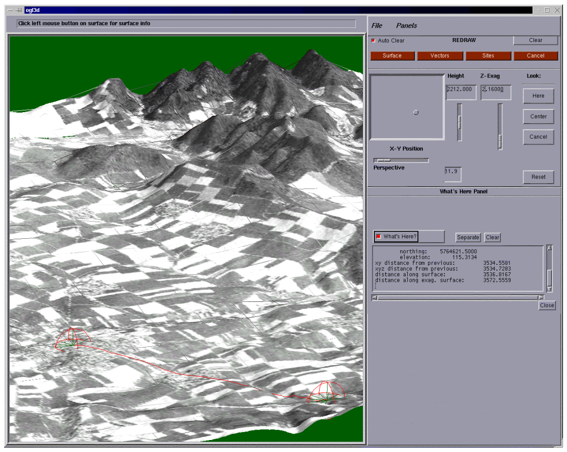
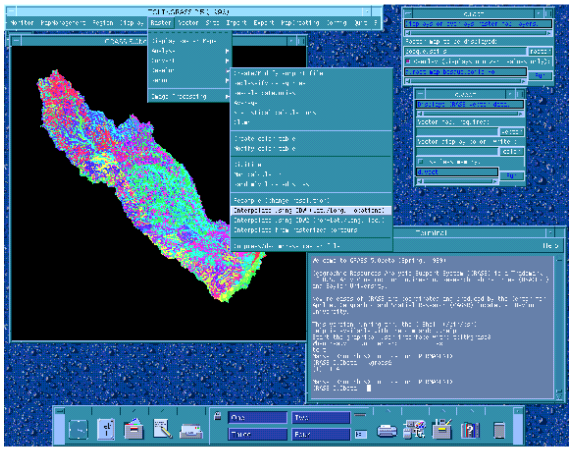
# GRASS Reference Manual

## Raster Commands





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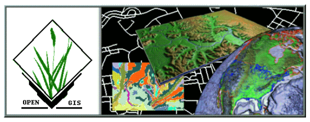

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## GRASS Introduction

GRASS (Geographic Resources Analysis Support System) is a raster based GIS, vector GIS, image processing system, and graphics production system. GRASS contains over 200 programs and tools to render maps and images on monitor and paper; manipulate raster, vector, and sites data; process multi-spectral image data; and create, manage, and store spatial data. GRASS uses both an intuitive windows interface as well as command line syntax for ease of operations. GRASS can interface with commercial printers, plotters, digitizers, and databases to develop new data as well as manage existing data.

GRASS is ideal for use in engineering and land planning applications. Like other GIS packages, GRASS can display and manipulate vector data for roads, streams, boundaries, and other features. GRASS can also be used to keep maps updated with its integral digitizing functions. Another feature of GRASS is its ability to use raster, or cell, data. This is particularly important in spatial analysis and design. GRASS functions can convert between vector data to raster data for seamless integration.

GRASS' strengths lie in several fields. The simple user interface makes it an ideal platform for those learning about GIS for the first time. GRASS is capable of reading and writing maps and data to many popular commercial GIS packages including ARC/Info and Idrisi. Users wishing to write their own code can do so by examining existing source code, interfacing with the documented GIS libraries, and using the GRASS Programmers Manual. This allows more sophisticated functionality to be integrated in GRASS.

The ability to work with raster data gives GRASS the unique ability to function as a surface modeling system. GRASS contains more than 100 multi-function raster analysis and manipulation commands. Surface processes such as rainfall-runoff modeling, flowline construction (as shown), slope stability analysis, and spatial data analysis are just a few of the many applications of GRASS to engineering and land planning. Since many of the raster tools are multi-functional, users can create their own maps from GRASS data analysis.

In addition to standard two-dimensional analysis, GRASS allows users to view data in three-dimensions. Raster maps, vector maps, and sites data can be used for visualization. Example applications of such capabilities include airspace analysis for airport planning (as shown), terrain analysis and "flybys", and spatial trends. Tools in GRASS allow the user to animate any spatial data available with options to switch between data layers "on-the-fly". Data used in 3-D visualization may also be saved as still pictures, or as mpeg movie files for later replay and analysis.

Accompanying its land planning and engineering applications, GRASS contains a suite of tools to aid in hydrologic modeling and analysis. Currently, tools are also available for performing such functions as watershed analysis, curve number generation, flood analysis, and stream channel characteristics for comprehensive watershed modeling. Other GRASS programs can generate graphs, statistics, and charts of modeled and calibrated data. Additionally, GRASS can use field data for model input or simulate parameters based on numerical data.

