ADVANCES

in Hydrologic Engineering

Summer 2009

Director's Comments

By Christopher N. Dunn, P.E.

June 2009 the Hydrologic Engineering Center celebrated its 45th anniversary. A lot has changed within the hydrologic and water resources profession in the last 45 years but one thing that hasn't changed is HEC's mission. HEC was established 45 years ago to serve as a Corps Center of Expertise in the technical areas of hydrologic engineering and water resources planning analysis. We still conduct research and develop software, perform training and provide technical assistance that reflect the state-of-the-art in hydrologic engineering and the closely associated planning analysis. We continue to produce technical documents, computer software and user's manuals, provide technical assistance, and execute special projects. While we generally provide services to Corps HQUSACE, district and division offices, and laboratories, we have branched out and provide assistance to other Federal and local agencies, the US private sector in support of international work, and international institutions. And finally, while the software we produce is developed for the Corps, this software is still available for free in the public domain. Like I said, much has changed but much has stayed the same.

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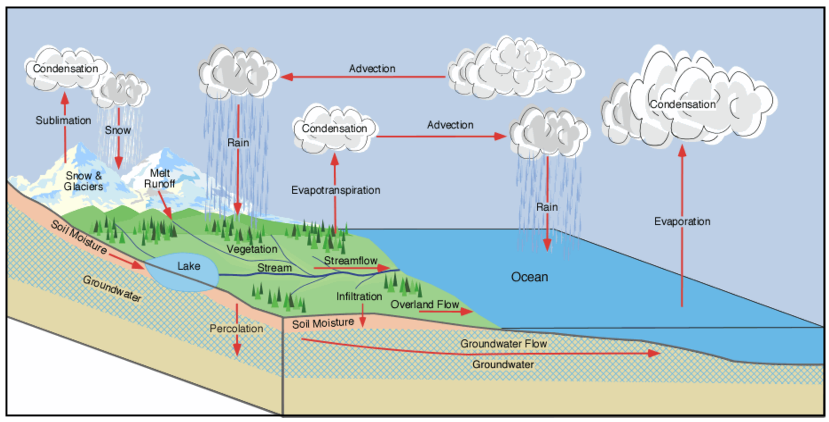
The HEC-1 to HEC-HMS Transformation

Contributed By William Scharffenberg, PhD

It is not an understatement to say that HEC-1 changed the way engineers performed hydrologic analyses. The first version was completed in the fall of 1968 with most of the work done by the late ongoing maintenance that supported HEC-1. Third, the software was very fast compared to the alternative of slide rules and mechanical calculators. For the first time it was becoming possible for engineers to



Hydrologic Cycle (source: PhysicalGeography.net)

Mr. Leo R. Beard. It quickly gained wide acceptance for a number of reasons. First, HEC-1 provided a comprehensive description of the hydrologic cycle, combining precipitation, infiltration, surface runoff, baseflow, channel routing, and reservoir simulation. Previously it was necessary to use a separate software package for each logical component. The user was required to manually pass results from program output to program input until the final result was obtained at the outlet of the watershed. Second, HEC-1 benefited from being the first program available. University researchers were simultaneously working on similar software for hydrologic simulation. However, these tools were applied primarily on academic projects. They lacked the extensive documentation and

focus on the hydrologic processes at work instead of the methodologies of making manual calculations.

The HEC-1 program was enhanced through out the 1970s and into the

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In This Issue:

US Army Corps of Engineers
Hydrologic Engineering Center

Director's Comments (continued)

In observance of our 45th anniversary, this edition of the HEC Newsletter will focus on how our software has evolved over HEC's existence. We thought you might find these articles interesting as our current engineers reflect on where we have been and where we are going. We decided to focus on some of our featured software categories such as river hydraulics, hydrologic and reservoir modeling, water and data management, and flood damage evaluations. We also have an article from one of our "tenured" employees on her experiences over her career at HEC. This Newsletter also serves another purpose and that is that HEC's 50th anniversary is just around the corner and I wanted to use this opportunity to begin preparations for our Golden anniversary. I hope you enjoy the nostalgia.

However, before I sign off, I thought is was important to let you know about a couple of items that are currently taking place at HEC. We are involved in two American Recovery and Reinvestment Act (Stimulus) activities. One, through the Mobile District, includes reservoir and water quality modeling and is in support of the Alabama-Coosa-Tallapoosa (ACT) and Apalachicola-Chattahoochee-Flint (ACF) River basins study in the Southeastern part of the country. The second is an effort to accelerate the deployment of the Corps Water Management System (CWMS). In this case, HEC has awarded contracts through our existing Blanket Purchase Agreements (BPA) and the contractors are to develop hydrologic, hydraulic, and reservoir operation models, and implement a sophisticated data management and display system within CWMS. Initially, basins in eight Corps district and division offices were selected for implementation. The watersheds that will be modeled and implemented within CWMS include the Red River of the North in Minnesota/North Dakota, the Apalachicola-Chattahoochee-Flint (ACF) in Alabama/Georgia/Florida, the Santa Ana in Los Angeles, the Ohio, Tennessee and Cumberland Rivers, the Buffalo Bayou for the Galveston District, the Jackson and James Rivers in Virginia, a portion of the Missouri River, and the Puyallup River in Washington. These basins, identified by the CWMS Advisory Group, are critical watersheds where flooding, or potential flooding, and water supply are important concerns in operating Corps Reservoirs. The development of the models will be coordinated with partnering agencies, such as the National Weather Service River Forecast Centers, the Bureau of Reclamation and state and local agencies.

One of our larger efforts over the past several months included the study, development and reporting of a process that allows you to analyze flood risk management measures through a systems approach while using risk analysis. Released as a Project Report, PR-71, "Documentation and Demonstration of a Process for Risk Analysis of Proposed Modifications to the Sacramento River Flood Control Project (SRFCP) Levees", has been added to the Hydrologic Engineering Center's (HEC) website and is available in the Project Reports section as Project Report 71 (PR-71) at http://www.hec.usace.army.mil/publications/ProjectReports/PR-71.pdf. The report documents the process defined to apply risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alteration and modification to the Sacramento River Flood Control Project (SRFCP). This effort demonstrates that existing risk analysis tools can be applied in a systems context to reveal responses within one region of a system from perturbations to another region. For those involved in this effort, PR-71 is a culmination of a team effort in the design, execution, and analysis of the methodology. AFC Theme 2 funds and resources were used to make significant contributions to this effort.

Another project we recently became involved with and I'm sure will be a big part of our program over the next few years is the Columbia River Treaty (CRT) 2014/2024 Study. The CRT is an agreement between the United States and Canada. The purpose of the CRT, which became effective in 1964, is to provide flood control and power benefits to U.S. and Canadian regions. The Treaty called for Canada to build three storage dams in British Columbia (Mica, Arrow and Duncan) and the U.S. to build Libby Dam. These CRT projects doubled the storage capacity of the river system, providing better control of the rivers' flow which decreased flooding and offered an abundance of water for power generation. Under the Treaty, Canada is entitled to half of the downstream power benefits produced by Treaty projects (referred to as Canadian Entitlement). While the Treaty has no expiration date, it can be terminated by either party in 2024, provided the other party has been given a ten year advance notice-

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US Army Corps of Engineers
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http://www.hec.usace.army.mil

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Director: Christopher N. Dunn, P.E.

Water Resource Systems Chief: Matthew M. McPherson, P.E, D WRE

hence the importance of the 2014 milestone. The Northwestern Division, along with our partner Bonneville Power Administration, is undertaking a series of studies to collect critical information needed to support possible renegotiation of the Columbia River Treaty (CRT). The study team has initiated the Phase II study which will construct risk assessment tools and conduct baseline and alternative Expected Annual Damage (EAD) computations to allow risk informed decision making. We expect to provide technical support and application guidance for risk assessments and the development and application of hydraulic and reservoir simulation tools. The study will employ HEC-ResSim for the modeling of the Columbia River reservoir system with HEC-RAS supplementing definition of routing and stage outputs. Initially, HEC-FDA will be used to generate EAD for baseline and alternatives conditions with data collection and study process developed in a way to allow the transition to the HEC-FRM (Flood Risk Management) tool in the future.

International Activities:

Our International Activities focused on H&H training for two African nations, Ethiopia and Kenya, and hydrologic model development in Ethiopia. Also, H&H training and model development, was provided to Guyana, South America. The training in Ethiopia and the modeling effort focused on the Ogaden Basin. Our engineers presented hydrologic modeling training in Addis Ababa, Ethiopia as part of a continuing capacity building effort through the CJTC-HOA program. Funded by NAVFAC, the participants acquired practical skills with GIS technology and hydrologic software to develop a hydrologic model for the Genale watershed of the Ogaden Basin. Two of our engineers also taught an HEC-HMS and HEC-RAS course in Georgetown, Guyana, South America. This effort is part of the Corps Military Emergency Preparedness (CMEP) program and is being funded through SOUTHCOM. They taught the theory behind each program and will help the students understand the application of the software to a local watershed. Prior to this training class, HEC had worked on the development of HMS and RAS models for the Mahaicony River located in that country. These models were used in the training and the CMEP table top exercise in Georgetown.

CWMS:

A full accounting of the status of the Corps Water Management System (CWMS) was provided in our previous Newsletter, however, much of it is repeated here for completeness. The goal of our Water Management Division is to have CWMS Version 2.0 at every USACE water management office by the end of the calendar year. Before we release Version 2.0, we are proceeding through a well defined testing plan. The testing plan includes detailed testing at HEC and also at a few of our water management offices. When the testing sites are comfortable with this version of the software, further distribution of CWMS will occur. Version 2.0 includes major revisions to the basic database structures, allowing water control users more direct access to their data and enabling them to make more effective use of the features inherent in the commercial Oracle database at the center of CWMS. It also includes the incorporation of RiverWare from CADSWES in Boulder, Co, the latest versions of the modeling programs and numerous enhancements. It should be noted that the Corps and the Regents of the University of Colorado have formally entered into an agreement that grants the Corps a license for the RiverWare software. The expiration date for this agreement is 30 June 2011. Information about CWMS and other HEC software is available on the HEC web site www.hec.usace.army.mil/cwms/.

A public release of the modeling component of CWMS, named HEC-RTS (Real Time Simulation) is also scheduled for release shortly after the release of Version 2.0 of CWMS.

