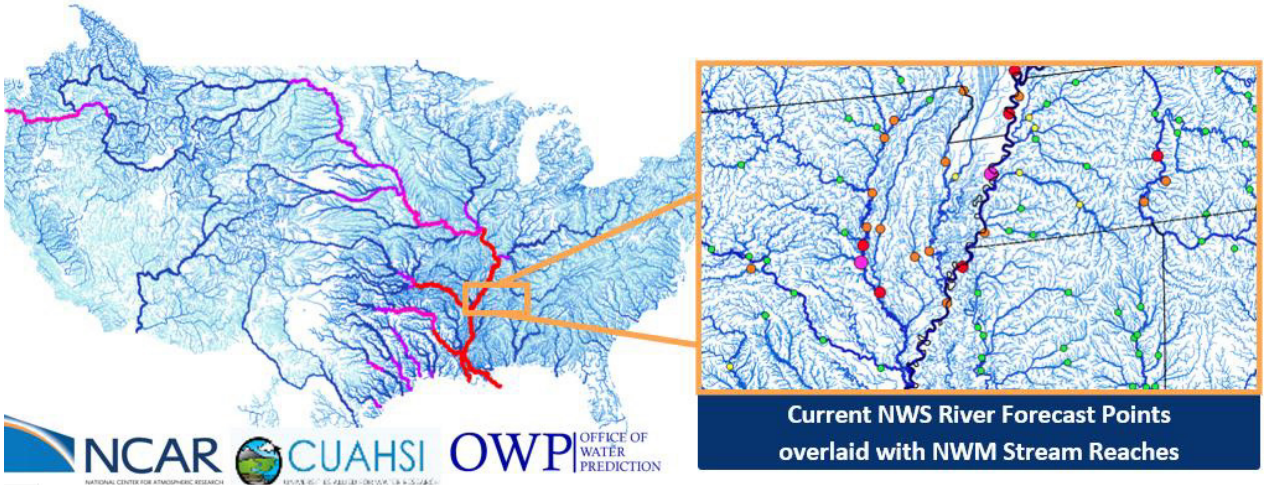
This integrated approach is also reflected in The Weather Research and Forecasting Innovation Act of 2017 (WRFIA), Public Law 115-25, passed on April 18, 2017 and reauthorized in January 2019. The law directs NOAA to prioritize improving weather data, modeling, computing, forecasting, and warnings. Specifically, Title II Section 201 includes guidance requiring the NWS to "make usable, reliable, and timely foundational forecasts of sub-seasonal and seasonal temperature and precipitation," as such forecasts may impact droughts, floods, coastal inundation, snowpack, and other weather-related phenomena. In addition, the National Integrated Drought Information System Reauthorization Act of 2018 (NIDISRA), P.L. 115-423, instructs NOAA to establish the Earth Prediction Innovation Center (EPIC) to accelerate community-developed scientific and technological enhancements into the operational applications for numerical weather prediction.

National Water Model

The OWP deployed the NWM version 1.0 in August of 2016. This was a direct result of rapid development in partnership with the National Center for Atmospheric Research (NCAR) and an initial demonstration during the first Annual Innovators Program and Summer Institute in 2015 at the NWC. This new continental scale, state-of-the-science water prediction model provides service equity by creating forecast guidance for over three million miles of rivers and streams nationwide.

It provided high resolution hydrologic guidance that significantly expands geographic coverage and provides water budget information. Guidance and information provided by the NWM includes, but is not limited to, streamflow anomalies, evapotranspiration, high flow magnitude, and bankfull arrival time. The NWM runs on the NOAA Weather and Climate Operational Supercomputing System (WCOSS) at the NWS National Centers for Environmental Prediction (NCEP). Appendix D provides associated NWM visuals.

The model provides data that the RFCs and other field offices use to support the delivery of expanded water services as



part of NOAA's integrated environmental intelligence and prediction capabilities. It produces a full range of hydrologic fields, which can be leveraged by a multitude of stakeholders including state and local emergency responders, the drought and water resource communities to transportation, energy, recreation, agriculture interests, and other water-oriented applications in the government, academic, and private sectors. Since launching the NWM, OWP continues to innovate and mature the model which has transformed the water services that NWS is providing. Table 2 provides an overview of the NWM maturation.

OWP's National Water Model Successful Innovations and Capabilities

Version 1.1

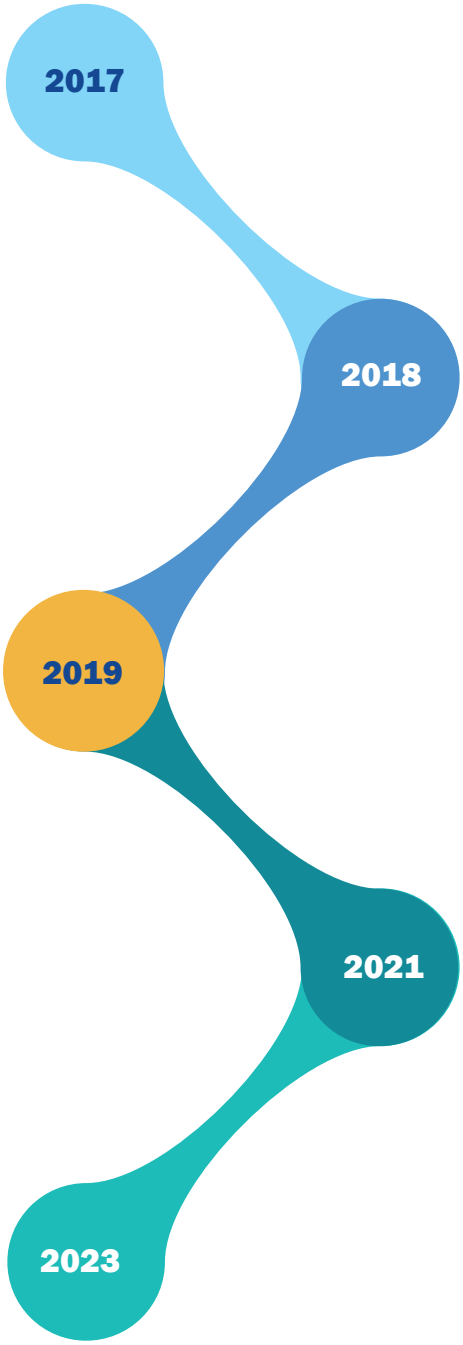
- Extension of the Short-Range forecast from 15 to 18 hours and an increase in the frequency of Medium-Range forecast cycling from one to four times per day.
- Improved parameter calibration and forcing input for the Analysis and Short-Range forecasts.
- Enhanced underlying hydrofabric, soil infiltration, and snowpack model schemes.
- Optimized dissemination with reduced file sizes.

Version 2.0

- Provided the first-ever stream and river forecasts for Hawaii.
- Introduced a new seven-member ensemble Medium-Range configuration.
- Initiated effort to increase model code modularity to support collaborative development.
- Lengthened the Analysis period through use of RFC Multi-Sensor Precipitation Estimate data.
- Upgraded NWM code to include compound channels.

Version 3.0 - Expected Capabilities

- Improve runoff generation calculation, inland hydraulic routing, coastal hydraulics and freshwater-estuary-ocean coupling (compound flooding), hydrofabric, channel representation, modularity, reservoir module, and calibration.
- Expand to include Cook Inlet and Copper River Basin portions of Alaska.



Version 1.2

- Expanded scope of calibration increasing number of calibrated basins from 48 to 1,164.
- Expanded hydrofabric to include ~37,000 square miles of Outside Continental United States
- (OCONUS) contributing basin along the borders with Canada and Mexico.
- Improved streamflow data assimilation through the addition of 680 USGS gauges.
- Added capability to dynamically ingest land surface parameters.

Version 2.1

- Expand the NWM domain to include Puerto Rico, the U.S. Virgin Islands, and the entire Great Lakes drainage basin.
- Upgrade reservoir module to include projected releases from partners, physics improvements, model forcing data bias-correction, improved calibration and incorporated Multi-Radar Multi-Sensor observation-based precipitation for Hawaii.
- Add configurations of the short- and medium-range forecasts that do not include assimilation of USGS stream flow.

The Next Generation National Water Model

Over the next five years OWP will continue to mature the NWM. The OWP is investigating the accessibility of the current instance of the NWM code for review and development by research and academic partners. This was based upon OWP priorities and recommendations from the Community Advisory Committee for Water Prediction (CAC-WP) and collaboration among Federal agencies as part of the Subcommittee on Water Availability and Quality (SWAQ). The NWM is supported by a best-in-breed hydrometeorological forcing engine that delivers stable inputs to the hydrologic simulation processes.

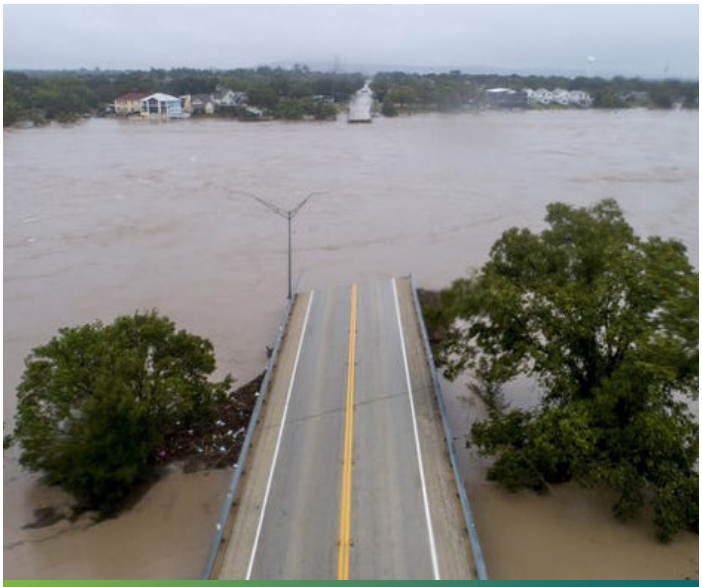
While robust and operationally transformative, the current hydrologic model code is difficult to modify because of its complex nature. The OWP has begun and will continue to take actions to develop a Next Generation (NextGen) water resources modeling framework using modern, modular, open software development best practices based upon additional input by the GSA 18F group[4] and the CAC-WP. Requirements for the NextGen NWM framework include:

- Heterogeneous hydrologic process representations;
- Evidence-based selection of formulation features for optimal performance;
- Cross-platform portability from desktops to supercomputers; and
- Modularized, modernized software development using open source, community-accessible best practices.

