Recommendation on the use of Delft-FEWS

for

Community Hydrologic Prediction System (CHPS)

Hydrometeorologic modeling is a
private / public / academic partnership

Report of the CHPS Acceleration Team (CAT)

December 31, 2007

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Weather Service

Silver Spring, Maryland

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1 Purpose of this Report

This report represents the culmination of a series of NOAA Hydrology Program related activities that took place between September 2006 and December 2007. Those activities focused on the identification of a software solution for the Community Hydrologic Prediction System (CHPS). The majority of activities described in section 2 below relate to a demonstration system developed for CHPS by WL | Delft Hydraulics: the "CHPS FEWS Pilot" system.

A CHPS Acceleration Team (CAT) was formed in early 2006, consisting of the following RFC representatives and the OHD Senior Scientist:

Rob Hartman, Hydrologist In Charge, CNRFC
John Halquist, Development & Operations Hydrologist, NCRFC
Harold Opitz, Hydrologist In Charge, NWRFC
Billy Olsen, Hydrologist In Charge, ABRFC
Pedro Restrepo, OHD Senior Scientist

This team was originally charged with identifying a solution for CHPS.

The CAT has now completed its activities and, via this report, makes its recommendation to Gary Carter, Director OHD for his final approval regarding a software solution for CHPS.

2 Introduction and Overview

2.1 Background

The desire to modernize the software infrastructure for NOAA NWS River Forecast Center (RFC) forecasting operations has been discussed within the OHD for more than a decade. Prior to CHPS, the OHD had considered migration of its primary river forecasting tool, the NWSRFS, to a Common Object Request Broker Architecture (CORBA), but found CORBA to be too complex and too proprietary in nature, potentially resulting in unacceptably high costs. It was also unclear how the migration of the NWSRFS to a CORBA-based solution could be accomplished without seriously impacting operations.

Beginning in 2003, the OHD contracted with Apex Digital Systems in Silver Spring, MD in an effort to find an alternative for the software infrastructure. In their final report "Software Architecture Engagement Summary", dated January 14 2004, Apex recommended that the OHD adopt a Service Oriented Architecture (SOA), using open source (i.e., free) software components where possible. This approach would involve development of a SOA-based infrastructure, then removing and "wrapping" existing NWSRFS components to form custom-built services.

At the time the expected approach was to incrementally upgrade the existing computational infrastructure of NWSRFS. Some early proof-of-concept projects demonstrated that this approach might be feasible. Beginning in 2005, OHD initiated several contract tasks to begin the process of modernizing existing components of the NWSRFS. Unfortunately that effort proved unsuccessful; it was evident that the task would take many years with little - or no - benefit to operational forecasters.

As an alternative strategy, the OHD began to look to ready-made solutions. OHD staff evaluated a small number of service oriented forecasting frameworks that might serve to accelerate the deployment of CHPS. One such system was the Object Modeling System (OMS) developed by the US Department of Agriculture's (USDA) Agricultural Research Service (ARS). An OHD review team looked at OMS in detail, and determined that, although the basic OMS architecture was highly compatible with that of CHPS (SOA, XML file description), the level of development of OMS was still far behind other competing options; and, because of that, programming support from ARS was going to be extremely limited.

Another system referred to as GISRS, developed by the NOAA NWS National Operational Hydrologic Remote Sensing Center (NOHRSC), was evaluated during an informal study conducted by OHD in early 2005; it was also found to be inadequate in meeting OHD's needs, given the excessive execution time required to run OHD's distributed Sacramento model.

Both of these software systems were thus found to be either lacking the maturity needed to serve as a reliable, robust infrastructure for hydrologic/hydraulic software components, or the performance required to meet the requirements of real-time RFC forecasting.

No other government-developed systems were identified as potential candidates.

Then in October 2005, at the invitation of the OHD Senior Scientist, representatives from the Dutch company WL | Delft Hydraulics traveled to NWS headquarters and provided OHD staff with a demonstration of Delft's open source software framework called the Delft Flood Early Warning System (Delft-FEWS), originally developed for the U.K. Environment Agency, one of Delft's customers.