HEC Software:

Since the last newsletter only HEC-SSP (Statistical Software Package) has seen a new release. Version 1.1 of HEC-SSP is now available. However, HEC continues to enhance and introduce new products all the time so please review our website to see the latest activities. We expect to release new versions of a number of pieces of software soon including HEC-ResSim (Reservoir Simulation), HEC-RAS (River Analysis System), HEC-FIA (Flood Impact Analysis) with its loss-of-life capabilities, and the new Watershed Analysis Tool, HEC-WAT, (which includes HMS, RAS, SSP, ResSim, EFM and FIA software).

Summary:

We hope you enjoy our 45th Anniversary edition of the HEC Newsletter and as always, if we can help you in any way, please let us know.

Chris Dunn, P.E.
Director

The HEC-1 to HEC-HMS Transformation (continued)

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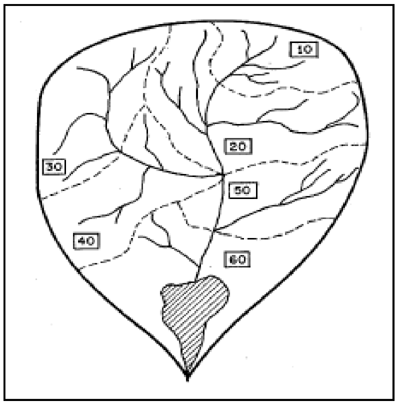
1980s. Engineers working on the project at various times during that period included Arlen Feldman, John Peters, Dr. David Goldman, Gary Brunner, Darryl Davis, Michael Burnham, Paul Ely, and Troy Nicolini. It was connected to the Data Storage System (DSS) in the early 1980's for storing and retrieving time-series data. This made it possible to develop large databases of precipitation and observed flow data for use in comprehensive studies. The DSS connection also made it possible to connect surface runoff from HEC-1 to the companion HEC-2 program for detailed one-dimensional hydraulic analysis. But more than data management features were added to the program. The kinematic wave surface runoff component was added for urban hydrology needs. The Muskingum-Cunge channel routing method was also added during this period to improve the physical representation of flood wave routing. The Green and Ampt infiltration method was added as well. A parameter optimization feature was added to help with model calibration. Finally, a dam break module was added to the reservoir.

The success of HEC-1 bred several products for specialized application. The best known of these was called HEC-1F. HEC-1F was used as the hydrologic component of the Water Control Data System (WCDS). HEC-1F helped usher in an era of system operation based on near real-time simulation. This proved a significant improvement over using measured precipitation (rain on the ground) and static regulation manuals. A lesser known variant was called HEC-1C. This software experimented with continuous simulation. However, while the continuous capabilities it demonstrated where similar to cutting edge research happening at the time in academia, the capabilities were never merged with the main HEC-1 program. The



Subbasin schematic for HEC-1

final variant was the HEC-IFH software for interior flood system simulation. It borrowed heavily from the algorithms and other codes used to make HEC-1, but it was optimized for very small watersheds with only a couple of subbasins and a routing reach. It had a very different reservoir component for simulating culverts and pump stations. It also experimented with a rudimentary graphical user interface.

By the end of the 1980s, engineers at HEC had developed extensive experience with HEC-1. Many application projects had been completed and the value of computer software for hydrologic simulation had been clearly demonstrated. However, HEC-1 and all of its related tools were conceived in the era before the invention of the Personal Computer. They were optimized for running on mainframe and mini computers, in environments where memory was scarce. As such they operated from input and output files and generally speaking had crude graphical user interfaces, if they had interfaces at all. The internal code structures were also difficult to maintain because the memory optimizations often resulted in algorithms that were difficult to read.

HEC-1 had been stunningly successful within the scope of past application projects. However, it did have one important technical limitation; it could only compute hydrographs with up to 2,000 ordinates. This was sufficient for modeling a single storm event in a watershed of moderate size. However, Dr. David Goldman began to envision a replacement to HEC-1 working with much larger watersheds that would require longer hydrographs. Beyond just working in larger watersheds, it was also deemed desirable to begin working with continuous simulation models that could provide for multi-decade simulations. This requirement would demand a fundamental shift in the technology used to build the software, since the original program framework was built with software design approaches originally developed for punch card data entry.

In 1991 a new Research and Development project started at HEC called "NexGen". The sole purpose of the project was to design and develop the Next Generation of HEC software. Several teams were formed, including: hydrologic analysis, river hydraulics, reservoir systems modeling, and flood damage analysis. This research and development project was the beginning of several new pieces of software at HEC, including the Hydrologic Modeling System (HEC-HMS). HEC-HMS was designated to become the primary hydrologic software for HEC and replace HEC-1. The HEC-HMS team conducted a careful study, and then made the decision to move from the FORTRAN language used for HEC-1 to the C++ language. Language features in C++ like dynamic memory allocation would allow for very long hydrographs, and organizing simulation modules as reusable objects would increase flexibility. It was the first project at HEC to use an object-oriented programming language.

The conversion project began by building on the success of HEC-1. Engineers contributing to the project included Art Pabst, Bill

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The HEC-1 to HEC-HMS Transformation (continued)

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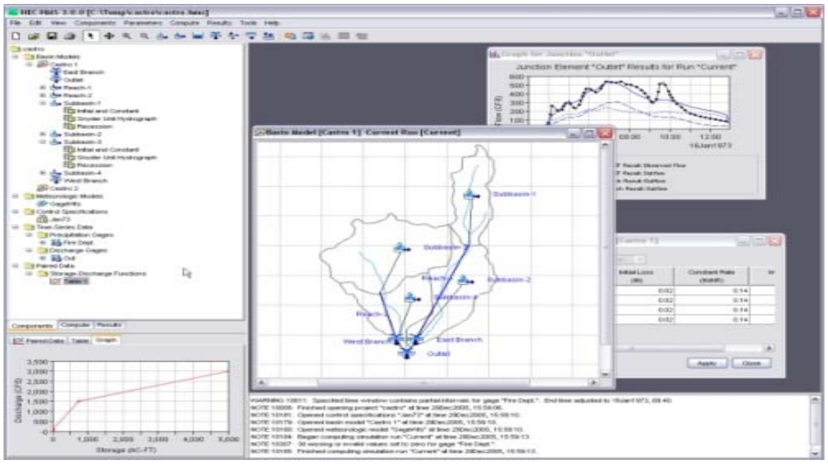
Charley, Dick Fong, John Peters, Lisa Pray, Paul Ely, and Tony Slocum. Many algorithms were extracted from the old software and organized as a library. Advances had been made in computer science and numerical analysis since the creation of HEC-1. These advances were used to modernize the algorithms before placing them in the library. The vision for HEC-HMS also included a graphical user interface as a fundamental component of the program. This requirement would mean important changes in the management of model data and simulations. A design template known as "model-view-controller" architecture was selected as the best way to meet the project requirements. This template separates the functions of managing data, from viewing the data and results, from manipulating the data. Separating the three software functions allows one portion of the software to be altered without impacting any of the remaining portions. As such it provides significant capability to "grow" with the software as new features and capabilities are added.



HEC-HMS Interface

Several years of work were required to build the new HEC-HMS software. Version 1.0 was finally finished and released for general use. It included many of the simulation features from HEC-1 including: precipitation, loss rate, transform, baseflow, channel routing, reservoirs, and diversions. All of the components were designed for simulating individual storm events. However, there was no limit on the number of ordinates in a hydrograph. For the first time with HEC software, it was possible to use very short time intervals, on the order of minutes, and still run a simulation for several days. HEC-HMS was also capable of importing an HEC-1 input file to make it as easy as possible for users to migrate to the next generation software. Finally, a new parameter optimization facility was built that provided significantly more capability and user control than was available previously. A Cooperative Research and Development Agreement (CRADA) was established with ESRI to develop HEC-GeoHMS. This companion tool uses a Geographic Information System (GIS) to automatically extract a watershed model from a digital elevation model.

There was a major new capability in the initial release of HEC-HMS that vaulted HEC hydrologic simulation software back to the forefront of hydrologic simulation: ModClark. Dr. Thomas Evans had been working for several years to find a way to use the precipitation radar product from the National Weather Service WSR-88D weather radar systems. It was hoped that the distributed precipitation product would prove useful in real-time operational requirements as well as application studies. The ModClark proved ingenious by utilizing unit hydrograph concepts familiar to many engineers, but expanding them for use with a gridded representation of the watershed. Best called quasi distributed, the ModClark opened the door for the first time to hydrologic simulation with data sources other than precipitation gages. The program was the first widely accessible program to use gridded precipitation.

Work continued on HEC-HMS with the focus shifting to continuous simulation. Technologies were borrowed from the legacy HEC-IFH software. The infiltration model included in that software used a single layer to represent water movement in the soil. The algorithm was converted to the "deficit constant" loss rate method within HEC-HMS. At the same time, graduate student intern Todd Bennett was evaluating other continuous simulation models in use by other agencies and in the academic community. A multi-layer model was developed and also added to HEC-HMS. This new model was called the "soil moisture accounting" loss rate method. The capabilities for continuous simulation were rounded out by adding a monthly average evapotranspiration method. The result of all the work on continuous simulation was Version 2.0. That important release made it possible for HEC-HMS to be used for either event or continuous simulation, depending on the choices made by the user for loss rate method.

Technology in the software development world was moving very fast. The development tools used to create the graphical user interface for HEC-HMS were becoming obsolete. The company that created the tools soon declared bankruptcy. The HEC-HMS development team evaluated a

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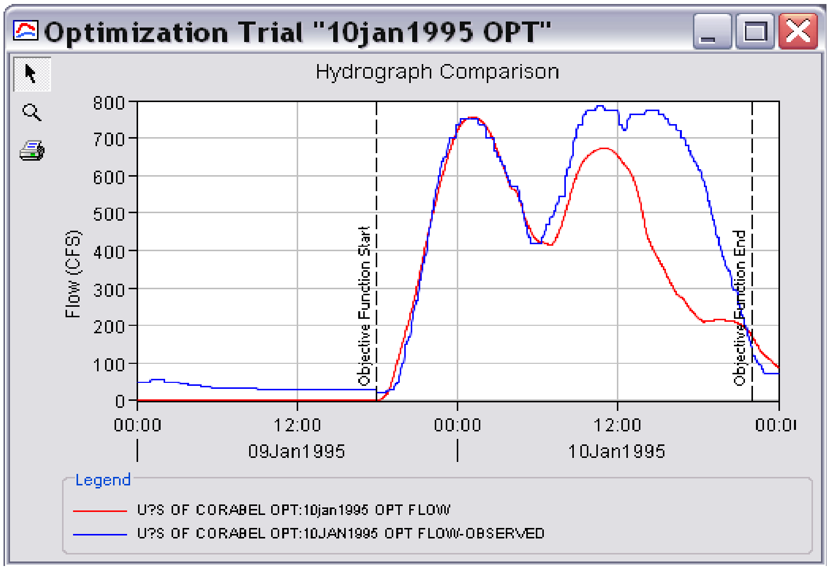
number of options. The decision was made to move the entire program from the C++ language to the Java programming language. Where previously the graphical user interface was created with third-party tools, all of the necessary interface tools were a native part of the Java language. The Java language also provided for operating on a wide variety of computer operating systems, including two used through out the Corps of Engineers. Both languages use the same syntax so the conversion process moved very quickly. Conversion began immediately on the data model, with Lisa Pray, Paul Ely, and William Scharffenberg performing most of the work. Instead of simply replicating the interface in Java, the opportunity was taken to completely redesign the interface to meet modern design guidelines and improve the user experience. The result of the conversion process was Version 3.0.

