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Internet-Based Interface for STRMDEPL08

Open-File Report 2010–1247

U.S. Department of the Interior
U.S. Geological Survey

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By Howard W. Reeves and A. Jeremiah Asher

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U.S. Geological Survey, Reston, Virginia: 2010

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
	Flow rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Internet-Based Interface for STRMDEPL08

Howard W. Reeves[1] and A. Jeremiah Asher[2]

Abstract

The core of the computer program STRMDEPL08 that estimates streamflow depletion by a pumping well with one of four analytical solutions was re-written in the Javascript software language and made available through an internet-based interface (web page). In the internet-based interface, the user enters data for one of the four analytical solutions, Glover and Balmer (1954), Hantush (1965), Hunt (1999), and Hunt (2003), and the solution is run for constant pumping for a desired number of simulation days. Results are returned in tabular form to the user. For intermittent pumping, the interface allows the user to request that the header information for an input file for the stand-alone executable STRMDEPL08 be created. The user would add the pumping information to this header information and run the STRMDEPL08 executable that is available for download through the U.S. Geological Survey. Results for the internet-based and stand-alone versions of STRMDEPL08 are shown to match.

Introduction

The STRMDEPL computer code (Barlow, 2000) implements two analytical solutions for streamflow depletion by a well and uses superposition to allow for varying pumping rates. The first solution is for a system with a stream that fully penetrates the aquifer with no streambed resistance between the stream and the aquifer (Glover and Balmer, 1954; Jenkins, 1968). The second solution is for a system with a stream that fully penetrates the aquifer with streambed resistance between the stream and the aquifer (Hantush, 1965). The code was modified by the addition of two more analytical solutions and the ability to evaluate time intervals other than one day. The new solutions are for a system with a partially penetrating stream with streambed resistance (Hunt, 1999), and for system with a stream in an aquitard with pumping from an underlying leaky aquifer (Hunt, 2003). The modified code is STRMDEPL08 (Reeves, 2008).

Both STRMDEPL and STRMDEPL08 are written in Fortran and require an ASCII text input file. Use of the input file can be confusing to users because of the units used in the programs and the use of diffusivity (transmissivity/storativity). In addition, STRMDEPL08 was written to allow for use of older STRMDEPL input files which also can be confusing because input variables have different meanings depending on the analytical solution selected by the user. To resolve these issues and to make access easier, a simple interface to STRMDEPL08 was developed to evaluate the analytical solutions on the internet. The internet-based program was developed by rewriting the core functions of STRMDEPL08 in Javascript which is a language that runs on the user's computer through web pages (client-side processing). The only major feature of STRMDEPL08 that was not incorporated into the internet version is the ability to evaluate time-varying pumping rates through superposition. This feature was not included because web-based applications with Javascript require fairly fast computations and the use of superposition for time-varying pumping rates can be computationally intensive. Users wanting to evaluate time-varying pumping rates can use the stand-alone, Fortran-based, program. The internet-based interface was written to generate an input file that will help with unit conversion and related issues.

Description of Interface

The web page that accepts input data for the analytical solutions was designed as a form with appropriate entry boxes for the four analytical solutions. The user enters the desired input data in the boxes for one of the solutions and submits the form for evaluation. The units for the required input data are given on the form. The user must ensure that the input values are in the correct units. Results are returned in a new window as a table. These values may be cut from the returned table and pasted into a variety of programs to plot the results if desired. The interface also allows the user to generate the header for an input file to STRMDEPL08; this header may be augmented with a pumping schedule to generate results using the stand-alone executable.

[1]U.S. Geological Survey

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Example Problems and Verification of Results

Results of the internet-based application are shown to match those from the Fortran STRMDEPL08 program. Input files and excerpts from output files for each of the four test cases are included as Appendix 1.

The first test case is for the Jenkins (1968) solution. The input data were:

Distance, ft	500
Transmissivity, ft^2/day	1000
Storage Coefficient	0.1
Pumping Rate, gallons per minute	250
Days of Pumping	365