Not only did the system appear to be a manifestation of the solution previously described by Apex, but the system was also specifically designed for use in hydrologic forecasting operations and was actively being used in U.K. river forecasting operations. OHD interviewed a representative from the U.K. Environment Agency to learn more about the quality of the product and customer satisfaction; both were found to be completely acceptable. Notes from this interview are available from OHD HSEB[1].

[1] Internal reference S:\OHD-11\Management\Contracts\AHPS_RTi\Done\T6-0013 FEWS\ Interview_UKEnvAgency_Sept2005.doc

The Delft-FEWS solution is free, but use of the software requires a licensing agreement between NOAA and Delft.

2.2 The CHPS Acceleration Team (CAT)

The CAT members listed in Section 1 above were tasked with the job of identifying a path from the NWSRFS of today to CHPS.

To help guide the CAT, OHD engaged Apex Digital Systems under contract to conduct a "discovery engagement" with the CAT members, to determine the strengths and weaknesses of the current system, and to solicit a minimal set of high level requirements for a modernized NWSRFS. Apex led a series of meetings during July through October 2006, the results of which were delivered in the report entitled: "OHD Software Development Roadmap Definition", dated December 4, 2006. This report is available from OHD HSEB[2].

During these discovery meetings the CAT members were asked to identify the advantages and disadvantages of the current system (NWSRFS). As the discussion evolved, it became clear that there were few redeeming qualities of the current system that should be propagated into the new system.

Thus, in September 2006 Apex arranged for Delft Hydraulics to provide the CAT with a presentation and live demonstration of the U.K. Environment Agency's implementation of Delft-FEWS. The CAT subsequently suggested that OHD task Delft to develop a demonstration system that would show how Delft-FEWS might be used in U.S. river forecasting operations. Through its contract with Riverside Technology, inc (RTi), OHD requested that Delft develop a system specifically geared toward an NWS RFC environment at two sample RFCs. The name of this demonstration system was the "CHPS FEWS Pilot".

2.3 The CHPS FEWS Pilot

The NWS worked closely with RTi, Delft, and a third contractor RS Information Systems, Inc (RSIS) to define and develop a minimally capable prototype CHPS system running at the Northwest River Forecast Center (NWRFC) and the North Central River Forecast Center (NCRFC). Basic functionality included the following:

- Unit Hydrograph model (Delft's existing Unit Hydrograph model)
- Snow model (Delft's existing SNOWMELT model)
- Sac-SMA with Heat Transfer model (SacSMA-HT application developed by OHD/RSIS)

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[2] Internal reference S:\OHD-11\Management\Contracts\ NWS_RSIS\L036\CHPS_RoadMap\ RealizationPlanFinal_20061204.doc

- Channel Routing model (Delft's existing Muskingham model)
- Reservoir routing model (Delft's existing reservoir model)
- Workflows that mimic existing Hydrologic Control Language (HCL) (Delft's existing XML-based control flow)
- Basic time series transformations (Delft's existing time-series transformation modules)
- Ability to conduct 'what-if' scenarios (Delft's existing what-if capability)
- Estimation of missing data and computation of basin area averages from point values (Delft's existing modules)
- Export of point data from the operational AWIPS hydrologic database to FEWS (Export Application was developed by RTi)

Since Delft-FEWS is a highly configurable system, there was little software development required by Delft for this effort. Delft's primary contribution was to assess NWSRFS features used at the two pilot sites, design some basin workflows to closely reflect the corresponding FEWS functionality, and then configure the Delft-FEWS accordingly. Meanwhile OHD converted an existing FORTRAN SacSMA-HT model into Java; and RTi wrote an application to extract data from the IHFS database.

After a relatively short 4-month period, the system was completed and a demonstration of the CHPS FEWS Pilot system took place at the NWRFC in Portland, Oregon on April 17-18, 2007. The well-attended demonstration generated a great deal of interest in the potential of Delft-FEWS.