Initially, the conversion from C++ to Java was envisioned as the only significant change for the Version 3.0 release. However, a decision was made to also add major new capability. A snowmelt module was added to the meteorologic model through the assistance of Dr. Steven Daly from the Corps' Cold Regions Research and Engineering Laboratory. The snowmelt module used a temperature index approach that had been used in the Distributed Snow Process Model (DSPM), which in turn, had taken the algorithm from the Streamflow Synthesis and Reservoir Regulation (SSARR) model. As implemented in HEC-HMS, the algorithm could operate on elevation bands or grid cells. The addition of a snowmelt module rounded out the major components necessary to simulate the entire hydrologic cycle. The reservoir element was also enhanced with the remainder of the functionality necessary to duplicate the capabilities of the HEC-IFH



HEC-HMS Plot

software. A culvert library from the River Analysis System (HEC-RAS) was borrowed to add true culvert flow to the reservoir outlets in HEC-HMS. A pump component was also built. The addition of these features made it possible for HEC-HMS to provide all of the simulation capability in the legacy software family.

Work has continued on HEC-HMS toward the next major release, led by Dr. William Scharffenberg and including Dr. Jay Pak, Matthew Fleming, and Paul Ely. This release will be called Version 4.0 and is scheduled for late 2009. Several years have been spent on the development of a complete set of sediment and water quality simulation modules. The sediment capabilities begin with two choices for surface erosion and wash off in the subbasin element. A very sophisticated erosion, deposition, and transport capability will be added to the reach element. Other modules will be added to the reservoir element to simulate settling, and to the diversion element as well. The water quality features will initially focus on nitrogen and phosphorus, from the subbasin, through the reaches, and into the reservoirs. The nutrient fate calculations are performed with the aid of the Nutrient Sub Module (NSM) developed by a team led by Dr. Billy Johnson at the Corps' Environmental Laboratory.

The Hydrologic Modeling System (HEC-HMS) now represents over forty years of HEC experience with hydrologic simulation. It has already been through several major changes in programming language and architecture and the software will continue to evolve to meet the future needs of the Corps of Engineers. For example, continuous simulation studies are becoming more common and requirements to evaluate potential future climate scenarios validate the investments already made in HEC-HMS in this respect. The integration of sediment and water quality simulation capabilities currently underway is expected to be similarly prognostic. One thing is sure, the HEC-HMS program will continue to grow and increase in capability in the future to the benefit of all who use it.

The Mustang and HEC

Contributed By Penni Baker

In June 2009, the Hydrologic Engineering Center (HEC) was 45 years old, right along with another national icon the Mustang. The Mustang was created to fill a niche in the car industry - muscle car.

Ford Mustang Emblem

HEC was created out of the Corps of Engineers need for a center of expertise in "hydrologic engineering". By July of 1964, HEC with a staff of five (the late Mr. Leo R. Beard as Director), was setup as an administrative unit in the Sacramento District, with a budget of $114,000. In January 1969, HEC moved to the City of Davis, about fifteen miles west of the City of Sacramento to obtain more space and to have easy access to UCD's (University of California at Davis) computing facilities and the faculty. The Center is still in the same building with a major remodel that occurred about seven years ago.

The original mission of HEC has not changed throughout the years, just like the Mustang, the appearance may be a little different, but what is under the hood is the same focus and attention to getting the mission accomplished. HEC's original mission was threefold: research, training, and technical assistance in the application of hydrologic engineering methodology. HEC accomplishes its mission goals through workshops and the PROSPECT training program (conducting on average about ten classes a year); by developing and maintaining state-of-the-art software; and, assisting Corps offices by applying advanced hydrologic engineering technologies in studies. The studies have covered a wide variety of topics in virtually every state and several foreign countries, and, the HEC engineering software includes: river hydraulics; hydrology and hydrologic statistics, sedimentation; reservoir system analysis and optimization; real-time water control; and, flood damage analysis.

In 1989 HEC celebrated its 25th anniversary with a staff of about forty and a budget of three million dollars. Also, during 1989, HEC transitioned from its second Director, Bill S. Eichert, to the third Director, Darryl W. Davis. At that time, HEC was considered a center of expertise for hydrologic engineering and planning assistance within the Corps of Engineers. HEC software was moving from mainframe computers to individual workstations, increasing use of GIS software in Corps of Engineers studies, and an emphasis on evaluating environmental impacts in water resource system operations. During this time with advances in the research and development program, HEC began moving into the areas of remote sensing; creating a package of statistical methods; emphasis on next generation mathematical models for river hydraulics and watershed runoff; and, developing materials concerning the concept of local sponsors sharing in the developmental cost of a project.

Since 2000 HEC has been a support office within the Institute of Water Resources (IWR) and continues to provide the hydrologic engineering and planning assistance expertise that is needed. HEC is now under the guidance of our fourth Director, Christopher N. Dunn, with a staff of about forty-five and a budget of about eight million dollars. From my vantage point HEC's mission has not changed over the years, but has evolved and stayed in step with changes in the hydrologic engineering and planning fields. HEC participates on several national teams which include Dam Safety, Levee Assessment, Map Modernization, and Dam Break Methodology. Other national activities include writing Corps guidance on levee certification; work with the National Weather Service and FEMA; assist with work on the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River basins; and, assisting the Corps' Engineering Risk and Reliability Directory of Expertise with a number of dam and levee safety studies. Another area that HEC has become more active is the international scene; partnering with the USGS in the renovation of the Iraqi streamgage program; helped develop a water management model for the Helmand Valley in Afghanistan; and, providing training in Iraq, Afghanistan, Africa, India, and Japan. HEC software now includes rainfall-runoff analysis (HEC-HMS), river hydraulics (HEC-RAS), reservoir system analysis (HEC-ResSim), flood damage analysis (HEC-FDA), flood impact analysis (HEC-FIA), statistical analysis (HEC-SSP), and, ecosystem function analysis (HEC-EFM). Also, in meeting the Corps of Engineers need to streamline and integrate the tools commonly applied within the field, HEC has developed in the real-time river forecasting arena the Corps Water Management System (CWMS), and for the modeling and planning arena the Watershed Analysis Tool (HEC-WAT) is in development. CWMS is a comprehensive data acquisition and hydrologic modeling system that supports field-level decision making with the Corps of Engineers water management mission.

In five years I will have spent forty years of my life at HEC; it will also be the golden anniversary for HEC and the Mustang. The Mustang has always been a dream car (sapphire) for me, but working at HEC has let me realize other dreams that have become realities, as it has for many of the staff that has come and gone. Stay tuned and in five years we will see where the road trip has taken HEC and the Mustang.

Contributed By Diane Cuming

Organizational Chart - 1964

Administration	
Leo R. Beard	Chief
Bill S. Eichert	Assistant Chief
Suzanne J. DiBuono	Secretary
Training & Methods Section	
Bill S. Eichert	Engineer
Alfred T. Onodera	Engineer Technician
Hydrologic Research Section	
Leo R. Beard	Engineer
Harold A. Keith	Engineer
William L. Morse	Mathematician
Special Projects Section	
Daniel D. Deneff	Engineer

Organizational Chart - 2009

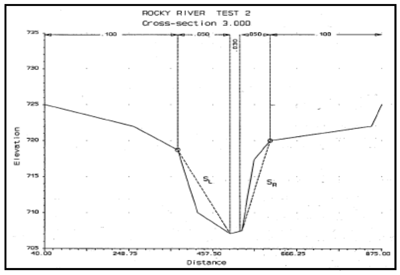
Executive	
Christopher N. Dunn	**Director**
Ozella Miller	Executive Secretary
Mona Thennis	Training Assistant
Traci Disario	Budget Technician
Diane Cuming	**Chief Administrative Officer**
Hydrology and Hydraulics Technology (H&H) Division	
David "Jeff" Harris	**Chief**
Cameron Ackerman	Hydraulic Engineer
James Doan	Hydraulic Engineer
Jon Fenske	Hydraulic Engineer
Matthew Fleming	Hydraulic Engineer
Stanford Gibson	Hydraulic Engineer
D. Mike Gee	Hydraulic Engineer
Mark Jensen	Hydraulic Engineer
Jang (Jay) Pak	Hydraulic Engineer
Bill Scharffenberg	Hydraulic Engineer
Gary Brunner	**Senior Technical Specialist, River Hydraulics**
Water Resource Systems (WRS) Division	
Matthew McPherson	**Chief**
Penni Baker	Software Programmer
Bob Carl	Hydraulic Engineer
Beth Faber	Hydraulic Engineer
John Hickey	Hydraulic Engineer
Jason Needham	Hydraulic Engineer
Sara O'Connell	Hydraulic Engineer
Marilyn Hurst	Hydrologic Technician (re-hired annuitant)
Michael K. Deering	**Senior Technical Specialist (Oregon)**
Water Management Systems (WMS) Division	
Tom Evans	**Chief**
Darren Nezamfar	Software Programmer
Carl Franke	Hydraulic Engineer
Fauwaz Hanbali	Hydraulic Engineer
Joan Klipsch	Hydraulic Engineer
Gerhard Krueger	Hydraulic Engineer
George "Chan" Modini	Hydraulic Engineer
Mike Perryman	Hydraulic Engineer (Tulsa)
Todd Steissberg	Hydraulic Engineer
Arthur Pabst	Senior Technical Specialist (re-hired annuitant)
Bill Charley	**Senior Technical Specialist, Water Control**

River Hydraulics Software at HEC From HEC-2 to HEC-RAS

Contributed By Gary Brunner, P.E.

