Quantitative Precipitation Forecast Process Assessment: 1999-2000 Evaluation and Recommendations for the Western U.S.

Executive Summary

On February 25, 1999, the Director of the National Weather Service (NWS), John J. Kelly, Jr., commissioned a team from diverse components of the organization to review the Quantitative Precipitation Forecast (QPF) process to support the NWS River Forecast System (NWSRFS). Over the CONUS, 12 River Forecast Centers (RFCs), whose areas of responsibility vary in size, topography, and precipitation climatology, depend upon the QPFs that ensue from this complex forecast process to generate operational hydrologic forecasts. The Director's charge to the QPF Process Assessment Team was to determine whether the existing QPF process constituted the most effective use of human resources to produce quality QPF information for hydrologic services. Director Kelly emphasized the need for efficient use of the substantial human resources involved in the QPF process, which presently includes meteorologists from the Hydrometeorological Prediction Center (HPC) of the National Centers for Environmental Prediction (NCEP), forecasters at the Weather Forecast Offices (WFOs), and personnel who comprise the Hydrometeorological Analysis and Support (HAS) function at the RFCs. The team was tasked with conducting an objective assessment of each step of the QPF process and making recommendations to ensure the most efficient and effective process.

During the summer of 1999, the Assessment Team made proposals to streamline and improve the QPF process. Findings and recommendations were initially presented to Director Kelly on June 18, 1999, a detailed 72-page report (see **www.nws.noaa.gov/er/hq/QPF**) was disseminated soon thereafter, and the NWS Corporate Board was briefed on August 25, 1999. The Corporate Board unanimously adopted the Assessment Team's recommendations and several additional/supporting recommendations. The principal Corporate Board decisions were:

- HPC and HAS personnel will produce QPF products for input to river forecast models for all RFCs east of the Continental Divide;
- any WFO may, if they have a local requirement, produce QPFs for other (internal and external) local uses;
- HPC and HAS QPF products will be distributed to external NWS customers and partners; and,
- the QPF process in the West (west of the Continental Divide) will be reevaluated by the QPF Process Assessment Team following the 1999-2000 wet season.

To implement the above decisions, HPC has subsequently expanded their QPF product suite extensively and improved some aspects of their products. In fact, HPC has met and even exceeded the requirements set by the assessment team, which is evident from the following summary of routine CONUS QPF product issuances and enhancements:

- continuous (vs. categorical) QPF graphics with grids of spatially-averaged precipitation beginning at 0.01 inches (i.e., measurable precipitation);
- 6- and 24-h QPFs issued four times daily through Day 2 for both the 1200 UTC and 0000 UTC forecast cycles to take advantage of four-per-day runs of the numerical weather prediction (NWP) models;

- 24-h QPFs for Day 3 issued twice daily for both the 1200 UTC and 0000 UTC cycles; and,
- 6-h QPFs for Day 3 for the 1200 UTC cycle during the Western Region (WR) "wet season," which generally extends from October 15 - April 15 (these QPFs are interpolated to forecast points, pre-specified by each of the WR RFCs, to enable direct editing and use in NWSRFS).

The new, 6-h QPF issuances for Day 2 and Day 3 commenced on December 6, 1999. The high frequency of issuance of these products should eliminate the requirement for additional updates, and free up human resources at both WFOs and RFCs during flooding events. Also, HPC will further enhance their QPF product suite with the qualification of forecast confidence beginning May 20, 2000. This will enable RFC staff to make better decisions regarding the useful range of the QPF products, particularly during significant hydrometeorological events.

To date, feedback from RFCs regarding the overall implementation process has been quite positive. The nine RFCs east of the Continental Divide have installed NCEP AWIPS software (currently in use at HPC) which will enable HAS forecasters to modify HPC QPF guidance prior to input for NWSRFS. NCEP has tailored this software for RFC use, provided for its operational support, and conducted on-station training for all of these RFCs. Additionally, the Northwest RFC (NWRFC) recently requested HPC to extend the production of the new Day 3 6-h QPFs beyond April 15 through June 1 to support their river forecast operations. Finally, for the eastern RFCs, a two-month operational test and evaluation is scheduled to begin June 1, 2000 to fully test the new QPF process. During this time, detailed HPC-RFC-WFO coordination strategies, applicable to all CONUS field offices, will be tested and enhanced and WFOs will terminate the generation of QPFs for use by NWSRFS.

