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Status and New Capabilities of Computer Program HEC-6: Scour and Deposition in Rivers and Reservoirs

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14. ABSTRACT
Last year the Hydrologic Engineering Center (HEC) and the Waterways Experiment Station (WES) incorporated the results from more than ten years of research and development into a new version of computer program HEC-6: "Scour and Deposition in Rivers and Reservoirs" (HEC, 1977). Because of the extensive modifications made to HEC-6, an entirely new User's Manual was also prepared. HEC released a Beta Test Version of the program in the Fall of 1989, for field testing. Public release of the new version of HEC-6 is scheduled for September 1990. This paper describes the present status of the programs as of April 1990, the expanded capabilities, and the improved documentation to be included in the forthcoming release of computer programs HEC-6.

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STATUS AND NEW CAPABILITIES OF COMPUTER PROGRAM HEC-6: "SCOUR AND DEPOSITION IN RIVERS AND RESERVOIRS"

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Abstract

Last year the Hydrologic Engineering Center (HEC) and the Waterways Experiment Center (WES) incorporated the results from more than ten years of research and development into a new version of computer program HEC-6: "Scour and Deposition In Rivers and Reservoirs" (HEC, 1977). Because of the extensive modifications made to HEC-6, an entirely new User's Manual was also prepared. HEC released a Beta Test Version of the program in the fall of 1989, for field testing. Public release of the new version of HEC-6 is scheduled for September 1990. This paper describes the present status of the program as of April 1990, the expanded capabilities, and the improved documentation to be included in the forthcoming release of computer program HEC-6.

General Background

Computer program HEC-6, "Scour and Depositions in Reservoirs" is a one-dimensional, movable boundary, open channel flow model designed to simulate streambed profile changes over fairly long time spans (typically years). The first nation-wide distribution of the program was made in 1973 and again in 1977 after considerable expansion and improvement was made to the original code. The Hydrologic Engineering Center has maintained and distributed the HEC-6 computer program, instructional materials and support documents since then. Research and development to further expand the capabilities of HEC-6 continues to occur at the Hydrologic Engineering Center and the Waterways Experiment Station. HEC-6 has become the "Industry Standard" for the Corps of Engineers as their primary mobile boundary model for one-dimensional applications.

Last fall (1989) a new version of computer program HEC-6 that incorporates results from more than ten years of research and development was released to select users for field testing. Along with the new program an entirely new User's Manual was also prepared. At the present time sixteen Corps District offices and the Waterways Experiment Station, are applying and testing the new "Beta Test Version" of the program for on-going project applications.

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Computer Requirements

The Beta Test Version operates on both microcomputers and Harris mainframe machines. HEC-6 has the following characteristics and requirements for IBM-compatible microcomputers:

640 Kilobytes (KB) of Random Access Memory (RAM) with 565 Kilobytes free.

MS DOS 2.1 or greater Operating System.

A math coprocessor (8087, 80287 or equivalent) is required.

One 5 1/4 inch floppy diskette drive and a 10 Megabyte (or larger) hard disk.

Users may apply COED (the Corps of Engineers Editor, HEC, 1987) or any other editor to create and edit input files, as long as they conform to the standard HEC-6 format requirements.

Beta Test Version files include the HEC-6 Executable Program, Test Input Data files, and Output files that correspond to the example input. The new User's Manual has been completely rewritten and includes: (1) installation and application instructions, (2) sections for "notation" that are indexed to the location in the manual where the terms are defined and used, (3) expanded discussions of the theory, (4) many useful diagrams and figures, (5) an "examples section" describing different problems and solutions using HEC-6, (6) an appendix containing the expanded input description, and (7) a complete glossary of mobile boundary modeling terminology.

Numerical Approach

The HEC-6 model is based on one-dimensional, gradually varied flow hydraulics and sediment transport theory. There is no provision for simulating the development of channel meanders or specifying lateral distributions of sediment load across a cross section. A continuous sequence of flows (hydrograph) is segmented into a series of steady flow "events" of variable duration. For each flow, the conservation of energy equation (Eq. 1) is solved to determine the water surface profile and pertinent hydraulic parameters such as energy slope, velocity, depth, width, etc. at each cross section. Potential sediment transport characteristics and rates (including sediment load, gradation of the load, gradation of the bed surface materials and depth of scour and/or deposition) are then computed at each cross section via the sediment continuity equation (Eq. 2) and user-selected transport functions of the form of Eq. 3. The numerical technique used to solve Eq. 1 is commonly called the Standard Step Method (HEC, 1985; Henderson, 1966; French, 1985). An explicit six-point finite difference method is used to solve Equation 2 as functions of time and space. Many empirical relationships of the form of Equation 3 are available for estimating sediment transport rates. These rates, combined with the duration of the flow, allow for volumetric accounting of sediment within each reach. The amount of scour or deposition within each reach is computed and the cross section geometry is then adjusted accordingly. The computations proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. The sediment calculations are done by grain size fraction thereby allowing for the simulation of hydraulic sorting and armoring (although the details of these processes are not well known).