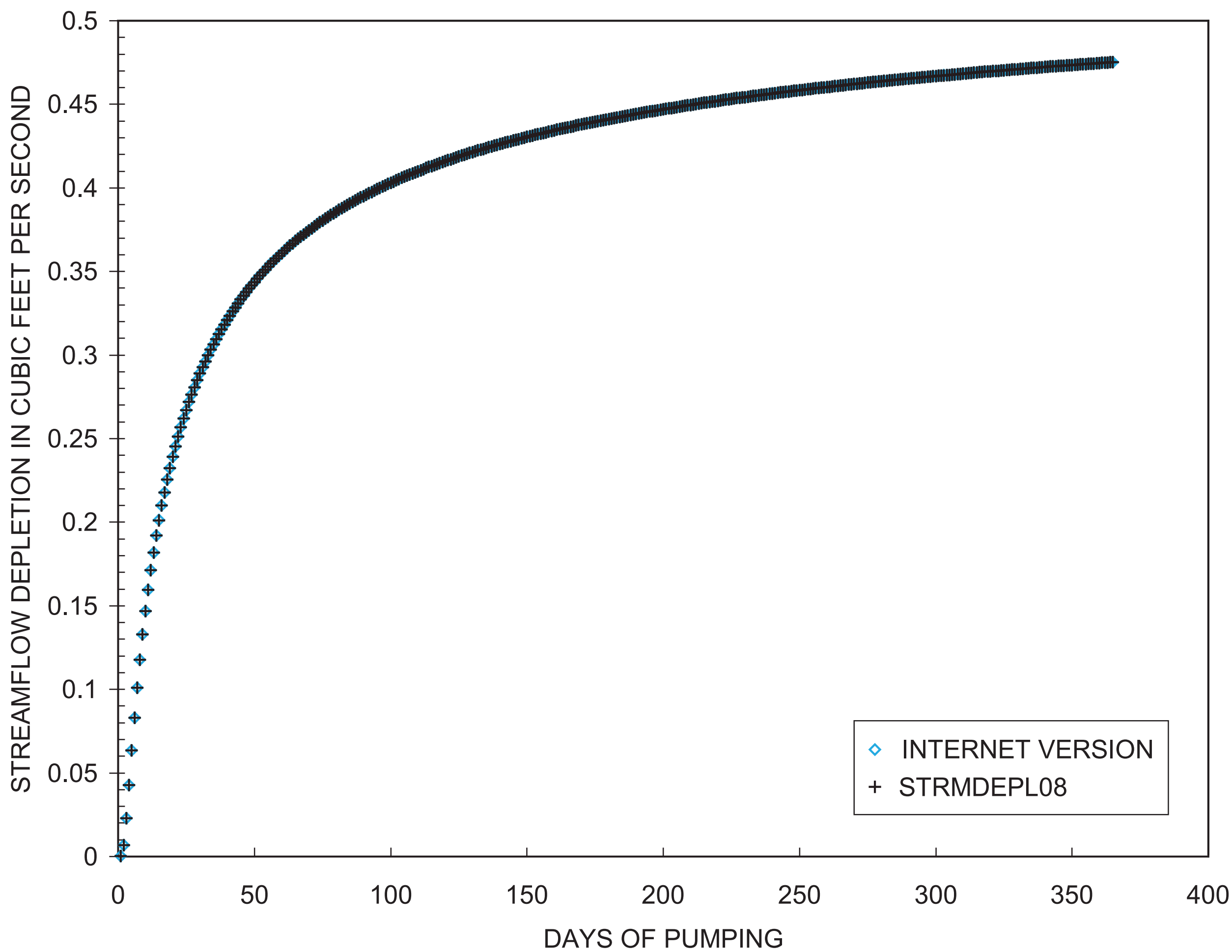

Figure 1. Comparison of results determined by the internet-based version and the Fortran version of STRMDEPL08 for the Jenkins (1968) (Glover and Balmer, 1954) analytical solution.

The second test is for the Hantush (1965) solution.

Distance, ft	500
Transmissivity, ft^2/day	1000
Storage Coefficient	0.1
Streambed Leakance, ft	100
Pumping Rate, gallons per minute	250
Days of Pumping	365