The phased implementation of the new QPF process in the eastern U.S. has ensued over the past eight months, and it will be completed in accordance with the Corporate Board directives by September 30, 2000. Thus, the focus of this Executive Summary is to present the findings and recommendations based on the recent reassessment of the QPF process in the West.

When the QPF Process Assessment Team reconvened on April 11, 2000 to reevaluate the QPF process for RFCs west of the Continental Divide for the 1999-2000 cool season, Director Kelly reiterated the charge to carefully analyze the value added in each step of the process and produce a technically sound business case recommendation that makes the most effective use of human resources in this region.

For the follow-on assessment of the QPF process in the West, the team gathered information related to the utility of the various QPF products via examination of several WR-selected moderate to heavy precipitation events and by the generation and analysis of comparative verification data. Additionally, the responses obtained last year from a nationwide survey of the participants in the QPF process were carefully scrutinized.

The basic procedures followed in this reassessment were similar to those in the 1998-1999 evaluation. However, some aspects of the objective comparative verification were modified and

expanded to remedy deficiencies encountered in the West in the previous assessment and incorporate substantial input from WR field personnel and WR headquarters staff. The guidelines and procedures, which were unanimously approved by the NWS Corporate Board in November 1999, were closely adhered to by the Assessment Team. The primary information used in the present follow-on reassessment was based on a comparative verification analysis of WFO and HPC QPF products for the California-Nevada RFC (CNRFC) and NWRFC areas over the full five-month period extending from November 1, 1999 through March 31, 2000. Improvements and enhancements to the 1998-1999 assessment included:

- the exclusion of updated WFO QPFs in the verification sample;
- the evaluation of 6-h QPFs for Days 2 and 3; and
- the uniform processing of QPFs for the WR RFCs in a manner consistent with their operational use (i.e., the evaluation of QPFs for the CNRFC and NWRFC focused on Mountain Mapper-rendered grids and pre-specified forecast points, respectively).

The QPF Process Assessment Team considered the same comprehensive set of verification statistics as used previously, and consistent with the 1998-1999 assessment, utilized the mean absolute error as the benchmark for QPF "skill." Following the Corporate Board specifications (and recommended by the WR), skill values for 6-h QPFs aggregated for Day 1, Day 2, and Day 3 were weighted equally in the evaluation. Additionally, the team utilized the following three decision criteria, as approved by the Corporate Board, in its ultimate assessment:

- If the overall skill comparison revealed WFOs > HPC and skill differences are important and clear-cut, then the WFOs west of the Continental Divide should retain the requirement to produce QPF for input to NWSRFS;
- If the overall skill comparison revealed HPC > WFOs and the skill differences are clear-cut, CONUS WFOs west of the Continental Divide should be relieved of the requirement to produce QPF for input to NWSRFS beginning October 2000; and,
- If skill differences between HPC and WFOs are nearly equal or not clear-cut, the team should examine other relevant factors (i.e., the cost of the production and delivery of the QPF forecasts to the RFCs, special coordination issues, or the apparent impact of the skill differences), and make a business case judgement of the best course of action.

The comparative verification of the WFO and HPC QPF products posed a variety of complexities associated with the fact that the formats of the WFO and HPC QPF products, and the observed precipitation data, were not identical. For both RFCs, the WFO QPFs were issued for a relatively small set of preselected points (stations), while HPC forecasts were provided on a rectangular grid (32 km grid spacing), which were then interpolated to the same WFO points. The NWRFC and CNRFC utilize point and Mountain Mapper-generated gridded QPFs, respectively, to generate basin average precipitation for use in the river forecasting models. Gridded QPF data for the NWRFC are not available. Thus, to maintain consistency with each RFC's operations, the baseline comparative verification for CNRFC was performed on the 32 km grid (the Mountain Mapper software application was also used to transfer the point observational data to a 4 km grid, which was subsequently remapped to the 32 km verification grid), while the verification for NWRFC was performed for the original WFO points. The Assessment Team

also considered the point verification for CNRFC, per WR request, as a secondary consideration in the evaluation. As noted previously, the evaluation over the full 5-month period was performed on the basis of several verification measures, with the primary one being the mean absolute error (MAE). Further details concerning the verification methodology and all results are available at **www.hpc.ncep.noaa.gov/npvu/wrfa**.