One significant outcome of the demonstration was the recognition that certain key capabilities, currently in widespread use via NWSRFS, are essential if Delft-FEWS is to be a viable solution for CHPS. These included:

- Provision of a MODS-like capability (to supplement what-if scenarios)
- Inclusion of the SNOW-17 model (to replace SNOWMELT)
- Implementation of a distributed architecture (currently standalone) to accommodate multiple forecasters working simultaneously on the same system
- Displays available in English units, not metric

Furthermore, the CAT members requested:

- A re-configuration of the Santiam basin at NWRFC to reflect existing NWSRFS segment definitions
- Additional training and documentation for the system
- Add a third CHPS FEWS Pilot installation at ABRFC in Tulsa, OK

Delft (through RTi) and OHD/RSIS implemented these additional requirements between April and December 2007, culminating in a demonstration and training workshop hosted by NCRFC in Chanhassen, MN during the week of December 17, 2007.

3 CHPS FEWS Pilot Evaluation

Under a separate contract through RSIS with Apex Digital Systems, OHD began the task of formally evaluating the Pilot system. The approach was to have been as follows:

- In collaboration with the CAT members, develop a set of evaluation criteria against which the CHPS FEWS Pilot system would be judged;
- Conduct the evaluation using the criteria;
- Summarize CAT recommendations to the NOAA Hydrology Program Manager regarding the potential of Delft-FEWS as an infrastructure solution for CHPS.

This contract task had been timed to coincide with the original CHPS FEWS Pilot schedule. However due to the extension of the Pilot project, the evaluation task was placed on temporary hold, and a Draft document was delivered to OHD [3] , with an expectation that the evaluation would resume after completion of the Pilot enhancements.

However by the time of the second workshop at NCRFC, the CAT members were already convinced that Delft-FEWS was promising enough that they did not require the additional 4 months originally proposed by OHD to come to a conclusion. Instead, the 4 months could and should be spent analyzing FEWS in greater detail to develop an implementation plan and specify the functional requirements for an NWSRFS replacement.

3.1 Evaluation Criteria

A summary evaluation of the CHPS FEWS Pilot, based loosely on Apex's Draft evaluation document mentioned above, is presented in this report. Apex has agreed to adjust the focus of their deliverable to document in detail the gap between the FEWS Pilot as it exists today, and a reasonable operational baseline at the CAT member RFCs. This effort is now underway.

3.2 Evaluation of the CHPS FEWS Pilot

A summary of the CAT's findings as a result of their evaluation of Delft-FEWS (represented by the CHPS FEWS Pilot) is provided in this Section. The evaluation is subdivided into eight broad categories.

3.2.1 Model Integration

The evaluation category of Model Integration includes such things as:

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[3] Internal reference S:\OHD-11\Management\Contracts\NWS_RSIS\L036\Pilot_Assessment\ FEWS_EvaluationCriteria_06_DRAFT-FINAL.doc

- Complexity of configuring and integrating existing hydrologic/ hydraulic models for operation within Delft-FEWS
- Complexity of configuring and integrating new hydrologic/ hydraulic models for operation within Delft-FEWS
- Amount of calibration data from the current forecasting system that can be carried over into Delft-FEWS

CAT Findings

OHD found it easier than expected to integrate modeling software into Delft-FEWS.

In their first example (SacSMA-HT), OHD began with Victor Koren's standalone prototype model source code (written in FORTRAN), "wrapped" the code, wrote an adapter, re-wrote in Java; and then delivered the package to Delft, who conducted integration testing.

In their second project (SNOW-17) OHD isolated the source code from the NWSRFS (written in FORTRAN), reengineered in Java, wrote an adapter, developed workflows for Pilot basins; and then delivered the package to Delft, who conducted integration testing.

Not considered

OHD ultimately expects some RFC staff to develop their own tools. There was no attempt to evaluate the amount of effort required to incorporate software modules developed by individuals who are not OHD software engineers.

3.2.2 Domain Modeling

The evaluation category of Domain Modeling includes such things as:

- Time required to model a complete basin and the complexity of such a domain model for use in forecasting operations
- Accuracy of domain model when compared to existing NWSRFS segment definitions
- Learning curve involved in domain modeling for on-site staff

CAT Findings

Basin configurations using FEWS workflows could accurately replicate existing segment definitions, but with the additional advantage that new, more efficient configurations could be also designed.