In the early 1960's, hydraulic engineers developed water surface profiles by solving the Energy equation using what was called the Standard Step Backwater method. It was a hand computational procedure that was iterative and very time consuming for even a short reach of a river. Early attempts at computerizing this technique were accomplished for simple shaped cross sections only (rectangular and trapezoidal). In 1964, the first Corps of Engineers water surface profiles program was developed by Mr. Bill Eichert. His program was originally called "Backwater - Any Cross Section", and it was written in a computer language called WIZ. As the program name implied, it could handle cross sections of irregular shape, so it was more applicable to real world cross section data. This software was re-written using the FORTRAN computer language in 1966 and released to the public as a generalized computer program for computing water surface profiles.

In 1968 the program was revised, with many new additions, and was released for the first time under the name HEC-2. This same year computer programs HEC-1, -3, and -4 were also released as a package of generalized computer programs from HEC. HEC-2 established HEC's role in river hydraulics. The software package quickly became an international standard for computing water surface profiles, as well as becoming an integral part of the Federal Emergency Management Agency's (FEMA) flood insurance studies program. Since its first release, many improvements were made to the software, prompting new releases in 1971, 1976, 1984, 1988, and 1991. The HEC-2 team throughout that timeframe consisted of the late William Johnson, John Peters, Richard Hayes, Arthur Pabst, Vernon Bonner, and Alfred Montalvo. Some of the new features included in the software were



HEC-2 Output

bridge hydraulics, culvert hydraulics, channel improvements, automated Manning's n value calibration, and several other features. Before personal computers were invented, HEC-2 was run on a main frame computer. The very first versions of the software required users to create their input data on what were called "Punch Cards". Each card represented one line of input data, and entire deck of cards would represent a single model run. The Punch Cards were fed into a card reader, the software was run, then an output file was printed on what was called a "Line Printer" (i.e., it printed one line at a time). In the early 1980's, "Punch Cards" gave way to entering data into a text file directly stored on the computer. The first PC version of the software was released in 1984. This version was able to run on an IBM compatible PC, but required a whopping 640 Kilobytes of RAM, a 10 Megabyte (or larger) hard disk, and MS DOS 2.1 or greater. The February 1991 version of HEC-2 (Version 4.6.1) was the final release of the software.

In 1991 a new Research and Development project started at HEC called "NexGen". The sole purpose of the project was to design and develop the Next Generation of HEC software. Several teams were formed, including: hydrologic analysis, river hydraulics, reservoir systems modeling, and flood damage analysis. This research and development project was the beginning of several new pieces of software at HEC, including HEC-RAS (River Analysis System).

The original HEC-RAS development team consisted of Gary W. Brunner (Team Leader and Software Designer), Mark R. Jensen (User Interface Programmer) and Steven S. Piper (Computational Engine Programmer). At the time of HEC-RAS's conception, several pieces of software were available from HEC for performing various aspects of river hydraulics. HEC-2 was used to perform steady flow water surface profiles, HEC-UNET was used to perform unsteady flow routing, HEC-6 was available for performing sediment transport and movable bed analyses, and WQRRS was available for evaluating riverine water quality. Unfortunately, each of these computer programs had a different format for their input data and model results. One of the very first design goals for HEC-RAS was to develop a system of river hydraulics software that would allow the user to enter and store data in a single format and to be able to perform many different types of hydraulic analyses with that data. A second major design goal of HEC-RAS was to get away from entering data in the old "Card/ Record" text file format. It was envisioned that a graphical user interface would be developed in which the river system, cross sections, and all other hydraulic features would be drawn in a graphical environment that the user could directly interact with for entering and editing data. Additionally this graphical user interface would handle data management, execution of the hydraulic computations, and visualization of the hydraulic computational output. A third major design goal was consistent hydraulic computations across all of the analyses types. HEC-2, HEC-6, and UNET all computed cross section conveyance and structure hydraulics slightly differently, which made it difficult to transition from one model to the other. The final major design goal for HEC-RAS was to improve the hydraulic

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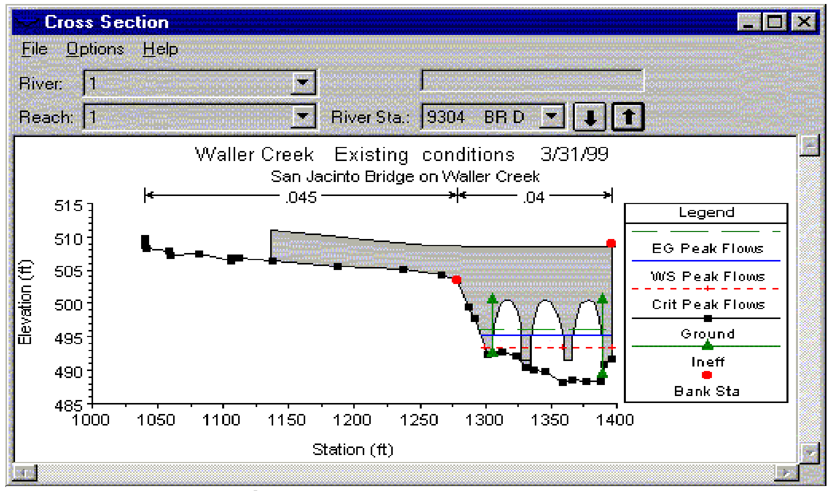
River Hydraulics Software at HEC From HEC-2 to HEC-RAS (continued)

continued from page 9

computations wherever possible. With these design goals in mind, it was decided to completely re-write all of the HEC hydraulic analysis tools from the ground up, and to combine them into a single system of software.

The development of HEC-RAS began in earnest in late 1991 with software designs, research, experimentation, and initial coding. The first version of HEC-RAS was released as a Beta test version (Beta 1.0) in May of 1993. A second Beta version followed in 1994, and then the first official release of the software (Version 1.0) was in July of 1995. This version of HEC-RAS had many similar capabilities to HEC-2, but it also had several advancements. First and foremost, the Graphical User Interface (GUI) made it much easier to enter and edit data, perform the computations, and visualize the output. Graphical displays of cross section and profile plots, rating curves, and even a 3D X-Y-Z plot of the river system and water surface profiles, were just a button click away. This capability alone was probably enough to sway most users away from HEC-2, but HEC-RAS was not just a pretty face on top of old technology. The basic way conveyance was computed for a cross section was changed to be more consistent with the hydraulic equations being used. The bridge routines were vastly improved. The geometry of a bridge was entered in much greater detail, and the computations performed were also more detailed. The users was given an array of bridge modeling approaches to choose from, without having to recode the input data. Culvert hydraulics were also improved with more detailed analyses, and a much wider array of culvert shapes to choose from. Additionally, users could mix and match bridge and culvert openings at a single road crossing, and the software would perform a multiple opening analysis. HEC-RAS could not only perform subcritical and



HEC-RAS - Cross Section Editor

supercritical water surface profiles, it could also perform mixed flow regime analyses, locating draw downs through critical depth and hydraulic jumps. An improved FEMA floodway algorithm was incorporated that employed optimization techniques in order to find the maximum encroachment allowed at a cross section without exceeding both a change in water surface criteria and a change in energy.

In the years that followed, a new release of HEC-RAS came out every year with minor improvements and changes. The second major release of HEC-RAS came in April of 1997 with Version 2.0. This version of HEC-RAS included: inline structures (weirs and gated spillways); channel modifications tools; the Federal Highways WSPRO bridge routines; bridge scour computations; additional culvert shapes; and the ability to import terrain data from a GIS and export hydraulic results back to the GIS for flood inundation mapping. Shortly after this release of HEC-RAS, the first version of HEC-GeoRAS was released. HEC-GeoRAS allowed engineers with limited GIS experience to develop geometric data for HEC-RAS from the digital terrain data, and to process HEC-RAS results into a flood inundation map. At this time, HEC-GeoRAS was a set of scripts that ran in the ARC/INFO GIS system. HEC-GeoRAS was developed at HEC by Mr. Cameron T. Ackerman and Dr. Thomas A. Evans.

At this point HEC-RAS had every feature that was available in HEC-2, as well as many new features. HEC-RAS was nationally accepted by the U.S Army Corps of Engineers, the Federal Emergency Management Agency (FEMA), the Federal Highway Administration (FHWA), the Natural Resources Conservation Service (NRCS), the U.S. Geological Survey (USGS), and many state agencies and private engineering firms.

After Version 2.0 was released, a couple of other releases became available with minor improvements to the steady flow hydraulic computations, but at this point most of our work focused on adding unsteady flow computations to the software. At this time, the Corps standard for unsteady flow computations was HEC-UNET, which was written by Dr. Robert Barkau, a long time employ of the Corps St. Louis District, but at the time was employed at HEC. HEC-UNET had a fantastic unsteady flow equation solver that was both very fast and very robust. So instead of re-inventing the wheel, in this case, we decided to use Dr. Barkau's equation solver as the heart and soul

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of the HEC-RAS unsteady flow solution scheme. All of the hydraulic computations for cross sections, bridges, culverts, inline structures, which were developed for steady flow computations, were utilized directly for the unsteady flow computations. So a new unsteady flow program was developed that was a combination of the HEC-UNET matrix solution scheme and the HEC-RAS steady flow hydraulic computations. The first version of HEC-RAS to contain unsteady flow computations (Version 3.0) was released in April of 2000.

In addition to the unsteady flow solution scheme, several new features were made available in Version 3.0 of HEC-RAS. An output Post-Processor was developed for the unsteady flow module. The base unsteady flow computations only computed flow and stage at each node for each time step. HEC-RAS users were already used to being able to see hundreds of hydraulic output variables at each cross section from a steady flow hydraulics run. The unsteady flow post-processor computed all of the same hydraulic variables at each node for a user set of selected time steps, thus allowing all of the same output to be visualized for unsteady flow that was currently available for steady flow. Additional new features added just for unsteady flow computations were the ability to plot computed stage and flow hydrographs, lateral hydraulic structures, storage areas, storage area connections, and the ability to animate all of the graphical plots over the time span of the simulation.

The release of Version 3.0 of HEC-RAS also coincided with a new release of HEC-GeoRAS (Version 3.0). This version was the first version of HEC-GeoRAS to run within the ArcView GIS system, and was a completely new re-write of the software package. HEC-GeoRAS was an ArcView extension extension written in the Avenue programming language, as part of a Cooperative Research and Development Agreement between HEC and the Environmental Systems Research Institute (ESRI).

