What's new in Scoops3D and Scoops3D-i

Note that all Scoops3D version 1.0 input files are forward compatible with version 1.1, version 1.1.1, version 1.1.2, version 1.3, and version 1.3.01.

Version 1.3.01
Updated March 2023

Bug fixes

Corrected error in calculations used to issue warnings for adequate DEM resolution.

Version 1.3
Updated September 2022

Enhancements
Version 1.3 contains several major changes which improve accuracy and efficiency. Our test runs show that version 1.3 computation times are 2.5 to 4 times faster than version 1.1.2. Note that model results using version 1.3 may differ slightly from earlier versions because of the changes listed below, such as the inclusion of single-node columns and a more accurate method for calculating volumes. Although the global critical surface may differ between versions, the regional factor-of-safety maps should generally look the same, with factors of safety of critical surfaces within a few percent of results from prior versions. Individual DEM cells near the borders of critical surfaces may have larger differences in factor of safety as a result of small differences in the areal extent of associated critical surfaces.

Version 1.3 has implemented several features that became available with Fortran 95 and Fortran 2003. Therefore, the user should be aware that self-compilation of the provided Fortran code requires use of a compiler that supports Fortran 2003.

Following is a list of updates contained in version 1.3.

<u>Changes to Input:</u>

- A user can now specify the input file name on the same line when calling the executable in a command window (using **Get_Command_Argument** available in Fortran 2003). For example, the user can type the following command on a single line:

  Scoops3D_1.3win64.exe *InputFilename.scp*

- If a user chooses to analyze multiple slip directions for each trial surface (in addition to the ground-surface overall fall direction) the method has changed to an automated search for the sliding direction which identifies the lowest factor of safety for each trial surface. Earlier versions used the parameters *deginc*, *degmax*, and *numdir*, which werespecified in the .scp input file with the following line pair:

LINE ID: `dr deginc degmax numdir`

or by setting the number of slip directions and maximum deviation angle in the Search Configuration box of Scoops3D-i.

The parameters *deginc*, *degmax*, and *numdir* are no longer used directly. In the current version, a new input parameter (*islipdirflag*), added as a new line pair in the .scp input file, can be used to trigger the slip direction search.

LINE ID: `islipdirflag`
islipdirflag flag to enable multiple slip direction search (1 to enable or 0 to disable the search)

If an input file contains the older parameters with *deginc* >= *degmax* > 0 (*numdir* is not required), then the automated search flag will be set to one. This feature enables backward compatibility with pre-exiting input files which specify a search of multiple slip directions. If valid older slip parameters are present the user will see the following screen message during run time to explain:

'Incremental slip direction search is specified using obsolete parameters:
new automated slip direction search will be implemented'.

For all cases, the initial slip direction is calculated by summing the volume-weighted components of land surface slope of each column included in the current failure mass, representing the overall fall direction. Note that this method of computing the overall fall direction using volume weighting is a slight change from the prior Scoops3D versions in which ground slope alone determined slide direction. Our empirical testing has shown that slip directions derived using volume weighting can produce slightly lower factors of safety.

When *islipdirflag* is set to one, a search for the slip direction with the lowest factor of safety is implemented. This search first computes factors of safety for slip directions one degree on either side of the overall fall direction. If a new trial direction results in a lower factor of safety, additional directions will be calculated using a secant method until either the change in factor of safety falls below a preset tolerance, the change in slip angle is less than 0.001 degrees, or the number of angles tried is greater than 10.

Note that the factor of safety calculated using the initial overall fall direction is typically very close (within a small fraction of a percent) to the minimum value obtained from other slip directions except in cases where the slip surface exhibits a significant amount of asymmetry of weight distribution or pore pressures. Sampling additional slip directions can require significantly more computational effort. We suggest initial testing with and without implementation of the multiple

slip direction search to determine if this option produces different results.

- *fostol* is a now an optional parameter and set to a default of 0.001 percent difference in factor of safety.

Computational Enhancements

- Factor-of-safety calculations now include single-node partial columns on the boundary of a potential failure mass, enabling more accurate results using coarser DEM resolutions and thereby potentially reducing computer memory requirements. Prior versions included partial columns with two and three nodes, but not one node.
- Volumes of full columns are calculated using the prismoidal formula with three parallel planes as before. However, the area of the central parallel plane is now calculated using the elevation of the sphere at the center of the column to better approximate the volume of a column truncated by a sphere. Prior versions of Scoops3D used only the sphere elevations at each column corner which slightly underestimates volume and tends to result in a slightly higher factor of safety. The new method provides a better volume approximation and retains computational efficiency.
- Calculation of the location of the midpoint of partial columns projected on the x-y plane has been revised to use the centroid formula for the polynomial representing the projected area. This method provides a more accurate estimate of slip surface elevation and slope at the column center and associated moment arms.
- Slip surfaces with land elevations above the rotational center are now allowed if these columns do not intersect the boundary of the slip surface to form a partial column. This approach avoids situations where a spherical surface wraps around on top of itself at the edge of the slide, which is not physically feasible.
- Subsets are now identified using a flood-fill routine to reduce computation time.
- Several large arrays used to process three-dimensional subsurface data have been eliminated, reducing memory requirements for this category of problems.
- Many other enhancements have been completed to reduce memory usage and improve computational efficiency.