3.2.3 Extensibility and Configuration

The evaluation category of Extensibility and Configuration includes such things as:

- Extent to which data can be exchanged with other systems
- Scalability of system to cover all U.S. river forecasting operations
- Complexity of system configuration (other than domain modeling)

CAT Findings

The system is well documented, and the files are well organized. It is not difficult to locate any relevant files.

Data exchange depends entirely on the systems involved in such an exchange. This holds true no matter which system - Delft-FEWS or other - is employed.

The Pilot can be configured for any RFC domain, independent of its size; the main limiting factor appears to be computer resources (e.g., disk space, disk I/O speed, memory). The system is extensible enough to cover more than one RFC if the system is configured accordingly; this should be considered in the future when addressing the RFC service backup requirement.

3.2.4 Deployment

The evaluation category of Deployment includes such things as:

- Complexity of Delft-FEWS deployment at a single RFC
- Complexity of Delft-FEWS deployment at all RFCs
- Requirement for special-purpose hardware or software not provided with basic Delft-FEWS
- Impact of Delft-FEWS system upgrades on existing system and basin configurations

CAT Findings

The Delft-FEWS software has a well-organized file directory structure which can be easily expanded to integrate custom modules as needed.

The Pilot sites were upgraded more than once; no problems were encountered with any of the pre-existing configuration files being removed or corrupted.

In one example, Delft was obliged to fix a software bug; they provided the corrected source code file to NCRFC, who updated the file in the relevant directory with no negative impact. Such a simple ‘patch’ procedure is highly desirable.

As a side note, the CAT developed a preliminary standard configuration for the Pilot system. This is expected to facilitate a nationwide deployment. The standard configuration includes use of a non-standard AWIPS workstation as a dedicated database server (refer to AWIPS Technical Authorization Note (ATAN) #909).

Not considered

The impact of AWIPS upgrades on the Delft-FEWS system.

The ability to revert back to a previous release of Delft-FEWS should the need arise.

3.2.5 Compatibility with AWIPS II

The evaluation category of Compatibility with AWIPS II includes such things as:

- Ability of Delft-FEWS to access data provided by AWIPS II
- Flexibility of Delft-FEWS to run in an AWIPS II hardware and software environment

CAT Findings

Delft-FEWS runs on standard AWIPS-provided equipment (the REP). In some cases the system requires different versions of Third Party Software (TPS), but such software is delivered along with FEWS.

As a risk reduction activity, OHD tasked Raytheon to propose a CHPS-AWIPS II interface that would require minimal changes to either system. The outcome of that task was a report which is available from OHD HSEB[4]. Raytheon, in collaboration with Delft, proposed a migration strategy which requires no changes in Delft-FEWS or in AWIPS II until such time as the CHPS program is ready.

Not considered

It was not possible to evaluate Delft-FEWS within an AWIPS II environment at this time.

3.2.6 Usability and Performance

The evaluation category of Usability and Performance includes such things as:

- Support for existing operational forecast processes
- Adequate information content of displays
- Extent to which operational forecast process must be changed to accommodate Delft-FEWS
- Ability of Delft-FEWS workflow management to accurately represent HCL
- Performance of Delft-FEWS on NWS-provided hardware (AWIPS)

[4] S:\OHD-11\Management\Contracts\AWIPSII_Raytheon\ AWP.RPT.FEWS-01.00.doc

- Response times when used by multiple forecasters simultaneously

CAT Findings

The MODs-like user interface was functional but not optimal, and would require further refinement.

Displays generally contained adequate and accurate information.

There remained one or two issues concerning the labeling of metric units versus standard or “English” units.

The CAT found that the Delft-FEWS XML-based workflow provides more flexibility than existing HCL; workflows can be nested to a high degree.

Poor system performance observed while running Ensembles was found to be related to a software bug in the SacSMA-HT application.

The CAT found that while Delft-FEWS is not custom-designed for NWS RFC operational forecasting processes, the software appears to be flexible enough to accommodate necessary changes and the company appears willing to work with the NWS on that aspect.

Not considered

The upgrade from a standalone to a client-server configuration will allow multiple users to access the same system simultaneously. However, the CAT has not had an opportunity to fully exercise this feature; training at NCRFC involved multiple users conducting exercises on individual standalone versions of the system.