In the years following several new versions of HEC-RAS were released with new features and improvements to both the steady and unsteady flow computations capabilities of the software. However, during this period, the HEC-RAS development team was concentrating mostly on developing sediment transport and water quality modules for the HEC-RAS system. The goal of added sediment transport computations into HEC-RAS, was to not only duplicate the capabilities of HEC-6, but to go beyond that with the latest in sediment technologies. A first step into the sediment transport world was to develop a set of sediment transport potential algorithms, as well as a set of stable channel design and analysis features, which we added to the HEC-RAS Hydraulic Design section of the software. From there we began coding our first sediment transport/movable bed module for HEC-RAS. Realizing that HEC-6 was the product of over thirty years of software development experience, and has had broad application around the world, we enlisted the help of the HEC-6 author Mr. Tony Thomas. At this point in time, Tony was retired from the Corps of Engineers, and had his own consulting firm built around the development and application of HEC-6T (T for Tony). Tony came to HEC through our Visiting Scholar Program and worked for seven months with our sediment development team, consisting of Mr. Stanford Gibson (HEC-RAS sediment lead), Steve Piper, Gary Brunner, and Dr. Michael Gee. During that time we were able to re-write the basic capabilities of HEC-6 into HEC-RAS.

During that same period of time, we also spent a lot of development time on adding water quality analysis capabilities to the HEC-RAS software system. Mr. Mark Jensen and Dr. Cindy Lowney headed up our water quality development team at HEC. The first capability developed was a detailed water temperature module. From there the fate and transport of arbitrary conservative and non-conservative constituents, dissolved nitrogen (NO3-N, NO2-N, NH4-N and Org-N), dissolved phosphorus (PO4-P, OrgP), algae, CBOD, and dissolved oxygen were added to the software. The water quality module in HEC-RAS solves the one-dimensional advection-dispersion equation using the QUICKEST-ULTIMATE explicit numerical scheme (Leonard, 1979, Leonard, 1991).

Once we felt we had a reasonable set of new tools for both sediment transport modeling and water quality analyses, we released a new version of HEC-RAS (Version 4.0) in March of 2008. Since that time we have continued working on sediment transport modeling, water quality analyses, and general hydraulic modeling improvements.

Currently we are working on a wide range of new capabilities for HEC-RAS, such as: adding sediment transport to our unsteady flow module in HEC-RAS; riparian shading algorithms for our water quality module; linking HEC-RAS with the 2-dimensional hydrodynamics model ADH (Adaptive Hydraulics); automated Manning's n value calibration algorithms; the computation of model uncertainty; and inundation mapping directly from within the HEC-RAS software.

Data Management at HEC

Contributed By Arthur F. Pabst, PhD, retired from HEC

There is an Ethiopian proverb that says, "*Little by little the egg will walk*". So it has been with the development of data management at HEC. In some respects the development of data management at the Hydrologic Engineering Center (HEC) parallels the development of its software products. In other cases it has followed behind software development and in a few cases it has lead the way dragging the software products into new vistas of capability and ease of functionality.

The initial software that HEC produced in the mid-1960's was a collection of independent programs. Written in FORTRAN they systematized the hydrologic computations that engineers had been doing for years with hand written tables and Marchant desk calculators. The two programs that most typified this work were "Unit

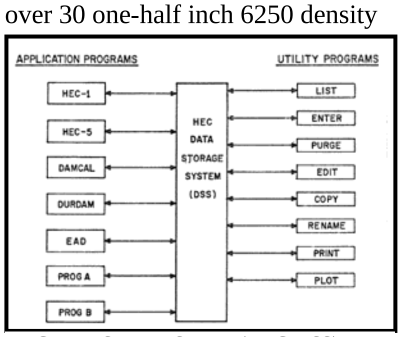
Marchant Desk Calculator (Laura Neal)

Graph & Hydrograph Computation" and "Combining and Routing". The first program was used to generate hydrographs by applying the rainfall excess from a storm to pre-defined unit hydrographs. Punched card output of the runoff hydrographs could then be supplied as input to the second program to combine and route the flows to produce basin runoff at the outlet of a larger watershed unit. So it was that data management in a most simple form was born.

So why not put all the computational capability into a single program so that the hydrograph generation, along with the combining and routing could all be "done at once". HEC-1 was born to meet this need. Now data management took place inside HEC-1, yet the same punched card transfer approach continued to be used when HEC-1 output was needed by another analysis tool like HEC-5 for reservoir operations. Into the early and mid-1970's data management remained at this level with line printer graphics serving the graphical display need.

It was not until the mid-1970's that thinking began on concepts to organize hydrologic information in a way that facilitated its passage between programs, but more importantly its persistence in retrievable form outside of the programs that used it. The three events that were seminal in bringing focus to this need were the National Hydro-Power Study, the evolving needs in Real-time Water Management, and the Kissimmee Basin Study.

The national hydropower study required a nationwide database of potential sites that could be developed for hydropower. The study involved extensive input from all Corps Districts, the identification of USGS stream gage sites and the processing of period of record daily streamflow data across the entire US. A massive request to the USGS for streamflow data yielded over 30 one-half inch 6250 density

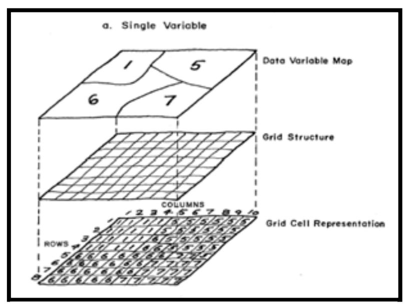


HEC Data Storage System (HEC-DSS)

magnetic tapes that were shipped to the Lawrence Berkeley Laboratory (LBL) site in California. Capabilities were developed to allow this study to be accomplished with access by each of the Corps Districts. While the products were single use specific for the National Hydro-Power Study, they planted many of the seeds that would sprout in later data management developments.

In November of 1975 a Real-Time Water Control Management seminar was held at HEC that surfaced the need for and set directions for data management in the Corps water management. The first elements of the systematic management of historical and real time data were surfaced at that seminar.

The Kissimmee Basin Study for the Jacksonville District required an organized way of generating hundreds of hydrologic inputs, evaluate them against hundreds of operational and environmental scenarios, and yield economic consequences that could be presented in well ordered reports and tables. The HEC Spatial Analysis Methodology (HEC-SAM) used in this study was the



Grid Cell Data Bank

forerunner of modern day Geographic Information Systems (GIS) used for capturing spatial information in a form that could be used in water resource investigations. This study was decisive in setting directions for future hydrologic and economic analysis in its use of a Grid Cell Data Bank technology.

Out of this conjunction of events came what is now the Hydrologic Engineering Center - Data Storage System (HEC-DSS). The first actual development of DSS was

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Data Management at HEC (continued)

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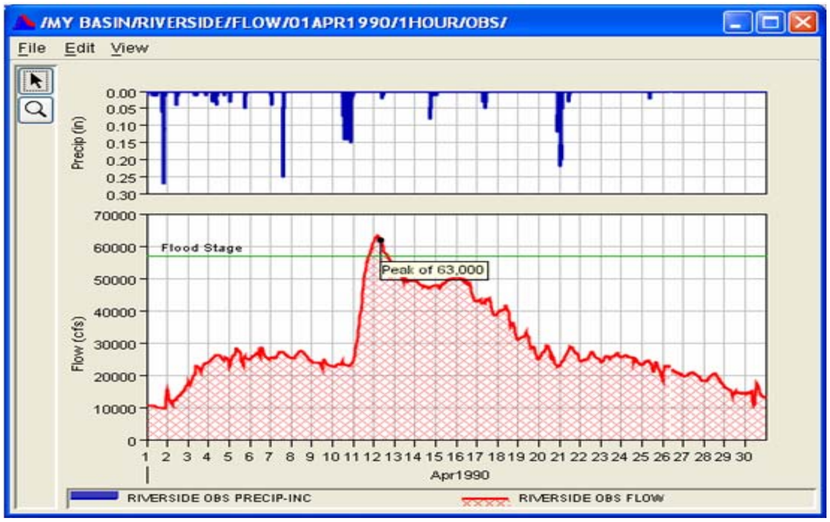
formulated to meet the needs of the Kissimmee Study, but was done with the then realized forethought of a system to meet many generalized data management needs. The first implementation of DSS was written in FORTRAN for execution on the LBL computer system. It was based on an index of "pathnames" that pointed to variable length data records. Early on major consideration of the design of DSS was focused on high performance and simplicity for users. The "pathname" was a simple way of identifying the data being stored so that users could create, store, retrieve, display, and otherwise know what data they had and be able to touch and see it conveniently. The system forced a flexible convention that allows user choice of names with fixed identifiers of data types that ensure consistent self-documentation of data, units, times, etc.

With the development of DSS came the realization that when hydrologic programs get their input from a database and return their results to a database, a set of utilities can be provided that are usable and re-usable by any applications.

On the heels of DSS functionality that was implemented in many of the suite of HEC programs there was a need for improved user interfaces. Who has not wanted to scream at some piece of software that makes you enter the same thing again and again! To help users be able to define a graphics plot and view the current data today and again tomorrow the PREAD user interface was implemented. It was a simple capability that could be imbedded within any FORTRAN program. With this capability users could define a "macro" that could be run easily to perform complex operations with a few key strokes, or mouse clicks. By the mid-1980's DSS was a critical component to efficient Corps hydrologic studies and water management activities.



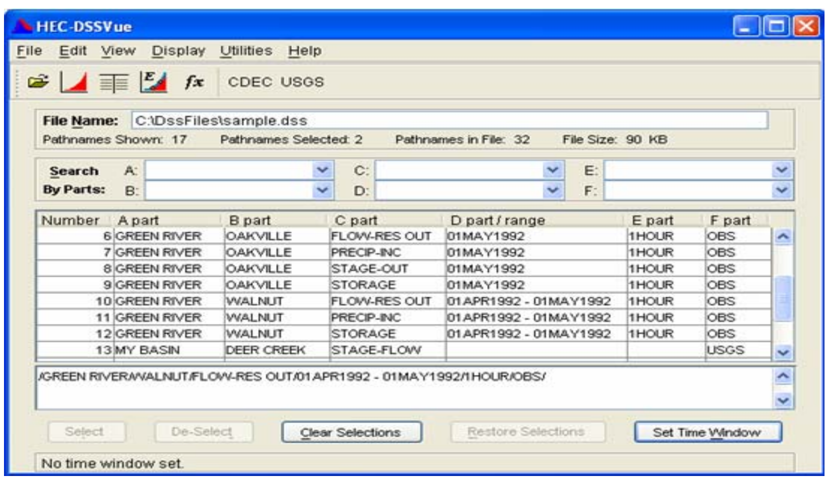
HEC-DSSVue Combination Plot—Precipitation & Flow

Because DSS was focused on providing capabilities for its user community its design continued to emphasize performance and simple user access. Over time DSS was ported to mini-computers, PC's, and UNIX systems.