Conservation of Energy: $$\frac{\partial H}{\partial X} + \frac{\partial\left(\alpha \frac{V^2}{2g}\right)}{\partial X} = S \qquad (1)$$

where
H = water-surface elevation, ft
X = distance in the direction of flow, ft
α = coefficient for the horizontal distribution of velocity
V = average flow velocity, ft/sec
g = acceleration due to gravity, ft/sec^2
S = slope of energy grade line

Continuity of Sediment Material: $$\frac{\partial G}{\partial X} + B \cdot \frac{\partial y_s}{\partial t} = q_s \qquad (2)$$

where
G = rate of sediment movement, ft^3/day
B = width of movable bed, ft
y_s = change in bed surface elevation, ft
t = time, days
q_s = lateral inflow of sediment, ft^3/ft/day

Sediment Transport Function: $G = f(V,y,B,S,T,d_{eff},d_{si},P_i)$ (3)

where
y = effective depth of flow, ft
T = water temperature, °F
d_{eff} = effective grain size of sediment in size class i
d_{si} = geometric mean of class interval
P_i = percentage of ith size class in the bed

Data Requirements and Program Capabilities

Data requirements include: (1) **geometry information** (in typical HEC-2 format), including channel shape, cross section spacing, bed slope, and bed roughness, (2) **hydraulic information**, including a continuous sequence of flows and durations, water temperature and specification of hydraulic controls and/or boundary conditions, and (3) **sediment information**, including bed material characteristics, inflowing load quantity and grain size distribution, bed armoring characteristics and selection of the sediment transport function or functions to be used for simulating sediment movement (scour and deposition).

General program capabilities are listed below. More detailed explanations of the theory and methods used for computing sediment transport quantities are found in the new users manual (HEC, 1990, Draft).

Geometry - The model is capable of simulating sediment transport in dendritic (network) river systems. A total of ten main stem, tributary, and local inflow and outflow points can be modeled simultaneously.

Hydraulics - Water surface profiles and channel hydraulic properties are determined by the standard step method (the simultaneous iterative solution of the one-dimensional energy equation and Manning's equation, HEC, 1985). Manning's "n" values for overbank and channel areas are specified by discharge or elevation. Manning's "n" within the channel can be adjusted to reflect bed material roughness by Limerinos' (1970) method. Expansion and contraction losses are included in the determination of head losses between each cross section and may be adjusted at any location along a study reach.

For each computational event, the starting water surface elevation at the downstream boundary is determined by a rating curve or a user specified water surface elevation. If desired, the downstream rating curve and any rating curves throughout the study area can change with time by specifying a new rating curve in the hydrologic data set.

Channel conveyance limits, flow containment within levees, ineffective flow areas, and overtopping of levees (but NOT split flow) are simulated in a manner similar to HEC-2. Supercritical flow is approximated using normal depth approximations, although, sediment transport phenomena occurring in supercritical reaches are not explicitly depicted by HEC-6. Detailed bridge hydraulics capabilities, like those in HEC-2, are not available within HEC-6.

HEC-6 can also be executed in a fixed-bed mode, similar to HEC-2, in which only steady water surface profiles are computed with no consideration of sediment transport effects in the channel.

Sediment Transport - Sediment transport effects are considered for all ranges of flows and for sediment grain sizes ranging from clays, 0.004 mm and finer, to gravels 64 mm in diameter. Sediment sizes larger than 64 mm may exist in a gravel bed stream, but they are not transported by the functions presently available in HEC-6. Fine clay and silt materials up to 0.0625 mm are resuspended (scoured) using Ariathurai's (1976) adaptation of Parthenaides' (1965) methods. Deposition of fine sediment material is simulated using Krone's (1962) relationships. User's choose the sediment transport function they wish to apply for a particular application. The twelve bed material load transport functions presently available in the Beta Test Version include:

a. Toffaleti's (1969) Relationship
b. Madden's (1963) modification (unpublished) of Laursen's (1958) Relationship
c. Yang's Stream Power for Sands Relation (1972)
d. Duboys (Brown, 1950)
e. Ackers-White (1973)
f. Colby (1964)
g. Meyer-Peter and Muller (1948)
h. Toffaleti (1969) and Schoklitsch (1930)
i. A combination of Toffaleti (1969) and Meyer-Peter and Muller (1948)
j. Madden's (1985) modification (unpublished) of Laursen's (1958) Relationship
k. Parthenaides (1965), Ariathurai (1976) and Krone (1962) methods for cohesive sediments
l. User specified curves for transport based on observed data

The above methods, except for method (a), utilize Colby's (1964) method for adjusting the sediment transport potential based on high suspended load concentration. Armoring and the destruction of the armor layer is simulated using Gessler's (1970) approach. Simulation of non-eroding geological controls and grade control structures is possible by specifying the elevation of the non-eroding model bottom. The lateral limits of deposition (movable bed limits) are automatically set according to the location of the water surface and high ground rather than a fixed width. Scour is limited laterally within specified limits or the computed water elevation, whichever is less. Sediment inflowing load curves for the main river and its tributaries can now vary with time. Water and sediment diversion (distributary flow) is possible at point locations along the main stem.

Other Enhancements

Many other options and features are available such as the capability to simulate channel dredging. HEC is presently developing a "Graphical Interface Program" (GIP) that prepares data for the HEC-DSS (DISPLAY) [HEC, 1987], system for graphical display of computed results. The user's manual has also been completely rewritten to provide more explanation of the theory and procedures available to users.

Summary

HEC and WES are working to release a new version of HEC-6 that incorporates the improvements and results from research and development conducted during the last decade. The following major additions and improvements are available with the new release of the HEC-6 computer program package:

1. Capability to simulate sediment transport in dendritic (network) river systems.
2. Lateral limits of scour and deposition (movable bed limits) are automatically set at each cross section according to the location of the water surface and high ground rather than a fixed width.
3. User's may choose any one of twelve different sediment transport functions.
4. Resuspension of silts and clays is now available.
5. Sorting and armoring algorithms have been improved.
6. HEC-DSS/DISPLAY for graphical display and data manipulation is being developed.
7. The user's manual has been updated and completely rewritten.

Future research activities include the investigation of (1) lateral migration, (2) coupling of boundary roughness and bed forms with sediment transport, (3) use of HEC-2 for hydraulic input, and (4) inclusion of HEC-6 within an integrated system of river analysis programs driven by digital terrain data and operated within the Corps' contemporary CADD workstation environment.

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