3.2.7 Documentation and Support

The evaluation category of Documentation and Support includes such things as:

- Quantity, quality, and access to documentation available for the pilot and for FEWS
- Availability of in-built help capability
- Complexity of technical maintenance and support
- Level of training required for a forecaster to accomplish existing duties

CAT Findings

Documentation has been adequate. Online help must be developed by Delft for Linux (a temporary solution has been implemented).

Responsiveness to questions and issues has been very good. The CAT is limited to e-mail, because they are not allowed to make international calls from their desks. The NWS

is considering use of instant messaging (IM) packages on AWIPS, but this may take years to happen.

The CAT must consider operational support in the long term, as AWIPS security policy prohibits direct access to an operational RFC system through the AWIPS firewall.

The CAT must also consider impact on operational staff at RFCs, and must engage the NWS Employees Organization (NWSEO).

A 2 ½ day workshop was given by Delft to train staff how to configure the Delft-FEWS Pilot. CAT response to the training was positive; the exercises and quality of training was considered excellent.

3.2.8 Other Key Gaps

Other Key Gaps includes such things as:

- Identification of "show stoppers"
- Long-term commitment by WL Delft for on-going FEWS enhancement, technical support, training and consulting services, etc.
- Availability of contract vehicles to engage Delft
- Potential for Delft-FEWS to meet the future needs of CHPS

CAT Findings

The CAT found that Delft is very eager to accommodate NWS needs. Their willingness to work with the CAT on the uncharted issue of carryover MODs provided insight into their technical agility and customer focus.

While no other "show stoppers" were identified, the CAT acknowledges that such items could still surface. Early and thorough identification of requirements will mitigate the risk.

Delft has assured the CAT that they will open an office in Silver Spring, MD in early 2008. A high risk is whether Delft's can continue to hire the same caliber of employee (customer focused, technically astute) in the U.S. as they have hired in the Netherlands.

NOAA has yet to sign the software license agreement with Delft on the operational use of Delft-FEWS; however NOAA lawyers have informed OHD that a Delft presence in the U.S. would facilitate such an agreement.

To date, OHD has used several contract vehicles to access Delft: NOAA's AHPS contract with RTi; NWS's IT Services contract with RSIS; and OS&T's AWIPS contract with Raytheon. The AHPS contract carries a high cost overhead but also provides access to RTi. The RSIS contract is currently being re-competed, and is reaching its $ ceiling. OHD regards the AWIPS contract as a last resort only. NOAA is currently pursuing a

new Blanket Purchase Agreement (BPA) that might allow access to Delft through Apex. There is a minor possibility that Delft may become directly accessible via such a BPA.

Future needs of CHPS include: introduction of an eXperimental Ensemble Forecasting System (XEFS), introduction of a distributed hydrologic model, introduction of the USACE HEC's River Analysis System (RAS) into NWS forecasting operations, further collaboration with a wider hydrologic community, and more. The CAT found that implementation of Delft-FEWS would have some of these capabilities already built-in. The NWS RFCs would have access to hydrologic and hydraulic models not compatible with the NWSRFS and therefore not easily accessible today; the Delft hydrologists are very interested in collaborating with NWS hydrologists; Delft-FEWS already has an infrastructure in place to accommodate hydrologic ensembles.

3.2.9 Other Considerations

Under a separate project, Delft worked with Apex to implement a solution at CNRFC (CNRFC is a CAT member) that permits incorporation of the USACE HEC Reservoir Simulation (ResSim) model within CNRFC forecasting operations. In this case, an interface between NWSRFS and the ResSim was designed by implementing Delft-FEWS as a "broker" between the two software applications. In this way, the interface to ResSim is intended to be "CHPS-ready". The project has proved highly successful, demonstrating the quality and robustness of the Delft-FEWS, and a high quality of service.

The NWS International Activities Office (IAO) currently supports deployment of the NWSRFS in the various water forecasting organizations of foreign countries. By signing an agreement with Delft and deploying the Delft-FEWS with available non-proprietary models, such countries could gain access to the wider hydrologic community, and could potentially benefit from the science advances.