These requirements allow creation of a more extensible modeling framework that lowers the barrier for broader community participation in model development and application. The OWP envisions the establishment of a Community of Practice supporting the NextGen NWM framework that leverages community platforms such as GitHub and industry best practices. As a community platform, the NextGen NWM framework will enable future capabilities to enhance model performance and characterize water quality conditions, such as temperature, salinity, turbidity, and constituent chemistry with applications extending to ecosystem, species, and habitat management.

Community Hydrologic Prediction System (CHPS)

The NWS RFCs and WFOs provide critical water resource information at the state and local levels. RFC water forecast operations are carried out on the NWS Advanced Weather Interactive Processing System (AWIPS) using the CHPS as the main forecasting tool. CHPS is an operational framework that allows for broad system interoperability at the 13 RFCs and supports new water resources-related forecasts. It reinforces NOAA's national water information strategy, allowing for integration of research, development, and operational service delivery infrastructure, and effective leveraging of activities at other Federal water



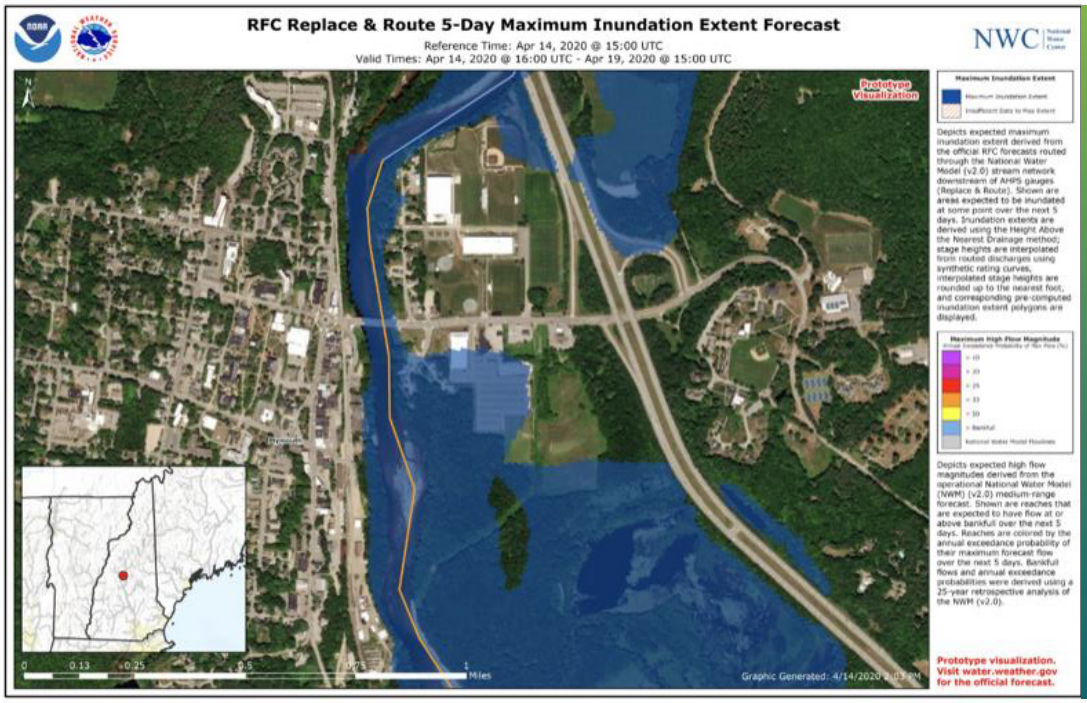
CHPS provides for operational services to be integrated with other Federal water agency activities, academia, and the private sector.

4 https://18f.gsa.gov/about/ 18F is a component of the Technology Transformation Services group within the Federal Acquisition Service of the GSA, which works with federal agencies to address technical problems, build products, and improve services through technology.

agencies, academia, and the private sector. The OWP supports the annual development and release of CHPS updates and enhancements in partnership with the Analyze Forecast Support Office (AFSO)/Water Resource Service Branch (WRSB), RFCs and the NWS Office of Central Processing AWIPS Operations and Maintenance support staff.

Flood Inundation Mapping (FIM)

The demand from Water Resource and Emergency Managers for real-time flood inundation mapping has been growing for the past 20 years. Now, the NWC, in coordination with RFCs and WFOs along with Federal and other partners, is developing tools to meet this demand in an event-driven, high resolution, user friendly, intuitive way. This effort builds on a successful Department of Commerce (DOC) Agency Priority Goal (APG) demonstration for over 20 million Texas residents during FY18-19, and an ongoing demonstration for an additional 95 million US residents in FY20-21 of a new flood inundation mapping capability. This new capability leverages both the RFC official forecasts for 110,000 miles of river across the lower 48 states, as well as forecast guidance from the NWM. Additionally, the NWS in partnership with the National Ocean Service (NOS), is expanding and improving real time FIM in the coastal zone by developing the capability to couple the NWM with the Extratropical Surge and Tide Operational Forecast System (ESTOFS) to generate total water forecasts which will account for the additive impacts of freshwater and storm surge flooding.



National Water Model Bankfull Arrival Time (hours, days) from a reference time of May 21, 2020 00:00 UTC.

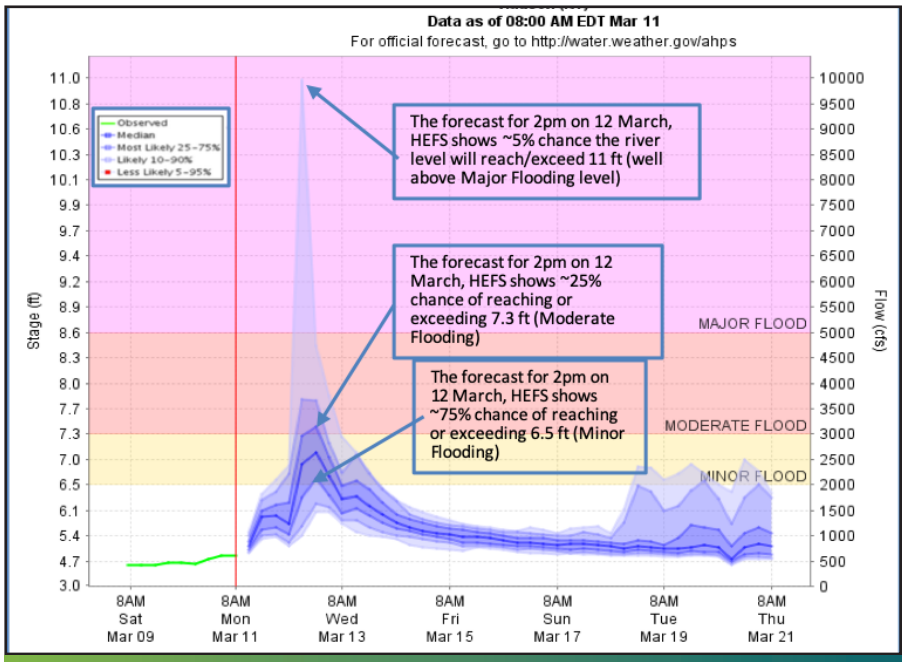
The NWC real time and forecast FIM deploys a model agnostic approach the map the extent and depth of volumetric discharge within the National Hydrography Dataset (NHD) using both a series of synthetic rating curves developed for channel geometry and a technique referred to as height above nearest drawing (HAND) to map the water surface elevation in the channel to neighboring cells in the digital elevation model (DEM). HAND is applied to the official RFC forecast as issued by the WFOs for over 110,000 miles of river downstream from Advanced Hydrologic Prediction Service forecast points. Leveraging the NWM short and medium range streamflow guidance, and additional 3.4 million miles of river and streams are mapped in the lower 48 contiguous states, enabling critical environmental intelligence to be provided equitably to all communities. As of 2021, these new FIM services are being demonstrated in partnership with NWS field offices and Federal Partners, while policy, training, and outreach materials are developed. The NWC continues to refine and improve the FIM techniques while continuously integrating DEM enhancements in collaboration with NOAA field offices and other Federal partners.

Hydrologic Ensemble Forecast Service (HEFS)

Water Resources Managers continue to grapple with the nature of the uncertainty inherent in the streamflow forecast. Quantifying and communicating the uncertainties associated with hydrologic forecasts at a range of time and space scales is essential in operational hydrology to inform risk-based decision making for a spectrum of applications. To address this need, the NWS developed and is implementing HEFS in the CHPS. The HEFS service-level objectives are to produce ensemble streamflow forecasts that:

- Seamlessly span lead times from one hour to one year or more.
- Are calibrated/unbiased for different aggregation periods.
- Are reliable, skillful, and account for both the meteorological and hydrologic uncertainties.
- Are spatially and temporally consistent.
- Leverage information from operational NOAA and the NWS weather and climate models.
- Are dependable (consistent with retrospective forecasts).
- Are properly validated, allowing for identification of strengths and weaknesses of the forecasts and to guide forecasting operations and decision support.

