

# **Advanced Hydrologic Prediction Services Concept of Services and Operations**

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**U.S. DEPARTMENT OF COMMERCE  
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Office of Climate, Water, and Weather Services  
Hydrologic Services Division**

## **Preface**

Our country has grown tremendously since the National Weather Service first started providing hydrologic services decades ago. Urbanization, industrial growth, the increased inhabitation of flood-prone regions, advanced technologies, applied research, and more sophisticated customers present unique challenges and a breadth of opportunities. In light of these changes, it is important we reassess our hydrologic services and determine the enhancements necessary to sustain our important mission: to provide water information for life's decisions to protect life and property, and ensure the health of our Nation's economy.

NWS leaders agree we will enhance hydrologic services through the national implementation of Advanced Hydrologic Prediction Services (AHPS). Enhanced services described in this document are presented from the viewpoint of what can be, given the appropriate resources. New services are expected to be implemented in phases as budgets and priorities are established. This document presents a common vision of future services and operations. These new services will be provided through the combined efforts of Weather Forecast Offices, River Forecast Centers, and the National Centers for Environmental Prediction.

We will continue our long tradition of service excellence by improving our suite of hydrologic products and information to meet the evolving needs of our partners and customers. A major thrust of AHPS is to provide better services to a broader audience in a consistent format. This document is designed to provide a basic description of new AHPS products and information. Descriptions included represent conceptual ideas. The format and content of products and information will evolve as we continue to work closely with our partners and customers and new services become operational.

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# Advanced Hydrologic Prediction Services

## Concept of Services and Operations

### 1. Introduction

This document provides a concept of services and operations for Advanced Hydrologic Prediction Services (AHPS) in the National Weather Service (NWS). AHPS are enhanced information and products provided through the infusion of new science and technology. These services will improve flood warnings and water resource forecasts nationwide to meet the diverse and evolving needs of our partners and customers.

AHPS will affect many aspects of the NWS Hydrologic Services Program. The content and format of hydrologic products and information will be improved as well as the science and technology used to produce them. AHPS will deliver the following enhancements to the Hydrologic Services Program:

- ? ***Better forecast accuracy*** - by incorporating advanced science into hydrologic modeling systems and coupling more effectively atmospheric and hydrologic models and forecast information on all time scales.
- ? ***More specific and timely information on fast-rising floods*** - by using tools which make it easier to: (a) rapidly identify small basins affected by heavy rainfall, identify excessive runoff locations, and predict the extent and timing of the resulting inundation, and (b) forecast the impacts of dam failures.
- ? ***New types of forecast information*** - by incorporating new techniques for quantifying forecast certainty and conveying this information in products which specify the probability of reaching various water levels.
- ? ***Longer forecast horizons*** - by regularly issuing hydrologic forecast products and information covering one to two weeks into the future and beyond.
- ? ***Easier to use products*** - by delivering information in new and easier to understand formats, including graphics.
- ? ***Increased, more timely, and consistent access to products and information*** - through the expanded use of advanced information and communications technologies.
- ? ***Expanded outreach*** - by engaging partners and customers in all aspects of the hydrologic services improvement effort.

### 2. Hydrologic Service Improvements

#### 2.1 New Products and Information

AHPS products and information will cover future hydrologic events ranging from minutes out to months. These new services will enable partners and customers to make more informed decisions and better manage risks. Incorporated into products will be applicable data from the historical record, current

observations, forecast point descriptions, maps, geographic information, and other data which enhance partner and customer understanding of the likelihood and impact of potential and forecasted hydrologic events. Key features of AHPS products will include:

- ? Coverage of the full spectrum of hydrologic events. This includes short-fused flash floods on small streams and in urban areas, slow-rising floods on large rivers, and droughts over regional areas.
- ? Expanded use in water resources applications such as water supply and environmental impact mitigation.
- ? Displays of information in graphical and numerical formats which maximize usefulness to partners and customers.
- ? Inclusion of probability information on the possible range of future flow conditions and areas of inundation, to enable users to make more informed decisions and better manage risk.
- ? Consistency of format and information content of core products nationwide.
- ? Use of geographic information systems (GIS) in the graphical depiction of forecast information.
- ? Internet-based and wireless dissemination of products and information to broaden access to hydrologic information and facilitate efficient decision making.