In addition to the traditional command line version of GRASS, a new user interface, based on Tcl/Tk has been written. This puts the power of spatial analysis and modeling into an easy to use Graphical User Interface that is platform-independent. This intuitive user interface lets users quickly and easily view, manipulate, and use data. Nearly all of the programs available in GRASS are available in the new GUI, with the standard command-line still available, giving users all of the functionality of GRASS.

This manual is part of a comprehensive set of documentation written to support GRASS. This Users Guide consists of a complete set of command references for all current GRASS functions and tools, including examples. An installation guide and fact sheet guides users through the installation process. For those wishing to write their own spatial analysis and modeling applications for GRASS, a Programmers Guide is also available. GRASS runs on a variety of UNIX and Linux platforms including SUN SPARCstations and Ultras, HP, Silicon Graphics, and PC's running Windows 95 and Windows NT.

The GRASS Development Team is currently working to further upgrade and enhance the capabilities of GRASS. Future developments include tools that give the user the ability to work completely in 3-D, a capability that does not exist in any other GIS package. Users will be able to work with raster elevation data as well as vector and sites data in the 3-D environment, adding to the visualization capabilities of GRASS. Enhancements in the numerical processing functions of GRASS also now allow for floating-point operations to be performed on data.

For the latest information on GRASS contact the GRASS Development Team at grass@baylor.edu or visit our web sites at:

http://www.baylor.edu/~grass if you're in the U.S.

http://www.geog.uni-hannover.de/grass if you're in Europe

Look for our worldwide mirrors!

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Bruce Byars and Markus Neteler are the development team leaders and coordinators.

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*Note:*

Many other people have contributed to the GRASS GIS. Without any one of them, GRASS would not exist in its current form. The authors of the individual programs are listed at the end of their manual page in the GRASS users manual, however, numerous authors of bug fixes and enhancements as well as people who have been working on coordination, integration, documentation and testing are not mentioned.

Please allow us to extend our most cordial thanks to all of you. If you contributed to GRASS at any point during its existence, let us know your name and e-mail address so we can add your name to the comprehensive on-line list.

*To reference GRASS:*

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## *r.answers*

**NAME**
*r.answers* - Menu-driven interface from GRASS to ANSWERS

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.answers*

**DESCRIPTION**
*r.answers* integrates ANSWERS with GRASS. ANSWERS (Areal Non-point Source Watershed Environmental Response Simulation) is an event oriented, distributed parameter model that was developed to simulate the behavior of watersheds having agriculture as their primary land use. Its primary applications are watershed planning for erosion and sediment control on complex watersheds, and water quality analysis associated with sediment associated chemicals.

*r.answers* provides a menu of steps to complete the input required to run an ANSWERS simulation. Each simulation is treated as "project" by *r.answers*. The inputs collected for the steps completed are recorded under a project name, so that they may be copied or recalled for further completion or modification. The first menu one encounters when running *r.answers* includes functions to create a new project, work on existing projects, copy an existing project, and remove existing projects. The main menu (shown below) lists steps to be completed to prepare ANSWERS input, to run ANSWERS, plus other miscellaneous functions.

```
ANSWERS on GRASS Project Manager Main Menu
Project Name: [sample]

Status Option Description
---------------------------------------------------------
0    Quit
1    Set mask, region, and resolution
2    Catalogue soils parameters
3    Catalogue land use and surface parameters
4    Identify elevation-based input layers
5    Prepare rain gauge data
6    Identify outlet cell
7    Specify areas with subsurface drainage
8    Catalogue channel parameters
9    Define channel slopes
10    Specify BMP's in watershed
11    Prepare ANSWERS input and run simulation
12    Miscellaneous Command Menu

 Option: 0__
```

Steps 1-11 record and display their status to the left of the step number. If a step has not been run, no status is displayed (as seen above). If the step has been successfully completed, the status will be listed as "done". In some cases, a change in one step will cause the need to run another step again, in which case the status will read "rerun". If a step has a status of "done" or "rerun", if it is run again it will attempt to offer previous inputs as defaults.

Interface Operation Notes
Throughout *r.answers* two primary types of interface/input are used:

1) Text input that can be completed by hitting the RETURN key. In most cases, if no text was entered, the given question or operation is canceled. Often times text input will consist of the name of a new or

existing map or project name, in which case entering the word "list" will provide a list of currently used names.