For many years NWS routinely issued single-value river forecasts (stage and flow) at approximately 4,000 USGS stream gage locations and provided long-range (e.g., monthly to seasonal) probabilistic river forecasts at approximately 2,500 of these locations. Historically, these operational probabilistic forecasts were generated by the Ensemble Streamflow Prediction (ESP) function in CHPS, leveraging historical observations of precipitation and temperature. While useful for long-range forecasts (typically beyond 30 days where climatic uncertainty dominates other sources of uncertainty), the ESP forecasts do not incorporate any weather forecast information or account for hydrologic model, parameter, and initial condition uncertainty.



HEFS hydrograph depicting streamflow forecast uncertainty with time relative to stages associated with minor, moderate, and major flooding.

HEFS extends the existing hydrologic ensemble services to include short-range forecasts, incorporate additional weather and climate information, and better quantify the major uncertainties in hydrologic forecasting. The HEFS utilizes weather and climate forecasts from a variety of sources including the RFC and Weather Prediction Center (WPC) precipitation and

HEFS is being used by the NYCDEP to optimize their water supply management operations.

temperature forecasts, as well as ensemble forecasts from Environmental Modeling Center's (EMC) Global Ensemble Forecast System (GEFS) and Climate Forecast System (CFS). In addition to incorporating weather and climate forecasts, the HEFS captures the total uncertainty in the hydrologic predictions and corrects for biases in the forecast probabilities, delivering ensemble forecasts and verification products that can be tailored to users' needs. An example of the value of HEFS is its application by the New York City Department of Environmental Protection (NYCDEP). They use HEFS ensemble streamflow forecasts as an input to their Operations Support Tool to optimize NYC water supply management operations. This provides the NYCDEP operators better predictions of the amount of water that will enter reservoirs, which enables more accurate predictions of reservoir levels and water quality in the future. Specifically, HEFS forecasts are used to inform NYCDEP decisions related to diverting or releasing water from its reservoirs at the most opportune times to reduce the level of turbidity; helping ensure the highest quality drinking water is delivered to more than 9 million New Yorkers; and benefiting downstream communities by enhancing the health of local streams while reducing the risk of flooding. By leveraging HEFS forecasts in their routine decision making, the NYCDEP avoided multi-billion-dollar infrastructure costs for new water filtration capacity.

The benefit of HEFS forecasts is being evaluated for Forecast Informed Reservoir Operations (FIRO). FIRO is a reservoir-operations strategy that employs observations and forecasts, including HEFS forecasts, to better inform decisions related to retaining or releasing water from reservoirs. These FIRO-based decisions are designed to optimize water allocation considering competing demands associated with applications that can include water supply, agriculture, recreation, hydropower generation, flood mitigation, navigation, and ecosystem management. This approach allows existing water infrastructure to be optimized while reducing the need for costly construction projects.

GOAL 2

Strengthen Operational Infrastructure

Strengthen NWS operational infrastructure, through the provision of a robust, resilient, and sustainable NWC Water Prediction Operations Division (WPOD) that delivers water prediction and information services.

Operational Objectives

2.1 Achieve the Final Operating Capability (FOC) for the NWC to deliver a 24-hours-a-day, 7-days-a-week, cross-NWS, NOAA, and Federal common operating picture and decision support services for water resources.

2.2 Implement a continuity of operations strategy that provides a reliable national service backup capability for RFCs and enables uninterrupted continuity of service and forecast operations on demand.

2.3 Enhance data integration, analysis, dissemination, and forecast services to provide integrated production, analysis, and delivery of a suite of national hydrologic data, forecast guidance, and related services.

Collaboration and Communication Objectives

2.4 Provide impact-based decision support services to enable timely and actionable critical decision making for event driven, high-impact, and routine high-value events, from flash floods to water supply and droughts.

2.5 Develop and improve core NWS software and web-based capabilities for hydrology, including the AWIPS, the National Water Prediction Service (NWPS), the CHPS, and other decision assistance tools for situational awareness, IDSS, and watch/warning decisions.

The National Water Center

The NWC is a world-class facility designed to serve as a catalyst to accelerate the transition of research into operations and a center of excellence for water resources science, information, prediction, and related decision support services. It houses a state-of-the-art Operations Center, and a cadre of Federal staff, contractors, and grantees to support it and provide lifesaving water information services for high-impact events. The Operations Center staff work collaboratively with the NWS field, and Federal, state, and local agencies to deliver fully integrated, timely, and relevant water resource services to partners and customers across the country. Since 2015, the OWP has hosted over 150 scientific and technical meetings with over 3,500 participants at the NWC. These meetings have included five Summer Institutes planned with the National Science Foundation (NSF) and the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI). The Summer Institutes, held annually at the NWC for six weeks, recruit the best and brightest graduate students from around the world to work hand-inhand with leading Federal scientists and academics to address challenging water resources problems and transform water prediction.

Over the last five years since it opened, the NWC has strengthened the nation's water prediction capabilities and related services by operating as an innovation incubator and research accelerator; bring the most cutting-edge technologies to bear on national water challenges. NOAA is leveraging the NWC, in partnership with other Federal agencies and enterprise partners, to deliver a new generation of water information and services to the nation. The NWC also serves as a coordination center for integrated Federal flood inundation mapping (FIM) efforts across USGS, Federal Emergency Management Agency (FEMA), NOAA, and U.S. Army Corps of Engineers (USACE). These services strengthen the nation's water forecast capabilities for floods and droughts, improve preparedness for water-related disasters, and inform high-value water decisions at the local, tribal, state, and national levels. By complementing existing water resource services delivered by regional RFCs, Regional Operations Centers (ROCs), and local WFOs with a national center, the NWS water mission area mirrors the highly successful structure of the meteorological services components of the NWS.

Water Prediction Operations Division and Operations Center

The Water Prediction Operations Division (WPOD)[5], in collaboration with NOAA field offices and other Federal water agencies, is responsible for the delivery of forecast guidance and analyses, and inundation information for hydrologic events in the United States. The WPOD leads the NWS' national and multiregional water resource activities to ensure consistent IDSS delivery and messaging in coordination with NCEP, NWSOC, ROCs, RFCs, and WFOs. Building relationships for successful IDSS requires engagement with the NWS fully integrated field structure, NOAA line offices, and other Federal water agencies, as well as external national level partners and stakeholders, to better understand their operations, decision points, and requirements for water resource information. This includes flash flooding, riverine flooding, and water resources outlooks and providing decision-support services to inform emergency and water resources management decisions. The analyses are leveraged by NCEP, RFCs, and WFOs for their official outlooks, forecasts, watches, and warnings. The Operations Center of the NWC is designed to accommodate WPOD staff along with staff from other NOAA Line Offices and multiple agencies. It is the intent of NOAA to include personnel from other Federal water agencies in the Operations Center.

5 https://www.weather.gov/media/organization/WPOD%20CONOPS%2020190916%20final.pdf

GOAL 3

Enable Collaboration & Organizational Excellence

Enrich water prediction and information services through strengthened collaborations, social science, and organizational excellence.

Internal Stakeholder Engagement Objectives

3.1 Sustain traditional stakeholder engagement in collaboration with NWS, AFSO/WRSB, and other NOAA entities to identify and refine new water information services.

3.2 Sustain science collaborations through the Joint Technology Transfer Initiative (JTTI) with NSF and CUAHSI through the annual Innovator's Program and Summer Institute; USGS bilateral collaboration; cross agency collaboration with USGS, FEMA and USACE; continued engagement of the CAC-WP; and establishing communities of practice for NWM development and evolution, including the development of targeted communities of practice around coastal coupling.

3.3 Enhance intra-agency coordination and collaboration to ensure a common operating picture for water resources prediction and services and provide subject matter expertise, training, and outreach for RFCs and WFOs.

External Stakeholder Engagement Objectives

3.4 Enhance interagency coordination and collaboration through continued leadership and support of the NOAA Water Initiative (NWI), the NOAA Weather, Water, and Climate Board (WWCB), the NOAA Water Team, and ongoing engagement with the Integrated Water Resources Science and Services (IWRSS) consortium, and National Integrated Drought Information System (NIDIS).

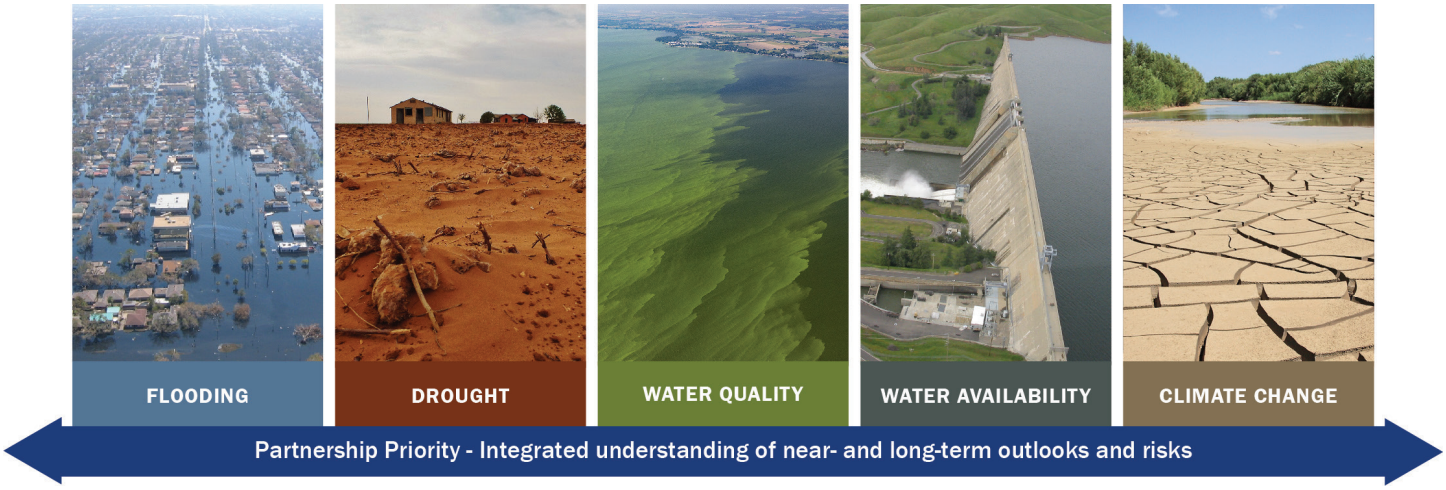
3.5 Infuse social science in water prediction through engagement with social science leaders in the water resource science community.