AHPS products and information can be grouped into three general categories: (1) a national core suite following a consistent format; (2) locally-developed products designed to meet the needs of partners and customers in specific areas; and (3) products interactively generated through menu-driven access to an information database. Taken together, these three categories will form a seamless suite of products addressing more fully the requirements of customers and partners. The vision for AHPS products and information is summarized below.

**2.1.1 Flash Flood and Small Basin Products.** Flash floods are defined as short-fused floods occurring within six hours of the causative event. To augment conventional text-based flash flood warnings and related products, graphical watch/warning products and information will be provided. The probability of detection (i.e., accuracy) and warning lead time for flash floods will be increased. The false alarm rate will be reduced. These service enhancements will be realized through the use of a monitoring and prediction system which incorporates high-resolution quantitative precipitation estimates (QPE) from radar, ground-based gages, and satellites as well as short-term quantitative precipitation forecasts (QPF). Advanced hydrologic models, dam failure analysis tools, and processing of high resolution GIS and hydrometeorological data sets will allow products to include much more detailed information on the location and magnitude of events. New products for additional locations in smaller basins will contain information in the form of numerical forecast values (e.g., stage or water level) or categorical threat levels (e.g., minor, moderate, major).

**2.1.2 Short-, Medium-, and Long-Term Hydrologic Forecasts.** Products covering the short-term (out to 7 days), medium-term (7 out to 14 days), and long-term (2 weeks out to 3 months or more) forecast periods<sup>1</sup> will be provided as appropriate for forecast points on larger streams and main-stem rivers. These products will include information needed to better assess and manage risk. A hydrologic

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<sup>1</sup>The actual forecast period covered by these products will vary across the United States depending on local hydrologic characteristics, customer requirements, and policies established in cooperation with local partners.

modeling system which is tuned or calibrated optimally to produce the best forecast output for each stream basin will be used in the preparation of these products. Graphical products will combine observed stage/flow data, standard forecast hydrograph information, and probability information quantifying the forecast certainty. This probability information will be generated through an ensemble hydrologic modeling process which incorporates QPF information produced by the RFCs from guidance provided by the Hydrometeorological Prediction Center (HPC) and the Climate Prediction Center (CPC) of the National Centers for Environmental Prediction (NCEP). Other graphics will relate forecasts to historic water levels and their impacts at a given site. Long-term hydrologic forecast information will be provided for points where it is both needed by users and physically realistic to run extended-range simulations. These enhanced long-term products will benefit users during high flow situations as well as normal flow regimes and droughts.

**2.1.3 Flood Forecast Graphics.** New graphical products will be provided enhancing user understanding of flood warnings and related products such as watches, outlooks, and statements. Displays will provide graphical warning information including the forecast hydrograph, a visual illustration of local flood impact, and a map showing forecasted areas of inundation. Maps depicting forecast areas of flood inundation will be produced for select urban, and other high-impact areas. An animation capability will allow an event scenario to be reviewed through the short-, medium-, and long-term forecast horizons as appropriate. Graphics depicting the areas, river reaches, or locations under current watches and warnings will also be available. Some of these graphical capabilities will require high resolution topographic information. The NWS will work closely with Federal and state partners to obtain this information.

**2.1.4 Precipitation Information.** Observed and forecast precipitation information produced by RFCs and the NCEP will be archived and accessible in both digital and graphical form. Observed precipitation will include data from in-situ gage networks; radar networks; and multisensor estimation procedures which integrate gage, radar, and other remotely-sensed (e.g., satellite-derived) precipitation information. Forecast precipitation will include QPF products on a spectrum of spatial and temporal scales. Experts at the HPC and the CPC will produce national guidance for the short and long terms, respectively, while experts at RFCs will tailor national guidance for their individual areas of responsibilities.