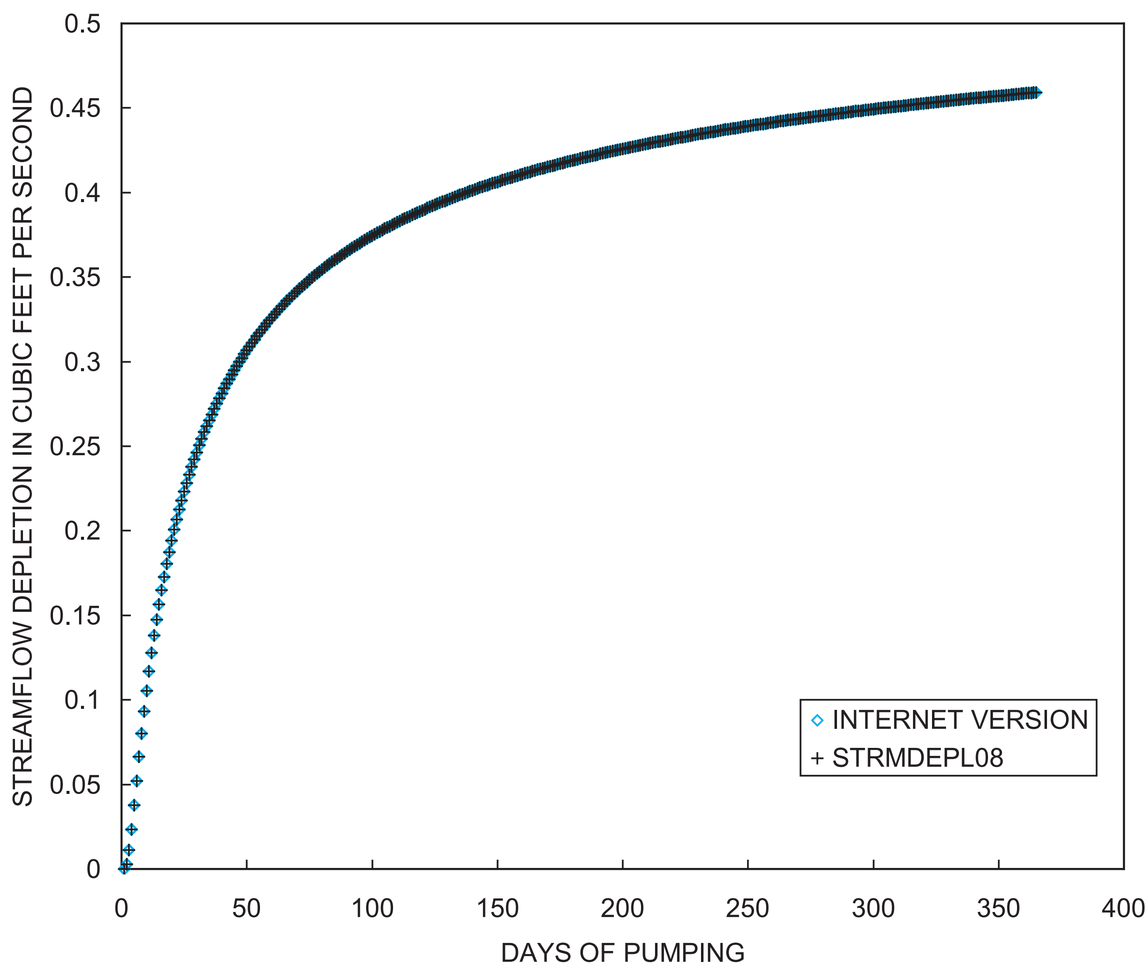

Figure 2. Comparison of results determined by the internet-based version and the Fortran version of STRMDEPL08 for the Hantush (1965) analytical solution.

The third test is for the Hunt (1999) analytical solution.

Distance, ft	500
Transmissivity, ft^2/day	1000
Storage Coefficient	0.1
Streambed Conductance, ft/day	20
Pumping Rate, gallons per minute	250
Days of Pumping	365