Workforce Objectives

3.6 Foster excellence in individual and collective performance through a commitment to diversity and inclusion, training, employee development, strong labor-management relations, and administrative excellence.

Partner and Stakeholder Priorities

NOAA and the NWS continue to anchor its work and services to address the priorities of its partners and stakeholders which include a broad spectrum of decision-makers from the emergency management, transportation, agriculture, power generation, recreation, flood control, ecosystem management, river commerce, and water supply communities. NWS' services inform essential emergency management and water resource decisions across all timescales, including drought, low-flow risks, and information needs for routine and seasonal water management and planning. NWS and OWP conduct various partner and stakeholder engagement activities to identify service and information gaps that inform our goal and objectives. They have expressed a need for integrated outlooks and risks concerning flooding, drought, water availability, water quality, and climate change impacts. Consistent, high-resolution "street-level" analyses, predictions, and data are needed, and OWP must continue to transform data into actionable intelligence by linking hydrologic, infrastructural, economic, demographic, environmental, and political data.



Additionally, our partner priorities require the development and implementation of enhanced modeling, data services, and applications which we are implementing now and over the next 5 years. OWP will continue to transform our hydrologic modeling framework to a more physically-based modeling approach that represents the physical processes of the hydrologic cycle.

Key Partnerships

The OWP values collaboration and will continue our partnerships with offices and agencies across the NWS, NOAA, the Federal Government, academia, and the private sector to accomplish its goals. Working together, we will fast-track innovations to eliminate organizational barriers, share best practices, and focus on continuous improvements. Our approach leverages the experiences and investments from a broad range of researchers and developers worldwide while advancing the science and application of water prediction capabilities. Outlined below are the specific partnerships that will continue to be fostered in the coming years.

OWP's Coordination across NWS and NOAA: In 2015, in addition to establishing the OWP, the NWS implemented a new headquarters structure and portfolio management framework. This has facilitated an evolution towards a more partner and customer-centric service model as well as enhanced NWS organizational agility to respond to emerging needs more quickly and deliver enhanced IDSS. The OWP focuses on seamless collaboration across the NWS and works with both the NWS Portfolio Offices and the field units engaged in the hydrologic forecast and warning program including the RFCs,

ROCs, WFOs, and the Analyze Forecast and Support Office's Water Resources Services Branch. The OWP also works closely with other NWS forecasting centers, particularly the National Hurricane Center, Weather Prediction Center, the Climate Prediction Center, the Environmental Modeling Center, and NCEP Central Operations.

The OWP works across all the NOAA lines offices and Chairs the NOAA Water Team. As part of this effort, The OWP works closely with the National Environmental Satellite, Data, and Information Service (NESDIS); the National Ocean Service (NOS); NMFS; the Office of Oceanic and Atmospheric Research (OAR); the Office of Marine and Aviation Operations (OMAO); as well as with ex officio representatives from NOAA's Regional Collaboration Teams and the National Integrated Drought Information System (NIDIS) program, housed in OAR. These collaborations will continue to be a focus as NOAA delivers enhanced water services and as part of an integrated earth system prediction modeling capability.

Federal Partners: The OWP partners with other Federal agencies including USGS, USACE, and FEMA. The USGS maintains a network of over 8,000 gages, which provide critical monitoring of the nation's rivers, lakes, groundwater, and coastal estuaries. NOAA relies on these observations, both historical and in real-time, to develop and calibrate hydrologic models, to maintain situational awareness, and to produce streamflow forecasts. Moreover, USGS is critical to Federal efforts in developing water resources science and analytical tools designed to improve prediction of streamflow and water quality including temperature, constituent capture (erosion), fate, and transport, and to establish a joint model-development environment and associated governance for the NWM. The OWP's partnership with the USGS, USACE, and FEMA is codified in a Memorandum of Understanding (MOU) for the IWRSS consortium. The OWP's other Federal partners include the U.S. Bureau of Reclamation (USBR), NSF, the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Department of Energy (DOE).

Research and Academia: The OWP particularly values its research and academic partners, including federally funded research and development corporations such as the National Center for Atmospheric Research (NCAR), the University Consortium for Atmospheric Research (UCAR), CUAHSI, the Cooperative Institute for Satellite Earth System Studies (CISESS), the Water Science and Technology Board (WSTB) of the National Academies of Sciences, Engineering and Medicine, and the University of Alabama. Even broader outreach and engagement with academia is anticipated as the science and the OWP's science and service capabilities continue to evolve.

By FY2022, the Congress has directed NOAA's NWS to establish a new NOAA Cooperative Institute with the following foci:

- Expand water resources prediction capabilities, including real-time and forecast flood inundation mapping products and decision support services
- Advance and augment hydroinformatics and community water resources modeling, geographic information systems and remote sensing, data assimilation, computational science and high-performance computing, artificial intelligence, and machine learning
- Integrate social, economic, and behavioral sciences into the water sciences enterprise
- Cultivate the next generation of water resources scientists and engineers

The OWP is leading the effort to establish this new water resources Cooperative Institute, which is vital for accelerating the transformation of NOAA's water prediction science and related services, advancing climate resilience and water security, and promoting service and social equity for communities nationwide.

Independent Community Advisory Committee: The OWP receives non-consensus advice from an independent committee assembled by UCAR: The Community Advisory Council for Water Prediction (CAC-WP). This rotating membership committee consists of representatives from Federal agencies, academia, non-governmental organizations (NGOs), and the private sector, and provides independent review of OWP's strategic modeling and related data and information services

plans. The FY21 membership includes water resources experts from other Federal partners as well as the University of Texas, Duke University, Columbia University, Utah State University, Tufts University, and Tulane University. Private sector participants include Esri and Kisters.

International Collaboration: The OWP engages in international activities through a bilateral agreement with NOAA and Environment and Climate Change Canada (ECCC) and through participation in the hydrology activities of the United Nations World Meteorological Organization (WMO), specifically the newly formed Hydrology Assembly and Hydrological Coordination Panel (HCP). The OWP also contributes to the water activities of the intergovernmental Group on Earth Observations (GEO) by supporting GEO's Global Observations for Water Sustainability (GEOGLOWS) initiative.

Workforce and Culture

The OWP has a world class workforce that is dedicated, motivated, and committed to realizing our vision of a Weather-and-Water-Ready Nation and mission of protecting lives and property. The OWP is committed to creating a best-in-government workplace which is diverse and has a culture of inclusion. Along with the DOC, NOAA, and NWS, we have and will continue to prioritize the importance of fostering a culture of workforce excellence, continuous engagement, and diversity and inclusion. We recognize and acknowledge the need to adapt to the ever-changing needs of our workforce to create a healthy organizational culture.

We appreciate that success will require additional investments in workforce recruitment, training, performance, and retention. This includes emphasizing diversity, inclusion, and belonging; comprehensive training and professional development; sustainment of workforce capacity and skills; enabling organization leaders to manage and lead through change; and prioritizing strong labor-management.

OUR VALUES

Scientific and technical integrity

Leadership in Science, Technology, and Service

Creativity and innovation

Evidence-based decision making

Workforce excellence

Transparency

Collaboration and partnership

Effective communication

Accountability

Teamwork

Respect Conclusion

OWP | OFFICE OF WATER PREDICTION

To achieve this goal, the OWP will focus on the below initiatives:

- Enhanced Employee Experience – The OWP will remain focused on enhancing the employee work experience by creating a culture of belonging, inclusion and diversity and investing in the necessary infrastructure to ensure an effective and collaborative work environment. OWP will prioritize creating an agile workforce which encourages collaboration and provides the tools to do so.
- Promoting Training and Development Opportunities – The OWP is committed to providing comprehensive workforce training and development to advance employees skillsets. We are committed to providing employees the opportunity to develop leadership skills, understand the performance management process, and create awareness of training opportunities.

OWP is committed to Organizational Health and Culture.

- Dedicated to Organizational Health and Culture – The NWS developed an Organizational Health and Culture Action Plan based on employee feedback and surveys including FEVS, and OWP is committed to its implementation. We recognize the importance of creating a culture that is supportive, welcoming, and inclusive which allows employees to feel committed and empowered to contribute meaningfully to the organization's mission. The OWP is also committed to protecting employee health and safety, to include extended telework processes to ensure employees can maintain productivity when they cannot access traditional office spaces, such as during the COVID-19 pandemic.

A PATH FORWARD

NOAA's establishment of the OWP and the NWC, together with the launch of the NWM and the implementation of the HEFS, are the first critical steps in the transformation of NOAA's water prediction capabilities and related services. Moreover, the demonstration and implementation of real-time and forecast flood inundation mapping have provided critical new intelligence and related decision support services that will revolutionize the delivery of critical and life-saving information before and during floods. Together, these assets and services are the backbone of water resources information capabilities that deliver analyses, forecasts inundation information, and guidance to partners and stakeholders in all sectors. This enhanced information informs event-driven, high-impact, and routine high-value decision-making for all hydrologic events across the United States, which range from flash floods to devastating droughts. Additionally, these tools, information, and services help inform the optimal use of increasingly limited water supplies in the face of competing demands.