**2.1.5 Verification.** Enhanced hydrologic services provided through AHPS will be verified to document improvements in forecast and warning accuracy. Initially, a baseline set of statistics will be produced to quantify improvements achieved through use of new hydrologic models and forecast systems. Additional enhancements will be implemented to verify other types of forecast information, such as the probability distributions and forecast inundation maps.

## **2.2 Science and Technology**

Advanced science and technology will be the foundation for improved quality and content of hydrologic products and information.

**2.2.1 Distributed Hydrologic Modeling.** A more sophisticated hydrologic modeling capability will be implemented which accounts for the variability of precipitation and rainfall-runoff characteristics within a basin. This distributed modeling capability will allow short-term forecasts to more realistically reflect the

streamflow response to precipitation. Distributed models will be developed in collaboration with the hydrologic research community and other water management agencies.

**2.2.2 Hydraulic Modeling.** Implementation of hydraulic modeling on key streams will allow a forecast water surface profile to be produced for an entire river reach as opposed to a forecast stage at a specific point. This capability can account for the influence of natural and human-induced controls on the river surface elevation, including tides, tributary streams, and downstream lakes, reservoirs, and bridges. Where the appropriate topographic information is available, real-time flood forecasts, depicting the areal extent and probability of inundation, will be produced.

**2.2.3 Integration of Water, Weather, and Climate Information.** More effective approaches to integrate water, weather, and climate information will be used to improve hydrologic forecasts. A procedure for blending historical, observed, near-term forecast, and climatic outlook data sets into the hydrologic modeling process will be implemented.

**2.2.4 Operational Forecast System Upgrade.** The NWS River Forecast System (NWSRFS) operational forecast system serves as the foundation for AHPS. The system will be upgraded to reduce the time required to produce forecasts and make it easier to implement new models. NWSRFS consists of several hydrologic model components, each of which will be fine-tuned or *calibrated* for each basin or river reach to ensure the best possible simulations and forecast accuracy. Operational forecast systems at each RFC will be updated using the latest calibration techniques and historical records.

**2.2.5 Computational Systems.** RFC computer system hardware will be upgraded to accommodate the increased processing and storage demands of AHPS. These demands arise from the computation-intensive nature of ensemble streamflow prediction and hydraulic modeling processes as well as the requirement to archive large volumes of historical and geographic data and verification information.

**2.2.6 Hydrometeorological Data Sources.** Accurate, real-time observations are essential to the hydrologic forecasting process. Point data (e.g., stream stage, precipitation, and temperature) are needed from as many locations as possible. Stream stage observations are required at over 4000 NWS river forecast locations, with most of these data provided by the U.S. Geological Survey (USGS). Products derived from remotely sensed data (e.g., gridded multisensor precipitation and snow water equivalent estimates) will be used to provide the best possible model inputs for data-sparse areas and improve spatial and temporal resolution of all forecasts. Improved approaches for remote sensing of precipitation, snow, and other inputs, especially as they apply to areas of complex terrain, will be integrated into hydrologic forecast operations. Efforts to maintain and enhance point data networks will be supported. The NWS will work aggressively with Federal, state, and local partners to ensure the optimum level of hydrometeorological data required for AHPS.

## **2.3 Expanded Delivery and Accessibility**

**2.3.1 Traditional Mechanisms.** Current mechanisms used by the NWS for product dissemination, including NOAA Weather Radio, NOAA Weather Wire Service, Family of Services, Emergency Managers Weather Information Network (EMWIN), and the Interactive Weather Information Network

(IWIN), will be used to disseminate AHPS products to the extent technologies permit. Subsequent replacement systems will be used to provide AHPS products to the maximum practical extent.

**2.3.2 Web Distribution.** Access to hydrologic information and forecasts will be provided through national and local Web pages. Information will be accessed through user-friendly menus and scalable maps which zoom in or out of the area of interest. A national Web page will provide one-stop shopping access to the core suite of AHPS products. WFO and RFC web pages may include hydrologic products outside the national core suite which are designed to fulfill the NWS mission and meet the needs of local customers and partners.