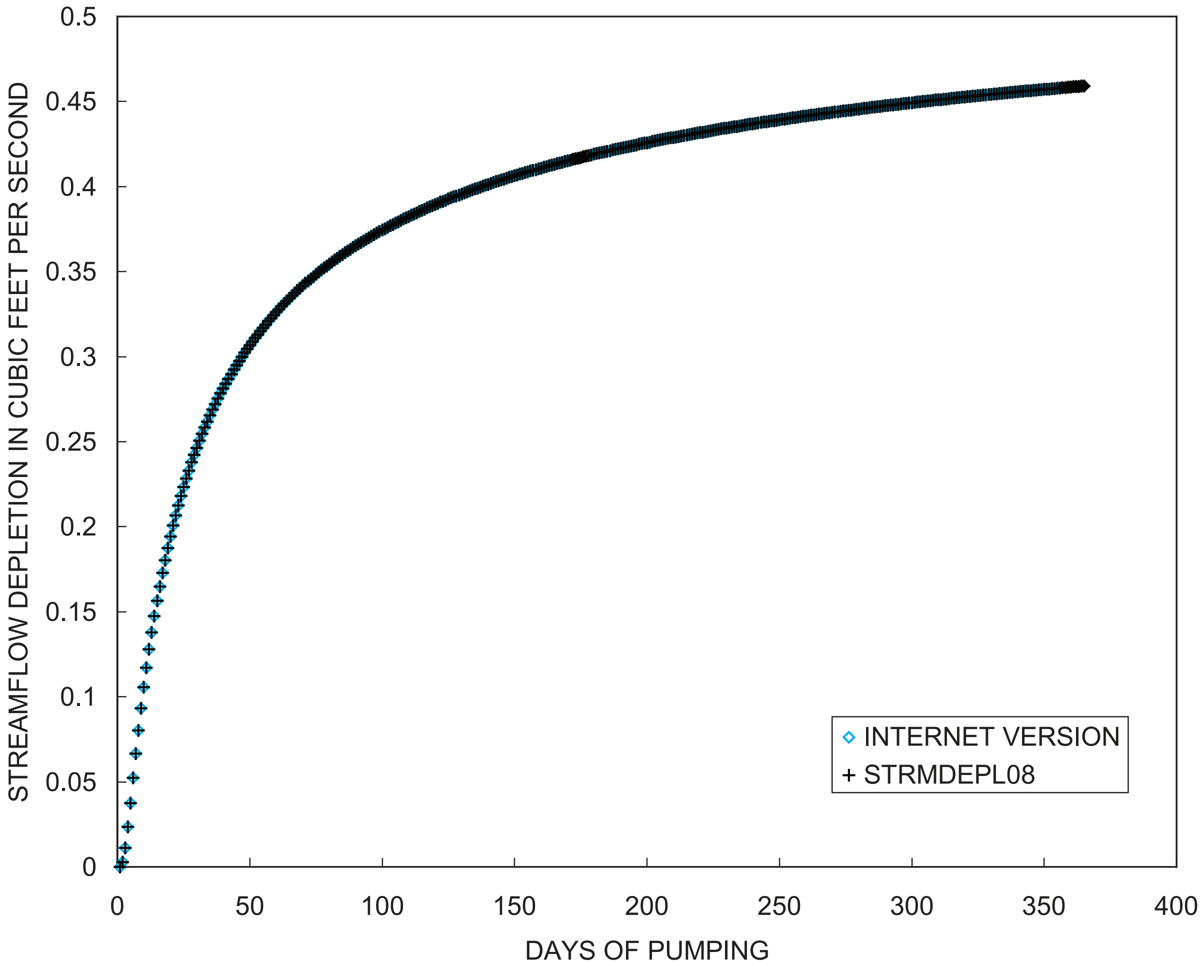

Figure 3. Comparison of results determined by the internet-based version and the Fortran version of STRMDEPL08 for the Hunt (1999) analytical solution.

The final test is for the Hunt (2003) analytical solution

Distance, ft	500
Transmissivity, ft^2/day	1000
Storage Coefficient	0.0001
Specific Yield of Aquitard	0.1
Hydraulic Conductivity of Aquitard, ft/day	0.1
Stream Width, ft	10
Thickness of Aquitard, ft	20
Distance from Streambed to Bottom of Aquitard, ft	15
Pumping Rate, gallons per minute	250
Days of Pumping	365