2) Text or menu options that can be completed by hitting the ESC (escape) key. This type of interface is used for menus or for entering tables of parameters. All menus have a default answer of Exit (0), so that by simply hitting ESC one may leave the program's menus. The following keystroke guide is helpful to know when using the parameter entry worksheets that use this interface:

[RETURN] moves the cursor to next prompt field
[CTRL-K] moves the cursor to previous prompt field
[CTRL-H] moves the cursor backward non-destructively within the field
[CTRL-L] moves the cursor forward non-destructively within the field
[CTRL-A] writes a copy of the screen to a file named "visual_ask" in your home directory
[CTRL-C] where indicated (on bottom line of screen) can be used to cancel operation

Description of Main Menu Steps
The following section describes each option of the main menu. All steps are verbose to provide as much immediate information as is practical, however it is necessary that the user also be familiar with the operation of ANSWERS. (Obtain a copy of the ANSWERS User's Manual (1991) by David Beasley and Larry Huggins. Available from Bernard Engel, Agricultural Engineering, Purdue University, W. Lafayette, Indiana, 47907).

Steps 1 through 10 collect inputs (either maps from the currently available mapsets or other text/numerical inputs) in order to create or extract the necessary portions of ANSWERS inputs for that step. After steps 1 through 10 are done, step 11 can be run to assemble an ANSWERS input file. ANSWERS can then be run using the inputs, and the output from the simulation is captured and processed, as described under step 11.

<u>Step 1</u> Set mask, region, and resolution
<u>Map input</u>: Watershed mask
<u>Other inputs</u>: Project resolution, project region (optional)
<u>Description</u>: All raster values in the input mask map greater than zero will be used to create reclass rules to set the project MASK to the watershed area. Each time the project is called, the MASK will be automatically set. Project resolution is input in meters and it used to set the size of the watershed elements to be used in the simulation. The part of this step attempts to find the minimal region needed to contain the watershed mask at the given resolution. A region will be calculated to allow at least a one-cell border around the watershed area. This region is then presented in an input screen (much like that of *r.region*) for editing or approval. After the project mask, region and resolution are set, the information is recorded and will be reset automatically each time the project is called. This step will create a new raster map in the user's current mapset entitled project name].ELEMENT. This map will act as a reference to ANSWERS' methods of referring to raster cells. Raster values of the map will indicate element number, with the category description giving row and column numbers. If any of the inputs in this step are subsequently reset, all other steps that may have been completed will be marked with a status of "rerun", since changing mask, resolution or region will require that inputs will have to be resampled.

<u>Step 2</u> Catalogue soils parameters
<u>Map input</u>: Soils
<u>Other input</u>: Soils parameters, tile drainage coefficient, groundwater release fraction.
<u>Description</u>: This step prompts for the name of a soil map, then reads the map and lists all soil categories found in the watershed mask. For each soil found in the watershed, ANSWERS requires values for the parameters listed below. The Project Manager facilitates preparation parameters by input into a table.

```
 Soil Parameters for ANSWERS (see ANSWERS Users Manual for more details)
_________________________________________________________________________
 1   total porosity (percent pore space volume of soil)
 2   field capacity (percent saturation)
 3   steady state infiltration rate (mm/hour)
 4   difference between steady state and maximum infiltration rate (mm/hour)
 5   exponent in infiltration equation
 6   infiltration control zone depth (mm)
 7   antecedent soil moisture (percent saturation)
 8   USLE 'K'
_________________________________________________________________________
```

After the soil parameters are input, a screen will prompt for groundwater release fraction and tile drainage coefficient, which will apply to the entire watershed. The tile drainage coefficient indicates the design coefficient (mm/day) of tile drains in those areas designated as having tile drainage. The groundwater release fraction is measure of the contribution of lateral groundwater movement or interflow to total runoff.

After this step is completed, it will provide an option to save the entered parameters to a file or printer for reference. ANSWERS soils inputs will then be extracted and stored. This step may be rerun to change any of the information. Previously entered information will be recalled and may be modified.

<u>Step 3</u> Catalogue land use and surface parameters
<u>Map input</u>: Land cover/use.
<u>Other input</u>: Land cover parameters
<u>Description</u>: For each category in the land use map found in the watershed, ANSWERS requires values for the parameters listed below. The Project Manager facilitates preparation parameters by input into a table.

```
_____________________________________________________________________________
 Land Cover Parameters for ANSWERS (see ANSWERS Users Manual for details)
_________________________________________________________________________
 1    short (8 characters) description of land use and management
 (program will attempt to use map category description, if any)
 2    mm of potential rainfall interception by land cover
 3    percentage of surface covered by specified land use
 4    roughness coefficient of the surface (a shape factor)
 5    m of maximum roughness height of the surface profile
 6    Manning's n (a measure of flow retardance of the surface)
 7    relative erosiveness (function of time and USLE 'C' and 'P')
_________________________________________________________________________
```

After this step is completed, it will provide an option to save the entered parameters to a file or printer for reference. ANSWERS cover inputs will then be extracted and stored. This step may be rerun to change any of the information. Previously entered information will be recalled and may be modified.

