Contract No:

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Date: February 22, 2017

To: B. T. Butcher, 773-42A

From: K. L. Dixon, 773–42A

Reviewer: J. A. Dyer, 773-42A

Topic 34.2: QA/QC Documentation Updates for Software and Data

Recommendation 123a: Evaluate list of existing PA software to determine which software needs to be retired and whether additional software testing may be needed for remaining software due to new versions or operating environments. Perform and document testing before next PA revision.

HELP 4.0 Documentation and Software QA

Scope Abstract: This memorandum documents the update and verification of the HELP model which is used to provide infiltration estimates for facility closure caps.

Results/Conclusions: The HELP model was recompiled for use with Windows 7 and Windows 10 using the open source GFORTRAN compiler. Verification testing of the recompiled code was conducted in accordance with Q-SQA-A-00005, Rev. 1 using the test case provided. Minor differences between the results of the recompiled model and those presented in Q-SQA-A-00005, Rev. 1 were attributed to improved numerical precision, rounding, and compiler variations.

Discussion: The Savannah River National Laboratory (SRNL) uses the Hydrologic Evaluation of Landfill Performance (HELP) model to estimate water infiltration through various facility closure caps. The HELP model was developed by the U.S. Army Corp of Engineers (USACE) in conjunction with the U.S. Environmental Protection Agency (USEPA). The latest version of the software available for download from USACE is version 3.07, issued on November 1, 1997. The executable files associated with this download are no longer compatible with current versions of the Microsoft Windows operating system. To use the software, the end user must install the Microsoft Windows XP Virtual Machine shell and operate the code within the shell.

The USACE HELP model consists of multiple executable files that are initiated using DOS batch files. These executable files were created from both FORTRAN and BASIC source codes. The FORTRAN code was compiled using Ryan-McFarland Fortran Version 2.44 and the BASIC code was compiled using Microsoft Basic Professional Development System Version7.1. The BASIC executables provide a

crude graphical user interface (GUI) that may be used to create or modify the necessary soil and design data files as well as weather data files (precipitation, solar radiation, evapotranspiration, and temperature). The requirements of these files are given by Schroeder et al. (1994a and b). These fixed format files are used by the main FORTRAN computational code (HELP3O.FOR) to simulate closure cap performance. Both the FORTRAN and BASIC source codes that comprise the USACE HELP model are included with each install of the model.

As previously mentioned, the HELP model as provided by USACE is not compatible with current 64-bit Microsoft Windows operating systems and must be executed inside a Windows XP shell. This provided the motivation to recompile the computational component of the model (HELP3O.FOR) for use on 64-bit Microsoft Windows operating systems. The GNU open source GFORTRAN compiler was used to recompile the code. The only change to the code that was required to successfully recompile the executable was eliminating a call to a function defined as UTLTY. USACE personnel described UTLTY as a compiler specific object used for positioning the cursor to update the status of program execution and confirmed it has no impact on the operation of the code. At the recommendation of USACE, the call to UTLTY was commented out of the code. To preserve version integrity, the newly modified HELP Fortran code was named Help4.for and the resulting executable was named Help4.exe. It is important to note that Help4.exe is not compatible with the USACE HELP GUI but can read any input files created with the GUI.

Once the code was successfully recompiled, several changes were made to preserve functionality and improve the usability of the code. The changes include:

1. A subroutine was added to perform the SCS curve number calculations previously handled by the GUI.
2. The code was modified to allow both fixed format and free format data input for the soil and design data file (*.D10). A user selected flag was added to the main user input file "OUTPARAM.DAT" to identify the type of input data.
3. Several write statements were added to the output subroutine to provide output data in tab separated text files. The code was modified to read the path and filenames for the output data from the main user input file "OUTPARAM.DAT".
4. The output header for the HELP code was changed from Version 3.07 to Version 4.0 and "Modified by Savannah River National Laboratory" was added to prevent version ambiguity.

Verification testing of the recompiled code was conducted in accordance with Q-SQA-A-00005, Rev. 1 using the test case provided in Table 1 (Page 5). The recompiled code was tested with both Windows 7 and Windows 10 operating systems and the results were identical. The results are presented in Table 1 for both fixed format and free format input. In addition to the test case presented in Q-SQA-A-0005, verification testing was conducted using inputs documented in Phifer (2007 and 2012) and McDowell-Boyer et al. (2011). The results for these comparisons are presented in Tables 2 and 3.