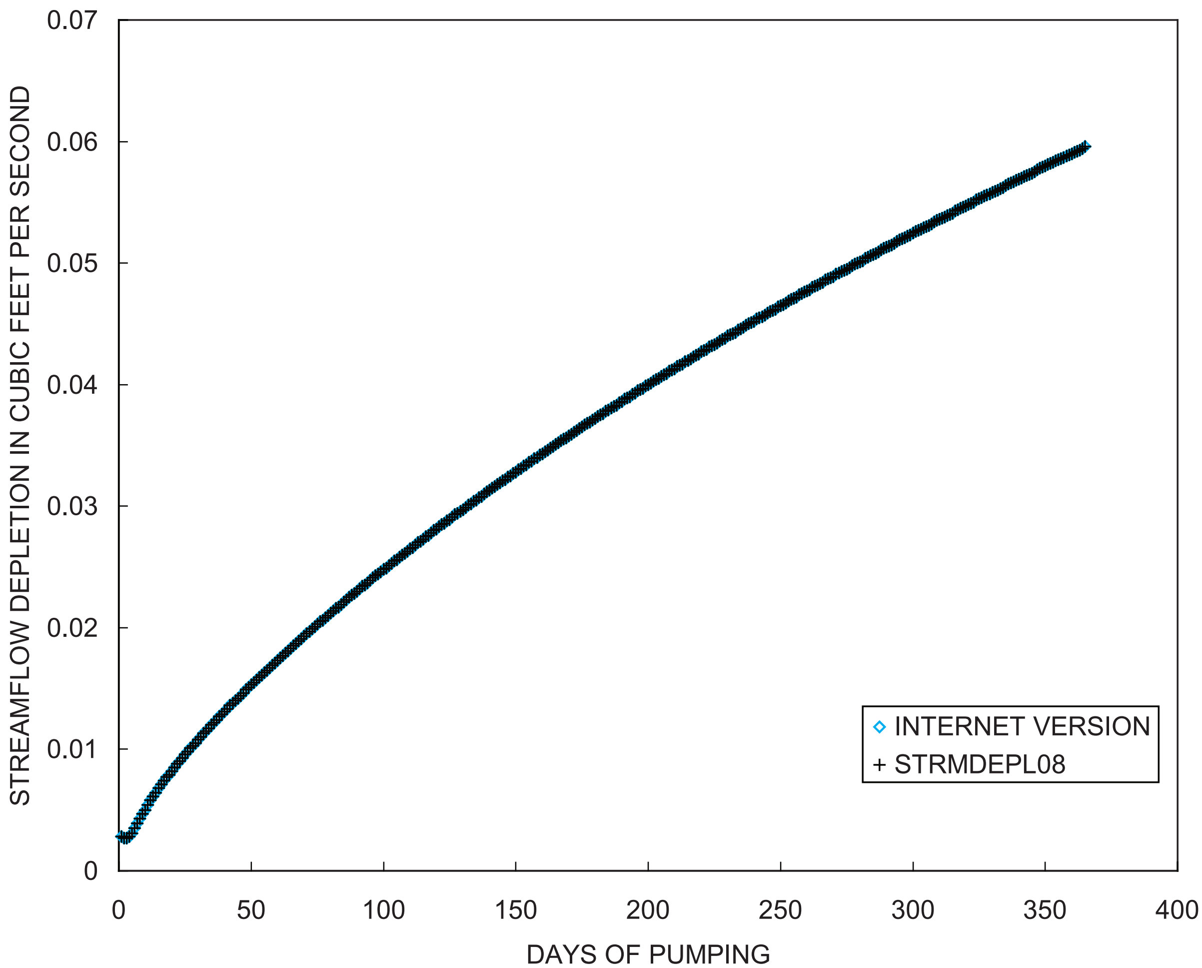

Figure 4. Comparison of results determined by the internet-based version and the Fortran version of STRMDEPL08 for the Hunt (2003) analytical solution.

Using a Spreadsheet To Develop Intermittent Pumping Input

After the aquifer characteristics and pumping well location are listed, the STRMDEPL and STRMDEPL08 programs require two columns of input. The first column has the date in a YYYYMMDD[HH] format. The second column is the pumping rate in cubic feet per second. A spreadsheet can be used to help generate these input data (Figure 5).

Date	Year	Month	Day	Pumping Rate, gpm	YMDH	Pumping rates, cfs
1/1/2010	2010	1	1	0	2010010100	0
1/2/2010	2010	1	2	0	2010010200	0
1/3/2010	2010	1	3	0	2010010300	0
1/4/2010	2010	1	4	0	2010010400	0
1/5/2010	2010	1	5	0	2010010500	0
1/6/2010	2010	1	6	0	2010010600	0
1/7/2010	2010	1	7	0	2010010700	0

Figure 5. Example spreadsheet that may be used to help generate intermittent pumping input information for STRMDEPL08.

The first column has the date for pumping. The user can type a starting date and then fill in remaining rows of the spreadsheet with subsequent dates for the desired simulation period. The adjacent columns are used to format the date and input the intermittent pumping for use in STRMDEPL08:

Column 2: extract the year from the date in column 1. In Microsoft Excel, the command =year(A2) can be entered into cell B2 and then filled down.

Column 3: extract the month from the date in column 1. In Microsoft Excel, the command =month(A2) can be entered into cell C2 and then filled down.

Column 4: extract the day from the date in column 1. In Microsoft Excel, the command =day(A2) can be entered into cell D2 and then filled down.

Column 5: user input of the desired pumping rate in gallons per minute (gpm). This column can be used to input the pumping rate and intermittent schedule. The values must be converted to cubic feet per second for input to the analytical solution.