<u>Step 4</u> Identify elevation-based input layers
<u>Map input</u>: Slope and aspect.
<u>Description</u>: This step prompts for the names of previously prepared maps of slope and aspect for the project watershed. It is important to note that the required format of slope and aspect maps vary from that created by the *r.slope.aspect* program. Programs have been developed to process an elevation surface map and create ANSWERS slope and aspect map. The elevation map should be true elevations in meters. The elevation map can be "filtered" to remove "pits" and other potential problems to ANSWERS with the *r.fill.dir* program. The *r.direct* program can be used to prepare an ANSWERS aspect map from the elevation layer created by *r.fill.dir*. The *r.slope program* can be used to prepare an ANSWERS slope map from the elevation layer created by *r.fill.dir*. ANSWERS requires slope values which are percent multiplied by 10 (so a slope map value of 35 indicated a slope of 3.5%). The aspect map is a critical input to ANSWERS, since it defines the routing of runoff through the watershed, and should be carefully examined, since the *r.direct* program is unable to create flawless output. The *d.rast.arrow* and the *d.rast.edit* programs have been developed to assist this manual inspection and editing process. When

editing the flow direction map, pay careful attention to 1) cells on the watershed border, which all must flow into the watershed. 2) cells that will be declared as "channels" must flow directly from one to another (therefore it is suggested that channels should be identified in conjunction with this step). 3) flow from two cells must not point directly to each other (-][-) or otherwise form circuitous routes. In the final flow map, one should be able to start at any cell in the watershed and follow the flow directions from cell to cell until arriving at the outlet cell.

Step 5 Prepare rain gauge data
Map input: Rain gauge areas (for multiple gauges)
Other input: Rain gauge data
Description: This step is designed to organize data used to describe the precipitation event to be simulated. ANSWERS permits up to four rain gauges to be used, each of which will require a table of rainfall data (time in minutes and rainfall intensity in millimeters per hour). Data from at least one rain gauge are required. If more than one gauge is used, you will need to prepare a raster map of the watershed area to indicate which cells are to be represented by a given gauge's data.

To facilitate the modeling of a number of storms this step will prompt for a rainfall event name. The data tables entered will be stored in the ANSWERS database under the event name.

Rain gauge data for ANSWERS consists two columns of numbers. The first is Time (in minutes) and the second is Rainfall Intensity (in mm/hour). Decimal values will be rounded to the closest whole number. To input rain gauge data to the Project Manager, a file must first be prepared with rain gauge data. If multiple gauges are to be used, one input file is still used, data for each gauge are separated by should occur sequentially by gauge; so that data for gauge 1 is first in the file, data for gauge two is the second group of data, and so on.

Example rain gauge data input files:

```
_____________________________________________________
 one gauge   |two gauges
_____________________________________________________
 00    |    00
 103   |   111 data for gauge 1
 20    |   10   |   257
 35    |   22   |   -1 -------- delimiter
 559   |    00
 674   |   156 data for gauge 2
 1000  |   104
_____________________________________________________
```

This step will prompt to determine if multiple rain gauges are to be used. If so, it will prompt for the name of a map that represents areas to be assigned to the given gauges. The number of categories and their value should match the number of rain gauges. Next the program prompts for the name of the rain gauge data file. The program reads the file and displays what it found to the screen for approval. Having this, it will create the appropriate ANSWERS input files.

Step 6 Identify outlet cell
Map input: none
Other input: row and column number of watershed outlet element
Description: ANSWERS needs to know the row and column number of the element at the watershed outlet. To facilitate your finding this information, the raster map [project name].ELEMENT has been created. The category values of this map are the sequentially numbered cells of the watershed. The category descriptions are the cell's row and column number. Using a tool such as *d.what.rast*, the row and column number of the outlet cell can be queried from the displayed element map.

Step 7 Specify areas with subsurface drainage
Map input: Areas with subsurface drainage (optional)

Description: This step offers a menu which allows the delineation of 1) all the watershed with subsurface drainage, 2) none of the watershed with subsurface drainage, or 3) areas with subsurface drainage specified with a raster map (all elements with a value greater than zero will be input to ANSWERS as having subsurface drainage. Note: the drainage coefficient for areas with subsurface is set with the other soils parameters in step 2. If "all" or "none" of the watershed is simulated as having subsurface drainage, no input map is required; otherwise a raster map is used to specify areas with subsurface drainage.

Step 8 Catalogue channel parameters
Map input: Channels
Other input: Channel width and roughness coefficient for each category of channel
Description: Watershed cells with a well-defined channel should be defined to ANSWERS. ANSWERS assumes the channel is rectangular in cross-section and is sufficiently deep to handle runoff.

To prepare channel data for use with ANSWERS, the following is needed: a raster map layer of the channels in the watershed and a description of width (meters) and roughness (Manning's "n") for each channel category found in the layer.