The OWP will continue strong engagement with our partners and stakeholders, and collaborative development with other NWS and NOAA offices, Federal agencies, academia, and the commercial sector, as we continue to transform our water prediction capabilities. The NWC will continue to be a center of excellence for next generation water intelligence to support enhanced and informed decision making as the nation faces the increasingly complex, multi-disciplinary, and growing water challenges in the 21st century.

KEY OUT-YEAR ACTIVITIES

FY 21

- Implement NWM v2.1 with domain expansion to Puerto Rico, U.S. Virgin Islands and Great Lakes*
- Demonstrate a prototype FIM for 115M U.S. residents living in flood-vulnerable freshwater basins
- Demonstrate the delivery of Experimental real-time FIM via Cloud Services
- Demonstrate V1.0 of a Water Resources Evaluation Service
- Re-calibrate HEFS with GEFS v12 and transition existing operations, ending the use of GEFS v10
- Expand support for Forecast Informed Reservoir Operations (FIRO)
- Implement a first-ever National RFC Service Backup Capability
- Implement the National Water Prediction Service (NWPS), a modernized & integrated web portal for water forecasts and information
- Prototype the capability to couple NWM with ESTOFS and National Hurricane Center (NHC) products for Total Water Prediction in the coastal zone
- Prototype a continental-scale hydraulic routing capability
- Prototype NWM in Cook Inlet and Copper River Basin (AK)
- Define the requirement for a modular and community accessible Next Generation NWM framework
- Demonstrate the National Snow Analysis B/U capability in Cloud

FY 22

- Achieve Full Operating Capability for the NWC Operation Center (24x7 Ops)
- Implement real-time FIM operationally for at least 15% of U.S. residents via Cloud Services
- Create and distribute authoritative, composite FIM products that integrate information from multiple Federal agencies
- Complete the development, calibration, and testing of NWM v3.0 with domain expansion to Alaska, inland hydraulic routing, and coastal freshwater-estuary-ocean coupling*
- Develop and test a Next Generation NWM Framework and Modular Architecture
- Implement HEFS and disseminate via AHPS at an additional 800 locations
- Evaluate and implement HEFS hydrologic post-processor
- Implement HEFS/MEFP enhancement to improve extreme event performance
- Provide access to all HEFS forecast information via a Modernized & Integrated Web Portal
- Develop and test v2.0 of a Water Resources Evaluation Service
- Demonstrate the National Blend of Models as a forcing for NWM
- Establish an initial Community of Practice for NextGen NWM framework
- Establish a Cooperative Institute on water resources

FY 23

- Deploy NWM 3.0 into operation and make the model output available via a Modernized & Integrated Web Portal
- Implement the National Blend of Models as a forcing of NWM
- Implement real-time FIM operationally for at least 30% of U.S. residents
- Complete the development and testing of a Next Generation NWM Framework suitable for integration within the NOAA UFS
- Complete the development, calibration, and testing of NWM v4.0 using the Next Generation Framework heterogeneous runoff process representations
- Develop and demonstrate a river water temperature forecast capability within the Next Generation NWM Framework
- Complete implementation of HEFSv1.0 at ALL REMAINING locations
- Implement Drought and Post-Fire Decision Support Services via the NWC Operations Center
- Implement v2.0 of a Water Resources Evaluation Service
- Complete the development, calibration, and testing of Snow DA capabilities utilizing the JEDI framework
- Demonstrate one-way coupling to 3-D NOS hydrodynamic models

FY 24

- Implement NWM v4.0 based on the Next Generation Framework, into operations
- Complete development, calibration, and testing of NWM v5.0 using the Next Generation Framework, including new Snow DA capabilities
- Implement FIM operationally for at least 60% of U.S. residents
- Complete the testing and validation of a streamflow temperature forecast capability
- Define requirements/plans for HEFS v2.0
- Demonstrate nested hyper-resolution capability within Next Generation NWM Framework, which accounts for urban hydrologic control structures such as bridges, levees, and detention basins
- Deploy low-flow/Flash drought decision support services via NWC Operations Center in coordination with NOAA partners
- Demonstrate Dam Break support services for NWS field offices

FY 25

- Implement NWM v5.0 into operations, capability, and a streamflow temperature forecast capability
- Implement FIM operationally for at least 80% of U.S. residents
- Complete Development and Testing of a Next Generation NWM v6.x, introducing a capability to track constituents through the NWM stream network
- Optimize the use of probabilistic water resources forecasts in WFO warning operations leveraging FACETS and Hazard Services
- Implement v3.0 of a Water Resources Evaluation Service
- Implement a coastal freshwater-estuary-ocean coupled model capability which incorporates a 3D Hydrodynamic Estuary Model
- Demonstrate advanced coupling with NOS Hydro-dynamic models on a regional scale
- Establish operational Dam Break support services for NWS field offices
- Demonstrate the Next Generation NWM Framework within the NOAA Unified Forecast System (UFS)

FY 26

- Implement NWM v6.0 into operations
- Complete Development and Testing of a Next Generation NWM v6.x
- Implement FIM operationally for 100% if U.S. residents
- Implement a nested hyper-resolution capability, which accounts for urban hydrologic processes, within the Next Generation NWM Framework
- Integrate the Next Generation NWM Framework within the NOAA UFS for global application
- Validate, recalibrate, and implement GEFSv13

APPENDIX

Key Drivers and Authorizing Legislation

In the late 2000s, Congressional leaders noted the growing risks of flooding and severe weather across the country, leading them to call for a new national center to address the Nation's growing water challenges with new technologies. Around the same time, the National Academies of Science, Engineering, and Medicine released an influential report in 2012, entitled, Weather Services for the Nation, Becoming Second to None, which called for a reorganization and modernization of key NOAA water prediction functions. NOAA was already collaborating with the USGS and USACE through the IWRSS consortium to develop shared plans for a virtual or physical national center, to establish a common operating picture for water, and advance water resources prediction and related services nationwide. FEMA joined the consortium in 2015. When Congressional vision met with NOAA and NWS planning, the NWC was established as the cornerstone facility of the new OWP. The Fourth National Climate Assessment, released in November 2018, found that "the quality and quantity of water available for use by people and ecosystems across the country are being affected by climate change, increasing risks and costs to agriculture, energy production, industry, recreation, and the environment."[6]

Authorizing Legislation

On December 31, 2020, the Senate unanimously passed the Coordinated Ocean Observations and Research Act which became Public Law 116-271. Title III, Section 301(a) of that legislation formally authorized the establishment of the National Water Center and defines its role as follows:

- to serve as the research and operational center of excellence for hydrologic analyses, forecasting, and related decision support services within the National Oceanic and Atmospheric Administration and the National Weather Service; *and*
- to facilitate collaboration across federal and state departments and agencies, academia, and the private sector on matters relating to water resources.

The law defines the functions of the NWC as follows:

- Improving understanding of water resources, stakeholder needs regarding water resources, and identifying science and services gaps relating to water resources.
- Developing and implementing advanced water resources modeling capabilities.
- Facilitating the transition of hydrologic research into operations.
- Delivering analyses, forecasts, and inundation information and guidance for all hydrologic events in the United States, including flash flooding, riverine flooding, and water resources outlooks.
- In coordination with warning coordination meteorologists, providing decision-support services to inform emergency management and water resources decisions.

The law also calls on NOAA/NWS to create an operations and services policy directive for the National Water Center within one year of the date of the act, including the following:

- Operational staff responsibilities

6 https://nca2018.globalchange.gov/#sf-6

- Guidelines for content, format, and provision of hydrologic and inundation products developed by the National Water Center
- Procedures for cooperation and coordination between the National Water Center, the National Weather Service National Centers for Environmental Prediction, National Weather Service River Forecast Centers, and National Weather Service Weather Forecast Offices.

The law further describes specific duties for the Director of the Office of Water Prediction regarding total water prediction as follows:

- Initiate and lead research and development activities to develop operational water resource prediction and related decision support products.
- Collaborate with, and provide decision support regarding total water prediction to—
    - the relevant federal agencies represented on the National Science and Technology Council, Committee on Environment, Natural Resources, and Sustainability and the Subcommittee on Disaster Reduction.
    - State water resource agencies; *and*
    - State and local emergency management agencies.
- In carrying out the responsibilities described in paragraphs (1) and (2), collaboratively develop capabilities necessary for total water predictive capacity, including observations, modeling, data management, supercomputing, social science, and communications.

Finally, the law authorizes appropriations up to $225 million through 2024 to accomplish these objectives.

Table 4 below summarizes the legislation applicable to OWP and the National Water Center over the period FY 2013 to FY 2020.one year of the date of the act, including the following:

- Operational staff responsibilities
- Guidelines for content, format, and provision of hydrologic and inundation products developed by the National Water Center
- Procedures for cooperation and coordination between the National Water Center, the National Weather Service National Centers for Environmental Prediction, National Weather Service River Forecast Centers, and National Weather Service Weather Forecast Offices.

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Finally, the law authorizes appropriations up to $225 million through 2024 to accomplish these objectives.

Table 4 below summarizes the legislation applicable to the OWP and the NWC over the period FY 2013 to FY 2020.