Column 6: combine the year, month, and day columns to form the date required by STRMDEPL08. In Microsoft Excel, the command =CONCATENATE(B2,IF(C2<10, CONCATENATE("0",C2),C2),IF (D2<10,CONCATENATE("0",D2),D2),"00") can be entered into cell E2 and then filled down.

Column 7 has the intermittent pumping in cubic feet per second (cfs). The pumping rate can vary daily. It can be entered directly or the user can enter the pumping rate in gpm into column 5 and allow the spreadsheet to convert the values to cfs with the entry =E2/448.8 and filling down.

To generate an input file for STRMDEPL08, copy columns 6 and 7 and paste at the end of the aquifer and well information generated by the web-page interface.

Acknowledgements

Shuangshuang Xie (Institute for Water Research, Michigan State University) worked on the conversion from Fortran to Javascript, along with contributions from Scott McPherson and Brian McPherson (Michigan State University) on the web page layout. Marie Reynolds resolved issues with USGS web-page style requirements and finalized the web version. The authors would like to thank Ralph Abele (U.S. Environmental Protection Agency), and Corinne Fitting and Kevin Neary (Connecticut Department of Environmental Protection) for their review of early versions of the interface, helpful comments, and patience with the pace of the development. This work was done in cooperation with the U.S. Environmental Protection Agency.

References

Barlow, P.M., 2000, Documentation of computer program STRMDEPL—A program to calculate streamflow depletion by wells using analytical solutions, in Zarriello, P.J., and Ries, K.G., III, A precipitation-runoff model for analysis of the effects of water withdrawals on streamflow, Ipswich River Basin, Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 00–4029, p. 77–89.

Glover, R.E., and Balmer, G.G., 1954, River depletion resulting from pumping a well near a river: Transactions, American Geophysical Union, v. 35, no. 3, p. 468–470.

Hantush, M.S., 1965, Wells near streams with semipervious beds: Journal of Geophysical Research, v. 70, no. 12, p. 2829–2838.

Hunt, Bruce, 1999, Unsteady stream depletion from ground water pumping: Ground Water, v. 37, no. 1, p. 98–102.

Hunt, Bruce, 2003, Unsteady stream depletion when pumping from semiconfined aquifer: Journal of Hydrologic Engineering, v. 8, no. 1, p. 12–19.

Jenkins, C.T., 1968, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. D1, 17 p.

Reeves, H.W., 2008, STRMDEPL08—An extended version of STRMDEPL with additional analytical solutions to calculate streamflow depletion by nearby pumping wells: U.S. Geological Survey Open-File Report 2008–1166, 22 p. (also available at *http://pubs.water.usgs.gov/ofr20081166/*.)

Appendix

Appendix 1

Input file for Jenkins (1968) [Glover and Balmer, 1954] test:

```
Jenkins test
hypothetical_well
500, 0.115740740740741, 0, 0, 0.0, 0, 0, 0, 0, 0, 0.0
3650, 0.0
365
2000100100  0.5570
2000100200  0.5570
2000100300  0.5570
Repeats for 365 days
```

Leading 60 lines of output file:

```
************************************************************
*                            *                             *
*          ***  U.S. GEOLOGICAL SURVEY  ***                *
*                            *                             *
*        ***  STRMDEPL08: PROGRAM OUTPUT  ***              *
*                            *                             *
*  ONE-DIMENSIONAL MODEL OF STREAMFLOW DEPLETION           *
*                            *                             *
*      BY WELLS, BASED ON ANALYTICAL SOLUTIONS             *
*                            *                             *
*   DEVELOPED BY JENKINS  (1968) AND HANTUSH (1965)        *
*                            *                             *
*   MODIFIED TO INCLUDE HUNT (1999, 2003) SOLUTIONS        *
*                            *                             *
*            VERSION 1.1, JANUARY, 2010                    *
*                            *                             *
************************************************************

         HW Reeves, USGS Michigan Water Science Center


                  SUMMARY OF INPUT DATA
                  ---------------------------------

WELL IDENTIFIER:                        hypothetical_well
WELL DISTANCE TO STREAM (XWELL):        0.500D+03 feet
DIFFUSIVITY (DIFFUS):                   0.116D+00 square feet per second
STREAMBANK CODE (ISOLN):                0 (semipervious streambank absent, Jenkins 1968)
INITIAL TIME (INTIME):                  3650 days
INITIAL PUMPING RATE (QWINIT):          0.000D+00 cubic feet per second
NUMBER OF PUMPING STEPS (NPD):          365
TIME STEP FOR PUMPING  (DELT):          0.100D+01 days
```