Results from the 5-month overall comparative verification revealed no clear-cut difference in QPF skill between the WFOs and HPC. As an aid that led to this conclusion, the team considered MAE differences ≥10% to constitute meaningful differences in skill, and focused on 6-h precipitation in the upper three discrete categories in excess of 0.25" (i.e., 0.25 - 0.50", 0.50 - 1.00", and ≥1.00") given the greater hydrologic significance. At NWRFC, where only the point data were considered, the only meaningful difference in skill between the WFOs and HPC was for Day 3 where HPC showed a 12% improvement for the heaviest precipitation category (≥1.00"). For CNRFC, where the gridded data were used as the baseline QPF, the results were similar. The only meaningful differences in skill between the WFOs and HPC were for Day 2 and Day 3 where HPC showed 15% and 11% improvements, respectively, for ≥1.00". When the point data for CNRFC were considered, the only meaningful difference between the WFOs and HPC was for Day 1, where the WFOs showed an 11% improvement for the heaviest precipitation category. All other RFC - forecast day pairs for these precipitation categories did not meet the 10% skill difference threshold. It is important to note the absolute errors for the QPFs were rather large in comparison to the relatively small differences in skill between the WFOs and HPC. It is also noteworthy that the HPC forecasts scored a substantial relative improvement from 1998-99 to 1999-2000; specifically, for the Day 1 QPF category of ≥1.00", the advantage of the WFOs over HPC decreased significantly from a "meaningful" 28% to less than 10%. Finally, the corresponding QPF performances of NCEP models, especially the aviation model (AVN), were only slightly less skillful than those of the WFOs and HPC.

Nine case studies, characterized by moderate to heavy precipitation and flooding, were evaluated through both visual examination of plotted maps and analysis of verification scores. In the quantitative scoring analysis, the Assessment Team considered MAE differences ≥10% to be meaningful (consistent with the overall comparative verification analysis) and focused on precipitation in the highest two precipitation categories (0.50 - 1.00" and ≥1.00"). For the four NWRFC cases, the results were mixed. For Day 1, the WFOs achieved a meaningful improvement over HPC guidance in two cases, whereas for Day 2 and Day 3, where just two cases were available for analysis, the number of meaningful WFO and HPC improvements in the two precipitation categories were almost evenly split. For the five CNRFC cases, the results for Day 1 favored the WFOs in four cases. For Day 2, the HPC showed meaningful improvement in two cases and the WFOs in one. Similarly for Day 3, HPC showed meaningful improvement in three cases and the WFOs in one. The results based on this quantitative analysis were essentially confirmed in the visual map examinations. The latter evaluation also showed that the expert interpretation of an experienced meteorologist was required to identify and modify the most appropriate model guidance for a particular weather pattern.

Based on both the overall comparative verification and case study findings, the Assessment Team concluded for the two RFCs and the three forecast days, there was not a clear-cut difference in

QPF performance of the WFOs and HPC. Therefore, in accordance with the established guidelines for the assessment, other business case factors were considered.

An important source of relevant information in last year's QPF Process Assessment came from the analysis of responses to a nationwide survey of the WFOs and RFCs. For the WR, the WFOs and RFCs indicated the WFO QPF product was a critical part of the hydrologic forecast process. Accordingly, WFO resources related to forecaster training, shift scheduling, and coordination with other offices and the RFCs have been utilized to generate the QPF for input to NWSRFS. Further, this WFO activity, which in routine situations averaged 33 minutes per office for product generation and coordination, was perceived by the majority of the WR field offices to improve the accuracy of river forecasts. Nonetheless, the survey revealed the QPF effort was deemed to be a worthwhile use of resources by only 46% of the western WFOs. A simple computation of the aggregate expenditure of person-hours per forecast issuance and coordination for the Day 1 through Day 3 QPF in non-flooding situations yields approximately 6 h and 13 h for the HPC and western WFOs, respectively. In flooding situations, the totals are approximately 6 h and 22 h for the HPC and western WFOs, respectively. Since the HPC produces 6-h QPFs for the conterminous U.S. through Day 3 on a routine and scheduled basis, no additional resources will be required by the HPC to support hydrologic forecasting in the western U.S. Based upon our assessment that there is no overall clear-cut difference in QPF skill between the HPC and the WFOs, between 13 and 22 hours of forecaster labor could be saved daily and refocused on critical WFO forecast and warning operations and training.