Table 4: Legislation Applicable to OWP for FY 2013 - 2020

Laws referencing the Office of Water Prediction and National Water Center FY 2013 - FY 2020[7]

Public Law Citation	Summary	Accompanying Committee or Conference Report
116-260	Provides appropriations for OWP/NWC for **FY 21**	**S. Rept.**
116-93	Provides appropriations for OWP/NWC for **FY 20** according to Senate language with additional $1.5M for Dissemination. Senate report for FEMA to locate personnel at NWC.	**S. Rept. 116-125** *p.96 (FEMA)* **S.Rept.116-127** *p.53* **H.Rept. 116-101** *p.35*
116-6	Provides appropriations for OWP/NWC for **FY 19**, including directed funding to expedite hiring in WPOD	**H.Rept.116-9** *p.618*
115-141	Provides appropriations for OWP/NWC for **FY 18**, and direction and funding for 1) snow and soil moisture grant and 2) USACE Coastal Inlet Research Program to work with NWC	**H. Comm. Print Book I (Div. A-F)** *p.181, 712*
115-31	Provides appropriations for OWP/NWC for **FY 17**, and operating Integrated Water Prediction Program	**S.Rept. 114-239** *p.38*
114-113	Provides appropriations for operations and staffing of OWP/NWC for **FY 16**	**S.Rept. 114-66** *p.38*

7 List only includes law that contains references to "Office of Water Prediction" and "National Water Center" and excludes any Continuing Resolutions or Supplemental legislation.

Public Law Citation	Summary	Accompanying Committee or Conference Report
113-76	Provides appropriations to staff and operate OWP/NWC for **FY 14**, and direction to leverage NWC in implementation of the Consumer Option for an Alternative System to Allocate Losses (COASTAL) ACT	S.Rept. 113-78
113-6	Provides appropriations necessary to staff and operate OWP/NWC for **FY 13**	S.Rept. 112-158

OWP Key Activities

2015-2019

Note: Stairway indicated when activities began, not completed. Most OWP activities are multi-year efforts.

FY 15

Core Capability

Centralized Water Forecasting

Implement and enhance operational National Water Model (NWM)

- **"Street Level" water forecasts** for 2.7 million stream reaches at high temporal frequency for enhanced flash and river flood services
- Expand from only flow/stage forecasts to forecasts of **full water budget**
- Forecasts linked to geospatial informational to **provide water intelligence**

FY 16

Key Demonstration

Flash Flood and Urban Hydrology

Demonstrate NWM with nested hyper- resolution capability and urban hydrologic processes

- Explicitly **incorporate urban structures** such as bridges, levees, and storm drains
- **Street level flood forecasts** for selected urban demonstration areas
- Develop out year strategy to provide higher resolution guidance to NWS field offices to **enhance services for flash floods**

FY 16

Key Enhancement

Ensemble Streamflow Prediction

Hydrologic Ensemble Forecasting Service (HEFS)

- Streamflow forecasts which quantify hydrologic uncertainty on time scale from **hours to years**
- Utilize short, medium, and long range weather forecasts as forcings
- **Capture total uncertainty** and correct for biases in forcings and streamflow
- Critical input to **Forecast Informed Reservoir Operations** (FIRO)

FY 16

Key Enhancement

Event-Based Flood Inundation Mapping (FIM)

National real-time FIM for over five million river miles

- Utilize Height Above Nearest Drainage (HAND) approach to **generate FIMs for NWM guidance and River Forecast Center streamflow predictions**
- Provide Federal forecasters, emergency management partners, and the public with **street-level FIMs**
- **Revolutionize pre-planning and response** to high-impact flood events for protection of life and property

FY 17

Major Integration

Integrated Water Prediction

Couple NWM with marine models to predict combined effects of storm surge, tide, wave, and riverine impacts

- **Summit-to-sea** water prediction information linked to geospatial information to assess risk and vulnerability
- **More complete picture** of coastal storm impacts for 120+ million residents in the coastal zone
- **New service delivery model implemented** — increased stakeholder engagement and integrated information

FY 18

Key Enhancement

NWC Operations Center

National decision-support services to inform emergency management and water resources decisions

- Analyses, forecasts, inundation information and guidance for hydrologic events including **flash flooding, riverine flooding, and water resources** outlooks
- Support inter- and intra-agency efforts to **establish a common operating picture** for water prediction and related services
- Provide **reach-back capability** for NOAA and NWS field offices regarding water resources

FY 19

Key Enhancement

Next Generation NWM

New fully modularized, more computationally efficient architecture

- Implement code changes to facilitate **collaborative development** and accelerated testing and implementation
- Couple NWM with shallow groundwater and transport models to **predict low flows, drought and fire impacts**
- Incorporate improvements such as heterogeneous process representation, an enhanced land surface model, dynamic land use/ cover updates, and improved infiltration, routing, and calibration
- Expanded guidance for NIDIS U.S. Drought Portal and enhanced decision support including drought and post-fire events
- Integrate capabilities and in NOAA UFS and EPIC

FY 19

Major Integration

Water Quality

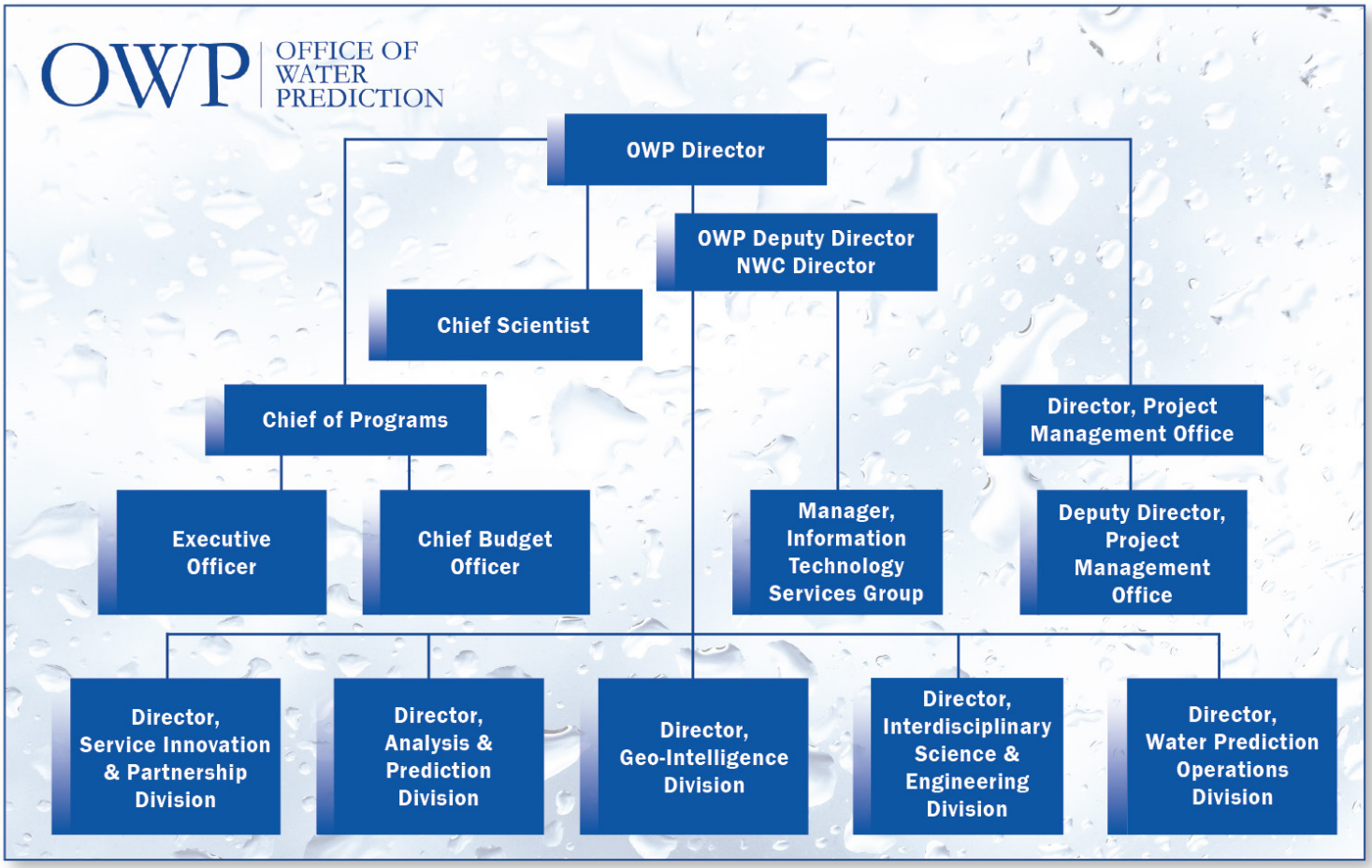
Integrate enhanced NWM with key water quality data sets, models and tools to begin water quality prediction

- Initial focus on water temperature and salinity prediction
- Link NWM output to NOAA ecological forecasting operations
- Incorporate water quality data from federal and State partners into NWM
- Add ability to track constituents through stream network
- Provide new decision support services for enhanced ecosystem and species management, and for water quality issues such as Harmful Algal Blooms

OWP Organization

In 2015, NWS established the OWP and the National Water Center which was built on the campus of the University of Alabama in Tuscaloosa, AL. Provided below is the OWP organization structure which includes the NWS Director and OWP Deputy Director.

With the NWC as the anchor, the entire OWP team works collaboratively to create a consistent and unified national hydrologic program with the Water Resource Service Branch (WRSB) of the NWS AFSO, the NWS Office of Central Processing (OCP), the Office of Dissemination (ODIS), the Office of Observations (OBS), the Office of Science Technology and Integration (OSTI), the NWS Regional Headquarters, the NCEP, the ROC, RFCs, and local WFOs. This integrated NWS team works across NOAA and with federal, state, local, tribal, academic, and private sector partners to respond to growing national needs for water prediction services to address growing national water resources challenges.