4 Summary and Recommendations

The CAT makes the following recommendations:

- The NOAA Hydrology Program should proceed with implementation of Delft-FEWS as the software infrastructure for CHPS
- No further potential candidate systems need to be evaluated

Furthermore:

- The NOAA Hydrology Program should aim for full operational use at all RFCs within 3 years
- The CAT recommends that a multi-phased approach be adopted, whereby CAT members continue to full operations in the first phase, and then act as mentors and focal points for the remaining RFCs in a second phase
- Pilot sites should continue to exercise the Pilot system over the course of the next 4-6 months with a view to identifying major issues as soon as possible
- NOAA Hydrology Program management should communicate these recommendations clearly and consistently to all RFCs at multiple levels and via multiple venues
- The NOAA Hydrology Program should leverage RFC resources where and when available to prototype additional capabilities, or migrate local applications
- OHD should re-align existing resources ($, FTEs) to focus on CHPS-based activities
- Carefully consider if, and how many, resources should be dedicated to continued NWSRFS support
- With support from the CAT members OHD should open a dialog with all other RFCs to secure their commitment
- OHD should re-evaluate all HSMB-originated projects that are currently undergoing a transition to operations to assess the impact of this recommendation on proposed solutions (e.g., XEFS, DHM)
- OHD should proceed with Raytheon's recommended approach for a CHPS-AWIPS II interface
- The NOAA Hydrology Program manager should assign a single project leader from within OHD to co-lead the implementation effort with one or more members of the CAT

- The CAT should remain in place, but under a revised charter (original charter is available from OHD HSEB[5]) and possibly with a new name

4.1 Assumptions

- Funding for CHPS (core goal #13, other core goals to be determined) for FY08, FY09, and FY10 is adequate to support the proposed migration to full operational use within 3 years.
- NOAA and Delft sign the software license agreement.
- Delft can provide the necessary local (i.e., U.S. based) resources to support this effort; also that the quality of support does not degrade.
- All RFCs commit to providing the necessary resources that will be required to migrate from NWSRFS to CHPS.

4.2 Next Steps

- NOAA Hydrology Program Manager (and OHD Director) Gary Carter, to make and announce a formal decision
- OHD, CAT, Delft, and Apex to work on a migration plan
- OHD to re-evaluate allocation of internal resources to its various projects
- OHD to open a dialog with the NWSEO for their review of and/or participation in future CHPS activities
- OHD to initiate the necessary contract tasks to engage Delft and other contractors such as Apex, RSIS, and/or RTi
- Conduct HOSIP Gate 4 for the CHPS FEWS Pilot Enhancements project
- Prepare for OSIP Gate 3 (project 07-017 “CHPS Infrastructure”)

[5] Internal reference S:\OHD-11\RFCOnly\CHPS\ CAT_Charter_092407-Final.doc

5 Acronyms

ATAN	AWIPS Technical Authorization Note
AWIPS	Advanced Weather Interactive Processing System
CAT	CHPS Acceleration Team
CHPS	Community Hydrologic Prediction System
CORBA	Common Object Request Broker Architecture ()
DHM	Distributed Hydrologic Modeling
FEWS	Flood Early Warning System
FTE	Full-Time Employee (or Full-Time Equivalent)
HCL	Hydrologic Control Language
HOSIP	Hydrologic Operations & Services Improvement Process
HSEB	Hydrologic Software Engineering Branch
HSMB	Hydrologic Science & Modeling Branch
IHFS	Integrated Hydrologic Forecasting System
IAO	International Activities Office
IM	Instant Messaging
NOHRSC	National Operational Hydrologic Remote Sensing Center
NWSEO	NWS Employees Organization
OMS	Object Modeling System
OSIP	Operations & Services Improvement Process
RAS	River Analysis System
REP	River Ensemble Processor
ResSim	Reservoir Simulation (model)
RSIS	RS Information Systems
RTi	Riverside Technology, inc
Sac-SMA	Sacramento Soil Moisture Accounting (model)
SOA	Service Oriented Architecture
TPS	Third Party Software
USACE	US Army Corps of Engineers
XEFS	eXperimental Ensemble Forecast System
XML	eXtensible Markup Language