**2.3.3 Forecast Information Database.** A database “harvesting” capability will accompany the Web-based system for national access to products and information. This database will include both deterministic (i.e., forecaster’s “best determination” hydrographs) and probabilistic forecast information. Users will be able to integrate warning and forecast information with other spatially referenced data. Private sector companies may access hydrologic forecast information in this database and supply hydrologic products to their customers.

## **2.4 Outreach, Training, and Service Evaluation**

Outreach, training, and service evaluation activities will be expanded on a local through national scale. These activities will ensure the NWS clearly understands our partners and customers needs and products and services continue to meet their needs. To accomplish this, recurring customer forums and Web-based surveys will be conducted to obtain feedback on current and planned products and services. To facilitate outreach, a tool kit will be produced which clearly articulates information on AHPS products and services. This tool kit will benefit local, state, regional, and national customers and partners.

Training information will be available to partners and customers on how to access and use the new AHPS products and information. Training will also be conducted for NWS personnel on the new science and modeling approaches used in AHPS and the operational use of the AHPS technology.

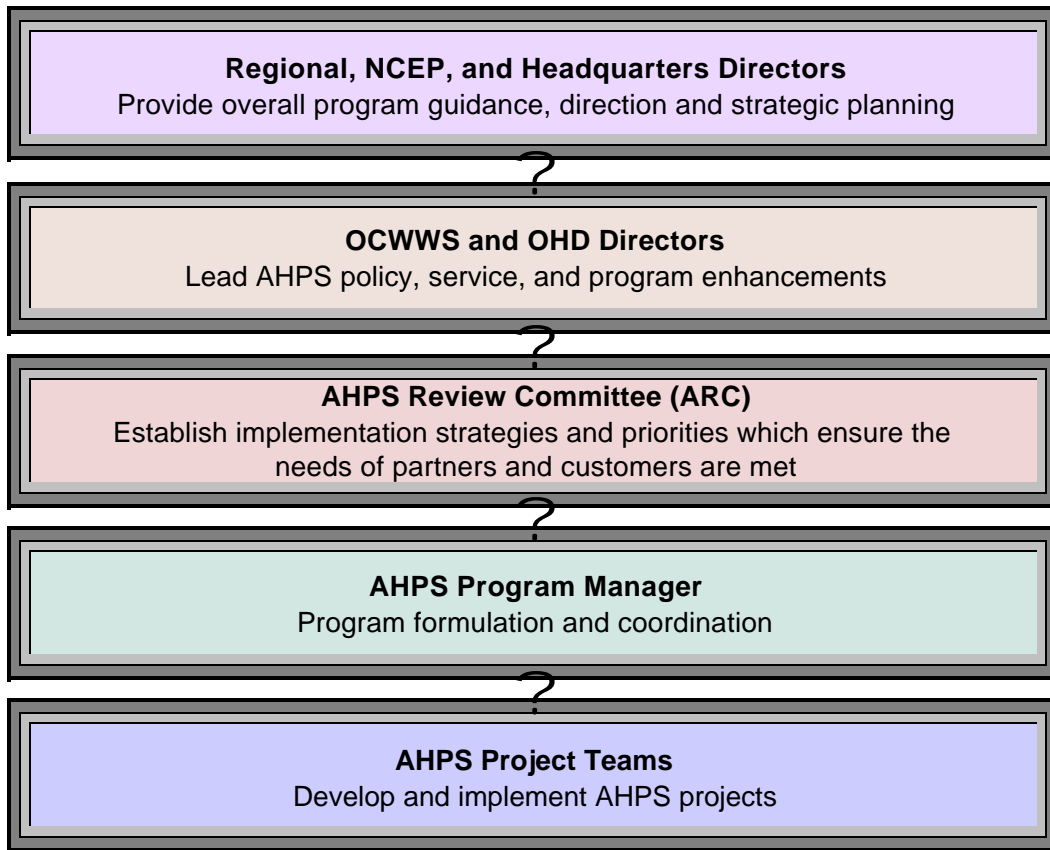
## **2.5 Establishing New Partnerships**

The NWS will strengthen existing and establish new partnerships with local, state, regional, and Federal agencies, universities, and the private sector to best use resources to improve services. Partnerships will be strengthened or formed through coordination activities which focus on how data quality and access, forecasts, warnings, and other related information can be enhanced through AHPS. Some new partnerships will focus on the development of new dissemination technologies, while others will be established which focus on science infusion.