OWP Offices and Divisions:

Chief of Programs

The Chief of Programs Office is responsible for program planning, day-to-day administrative activities, and budget planning and execution. Specifically, the office coordinates the development and reporting of OWP program annual and strategic plans with the NWS portfolios. It also handles day-to-day administrative activities including the coordination of responses to requests for information (from NWS, NOAA, Congressional, etc.), all OWP Federal personnel matters (including time and attendance, travel, recruitment, table of organization maintenance, and training), and facilities issues (Silver Spring location only). The Budget group is responsible for coordinating OWP budget formulation, execution, acquisitions, and reporting in coordination with the NWS portfolios and the NWS Chief Financial Officer.

OWP Chief Scientist

The OWP Chief Scientist ensures that OWP leads the NWS in the global and national hydrologic communities, particularly in terms of scientific, technological, and societal needs. The Chief Scientist advises OWP leadership, staff, and project teams on scientific matters. This may include recommendations on future projects, modeling approaches, and research activities. The Chief Scientist may also coordinate on the recruitment of qualified technical staff. The Chief Scientist works with OWP leadership and Service Innovation and Partnership Division (SIPD) to serve public relations functions by representing the scientific goals and interests of the hydrologic community, and participates in press conferences, meetings, conventions and stakeholder events.

Information Technology Services Group (ITSG)

ITSG provides administration and technical support of OWP information systems. ITSG maintains the computer infrastructures of OWP, both physically and logically. They provide user support to OWP personnel, specifically with government furnished computers and software issues. ITSG perform software updates to maintain operational capabilities, as well as ensuring compliance with NWS, NOAA, and DOC security requirements. ITSG ensures software and hardware licenses are up to date. ITSG plans for equipment refresh and maintains appropriate data storage options and data transport capabilities. ITSG ensures critical IT infrastructure is available to project, research, and operational staff.

Project Management Office (PMO)

The PMO provides OWP Offices and Divisions with management support, particularly for officially recognized projects. PMO personnel serve as project managers and in other support roles to ensure OWP teams deliver project lines on time and within resource constraints. PMO delivers overall project support through direct project management, developing project schedules (including an integrated master schedule), identifying resource requirements, and reporting project progress. PMO provides other management support to include managing enterprise risks, providing enterprise software/hardware solutions, and new project startup. PMO facilitates the Program Management Council, hosts Quarterly Progress Reviews to OWP leadership and partners, and facilitates OWP Strategic Planning conferences. PMO diagnoses team performance and recommends mitigation activities.

Analysis and Prediction Division (APD)

APD integrates science, software, and data components into operational water resources prediction systems for local, regional, national and global implementation. APD has both developmental and operational functions. It develops water-related integrated information systems and infrastructure, integrated models, modeling and data assimilation tools and systems, and integrated model calibrations and parameterizations. It operates numerical models, analytical tools, databases and information systems at national and global scales. It produces systems architecture and decision support products. It maintains systems, integrated models, databases, records and documents. APD supports OWP and

field operations, web data and product dissemination, external partners, customers and stakeholders, and corporate knowledge management.

Geo Intelligence Division (GID)

GID provides centralized and consistent data services, geospatial analyses, and cartographic expertise to support science and engineering development, systems implementation, and water resources operations at local, regional, national and global scales. GID has both developmental and operational functions. GID develops and maintains the public OWP web and data services hosted on official NWS dissemination platforms. It develops water-related geospatial data; actionable intelligence derived from data; geospatial software applications; maps and graphics; new products and product improvements; spatial discretization techniques; and analytical methods. It leverages airborne survey systems for snow and soil moisture; geographic information systems; mapping and graphics software, systems and tools; databases, models and geo-statistical analysis software. It produces and maintains enterprise geospatial datasets, maps, atlases, graphics, documentation and geo-intelligence. GID supports OWP and field operations, external partners, customers and stakeholders, and corporate knowledge management.

Integrated Science and Engineering Division (ISED)

ISED provides core science capacity, algorithm and software component development and operational decision support for local, regional, national and global scales. ISED has both developmental and operational functions. It develops water-related core scientific knowledge; software applications; model components; new products and product improvements; skill evaluation techniques; and modeling and analytical methodologies and algorithms. It operates models, analytical tools, databases and information systems. It produces scientific publications; software applications; evaluations of algorithms, techniques, tools, products and services; product documentation; incremental improvements in scientific or technical maturity of algorithms, models and tools; evaluations of skill and performance of models, products and services; new methodologies; and model parameterizations and calibrations. It maintains scientific expertise, product documentation, and developmental and operational software. ISED supports OWP and field operations, external partners, customers and stakeholders, and corporate knowledge management.

Service Innovation and Partnership Division (SIPD)

SIPD provides geographic and socioeconomic sector-specific water resources information, risk, impact and economic assessments and decision support services. It marshals local, regional, and national assets to ensure effective service delivery at all scales. SIPD has both developmental and operational functions.

It develops relationships with partners and stakeholders; decision support services; analyses of impacts and risks; requirements for improved information and services; and training and education programs. It operates socioeconomic hazards and impacts databases, models and information systems. It produces economic analyses, impact analyses, risk assessments, legal and policy assessments, outreach materials and scientific publications. It maintains socioeconomic databases and requirements databases. SIPD supports community resiliency, OWP and field operations, external partners, customers and stakeholders, training and corporate knowledge management.

Water Prediction Operations Division (WPOD)

WPOD collaborates across all levels of the NWS and NOAA, and with federal partners, to provide consistent national operational services, which complement, support and enhance water resources decision support services delivered by RFCs and other field offices. Leveraging the assets of the NWC, the WPOD performs major functions, which are inherently interconnected and include:

- Analyze and Integrate Data through the routine production, analysis, and delivery of a suite of national hydrologic data and services;

- Maintain Situational Awareness through continuous assessment, interpretation and collaboration of hydrologic data and model output, and related decision support activities;
- Ensure Service Backup/Continuity of Operations by providing a service backup capability for RFCs to conduct limited, remote operations when needed;
- Deliver Impact-based Decision Support Services by proactively supporting, and responding to, stakeholder-defined needs and requirements for information which supports decision making during high impact events, as well as routine, high-value operations; and
- Facilitate Service Development and Operations to Research by providing operational support and feedback, and promoting innovation with respect to new water resources services.

The WPOD combines these functions to support a fully-integrated field structure that delivers first class water resource services to partners and customers across the nation. Moreover, the WPOD supports water-related services across other parts of NOAA, as well as other Federal agencies to ensure a seamless suite of integrated water resource prediction services.

Water Prediction Figures

This appendix features examples of charts and figures related to water prediction.

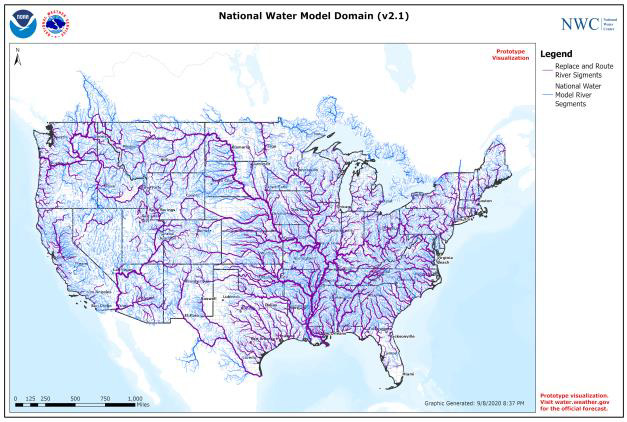


Figure 1: U.S. rivers and streams downstream of NWS AHPS forecast locations (shown in purple), represent only 3% of the total U.S. rivers and streams accounted for in the NWM (shown in blue).

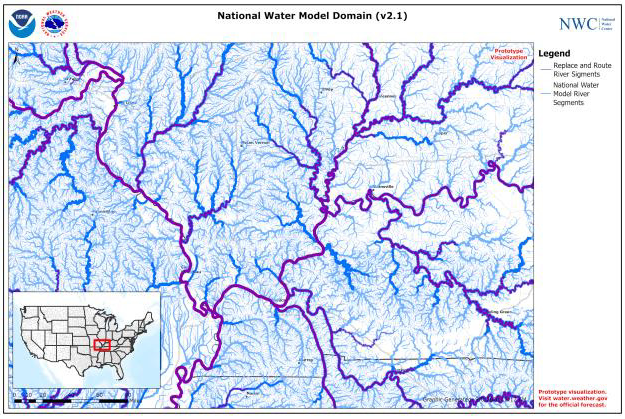


Figure 2: The National Water Model forecasts streamflow for ~3.5 million miles of rivers and streams across the continental U.S.

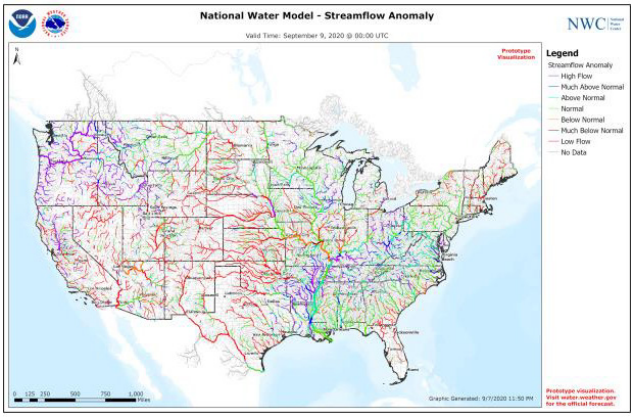


Figure 3: National Water Model streamflow anomaly (percentile) for 13Z on May 23, 2018.