The 1990's brought a realization that as computer hardware and operating systems evolved HEC software must also continue to change to meet new needs and utilize new system capabilities. The "NexGen" project was implemented to re-invent the suite of HEC software. DSS was re-written to interface with the Java language being used to develop new generation software.

HEC-DSS now exists on the PC as the Windows product DSSVue that features capabilities to imbed plug-ins extending its ability to meet changing user needs. Data can be easily imported from various sites on the Internet and can accommodate varying data formats.

HEC-DSS is not intended to meet the needs of a general relational database. It never was and never will. It does, however, provide an outstanding capability to manage time series data and related data needs of water resource engineers the world over. HEC-DSS came alive more than thirty years ago and it continues to adapt and improve over time.



HEC-DSSVue Interface

"Little by little the egg will walk"

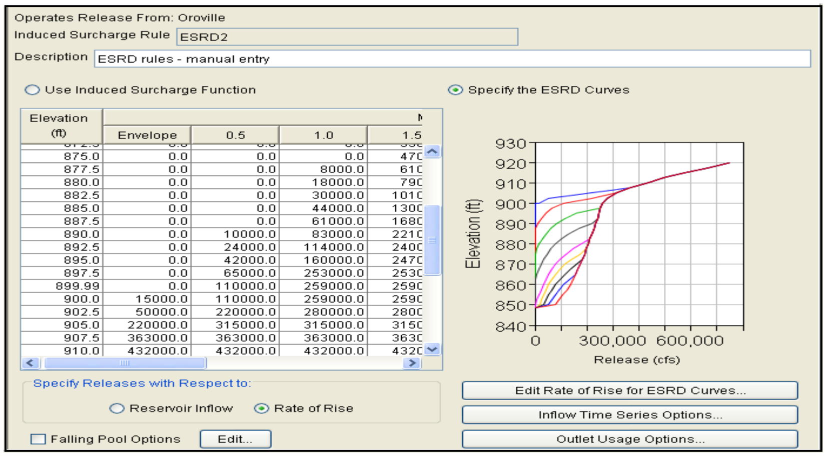
A History of Reservoir Modeling

Contributed By Joan Klipsch, Beth Faber, P.E., PhD, & Marilyn Hurst

The development of reservoir modeling software at HEC began with our first director, the late Mr. Leo R. Beard. Mr. Beard's first reservoir simulation program, RESYLD, could simulate the monthly conservation operation of one reservoir for one downstream demand center, and was first released in 1966.

To capture a more complex system of reservoirs and demands, Mr. Beard and his development team produced HEC-3 two years later. This generalized, multi-reservoir simulation program could simulate almost any configuration of reservoirs, diversions, and downstream control points for water supply, hydropower, and diversion demands, all on a monthly time-step. HEC-3 was eventually expanded by Mr. Augustine J. "A.J." Fredrich to include system hydropower simulation, incorporating a reservoir balance scheme that provided great flexibility for representing the operation and interaction of several reservoirs for a common objective.

To address the need to model flood control operation at an hourly or daily time step, Mr. Bill Eichert, the second director of HEC, released HEC-5 in 1973. HEC-5 incorporated most of HEC-3, but it initially considered only flood control operational constraints for a single event. HEC-5 was later expanded by Mr. Eichert, Mr. Vernon Bonner, Mr. Richard Hayes, Ms. Marilyn Hurst, and others, to include all the conservation features from HEC-3, including continuous simulation for period of record analyses. At the request of Corps district offices, HEC-5 was enhanced to include many additional features to expand its ability to represent flood control, water supply, hydropower, and real-time flood operation. Over the years, several utility programs were also created by the HEC-5 development team to facilitate the development and analysis of HEC-5 models, including INCARD, CKHEC5, INFIVE, MOD5, and MENU5. The last release of the HEC-5 package of programs was Version 8.0, October 1998.



HEC-ResSim Editor—ESRD Rules

As part of HEC's work on the National Hydropower Study, Mr. Gary Franc produced the HYDUR program. Released in 1980, HYDUR was used to analyze hydropower production at run-of-river reservoirs using flow duration techniques.

In addition to the variety of reservoir simulation capabilities, the next step in reservoir modeling at HEC was development of optimization capabilities (beyond HEC-5's basic flow & storage optimization options). In 1991, Dr. David Ford and Mr. Robert Carl began work on a "prescriptive" reservoir model, HEC-PRM. At a monthly time-step over a period of record, PRM optimizes the reservoir release sequence based on a set of penalty functions. PRM has been applied to a number of large scale watersheds including the Columbia and Missouri Rivers.

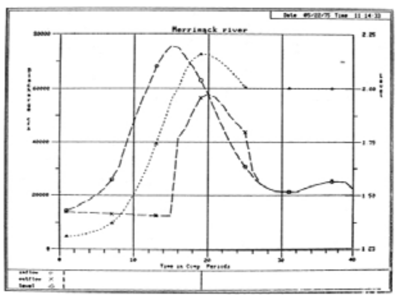
HEC started work on its graphically-oriented Next Generation Software Development Project in 1990, under the leadership of HEC's third director, Mr. Darryl Davis. HEC-ResSim, HEC's "NexGen" reservoir simulation program, is designed to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints, such as water supply, recreation, hydropower, navigation, and flood control. Development of HEC-ResSim began in 1998 and the first release, Version 1.0, was made to Corps water control offices in September 2001. It has a graphical user interface, a map-based schematic, and a zone- and rule-based schema for defining the operational objectives of each reservoir. ResSim can represent both large and small scale reservoirs and reservoir systems. It can simulate single events or a full period-of-record using time-steps from 15min to 1day. With the addition of conditional logic and user-defined scripted state variables and rules in Version 3.0 of HEC-ResSim, users can now model more complex reservoir systems and operational constraints than ever before. The interest in HEC-ResSim is ever expanding as it is being used on projects throughout the country and even overseas. HEC-ResSim's development of new features, continued maintenance of its extensive generalized capabilities, and the availability of the software and documentation merits the recognition as the current incarnation of the "free world's most powerful reservoir simulation program"!

Water Management at HEC

Contributed By Arthur F. Pabst, PhD, retired from HEC

There is an Ethiopian proverb that says, *"Don't catch a leopard by the tail, but if you do, don't let it go"*.

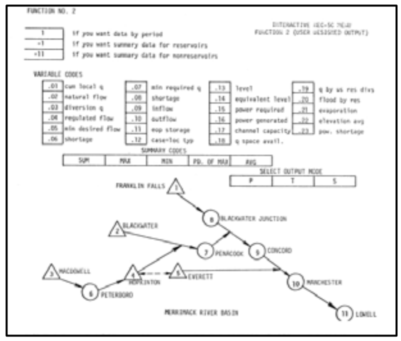
In November of 1969 HEC held a seminar on Reservoir System Analysis. It was attended by many individuals from Corps Divisions and Districts. Some of the participants were focused on design of reservoir systems others on their operation. By this time, the North Pacific Division (NPD) had been using computers to help regulate the Columbia River basin for ten years. Without doubt HEC's documented interest and involvement in Corps Water Management can be traced to this event and likely existed as a concern in those who first came together to form the HEC staff.



WCDS Plot

The first Director, the late Mr. Leo R. Beard was personally interested in reservoir system analysis and brought with him experience with reservoir system design and operation from work at Corps district offices. HEC-3 "Reservoir System Analysis Conservation" was an early attempt to bring a computer program to bear on reservoir operations.

When the New England Division (NED) implemented a satellite based real time data acquisition system HEC was asked to assist in developing a model that would forecast flows in the Merrimack River Basin. Because creditable precipitation measurements were not available in the mountainous areas of New Hampshire and Vermont, NED wanted a system that would be based only on measured streamflow. In 1975 HEC developed a forecast model that used regression equations to relate future streamflow at a location to current and past streamflow at upstream locations. The procedure used hydrograph routing and differences to estimate local flow areas. Flows were then input to the HEC-5C model to provide reservoir releases.



HEC-5C Schematic

It is interesting to note that the results of the analysis were saved in a form that could be accessed by a Tektronix 4014 terminal for graphical presentation. The 4014 also supported a graphics tablet that allowed the user to point to the location on the diagram to display a hydrograph or other desired plot. All the basics of today's graphical user interface (GUI) and display are reflected in this product implemented over thirty-five years ago.

The later 1970's were an era of focus on real-time data acquisition systems. Land line systems were often unavailable during storms when they were most needed. Satellite, meteor burst, and radio systems were all used with the satellite being most preferred. Established through interagency agreements, the Standard Hydrometorological Exchange Format (SHEF) came into its own to be the format for exchanging real-time data. In this period the need for a database became essential. The HEC-DSS system was developed to meet needs in water control and general water resource investigations. DSS was designed so that it handled both historical and real-time data seamlessly. Databases of other agencies were considered, but some had developed systems that separated historical data from real-time data imposing unnecessary restrictions on model users.

Software development for water control in the Corps lacked adequate R&D funding. Most developments were made when a Corps office provided funds for both developing a capability and implementing it for their office. That new software was then made available for use by other Corps offices.

There was a progression of computer resources used for water management. Limited in-house automated data processing (ADP) resources were then available for engineering and specifically real time water management needs. Computers at the Lawrence Berkeley Laboratory were used for some applications, but most Corps offices lacked direct communication access to them. From the late 1970's and through much of the 1980's the GSA-sponsored Teleprocessing Services Program (TSP) provided nationwide access to commercial computer resources. A series of TSP vendors (primarily Computer Sciences Corporation and Boeing Computer Services) helped to meet Corps water management and general engineering needs. As technology improved (early to mid 1980's) the in-house mini-computer (HARRIS Corporation) became the desired computer resource for water management applications. This trend has continued to this day with UNIX based Sun servers and PC's hosting current water management applications.