It is suggested that the aspect map from Step 4 b created in conjunction with the map, since ANSWERS will abort operation if a one channel element does not flow directly into another adjacent channel element.

Step 9 Define channel slopes
Map input: Channel slope
Description: An optional input to ANSWERS is the slope of channels. If a channel slope input is not given, ANSWERS assumes the slope for the channel is the same as the overland slope for the element.

If desired, a raster map may be used to define channel slope values. To do so, a raster map should be prepared with category values for channel slopes in tenths of a percent (i.e. a category value of 31 would indicate a channel slope of 3.1 percent).

Note: Even though channel slopes are an optional input to ANSWERS, this step must be run if only to say no map will be used.

Step 10 Specify BMP's in watershed
Map input: Tile Outlet Terrace, Sedimentation Pond, Grassed Waterway, and/or Field Borders.
Other input: Grassed waterway or field border width (meters)
Description: This step provides a menu to prepare any or none of the four structural Best Management Practices (BMPs) that ANSWERS recognizes. Many BMPs can be described to ANSWERS by changing variables describing the surface condition of the soil. Practices which are tillage-oriented, for example, are described in the soils and land use sections. Gully structures such as a drop spillway may be simulated by reducing channel slope. On the other hand, BMPs which are structural in nature require a change in land use (row crop to grass for waterways, for example). ANSWERS recognizes four optional BMP structures. Even though the use of BMP structures is optional, this step still must be run to verify this. NOTE: Since ANSWERS will recognize one BMP for a given watershed element, the most effective BMP should be used. The following is a brief discussion of the BMPs:

1. ANSWERS Tile Outlet Terrace Assumptions:

- Trap efficiency of 90%
- Only lowermost terraces are described

Also, if a terrace exists only in a portion of an element, the assumption is made that all incoming flow is influenced by the BMP. Thus, elements which have only a small portion of the practice within their boundaries should not be given credit for the practice.

2. ANSWERS Sedimentation Pond Assumptions:

- Trap efficiency of 95%
- Only ponds in upland areas should be defined. In stream structures are treated differently.

Also, if a pond exists only in a portion of an element, the assumption is made that all incoming flow is influenced by the BMP. Thus, elements which have only a small portion of the practice within their boundaries should not be given credit for the practice.

3. ANSWERS Grassed Waterway Assumptions:

- The vegetated area with in the affected element is no longer subject to any sediment detachment.
- The model deliberately prohibits deposition within the vegetation of a grass waterway, since any waterway that effectively traps sediment would soon fill and become ineffective.

For each category found in the layer, you will be prompted for width of the waterway

4. ANSWERS Field Border Assumptions

- The vegetated area with in the affected element is no longer subject to any sediment detachment. For each category found in the layer, you will be prompted for width of the field border.

<u>Step 11</u> Prepare ANSWERS input and run simulation
<u>Description</u>: Steps 1-10 must have a status of "done" before this step can be run. (Even steps for optional inputs must be run before an ANSWERS input file can be completed). Each of the prior steps will have prepared their part of the ANSWERS input. The first function of this step is to compile all the parts together. Once the input file is complete, the simulation can be run. (NOTE: *r.answers* will call the ANSWERS program, which must be compiled as a part of the r.*answers* installation. The source code for ANSWERS should be part of the software distributed with *r.answers*.) The error messages that ANSWERS may send to "standard output" are captured to a file by *r.answers* and displayed. If none, a message to that effect will be printed to the screen (although this doesn't mean that the simulation ran entirely error-free). The primary output of the simulation is captured to another file, then processed to separate it into component parts of 1) text - the verbose reiteration of the inputs and summary of watershed characteristics. This is useful for checking to insure that inputs were read in by ANSWERS properly; 2) outlet hydrograph data of rainfall, runoff and sediment yield and concentration. If these data are in order, they will be processed into a format readable by the *d.linegraph* program for display; 3) individual element net sedimentation showing sediment loss or deposition, if any, for each raster element in the watershed. Also, sediment deposition in channel elements. This step will prompt for names to use for new watershed maps it will create by extracting these data from the output. If the simulation event did not create sediment loss or deposition, or channel deposition for the scenario, the given map will not be created. To find out how to access the output files, see the description of step 12, below.

<u>Step 12</u> Miscellaneous Command Menu
This step calls a menu that 1) allows access to the project files in the project database and to 2) a function that prepares a summary of the project's current status.

The project database is where *r.answers* stores all the inputs, output, and other non-map data associated with the project. See the "FILES" section (below) for more information. There are two sections to the project data, since rainfall data are kept in a separate directory. When using this step to access database files, the program will list both the project data and the rain data files, and ask which section you wish to access. Next you will be prompted for the name of the file to access. This request will be turned over to the "file handler program" which facilitates sending a file to the screen, copying to another file, or printing.