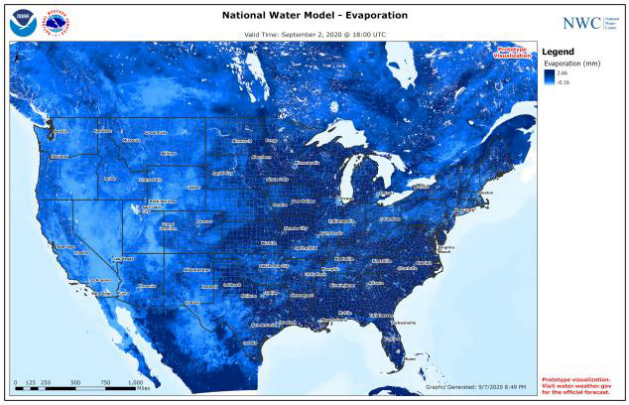


Figure 4: National Water Model Evapotranspiration (mm) for 15Z on September 2, 2020 10:00 UTC.

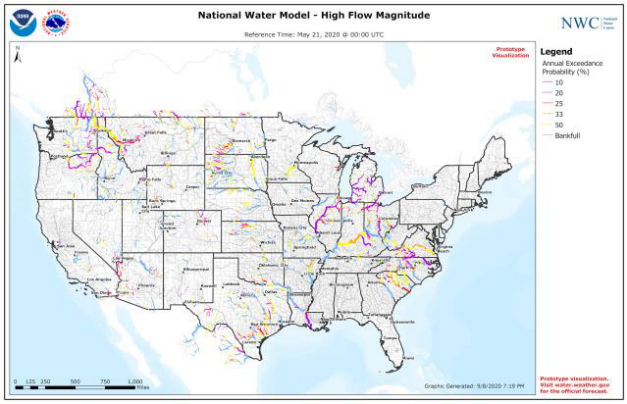


Figure 5: National Water Model High Flow Magnitude (Annual % exceedance) May 21, 2020 00:00 UTC.

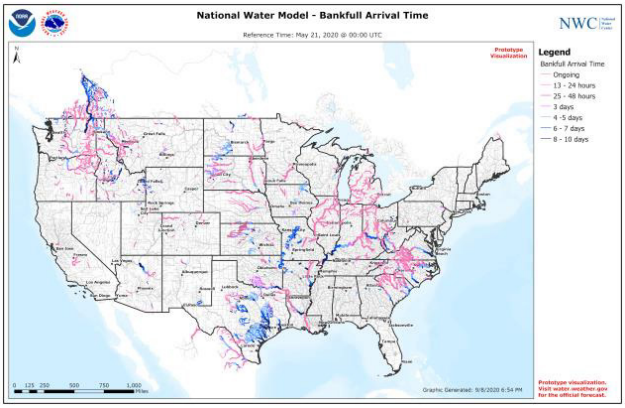


Figure 6: National Water Model Bankfull Arrival Time (hours, days) from a reference time of May 21, 2020 00:00 UTC.

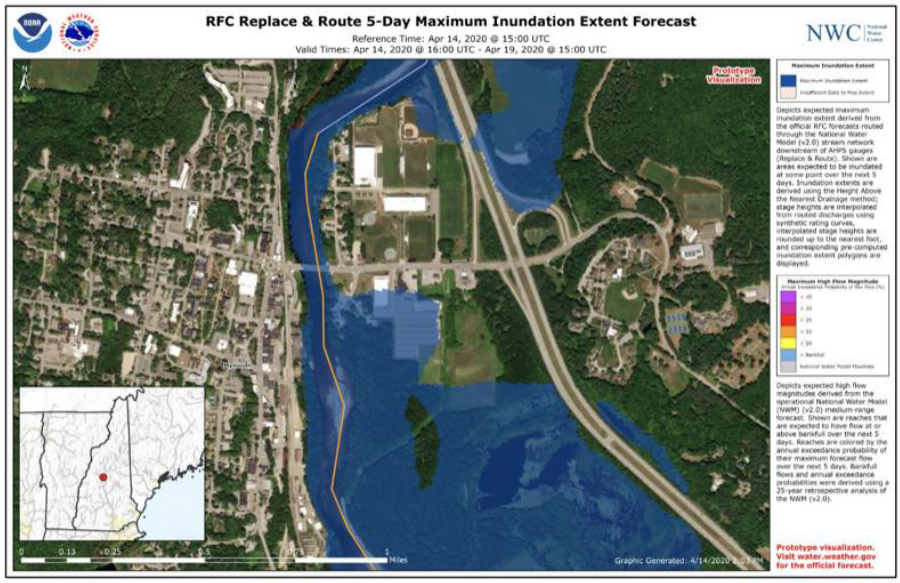


Figure 7: National Water Model Bankfull Arrival Time (hours, days) from a reference time of May 21, 2020 00:00 UTC.

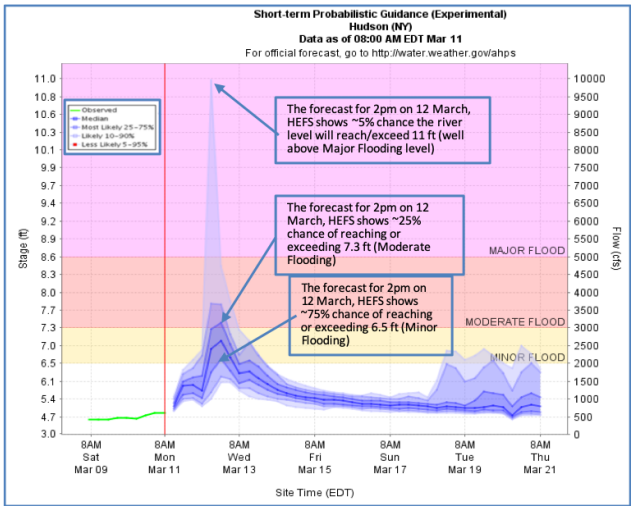


Figure 8: HEFS hydrograph depicting streamflow forecast uncertainty with time relative to stages associated with minor, moderate, and major flooding.

Figure 9: Image depicting Lake Mendocino and the Russian River Watershed.

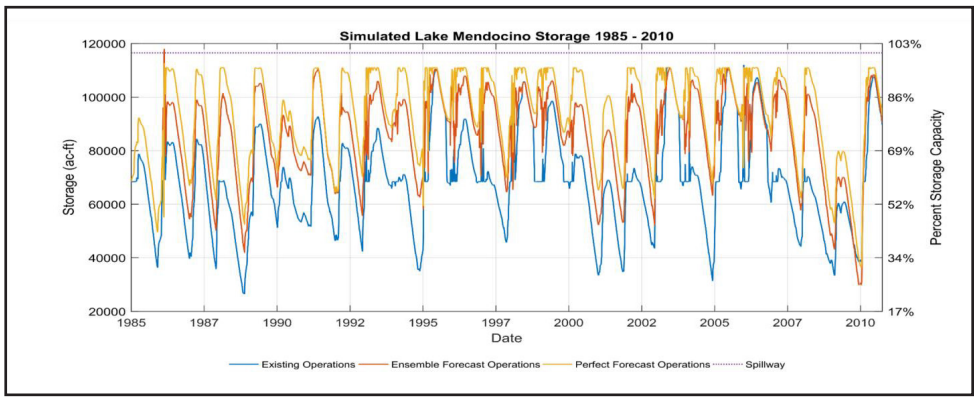


Figure 10: Image depicting a 15-year simulation of storage capacity for the Lake Mendocino for operations based upon three methodologies: existing operations (blue line); ensemble-based forecasts with HEFS (red line); and a "perfect" forecast (yellow line) using the observed rainfall for the forecast period.

List of Acronyms

The acronyms used in this document are defined in Table 5.

AFSO	Analyze Forecast and Support Office
AHPS	Advanced Hydrologic Prediction Service
APD	Analysis and Prediction Division
AWIPS	Advanced Weather Interactive Processing System
CAC-WP	Community Advisory Committee for Water Prediction
CFS	Climate Forecast System
CHPS	Community Hydrologic Prediction System
CISESS	Cooperative Institute for Satellite Earth System Studies
COASTAL	Consumer Option for an Alternative System to Allocate Losses
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Sciences Inc.
DOC	Department of Commerce
ECCC	Environment and Climate Change Canada
EMC	Environmental Modeling Center
EPA	Environmental Protection Agency
ESP	Ensemble Streamflow Prediction
FEMA	Federal Emergency Management Agency
FIM	Flood Inundation Mapping
FIRO	Forecast Informed Reservoir Operations
GEFS	Global Ensemble Forecast System
GEO	Group on Earth Observations
GID	Geo Intelligence Division
GEOGLOWS	Global Observations for Water Sustainability
HAND	Height Above Nearest Drainage
HCP	Hydrological Coordination Panel
HEFS	Hydrologic Ensemble Forecast Service
IHTM	Integrated Hydro-Terrestrial Modeling
ISED	Integrated Science and Engineering Division
ITSG	Information Technology Services Group
IWRSS	Integrated Water Resources Science and Services
JTTI	Joint Technology Transfer Initiative

NCEP	National Centers for Environmental Prediction
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSF	National Science Foundation
NWC	National Water Center
NWI	NOAA Water Initiative
NWM	National Water Model
NWS	National Weather Service
NYCDEP	New York City Department of Environmental Protection
OBS	Office of Observations
OCONUS	Outside Continental United States
OCP	Office of Central Processing
ODIS	Office of Dissemination
OSTI	Office of Science Technology and Integration
OWP	Office of Water Prediction

PMO	Project Management Office
RFC	River Forecast Center
ROC	Regional Operations Center
SIPD	Service Innovation and Partnership Division
SNODAS	Snow Data Assimilation System
UFS	Unified Forecast System
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WCOSS	Weather and Climate Operational Supercomputing System
WFO	Weather Forecast Office
WMO	World Meteorological Organization
WPC	Weather Prediction Center
WPOD	Water Prediction Operations Division
WWCB	Weather, Water, and Climate Board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