A generalized folder layout for Help 4.0 is provided in Figure 1 and a batch file for successful operation of the code is provided in Figure 2. The HELP model computational code reads multiple types of data

from several different text formatted input files. The first input file read by the code is OUTPARAM.DAT which provides the path for other required input files, general program control options, and the path for output files (Figure 1). Other input files required by the program include soil and design data (*.D10), precipitation data (*.D4), temperature data (*.D7), solar radiation data (*.D13), and evapotranspiration data (*.D11). These fixed format input files may be created manually using a text editor or by using the USACE HELP GUI inside a Windows XP shell. These input files are required for successful operation of the code and must be located in the path prescribed in OUTPARAM.DAT.

Table 1. HELP 4.0 Software Quality Assurance Verification Results

	QA Plan[1] (inches)	HELP 4.0 Fixed Format (inches)	% Diff (inches)	QA Plan[1] (inches)	HELP 4.0 Free Format (inches)	% Diff (inches)
Precipitation	54.52	54.52	0.00	54.52	54.52	0.00
Runoff	2.374	2.375	0.04	2.374	2.375	0.04
Evapotranspiration	34.046	34.037	-0.03	34.046	34.037	-0.03
Lateral drainage collected from layer	19.16763	19.17677	0.05	19.16763	19.17677	0.05
Percolation/leakage through layer	0.32661	0.32672	0.03	0.32661	0.32672	0.03
Average head on top layer	5.158	5.159	0.02	5.158	5.159	0.02
Lateral drainage collected from layer	0.12868	0.12867	-0.01	0.12868	0.12867	-0.01
Percolation/leakage through layer	0.14760	0.14760	0.00	0.14760	0.14760	0.00
Average head on top layer	0.000	0.000	0.00	0.000	0.000	0.00
Lateral drainage collected from layer	0.14751	0.14752	0.01	0.14751	0.14752	0.01
Percolation/leakage through layer	0.00001	0.00001	0.00	0.00001	0.00001	0.00
Average head on top layer	0.001	0.001	0.00	0.001	0.001	0.00
Change in water storage	-1.344	-1.344	0.00	-1.344	-1.344	0.00

[1]From Table 1, Q-SQA-A-00005, Revision 1.

Table 2. Comparison of Help 4.0 to Phifer et al. (2007).

Year	Help3 Model Output File	Help4 Model Output File	Phifer Infiltration[1] (in/yr)	Help4.0a Infiltration (in/yr)	% diff
0	FC1A00O.OUT	FC1A00.OUT	0.00088	0.00088	0.000
100	FC1A01O.OUT	FC1A01.OUT	0.01045	0.01045	0.000
180	FC1A02O.OUT	FC1A02.OUT	0.17264	0.17259	-0.029
290	FC1A03O.OUT	FC1A03.OUT	0.37093	0.37093	0.000
300	FC1A04O.OUT	FC1A04.OUT	0.50333	0.50343	0.020
340	FC1A05O.OUT	FC1A05.OUT	0.99561	0.99578	0.017
380	FC1A06O.OUT	FC1A06.OUT	1.45688	1.45639	-0.034
560	FC1A07O.OUT	FC1A07.OUT	3.22974	3.23001	0.008
1000	FC1A08O.OUT	FC1A08.OUT	7.01394	7.01547	0.022
1800	FC1A09O.OUT	FC1A09.OUT	10.65084	10.65504	0.039
2623	FC1A10O.OUT	FC1A10.OUT	11.47235	11.47275	0.003
3200	FC1A11O.OUT	FC1A11.OUT	11.52987	11.53166	0.016
5600	FC1A12O.OUT	FC1A12.OUT	11.63212	11.63172	-0.003
10000	FC1A13O.OUT	FC1A13.OUT	11.67048	11.6707	0.002

[1]Table 81 from Phifer et al. (2007) and Table 4 Phifer (2012).

Table 3. Comparison of Help 4.0 to McDowell-Boyer et al. (2011).