In view of results from the comparative verification, and other information gathered by the Assessment Team, it appears the WFO resources in the West could be utilized more effectively. ***Hence, the team recommends streamlining the QPF process west of the Continental Divide to rely on the QPF products provided by HPC.*** Although the Assessment Team recommends removing the requirement for WFOs to produce QPF for input to NWSRFS, the team recognizes the credible performance of the WFOs in WR and acknowledges that there may be individual WFOs who provide the most skillful product for their hydrologic service area (the team did not evaluate the skill of individual WFO QPFs). Also, it is recommended the HAS function at the RFCs, who have the ultimate responsibility for QPF input to the NWSRFS, take on a more active role in the QPF process, especially to provide updates for the first 6 hours of each forecast cycle. As part of the new QPF process, we expect the HAS will be able to add value to the Day 1 QPF guidance produced by the HPC. The HPC's routine, four-per-day, issuances of 6-h QPF out through Day 2 will reduce the HAS function time that would otherwise be expended to request and coordinate QPF updates during significant hydrometeorological events. Furthermore, the routine provision of these QPFs from HPC will enable western RFCs to produce more timely and frequent updates to their hydrologic forecasts.

Elimination of the QPF requirement for the WFOs does not, however, reduce the need for close coordination between the WFO and RFC, particularly when either flash flooding or main stem river flooding is forecast or occurring. Furthermore, WFOs should review the HPC QPFs prior to zone forecast issuance and coordinate needed adjustments with the HPC and/or the RFC. Since this QPF performance evaluation has indicated the HPC products have similar quality to those currently issued by WFOs, the servicing RFC should provide the final QPF to WFOs in a

format consistent with QPF products distributed to external partners and customers in the past. On the basis of the HPC-HAS QPF product, the WFOs should continue to coordinate with and support the needs of local partners and customers consistent with the NWS Corporate Board agreement for locations east of the Continental Divide.

There are additional, yet manageable, implementation issues associated with the proposed streamlined QPF process, which are related to the use of temperature and freezing level forecasts at RFCs. Senior field office managers from the WR briefed the Assessment Team wherein they highlighted the need for consistency between QPFs and freezing level forecasts. They also noted that, similar to RFCs east of the Continental Divide, western RFCs utilize forecasts of maximum and minimum temperatures as input to NWSRFS. East of the Continental Divide, RFCs utilize WFO-produced and/or HAS-modified Model Output Statistics (MOS) temperature forecasts, and a similar diversity exists among western RFCs. The NWRFC utilizes MOS temperatures forecasts augmented by temperature forecasts from the WFOs, while the Colorado Basin RFC (CBRFC) and CNRFC utilize MOS guidance directly. In support of the Assessment Team's recommended streamlined QPF Process, it is also recommended the Techniques Development Laboratory expand their provision of MOS daily maximum and minimum temperature forecasts to include all points critical to hydrologic operations for all CONUS RFCs, as soon as possible. Prior to the implementation of these MOS enhancements, the eight WFOs within the service area of the NWRFC should continue to generate and provide temperature forecasts to the NWRFC. For forecasts of the freezing level, the NWRFC and the CNRFC rely on a WFO-generated product, while the CBRFC uses direct NWP forecasts. Unfortunately, it is not known which product is better, as verification statistics do not exist for either product. To support the implementation of the streamlined and more efficient QPF process in the western U.S., the Assessment Team proposes that HPC routinely issue NWP model-based freezing level forecasts which are consistent with the HPC QPFs, for pre-specified WR forecast points beginning no later than October 1, 2000.