The project status function available under step 12 creates a helpful summary of the project, and then passes control to the "file handler program" for display, copying to a file, or printing.

Index of ANSWERS on GRASS database
Each project will create and use the following files in $LOCATION/answers/[project name]/data. For the most part, there isn't much to see, unless something is not working right. If that is the case, the first thing to check would be files listed here under the Output section or Input file. Furthermore, attempting to fix a problem by editing any of these files could prove to have unpredictable results. Once a problem is identified (with the input maps or parameters, most likely) fix the input maps if need be, run *r.answers* again to make any changes, such a using a different map or correcting parameters. Remember that if a map is changed the menu step that uses it must be run again to resample the inputs. Run step 11 again to create a new input file and re-run ANSWERS.

General project data
*reclass* reclass rules to create project MASK regionproject region coordinates

ANSWERS Input file
*answers_input* file created to use as input to ANSWERS

ANSWERS Output
When ANSWERS is run, output from stdout is sent to answers_output and anything that may go to stderr is captured in answers_error. After that the output is cut into sections. (if something unpredictable happened when ANSWERS ran, then the output and the files extracted from it may be garbled; reading answers_output and answers_error may provide clues).

*answers_output* complete output from running answers
*answers_error* errors captured when answers is run
*out_chnl* channel deposition data
*out_sediment* element sediment deposition/loss data
*out_text* verbose input reiteration
*out_hydro* outlet hydrograph data

The outlet hydrograph data is broken into 5 files to use as input to *d.linegraph*

*hydro_time* time increments of simulation (minutes)
*hydro_rain* rainfall (mm/h)
*hydro_runoff* runoff at outlet (mm/h)
*hydro_sed1* cumulative sediment at outlet (kg)
*hydro_sed2* sediment concentration in runoff (mg/l)

ANSWERS Element data
Element data files are extracted from input maps. Each line is data for a watershed cell element. When answers input is created, these files are used to create the element data section.

*in_row_col* watershed row and column number
*in_soil* soil type
*in_cover* land use
*in_elev* slope and aspect
*in_chnl* channel element data
*in_rain* rain gauge number
*in_tile* subsurface drainage flag

ANSWERS Predata
The following files are used to form the "predata" section of the answers input file.

| | |
|---|---|
| *chnl_predata* | description of channel types |
| *cover_predata* | description of cover parameters |
| *soil_predata* | description of soil parameters |
| *rain_predata* | rain gauge data |

Parameter data
These files are used by the project manager to "remember" parameters used to create the respective predata files, allowing the parameters to be read back by the program for editing.

| | |
|---|---|
| *chnl_data* | channel parameters |
| *cover_data* | cover parameters |
| *soil_data* | soil parameters |

**SEE ALSO**
*d.INTRO, d.rast.edit, d.rast.num, d.what.rast, r.slope, r.fill.direct, r.direct,*

**AUTHOR**
Chris Rewerts, Agricultural Engineering, Purdue University

## *r.average*

**NAME**
*r.average* **-** Finds the average of values in a cover map within areas assigned the same category value in a user-specified base map.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.average*
*r.average help*
*r.average [-c] base=name cover=name output=name*

**DESCRIPTION**
*r.average* calculates the average value of data contained in a cover raster map layer for areas assigned the same category value in the user-specified base raster map layer. These averaged values are stored in the category labels file associated with a new output map layer.

The values to be averaged are taken from a user-specified cover map. The category values for the cover map will be averaged, unless the -c flag is set. If the -c flag is set, the values that appear in the category labels file for the cover map will be averaged instead (see example below).

The output map is actually a reclass of the base map (see *r.reclass*), and will have exactly the same category values as the base map. The averaged values computed by *r.average* are stored in the output map's category labels file.

If the user simply types *r.average* on the command line, the user is prompted for the flag setting and parameter values through the standard *parser* interface (see *parser* manual entry).

Alternately, the user can supply all needed flag settings and parameter values on the command line.

Flag:
-*c* Take the average of the values found in the category labels for the cover map, rather than the average of the cover map's category values.

Parameters:
*base=name* An existing raster map layer in the user's current mapset search path. For each group of cells assigned the same category value in the base map, the values assigned these cells in the cover map will be averaged.

*cover=name* An existing raster map layer containing the values (in the form of cell category values or cell category labels) to be averaged within each category of the base map.

*output=name* The name of a new map layer to contain program output (a reclass of the base map). Averaged values will be stored in the output map's category labels file under the user's $LOCATION/cats directory.