Year	Period	Help3 Model Output File	Help4 Model Output File	Phifer Infiltration (in/yr)	Help4.0 Infiltration (in/yr)	% diff
-130 to -100	Operational	NA	NA	15.748	-	-
-100 to 0	Interim Cover	NA	NA	0.36	-	-
0	Closure Cap	ST0out.OUT	ST0.OUT	0.09761	0.09764	0.031
100	Closure Cap	ST100out.OUT	ST100.OUT	0.1074	0.10737	-0.028
300	Closure Cap	ST300out.OUT	ST300.OUT	1.2661	1.26545	-0.051
550	Closure Cap	ST550out.OUT	ST550.OUT	3.1202	3.12032	0.004
1000	Closure Cap	ST1000out.OUT	ST1000.OUT	7.28181	7.28147	-0.005
1800	Closure Cap	ST1800out.OUT	ST1800.OUT	12.25744	12.25745	0.000
2740	Closure Cap	ST2740out.OUT	ST2740.OUT	13.42916	13.43076	0.012
2805	Closure Cap	ST2805out.OUT	ST2805.OUT	13.4449	13.44265	-0.017
3400	Closure Cap	ST3400out.OUT	ST3400.OUT	13.55818	13.55573	-0.018
5600	Closure Cap	ST5600out.OUT	ST5600.OUT	13.7689	13.77246	0.026
7000	Closure Cap	ST7000out.OUT	ST7000.OUT	13.83042	13.82886	-0.011

[1]Table 81 from McDowell-Boyer et al. (2011).

References:

McDowell-Boyer, L., M. A. Phifer, and J. R. Cook. 2011. Data Package for HELP Models used in the E-Area Low-Level Waste Facility Performance Assessment. SRNL-STI-2010-00618, Rev. 0. Savannah River National Laboratory, Aiken, SC, 29808.

Phifer, M. A. 2012. Engineered Trench #3 Infiltration Estimates. SRNL-STI-2012-00782. Rev. 0. . Savannah River National Laboratory, Aiken, SC, 29808.

Phifer, M. A. W. E. Jones, E. A. Nelson, M. E. Denham, M. R. Lewis, and E. P. Shine. 2007. FTF Closure Cap Concept and Infiltration Estimates. WSRC-STI-2007-00184, Rev. 2. Savannah River National Laboratory, Aiken, SC, 29808.

Schroeder, P. R., N. M. Aziz, C. M. Loyd, and P. A. Zappi. 1994a. "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Users Guide for Version 3". EPA/600/R-94/168a, U. S. Environmental Protection Agency Office of Research and Development. September 1994.

Schroeder, P. R., T. S. Dozier, P. A. Zappi, B. M. McEnroe, J. W. Sjostrom, R. L. Peyton. 1994b. "The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3". EPA/600/R-94/168b, U. S. Environmental Protection Agency Office of Research and Development. September 1994.

C:\Help4.0
    \Proj
        \Input
            \OUTPARAM.DAT
            \Proj.D10
            \Help.bat
        \Output
    \Weather
        \Precip.D4
        \Temp.D7
        \Solar.D13
        \Evap.D11
    \Source
        \Help4.exe

Figure 1. Suggested folder layout for operating Help4.0. "Proj" may be replaced with an appropriate project name.