Changes in Output

- Elapsed run time is written at the end of the main output file, calculated by calling the Fortran 95 intrinsic function **cpu_time** at the start and end of each run.

Bug fixes

- Corrected bug where piezometric surface was not identified and moisture level parameter was not set prior to processing unit weight data when using the combination of 3D pore-pressure or pressure-head files with layer files.
- Revised input check to issue warning instead of terminating program when minimum volume or area of primary size constraint is likely to not include enough columns to provide an accurate factor-of-safety result.

- Corrected and optimized array handling, character strings, and other variables and eliminated obsolete Fortran syntax.

Version 1.1.2
Updated 14 March 2018

Enhancements
Minor changes to formatting of output were implemented. Additional warning messages are provided for potential failure size criteria that are smaller than recommended. Improvements to error traps in the case of memory allocation errors when insufficient computer memory is available.

Bug fixes

This version contains three important bug fixes: 1) corrected a bug for cases with search refinement when low values of maximum vertical extent (***zsmax***) in the search lattice were not always flagged in the boundary check file, 2) corrected a bug that prevented a run with the combination of a 3D pore-pressure or pressure-head file with layer files from working properly, and 3) revised calculation of moisture content for positive pore pressures when using a soil water characteristic curve (SWCC).

Version 1.1.1
Updated 9 February 2017

Enhancements
This version allows 25 potential failure subsets within a defined sphere before issuing a warning message; earlier versions (1.0 and 1.1) allowed 10 subsets. Improvements to handling of error/warning messages related to memory allocation of large datasets and subsets are included.

Version 1.1
Updated 28 July 2016

Enhancements

<u>3D pore-pressure files</u>
Scoops3D can now directly utilize 3D groundwater files containing pore-pressure data. The previous version only accepted 3D groundwater files containing pressure-head data. In Scoops3D, pore pressure, *u*, is related to pressure head, *h*, by $u = h\gamma_w$ where γ_w is the unit weight of water. If the pore-pressure option is used, the physical units for pressure must be consistent with the other physical units used in a simulation. For example, if ***m/kN*** is used, then pressure units should be ***kPa***. Other aspects of the 3D file data

coordinates, data representation, and file header lines remain the same as 3D pressure-head files used in Scoops3D.

- *Use with the graphical user interface, Scoops3D-i.*

In Scoops3D-i, if the user selects '3D groundwater file' or '3D variably saturated file' for the **Groundwater configuration** option in the main input window, the **Subsurface Parameters** window now requires selection of a data type, either pressure head or pore pressure. Selection of the either data type in Scoops3D-i will apply the necessary modifications to the Scoops3D main input file.

- *Use with main parameter input file.*

The Scoops3D parameter, ***water***, describing the groundwater configuration is now allowed several new values to accommodate pore-pressure data. These values are not described in the Scoops3D manual: Reid, M.E., Christian, S.B., Brien, D.L., and Henderson, S.T., 2015, Scoops3D—Software to analyze three-dimensional slope stability throughout a digital landscape, U.S. Geological Survey Techniques and Methods, book 14, chap. A1, 218 pages, http://pubs.er.usgs.gov/publication/tm14A1.

The new values supported in the main parameter input file are ***water*** = '3dpp', 'vspp', 'vgpp', or 'fxpp', where the suffix pp denotes a file containing pore-pressure data instead of pressure-head data. Other aspects of the 3D file remain the same as those for the corresponding '3d', 'vs', 'vg', and 'fx' options described in manual sections 4.4.2.2.4 and 4.4.2.2.5.

The following options for the parameter ***water*** are now supported in this version: 'no', 'ru', 'pz', '3d', '3dpp', 'vs', 'vspp', 'vg', 'vgpp', 'fx', 'fxpp'. The parameter-line id for 3D groundwater files or 3D variably saturated files has been changed from `pressure head file` to `pressure file`.

Bug fixes

This version corrects several minor bugs related to format statements and variable declarations. Additional error checking of input data for the main input file, 3D groundwater files, and 3D material property files was implemented.