**EXAMPLE**
Assume that farms is a map with 7 farms (i.e., 7 categories), and that soils.Kfactor is a map of soil K factor values with the following category file:

```
cat   cat
value   label
0no soil data
1.10
2.15
3.17
4.20
5.24
6.28
7.32
8.37
9.43
```

Then

*r.average* **-***c base=farms cover=soils.Kfactor output=K.by.farm*

will compute the average soil K factor for each farm, and store the result in the output map K.by.farm, which will be a reclass of farms with category labels as follows (example only):

```
catcat
value   label
1.1023
2.1532
3.172
4.3872
5.003
6.28
7.2345
```

NOTES
The **-**c option requires that the category label for each category in the cover map be a valid number, integer, or decimal. To be exact, if the first item in the label is numeric, then that value is used. Otherwise, zero is used. The following table covers all possible cases:

```
category label   value used by -c
_________________________________
.12               .12
.80 KF            .8
no data            0
```

(This flag is very similar to the @ operator in *r.mapcalc*, and the user is encouraged to read the manual entry for *r.mapcalc* to see how it works there.)

The user should use the results of *r.average* with care. Since this utility assigns a value to each cell which is based on global information (i.e., information at spatial locations other than just the location of the cell itself), the resultant map layer is only valid if the geographic region and mask settings are the same as they were at the time that the result map was created.

Results are affected by the current region settings and mask.

**SEE ALSO**
*g.region, r.cats, r.clump, r.describe, r.mapcalc, r.mask, r.mfilter, r.mode, r.neighbors, r.reclass, r.stats, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.basins.fill*

**NAME**
*r.basins.fill* **-** Generates a raster map layer showing watershed subbasins.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.basins.fill*
*r.basins.fill help*
*r.basins.fill number=value c_map=name t_map=name result=name*

**DESCRIPTION**
*r.basins.fill* generates a raster map layer depicting subbasins, based on input raster map layers for the coded stream network (where each channel segment has been "coded" with a unique category value) and for the ridges within a given watershed. The raster map layer depicting ridges should include the ridge which defines the perimeter of the watershed. The coded stream network can be generated as part of the *r.watershed* program, but the map layer of ridges will need to be created by hand, either through digitizing done in *v.digit*, or through the on-screen digitizing option accessible within *d.display* or *d.digit*.

The resulting output raster map layer will code the subbasins with category values matching those of the channel segments passing through them. A user-supplied number of passes through the data is made in an attempt to fill in these subbasins. If the resulting map layer from this program appears to have holes within a subbasin, the program should be rerun with a higher number of passes.

The user can run *r.basins.fill* either interactively or non- interactively. If the user simply types *r.basins.fill* without other arguments on the command line, the program will prompt the user for the needed parameters using the standard GRASS *parser* interface (see manual entry for *parser*).

If the user wishes to run the program non-interactively, the following parameter values must be specified on the command line:

Parameters:

| | |
|---|---|
| *number=value* | The number of passes to be made through the dataset. |
| *c_map=name* | The coded stream network file name. |
| *t_map=name* | The thinned ridge network file name. |
| *result=name* | The resultant watershed partition file name. |

**NOTES**
The current geographic region setting is ignored. Instead, the geographic region for the entire input stream's map layer is used.

**SEE ALSO**
See Appendix A of the GRASS Tutorial *r.watershed* for further details on the combined use of *r.basins.fill* and *r.watershed*
*d.digit, d.display, r.watershed, v.digit, parser*

## AUTHORS

Dale White, Dept. of Geography, The Pennsylvania State University
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## *r.bilinear*

**NAME**
*r.bilinear* **-** bilinear interpolation utility for raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.bilinear [-q] input=name output=name [north=value] [south=value]*

**DESCRIPTION**
*r.bilinear* fills a grid cell (raster) matrix with interpolated values generated from a set of input layer data points. It uses the bilinear interpolation method, a simple algorithm usually applied only to completely defined raster areas (input data void of null data values). Here the values of 4 input cells are used to define an interpolation function of constant gradient within each rectangular area defined by the cell centers. User should be aware that the gradient of the interpolation functions changes discontinuously across lines intersecting the cell centers of the input raster.

If there is a current working mask, it applies to the output raster file. Only those cells falling within the mask will be assigned interpolated values. The procedure for selection of input data will consider all input data relevant to interpolating values at the cell centers of the current geographic region, ignoring the current mask. Zero values of the input raster are assumed to be real values of a continuous variable, thus *r.bilinear* supports interpolation of variables that range from negative to positive values. If input zero values are in fact nulls, the user bears responsibility for controlling the quality of the output, either through post-interpolation editing of the output or pre-interpolation setting of the current mask. Note that cells of the output raster that cannot be bounded by 4 input cell centers are set to zero (null).