The Huntington District played a major role in HEC's continued involvement in water management software development. In about 1980 HEC was funded to provide a forecast model for the 16,900 square mile Scioto River Basin in Ohio. At

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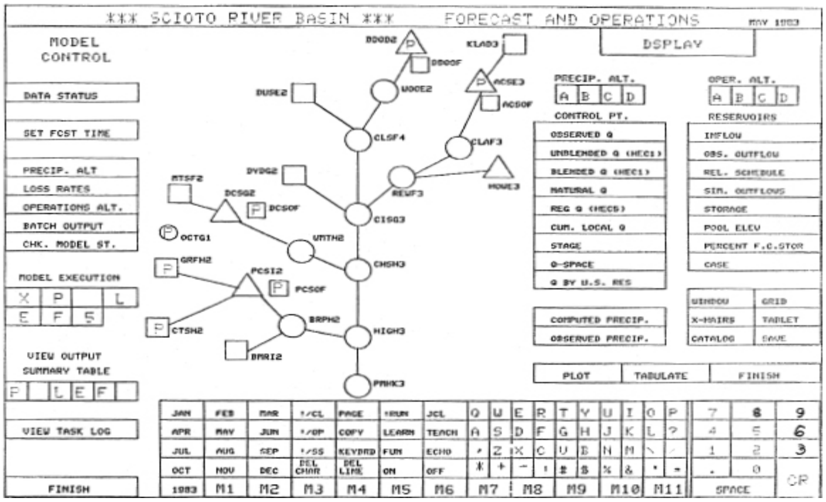

WCDS Schematic—Scioto River Basin

this time data in real-time was becoming available via the Data Collection Platform (DCP) and the Geostationary Operational Environmental Satellite (GOES). The HEC-DSS data system had become a reliable functional system. The dedicated mini-computer was a practical reality. Rainfall runoff and reservoir analysis models were available. New software had been developed to manage the orderly execution of a series of models which allowed a user to run, view, analyze, and evaluate operational decisions. From this effort the first generalized Water Control Data System (WCDS) became operational.

The WCDS was developed as a collection of inter-operational tools that could be used in a variety of ways to configure a data and modeling system. This initial development became the basis for other Corps offices to pickup all or portions of the WCDS for implementation in their own offices. A series of training classes led to wide application of the data acquisition, and data management parts of WCDS in the Corps. The setting up and regular usage of forecast and reservoir operation tools remained a daunting task.

The concepts of a graphical user interface improved. Extensive tools were developed to perform data manipulations necessary to prepare remotely sensed data for use in water management decisions. The GUI was extended adding a macro capability that allowed the easy processing of a wide variety of precipitation, stage and other environmental data. As the Internet developed, so did the capability to generate dynamic reports containing real-time data for local and web based data dissemination. As Corps offices implemented WCDS components there became a need to bring order to the wide variety of applications and products.

In 1983 the Southwest Division (SWD) commissioned the creation of a Water Control - Software Design Manual. The diagrams that depicted the WCDS components grew and changed as they incorporated changing technology in hydrologic analysis, computer systems and network architecture. The publishing of this manual contributed to the continued seeking of R&D fund to support the further development of water management products that were needed for project operations.

Many field funded improvements were incorporated into the WCDS. As radar technology developed the capability to ingest and utilize spatially defined precipitation was added. In parallel with water management software development efforts went forward with R&D funding for the NexGen effort to create new generation general hydrologic and hydraulic models. These NexGen models (HEC_HMS, HEC-RAS, HEC-ResSim) were developed so that they could be used for project design as well as water management purposes.

Several attempts for R&D funding and Army funding for new WCDS software development produced no results. By the mid 1990's it became apparent that the water management community themselves had to come together and to take responsibility for the modernization of the WCDS.

On October 22nd, 1996 sixteen people met at a hotel in Arlington, Virginia to begin the WCDS Modernization Program. The purpose was to develop a Corps-wide PRIP funded Automated Information System (AIS) to support water management throughout the Corps. This program was defined by the field, funded by the field, and managed by the field. Design teams were formed to identify the software needs and capabilities. A five year development period ensued finally leading to the release of the Corps Water Management System (CWMS) Version 1.0 in 2002.

The CWMS system incorporated a full suite of new capabilities. Written to use the latest object-oriented software development tools, it was configured in a client-server architecture utilizing a powerful UNIX database and modeling servers coupled with readily available desktop PC's. The Oracle® database is used for the storage and retrieval of both relational water management data as well as the time series information. Information stored in Oracle® is accessed from the CWMS user interface, the executing analysis

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Water Management at HEC (continued)

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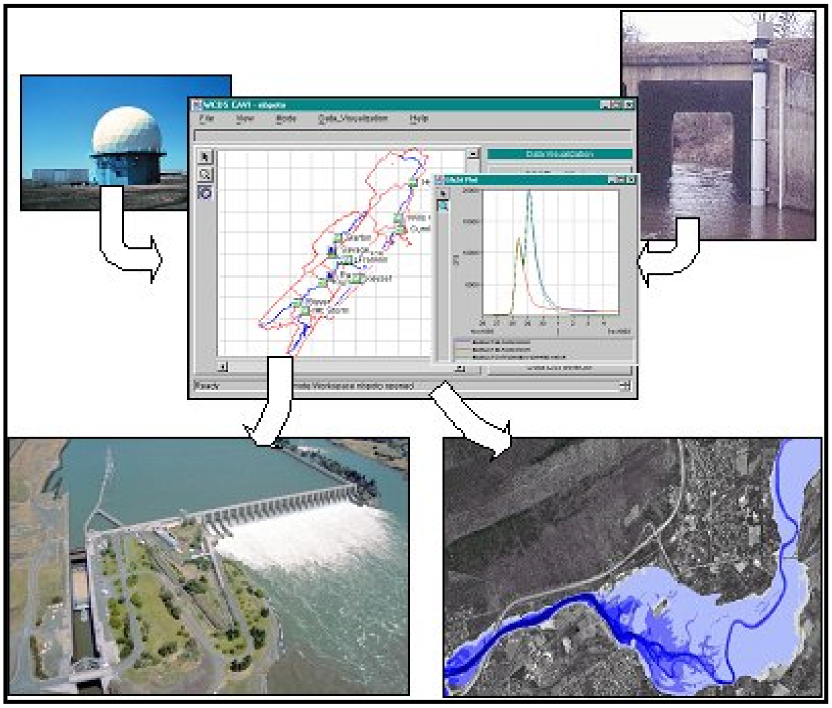

CWMS Watershed Study

models and through web based browser tools.

With the available suite of hydrologic analysis tools there are capabilities to provide vastly improved decision support products for use within the Corps and for dissemination to water management partners.

The interplay of computer hardware capabilities, wide-area communication networks, Continuity of Operations Plans (COOP), and ultimately the local office responsibility for water management decisions have always created interesting dilemmas in configuring water management systems. Many studies have been undertaken considering local, regional, and national configuration alternatives for water management. Consideration of all these factors weighted against the one fact of who has ultimate responsibility for decisions that have life threatening considerations have led to the present configuration, which incorporates standardized software, but leaves each operating office in control of its own data collection processes and the tailoring of the computer configurations to their needs. This is a very flexible arrangement, but a challenging one to support and manage nation-wide. but CWMS has that leopard by the tail and there is no letting go!

Flood Control to Flood Risk Management (HEC-FDA)

Contributed By Robert Carl, P.E. & Penni Baker

Flooded Structures

An early mission of the Corps of Engineers was to provide nationwide flood control. The implementation of this mission has evolved over time, moving from flood control to flood damage reduction and now most recently, to flood risk management. Regardless of what it is called, HEC has developed software and techniques for analyzing flood risk management and flood damage reduction for many years. During the early 1970's a study for the Philadelphia District (US Army Corps of Engineers) required a more comprehensive flood damage computer program, Expected Annual Damage (EAD), which was designed and developed by the late Harold Kubik, Darryl Davis, and the late William Johnson. It was first released in June 1977 for general use and was followed by several additional releases of the software.

In the early 1990's, several pieces of HEC software were combined into the Flood Damage Program Package. The EAD program was joined by the Damage Reach Stage-Damage Calculation (DAMCAL) program, the Structure Inventory for Damage Analysis (SID) program, and, the SIDEDT program. The SID software created a structure inventory and then computed stage-damage functions. DAMCAL processed the geo-spatial information of land use and then computed stage-damage functions. Other HEC software was used to provide without and with project discharge-probability curves and water surface profiles (HEC-1, HEC-2, HEC-5). This information was shared through HEC's Data Storage System (HEC-DSS) software. The analyst could use the

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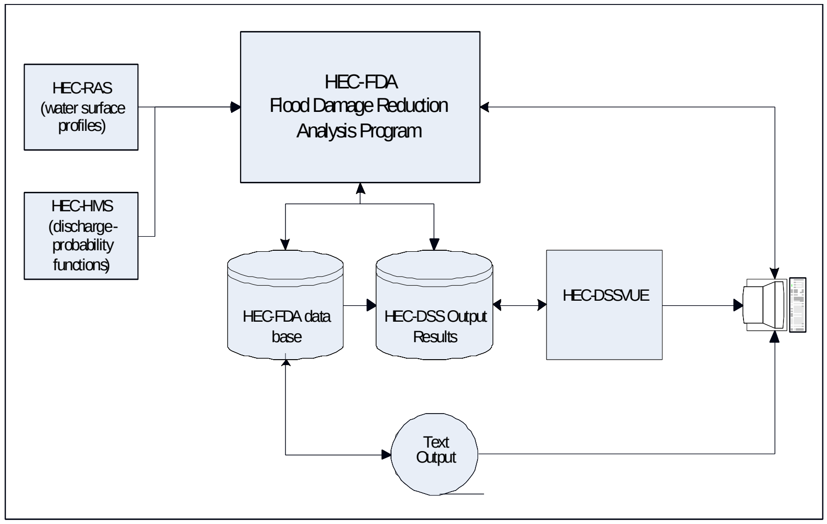
Flood Damage Program Package to formulate and evaluate alternative flood damage reduction plans by modeling existing and future conditions, as well as evaluate proposed flood damage reduction plans by computing expected annual damage (EAD) and equivalent annual damage. At this time the package was only available for mainframe computers.

In the late 1980's and early 1990's, USACE policy began requiring the use of risk-based analysis when formulating flood damage reduction projects. During this timeframe HEC began assisting IWR in presenting a series of workshops on understanding the concepts and methods of risk and uncertainty for project analysis. Also, under the direction of Earl Eiker and Darryl Davis, HEC developed a spreadsheet template add-on that allowed the practitioner to perform flood damage risk assessments using an event sampling methodology. During this timeframe, the Flood Damage Program Package was made available for the personal computer world, essentially the same package of software as for the mainframe, but with a menu to enter data and execute the software.

In the early 1990's HEC embarked on a next-generation hydrologic engineering program package development project for it's major pieces of software. This effort was an integrated, Center-wide effort with the focus on software for river hydraulics, catchment runoff, reservoir systems, and flood damage analysis. The initial target platform was UNIX based workstations, but the personal computer was taking over the computing world, so the focus soon became the personal computer workstation.