# **3. Roles and Operations**



This section describes the roles of partners and customers, and field and headquarters offices in the AHPS program. All organizational levels of the NWS participate in the management of AHPS (see figure 1). Program planning, oversight, and resource allocation is provided by the AHPS Review Committee (ARC). This cross-cutting committee is comprised of regional leaders as well as representatives of the Office of Climate, Water, and Weather Services; Office of Hydrologic Development; Office of Science and Technology; and the NCEP.



**Figure 1.** AHPS Program Roles.

### 3.1 Partners and Customers

The NWS is a service-centric organization and the needs of customers and partners are the driving force behind AHPS. Partners and customers will provide service requirements to the NWS and assist in the assessment of whether their needs have been successfully addressed. Depending on their organizational structure and area of responsibility, partners and customers will provide their requirements at the local (i.e., WFO or RFC), regional (i.e., to regional headquarters), or national (i.e., to NWS Headquarters) levels. Some customers may use AHPS products and information to tailor specialized products for their clients.

## 3.2 Field Offices

**3.2.1 River Forecast Centers.** RFCs will conduct hydrologic modeling operations for streams, reservoirs, and lakes within large river basins and provide forecast information which serves as the basis for NWS hydrologic products. RFCs will operate on a two-shift per day schedule during non-flood situations, extending to 24-hour operations during periods of significant flooding or flood threat. Their primary focus will be on river forecasts for the short-term period – i.e., from 0 out to 7 days – since these will continue to serve as key input to WFO flood products and the decision-making process of customers and partners. The operational forecast system used in short-term operations will produce both conventional forecast hydrograph output and probabilistic information which conveys forecast certainty. A conventional forecast hydrograph is basically a single set of forecast stages which is sometimes referred to as the “best determination” forecast time series. Updates to short-term forecasts will be provided as needed.

RFC forecasters will continually analyze the hydrometeorological situation in their areas of responsibility along with output from their operational forecast system. Based on these analyses, graphical 5-day flood outlooks will be prepared which identify areas at risk of significant river flooding. This product is intended to alert emergency managers and other users of the potential for river flooding.

When high water or flooding is imminent, RFC forecasters will prepare unscheduled or “event-based” river forecasts. These forecasts will be similar in content and format to daily forecasts. The same capabilities used in daily forecast operations to produce both conventional forecast hydrograph output and probabilistic information will be used for event-based products.

Forecasts will also be produced for selected river locations covering the medium-term period – i.e., from 8 out to 14 days. Like the short-term products, these forecasts will include both conventional forecast hydrographs and probabilistic information. For a subset of these locations, RFCs will also produce long-term hydrologic forecasts spanning 90 days or more into the future. Some long-term products will incorporate extended-range precipitation and temperature forecast information from the CPC. Long-term probabilistic products will be based on ensemble modeling runs or statistical water supply techniques.

Computation-intensive modeling operations will be required to generate the probabilistic time series needed to produce hydrologic forecast products which include certainty information. AHPS will use the ensemble hydrologic modeling approach to compute this probabilistic output. This approach basically involves using input data (e.g., precipitation and temperature) from multiple years in the historical record to simulate how each year of data would drive future river flow starting at the current date. The QPF input to short- and medium-term forecast operations will be a combination of the RFC developed products based on guidance from the HPC and gridded forecast data derived from medium-range NCEP atmospheric models. Software procedures will seamlessly integrate precipitation forecasts from various sources and time horizons, historical and observed data, and hydrologic models into the ensemble hydrologic modeling process.