RESULTS

STREAMFLOW DEPLETION AT BEGINNING OF ANALYSIS

0.0000 cubic feet per second

DAY	PUMPING RATE	STREAMFLOW DEPLETION
	(cubic feet per second)	
2000100100	0.5570	0.0002
2000100200	0.5570	0.0069
2000100300	0.5570	0.0230
2000100400	0.5570	0.0429
2000100500	0.5570	0.0634
2000100600	0.5570	0.0829
2000100700	0.5570	0.1011
2000100800	0.5570	0.1177
2000100900	0.5570	0.1329
2000101000	0.5570	0.1468
2000101100	0.5570	0.1595

Input file for Hantush (1965) test:

```
Hantush 1965 test
hypothetical_well
500, 0.115740740740741, 1, 100, 0.0, 0, 0, 0, 0, 0, 0.0
3650, 0.0
365
2000100100  0.5570
2000100200  0.5570
2000100300  0.5570
Repeats for 365 days
```

Leading 60 lines of output file:

```
************************************************************
*                            *                             *
*           ***   U.S. GEOLOGICAL SURVEY   ***             *
*                            *                             *
*         ***  STRMDEPL08: PROGRAM OUTPUT  ***             *
*                            *                             *
*  ONE-DIMENSIONAL MODEL OF STREAMFLOW DEPLETION           *
*                            *                             *
*      BY WELLS, BASED ON ANALYTICAL SOLUTIONS             *
*                            *                             *
*    DEVELOPED BY JENKINS  (1968) AND HANTUSH (1965)       *
*                            *                             *
*    MODIFIED TO INCLUDE HUNT (1999, 2003) SOLUTIONS       *
*                            *                             *
*            VERSION 1.1, JANUARY, 2010                    *
*                            *                             *
************************************************************

          HW Reeves, USGS Michigan Water Science Center


                    SUMMARY OF INPUT DATA
                    --------------------------------

WELL IDENTIFIER:                        hypothetical_well
WELL DISTANCE TO STREAM (XWELL):        0.500D+03 feet
DIFFUSIVITY (DIFFUS):                   0.116D+00 square feet per second
STREAMBANK CODE (ISOLN):                1 (semipervious streambank simulated, Hantush, 1965))
STREAMBANK LEAKANCE (SLEAK):            0.100D+03 feet
INITIAL TIME (INTIME):                  3650 days
INITIAL PUMPING RATE (QWINIT):          0.000D+00 cubic feet per second
NUMBER OF PUMPING STEPS (NPD):          365
TIME STEP FOR PUMPING  (DELT):          0.100D+01 days
```

RESULTS

STREAMFLOW DEPLETION AT BEGINNING OF ANALYSIS
0.0000 cubic feet per second

DAY	PUMPING RATE	STREAMFLOW DEPLETION
	(cubic feet per second)	
2000100100	0.5570	0.0001
2000100200	0.5570	0.0028
2000100300	0.5570	0.0112
2000100400	0.5570	0.0235
2000100500	0.5570	0.0376
2000100600	0.5570	0.0522
2000100700	0.5570	0.0665
2000100800	0.5570	0.0802
2000100900	0.5570	0.0932
2000101000	0.5570	0.1055

Input file for Hunt (1999) test:

```
Hunt 1999 test
hypothetical_well
500, 0.0115740740740741, 2, 0.000231481481481481, 0.1, 0, 0, 0, 0, 0, 0.0
3650, 0.0
365
2000100100  0.5570
2000100200  0.5570
2000100300  0.5570
Repeats for 365 days
```

Leading 60 lines of output file:

```
*************************************************************
*                            *                              *
*          ***   U.S. GEOLOGICAL SURVEY   ***               *
*                            *                              *
*        ***  STRMDEPL08: PROGRAM OUTPUT  ***               *
*                            *                              *
*  ONE-DIMENSIONAL MODEL OF STREAMFLOW DEPLETION            *
*                            *                              *
*      BY WELLS, BASED ON ANALYTICAL SOLUTIONS              *
*                            *                              *
*    DEVELOPED BY JENKINS  (1968) AND HANTUSH (1965)        *
*                            *                              *
*    MODIFIED TO INCLUDE HUNT (1999, 2003) SOLUTIONS        *
*                            *                              *
*             VERSION 1.1, JANUARY, 2010                    *
*                            *                              *
*************************************************************
           HW Reeves, USGS Michigan Water Science Center


                    SUMMARY OF INPUT DATA
                    ---------------------------------

WELL IDENTIFIER:                        hypothetical_well
WELL DISTANCE TO STREAM (XWELL):        0.500D+03 feet
TRANSMISSIVITY:                         0.116D-01 square feet per second
STORATIVITY                             0.100D+00
STREAMBANK CODE (ISOLN):                2 (partially penetrating stream with resistance, Hunt 1999)
STREAMBED CONDUCTANCE:                  0.231D-03 feet
INITIAL TIME (INTIME):                  3650 days
INITIAL PUMPING RATE (QWINIT):          0.000D+00 cubic feet per second
NUMBER OF PUMPING STEPS (NPD):          365
TIME STEP FOR PUMPING  (DELT):          0.100D+01 days
```