With regards to training requirements for the proposed streamlined QPF Process, two new Cooperative Program for Meteorology Education and Training (COMET) residence courses are being developed to meet the training needs and facilitate the transition to the new NWS QPF process east of the Continental Divide. The agendas and content of the courses have been reviewed and approved by the Field Requirements Group. These two new courses are entitled the Heavy Precipitation and Flash Flood Symposia and the RFC-HPC Hydromet Course. The Heavy Precipitation and Flash Flood Symposia is a five-day train-the-trainer course and scheduled for August 2000. The RFC-HPC Hydromet Course is a six-day course targeted for RFC HAS and HPC forecasters and other RFC staff who occasionally perform the HAS function. This will be offered beginning in early FY01. Companion web-based training will be developed for both of these courses.

If the NWS Corporate Board ratifies these recommendations for the western U.S., the successful implementation of a streamlined and more efficient QPF process throughout the conterminous U.S. will necessitate a substantial change in the NWS organizational culture. By relying on HPC as the primary source of guidance, all CONUS RFCs will be working from the same basic suite of QPF products. This will foster useful and necessary interaction between national experts

dedicated to generating QPF guidance with the experts at the RFCs who have the responsibility for the production of river forecast guidance products. Local weather experts and service providers at the WFOs will remain a vital and essential component of the QPF process via coordination with the HPC and HAS function forecasters, and through the provision, as necessary, of high-resolution QPF, and critical river flood and flash flood products to customers and partners. *For WFO resources to be truly utilized in a more productive manner, NWS managers at the national, regional, and local levels must be committed to deal with the ramifications of an important operational cultural shift, and work in harmony to provide forecasters with complete and accurate information to support the importance, desirability, and feasibility of these modifications.*

The benefits associated with streamlining and standardizing the QPF process for the full conterminous U.S. include: 1) the more efficient and effective use of human resources; 2) more timely and enhanced QPF input for river forecasting; 3) the provision of timely and consistent verification feedback; 4) the availability of more frequent and improved QPF products for NWS partners and customers; 5) standardization and national consistency in the QPF process; 6) the more effective infusion of science and technology in operations; and 7) the more rapid evolution to probabilistic QPF for probabilistic hydrologic forecasting.

In summary, a comprehensive QPF Process analysis, steered by guidelines established by the NWS Director and the Corporate Board and predicated on a detailed examination of a broad spectrum of diverse data, revealed an overall lack of meaningful difference in QPF skill between the WFOs and HPC in the Western United States. Western WFOs expend substantial resources to generate QPF which, at best, adds little incremental skill. Close inspection of the WFO and HPC verification statistics generally revealed small skill differences within relatively large forecast errors. Comparison of 1998-1999 and 1999-2000 verification statistics revealed a significant reduction in the Day 1 skill difference between the western WFOs and HPC, with a marked improvement in skill by HPC. Also, for the first time in its history, HPC issued 6-h Day 2 and Day 3 QPFs for this WR reassessment, and yet they performed slightly better than corresponding WR WFO products. The team also considered important, yet manageable, implementation issues related to RFC requirements for temperature and freezing level forecasts. *Hence, the QPF process Assessment team recommends streamlining the QPF process west of the Continental Divide to rely on the QPF products provided by HPC.* Additional and important supporting recommendations from the assessment include:

- HPC and HAS personnel will produce QPF products for input to river forecast models for all RFCs located within the conterminous United States;
- the RFC HAS function must take an active role in the QPF process, especially for the provision of updates for the first 6 hours of each forecast cycle;
- any WFO may produce QPFs for other (internal and external) local uses;
- HPC and HAS QPF products will be distributed to external NWS customers and partners;
- HAS, HPC, and WFO personnel should complete the new COMET residence courses;
- HPC should routinely issue NWP-based freezing level forecasts which are consistent with the HPC QPFs, for pre-specified WR forecast points beginning no later than October 1, 2000;

- the Techniques Development Laboratory should expand their provision of MOS daily maximum and minimum temperature forecasts to include all points critical to hydrologic operations at all CONUS RFCs; and,
- NWS managers at the national, regional, and local levels must effectively address forecaster apprehension related to this important operational cultural shift whereby the HPC and HAS function forecasters serve as the primary team to produce QPF for the NWSRFS.