Deterministic and probabilistic output from short-, medium-, and long-term hydrologic forecast operations will be encoded in a standardized format to allow merging with other data sets such as observed stage/flow and incorporation into graphical products. RFCs will continue to exchange such forecast information with

partnering water agencies such as the U.S. Bureau of Reclamation. They will also maintain an interactive capability on their Web pages which allows users to configure hydrologic products based on deterministic and probabilistic information stored in the RFC database.

RFCs will actively work with partnering water agencies at the Federal, regional, and state level to obtain requirements, coordinate forecasting efforts, maintain the two-way exchange of water information, and collaborate on hydrologic development activities.

The support each RFC provides for its local modeling and forecast operations will be critical to AHPS. This support includes developing local procedures and maintaining model calibrations. The Office of Hydrologic Development (OHD), in concert with the regional Hydrologic Services Divisions (HSD), will coordinate development activities to minimize duplication of efforts and ensure benefits of locally developed capabilities are extended to all RFCs.

**3.2.2 Weather Forecast Offices.** As NWS offices with the most localized areas of responsibility, WFOs will provide products for individual hydrologic events ranging from short-fused flash floods to slow rising floods on large rivers. Products include warnings, watches, and statements covering areas and streams of all sizes. WFOs will provide these products on Web sites and by normal dissemination methods for use by local partners and customers.

WFO forecasters will maintain a continuous hydrologic watch over their areas of responsibility, monitoring observed and remotely-sensed precipitation and near-term (0- to 3-hour) QPF using sophisticated decision-assistance tools. Observed data and QPF will be continuously compared to flash flood guidance to highlight areas of flood potential. Flash flood warnings for counties and portions of counties will be automatically formatted for editing and issuance by forecasters.

When analysis tools suggest the likelihood of small stream flooding, WFO forecasters will execute an operational hydrologic modeling system which can produce site-specific forecasts for these basins. This site-specific hydrologic modeling system will interface with a GIS and soil moisture information computed at a supporting RFC. It will automatically ingest precipitation and other data and execute at a time interval (e.g., hourly) specified by each office. Stage forecasts for small basins with stream gaging stations will be encoded for national distribution. Categorical information on expected flood activity will be produced for small basins without gaging stations. Numerical or categorical output from this modeling system will be incorporated into flash flood warnings and other products for short-fused events.

As part of their hydrologic watch, WFOs will monitor hydrologic observations. Appropriate event-based warnings will be generated based on the RFC's "best determination" forecast time series and associated probability information. If a WFO receives information indicating the need for a forecast update, the changes will be coordinated with the issuing RFC. If the RFC is unavailable for coordination, WFO forecasters will issue the appropriate product(s) with revised forecast values.

Each time a WFO issues or updates a site-specific flood or flash flood watch or warning for any stream, descriptive graphical and text information will be posted automatically on the Web. Geographic information

defining the reaches and areas covered by site-specific and areal watches and warnings will be automatically generated for incorporation into graphical displays on local and national Web pages.

Program management activities of a service hydrologist or hydrology focal point will be essential to the success of AHPS at each WFO. The following types of hydrologic field work will be especially critical:

- ? Visiting stream gaging stations and flood-prone locations to acquire information on the impact of flood waters at various levels.
- ? Collaboration with stream gaging experts in the USGS and other partnering agencies.
- ? Acquiring and maintaining the vast amount of static information required to deliver high-quality products which describe the local impacts of flooding.

Service Hydrologists, Hydrology Focal Points, and Warning Coordination Meteorologists (WCM) will obtain requirements for new hydrologic services from partners and customers and coordinate the best approaches for refining services. Working together, WCMs, Service Hydrologists, and Hydrology Focal Points will train customers and partners on use and interpretation of AHPS products as well as flood preparedness.