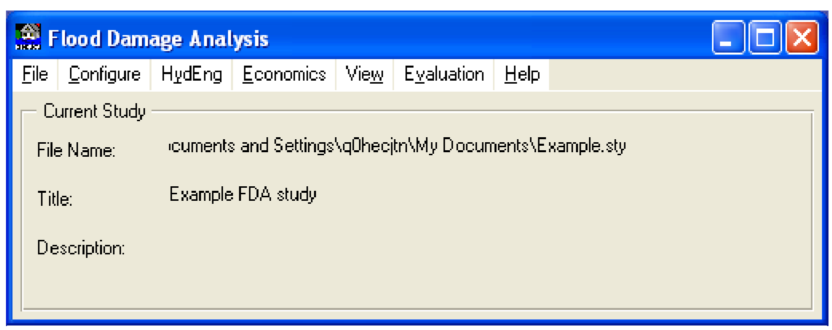
The first release of the next-generation software was in 1995, with the release of the HEC-RAS software.



HEC-FDA Flow Chart

The flood damage software was being developed that paralleled the earlier software of the 1970's and 1980's but included Monte-Carlo simulation techniques to analyze risk and uncertainty in both hydrologic and economic inputs and results. HEC-FDA also incorporated an advanced graphical user interface (GUI) and extensive database capability to manage extensive amounts of data. The first version was released in 1996 and the current Version 1.2.4 was released in November 2008.

HEC-FDA is designed to assist USACE study members in using risk analysis procedures for formulating and evaluating flood risk management measures (EM 1110-2-1619, ER 1105-2-101) and in analyzing the economics of flood risk management projects. The software, 1) stores hydrologic and economic data necessary for an analysis, 2) provides tools to visualize data and results, 3) computes expected annual damage (EAD) and equivalent annual damages, 4) computes annual exceedance probability (AEP) and conditional non-exceedance probability as required for levee certification, and, 5) implements the risk analysis procedures described in EM 1110-2-1619.



HEC-FDA Interface Version 1.2.4

The software follows functional elements of a study involving coordinated study layout and configuration, hydrologic engineering analyses, economic analyses, and plan formulation and evaluation. HEC-FDA is used continuously throughout the planning process as the study evolves from the base year without-

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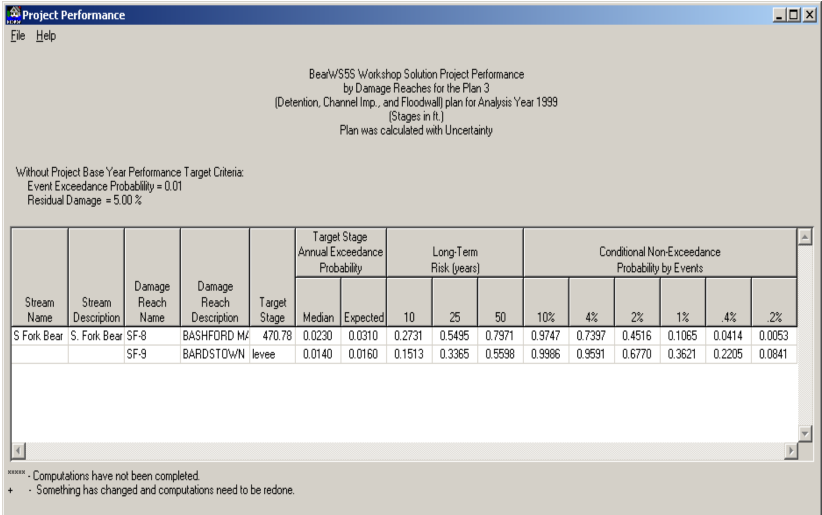
project condition analysis through the analyses of alternative plans over their project life. Hydrologic engineering and portions of the economics are performed separately, but in a coordinated manner after specifying the study configuration and layout, and merged for the formulation and evaluation of the potential flood risk management plans.

For the future, Version 1.4 of the software will be released towards the end of FY2009, with a fix to the order statistics algorithm that is used to compute exceedance probability functions. Toward the end of calendar year 2009, Version 2.0 will be released; this version will be a significant advance over the earlier versions of HEC-FDA. HEC-FDA 2.0 will have a new graphical user interface, that allows the user to more readily view and organize their study data. The new interface will contain geographic information system (GIS) components that will greatly enhance the applicability of HEC-FDA for flood risk management studies. Version 2.0 will also contain features for evaluating and comparing non-structural measures within a flood damage reduction study. Finally, damage in HEC-FDA 2.0 can be computed using the existing method (aggregated stage-damage functions) or on a structure-by-structure basis using depth grids.

The ability to use spatially referenced data to develop input for a new study or to upgrade the data in an existing database will be a key feature of HEC-FDA 2.0. GIS capabilities in the version will allow users to create structure inventories from parcel maps, census block data, or land use shapefiles. This capability will provide a cost effective way to update existing structure inventories or create approximate structure inventories for future conditions.



Project Performance

File Help

BearWS5S Workshop Solution Project Performance
by Damage Reaches for the Plan 3
(Detention, Channel Imp., and Floodwall) plan for Analysis Year 1999
(Stages in ft.)
Plan was calculated with Uncertainty

Without Project Base Year Performance Target Criteria:
Event Exceedance Probablility = 0.01
Residual Damage = 5.00 %

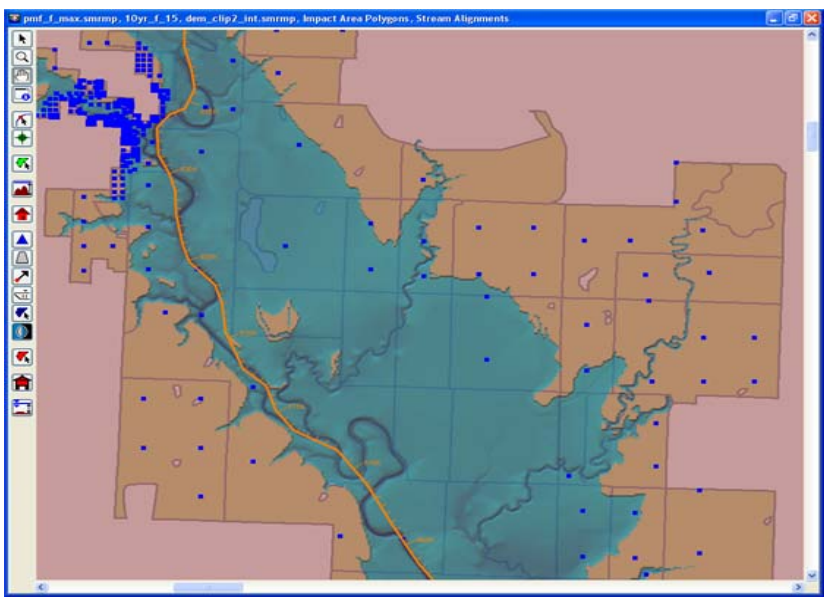
Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
					Median	Expected	10	25	50	10%	4%	2%	1%	.4%	.2%
S Fork Bear	S. Fork Bear	SF-8	BASHFORD M/	470.78	0.0230	0.0310	0.2731	0.5495	0.7971	0.9747	0.7397	0.4516	0.1065	0.0414	0.0053
		SF-9	BARDSTOWN	levee	0.0140	0.0160	0.1513	0.3365	0.5598	0.9986	0.9591	0.6770	0.3621	0.2205	0.0841

***** - Computations have not been completed.
\+ - Something has changed and computations need to be redone.

HEC-FDA Output

Another goal of HEC-FDA 2.0 is to allow an analyst, not proficient in GIS, to be able to readily manipulate, analyze, and display spatially referenced data layers on his or her workstation, which would improve their efficiency when completing a flood damage analysis study. Spatially referenced data layers commonly used will include stream system alignments, aerial photographs, flood inundations depth grids, county parcels and census blocks information, land use patterns, impact area polygons, and jurisdictional and political boundaries (communities, counties, states, watersheds and basins, Congressional districts, etc.).

HEC-FDA 2.0 will also have features that allow for clear-cut analysis of non-structural flood damage reduction measures. These measures will include removing, relocating structures and flood-proofing structures, as well as installation of a flood warning system.



HEC-FDA Version 2.0 GIS Capabilities

HEC PROSPECT Training Program

Contributed By Matthew McPherson, PE, D WRE

HEC submitted a proposed FY 2010 PROSPECT training schedule (see table below) to the Corps' Professional Development Support Center (PDSC) in Huntsville, AL, which finished a training survey in June 2009. The dates for all the classes are fixed. The course numbers in the table below marked with an asterisk remain subject to cancellation due to low enrollment. Please check the HEC website for the latest information about these courses.

HEC is offering the classes normally conducted each year such as Water and the Watershed, Hydrologic Analysis for Ecosystem Restoration and Risk Analysis for Flood Damage Reduction Projects, along with other classes presented in alternating years, Flood Frequency Analysis, and Hydrologic Modeling with HEC-HMS. If you are interested in any of the FY 2010 training classes, be sure to register as soon as possible.

To register for our classes, please contact the appropriate party in your office or contact PDSC, http://pdsc.usace.army.mil. Registration is handled by Training and Operations (CEHR-P-RG).

Course descriptions are provided in the "Purple Book" at the PDSC site (this link is for the FY 2009 Purple Book) (http://pdsc.usace.army.mil/downloads/PurpleBook2009.pdf). A short description along with course agendas is also provided on HEC's web site (http://www.hec.usace.army.mil/training/course_list.html). To obtain enrollment information, please contact the Huntsville District. When doing so, please note the course number, name, date, and location, then contact the address listed below:

CEHR-P-RG
USACE Professional Development Support Center (PDSC)
550 Sparkman Drive
Huntsville, AL 35817
Phone: (256) 895-7421
FAX: (256) 895-7465

Course Number	Course Title (all classes located in Davis, CA)	Dates
114	Steady Flow with HEC-RAS	26-30 October 2009
164	Water and the Watershed	16-20 November 2009
209	Risk Analysis for Flood Damage Reduction Projects	7-11 December 2009
98*	Reservoir System Analysis with HEC-ResSim	11-15 January 2010
320	H&H for Dam Safety Studies	25-29 January 2010
161*	Hydrologic Analysis for Ecosystem Restoration	22-26 March 2010
152*	Water Data Management with HEC-DSSVue	12-16 April 2010
123	Flood Frequency Analysis	17-21 May 2010
219	Hydrologic Engineering Applications for GIS	21-25 June 2010
188*	Unsteady Flow Analysis with HEC-RAS	26-30 June 2010
178	Hydrologic Modeling with HEC-HMS	16-20 August 2010

The above schedule is current as of August 2009, please be sure to access the PDSC site for the correct training schedule information.

Source for the Mustang emblem on page 7: www.fordvehicles.com/cars/mustang)