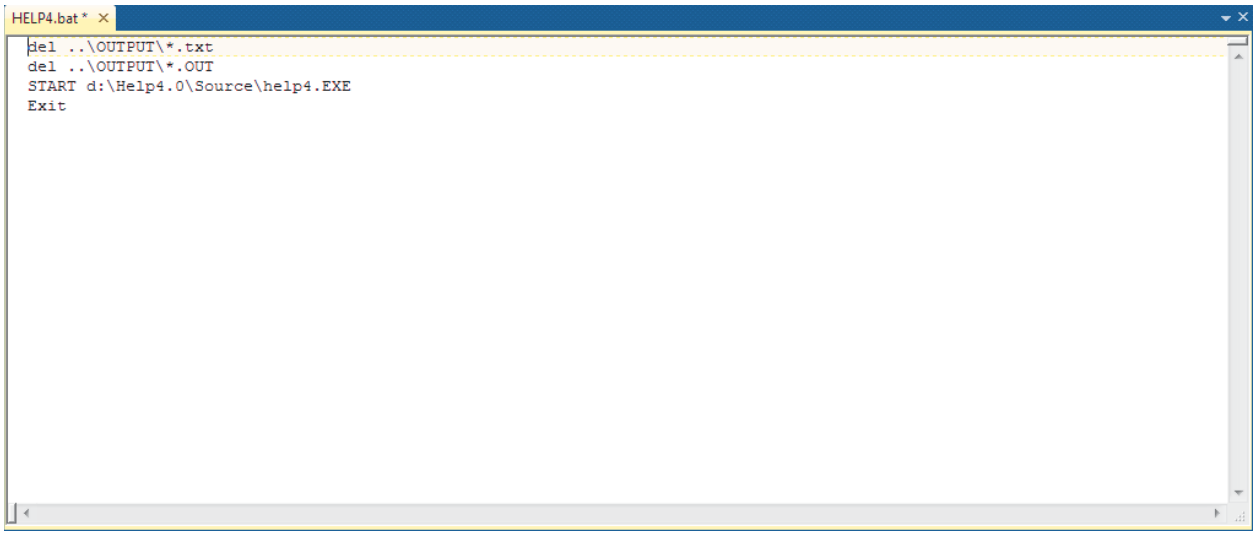

Figure 2. Batch file for operation of Help4.0.

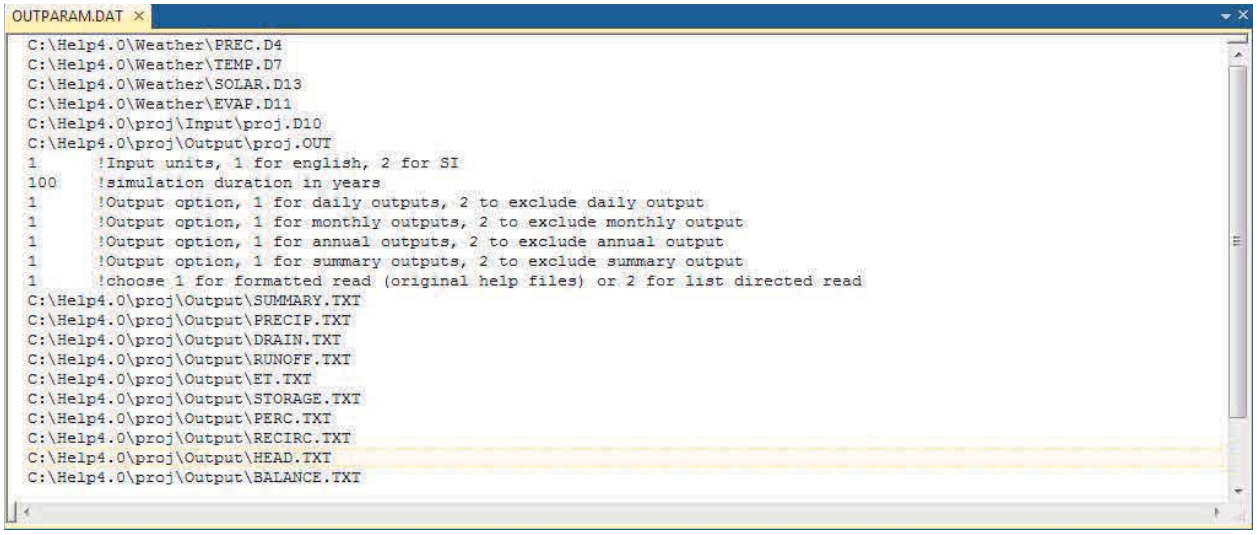

Figure 3. A typical OUTPARAM.DAT file used by Help4.exe.

Distribution:

S. E. Aleman, 735-A
B. T. Butcher, 773-42A
D. A. Crowley, 773-42A
T. L. Danielson, 703-41A
K. L. Dixon, 773-42A
J. A. Dyer, 703-41A
G. P. Flach, 773-42A
L. L. Hamm, 735-A
N. V. Halverson, 773-42A
L. O. Oliver, 773-42A
T. Hang, 773-42A
K. M. Kostelnik, 773-42A
R. L. Nichols, 773-42A
R. R. Seitz, 773-42A
T. Whiteside, 773-42A
J. L. Wohlwend, 703-41A
H. M. Cardona, EM File, 773-42A – Rm. 243