**3.2.3 National Centers for Environmental Prediction.** The NCEP will provide several forms of meteorological guidance which serve as input to the hydrologic forecasting process. NCEP Central Operations will execute the numerical analysis and atmospheric forecast models and ensembles of models used in everyday hydrometeorological analysis at RFCs and WFOs. The HPC will produce forecaster-developed QPF and probabilistic QPF (PQPF) products which are guidance used by RFC forecasters for input to RFC models. The HPC will also prepare a national mosaic of 5-day river flood outlook products from the RFCs. The Environmental Modeling Center will enhance the atmospheric models which produce the graphical and numerical output (e.g., forecast precipitation and temperature) used in short- and medium-term AHPS products. The Storm Prediction Center will produce event-based, short-term rainfall-rate forecasts. The Tropical Prediction Center will provide official NWS forecasts for the movement and strength of tropical weather systems. HPC will be responsible for the QPF and PQPF forecasts associated with these systems. The CPC will provide products which quantify how precipitation and temperature is expected to deviate from climatic averages for the short-, medium, and long-term forecast periods. These products will be provided in digital form which can be input directly to RFC hydrologic modeling systems.

### **3.3 Headquarters Offices**

**3.3.1 Regional Headquarters.** The Hydrologic Services Divisions (or branch) within regional headquarters (referred to as regional HSDs) will manage AHPS operations at the regional level. These activities include:

- ? representing the regional headquarters on the AHPS Review Committee (ARC);
- ? monitoring and assessing the procedural and technical aspects of AHPS operations at each WFO and RFC in the region;

- ? allocating, managing, and coordinating resources related to AHPS operations and development within the region;
- ? supporting WFO hydrology program management activities, including AHPS-related interactions with partners and customers;
- ? developing, overseeing, and ensuring compliance with policies specific to the hydrologic operations and services of WFOs and RFCs;
- ? providing new regional hydrologic requirements to NWS Headquarters; and
- ? representing the AHPS program during interagency, international, and river basin commission activities conducted at the regional level.

**3.3.2 National Headquarters.** Management of the AHPS Program will be provided by NWS Headquarters. Activities including planning and guiding implementation, budget administration, and project tracking will be managed by the OHD AHPS Program Manager in concert with the Hydrologic Services Division in the Office of Climate, Water, and Weather Services (herein referred to as National HSD). Guiding the activities of AHPS Program Manager and the Hydrologic Laboratory within OHD will be requirements received from the National HSD. Roles of headquarters entities which cooperate in the management and operation of AHPS are summarized in figure 1.

As part of their national program leadership responsibility for NWS hydrologic services, National HSD will perform the following in support of AHPS:

- ? Develop and refine general operations concepts for advanced hydrologic services as well as requirements documents and other plans for specific AHPS components.
- ? Assimilate service, science, and operational requirements originating from NWS field offices and oversee the requirements prioritization process.
- ? Develop policies addressing changes required to implement advanced hydrologic services.
- ? Conduct outreach leading to increased collaboration in AHPS-related activities.
- ? Provide on-call support to WFOs and RFCs on the implementation and continued use of advanced hydrologic forecast systems.
- ? Provide overall management for the national Web-based distribution mechanism for AHPS products. Facilitate the generation of selected national products required by customers and partners and respond to inquiries regarding these products.
- ? Assimilate hydrology-related training requirements for NWS personnel as well as external customers and partners.

National HSD's National Operational Hydrologic Remote Sensing Center (NOHRSC) will assimilate remotely sensed snow cover information and produce near real-time products which meet the requirements of WFOs, RFCs, and other customers. The NOHRSC will conduct the applied research needed to infuse new science into their hydrologic remote sensing activities.

Other components of the Office of Climate, Water, and Weather Services will help support AHPS activities. For example, the Performance and Awareness Division will maintain national databases and statistics for hydrologic forecast verification.

The Hydrologic Laboratory within OHD will support the operational hydrologic systems at field offices and develop specific hydrologic/hydrometeorologic models, systems, and procedures for AHPS in response to requirements. This encompasses the NWS River Forecast System for RFCs and the WFO Hydrologic Forecast System. In collaboration with outside research institutions, RFCs, and WFOs, OHD will conduct applied research activities needed to infuse new hydrologic science into the operational hydrologic modeling systems at field offices.