RESULTS

STREAMFLOW DEPLETION AT BEGINNING OF ANALYSIS

0.0000 cubic feet per second

DAY	PUMPING RATE	STREAMFLOW DEPLETION
	(cubic feet per second)	
2000100100	0.5570	0.0001
2000100200	0.5570	0.0028
2000100300	0.5570	0.0112
2000100400	0.5570	0.0235
2000100500	0.5570	0.0376
2000100600	0.5570	0.0522
2000100700	0.5570	0.0665
2000100800	0.5570	0.0802
2000100900	0.5570	0.0932

Input file for Hunt (2003) test:

```
Hunt 2003 test
hypothetical_well
500, 0.0115740740740741, 3, 7.71604938271605e-007, 0.0001, 0.1, 15, 20, 1.15740740740741e-006, 10, 0.0
3650, 0.0
365
2000100100  0.5570
2000100200  0.5570
2000100300  0.5570
Repeats for 365 days
```

Leading 60 lines of output file:

```
*************************************************************
*                            *                              *
*          ***   U.S. GEOLOGICAL SURVEY   ***               *
*                            *                              *
*        ***  STRMDEPL08: PROGRAM OUTPUT  ***               *
*                            *                              *
*  ONE-DIMENSIONAL MODEL OF STREAMFLOW DEPLETION            *
*                            *                              *
*       BY WELLS, BASED ON ANALYTICAL SOLUTIONS             *
*                            *                              *
*   DEVELOPED BY JENKINS  (1968) AND HANTUSH (1965)         *
*                            *                              *
*   MODIFIED TO INCLUDE HUNT (1999, 2003) SOLUTIONS         *
*                            *                              *
*             VERSION 1.1, JANUARY, 2010                    *
*                            *                              *
*************************************************************
         HW Reeves, USGS Michigan Water Science Center
```

SUMMARY OF INPUT DATA

WELL IDENTIFIER:	hypothetical_well
WELL DISTANCE TO STREAM (XWELL):	0.500D+03 feet
TRANSMISSIVITY:	0.116D-01 square feet per second
HYDRAULIC COND. OF UPPER LAYER:	0.116D-05 feet per second
STORATIVITY	0.100D-03
SPECIFIC YIELD OF UPPER LAYER:	0.100D+00
STREAM WIDTH:	0.100D+02 feet
THICKNESS OF UPPER LAYER:	0.200D+02 feet
BOT. OF STREAM->TOP OF AQUIFER:	0.150D+02 feet
STREAMBANK CODE (ISOLN):	3 (stream in overlying aquitard simulated, Hunt 2003)
STREAMBANK CONDUCTANCE:	0.772D-06 feet per second
INITIAL TIME (INTIME):	3650 days
INITIAL PUMPING RATE (QWINIT):	0.000D+00 cubic feet per second
NUMBER OF PUMPING STEPS (NPD):	365
TIME STEP FOR PUMPING (DELT):	0.100D+01 days

RESULTS

STREAMFLOW DEPLETION AT BEGINNING OF ANALYSIS
0.0000 cubic feet per second

DAY	PUMPING RATE	STREAMFLOW DEPLETION
	(cubic feet per second)	
2000100100	0.5570	0.0028
2000100200	0.5570	0.0027
2000100300	0.5570	0.0027
2000100400	0.5570	0.0028
2000100500	0.5570	0.0031
2000100600	0.5570	0.0035
2000100700	0.5570	0.0039
2000100800	0.5570	0.0043
2000100900	0.5570	0.0047
2000101000	0.5570	0.0050
2000101100	0.5570	0.0054
2000101200	0.5570	0.0058
2000101300	0.5570	0.0061
2000101400	0.5570	0.0064

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