**OPTIONS**
Flags:
-*q* specifies that *r.bilinear* run quietly (suppressing the printing of program messages to standard output)

Parameters:
*input=name* Name of an input raster map layer containing data values to apply in the interpolation.

*output=name* Name to be assigned to new output raster map that represents the surface generated from the data values in the input layer.

*north=value* Input raster value for the north pole (90N). Valid for longitude-latitude grids only.

*south=value* Input raster value for the south pole (90S). Valid for longitude-latitude grids only.

**NOTES**
The north* and south* parameters have been included to allow for specific input values to be assigned to the north and/or south poles for longitude-latitude grids. These data, if included, are used to interpolate values for cells that are north or south of a line intersecting the cell centers of the first or last row of input, respectively. When utilized, the interpolation procedure will be continuous from the north and/or south boundary of the current geographic region. This option is necessary, since the data structure defining a raster will not allow for data to be assigned to a cell centered at 90N or 90S. By including the option, the user can create output surfaces that are continuous between the poles. The interpolation will be "wrap-

around" from west to east (across latitude) only if the input raster has an east edge identical to its west edge.

For longitude-latitude databases, the interpolation algorithm is based on degree fractions, not on the absolute distances between cell centers.  Any attempt to implement the latter would violate the integrity of the interpolation method.

*r.bilinear* may be used in some instances as an alternative to the nearest neighbor approach inherent to *r.resample*.  Note, however, that the extent of non-null data area of the output raster must be less than that of the input raster.  The only exception to this occurs in the case where the north* and south* parameters are utilized for longitude-latitude rasters.

**SEE ALSO**
*r.surf.idw, r.surf.idw2, g.region, r.resample*

**AUTHOR**
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## *r.binfer*

**NAME**
*r.binfer* **-** Bayesian expert system development program.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.binfer*
*r.binfer help*
*r.binfer [-v] input=name [output=name]*

**DESCRIPTION**
*r.binfer* is an expert system shell containing an inference engine based on Bayesian statistics (reasoning from past experience). It is designed to assist human experts in a field develop computerized expert systems for land use planning and management. These expert systems are designed to aid non-experts make decisions about land use.

In Bayesian expert system programs like *r.binfer*, the system bases the probable impacts of a future land use action on the conditional probabilities about the impact of similar past actions.

**OPTIONS**
Flags:
-*v* Run verbosely, displaying messages on debugging output to standard output. Includes a listing of the symbol table used by *r.binfer*.

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing file containing analysis instructions. |
| *output=name* | Name to be assigned to the file to contain program output. Default: *binfer.out* |

Using appropriate *r.binfer* syntax, the human expert structures an input knowledge/control script with an appropriate combination of map layer category values (GRASS raster map layers that contain data on soil texture, slope, density, etc.) and attributes relevant to decision-making (e.g., rainfall, temperature, season, subjective judgement, etc.). Options exist for specifying a user interface and a data base containing prior and conditional probabilities necessary to infer the value of a goal attribute. The expert also specifies the format for display of end results (raster map layers) in the input script. New raster map layers -- one for each possible inferred attribute value -- are created that contain the probability of the inferred attribute value occurring in each grid cell.

Alternately, a single new map layer called *r.binfer* (or whatever output name is specified by the user) is also output. This map shows, for each grid cell, the inferred attribute value that has the highest probability of occurring in each grid cell, given the values of the input raster map layer and contextual attributes.

*r.binfer* scripts are typed into a file by the user using a system editor like *vi*, and then input to *r.binfer* as the input file named on the command line. For a complete description of the input syntax, see the document GRASS Tutorial: *r.binfer*. For example *r.binfer* scripts see the EXAMPLES section below. The results are used to generate the new raster map layers in the user's current mapset.

As stated above, *r.binfer* scripts contain descriptions of two types of input attributes. The map layer type attributes are actual GRASS raster map layers, with the values defined to be ranges of the categories within that raster map layer.  For example, if the user chooses slope as one of the layer attributes, the possible values for the slope attribute might be the following:

flat (slopes between 0 and 5 degrees)
low (slopes between 6 and 10 degrees)
medium   (slopes between 11 and 30 degrees)
steep(slopes greater than 31 degrees)

The contextual attributes are those that do not represent raster map layers, but rather, information that reflect criteria relevant to the specific decision being contemplated.  For example, if the user chooses "rainfall amount" as one of the contextual attributes, possible values assigned to the "rainfall amount" attribute might be the following:

low (rainfall amounts less than an inch)
medium   (rainfall amounts between one and three inches)
high  (rainfall amounts grater than three inches)

The inferred attribute values are specified along with a prior probability and a table of conditional probabilities that indicate the probability of that inferred attribute value occurring given that an input attribute value has occurred.

*r.binfer* will determine the value of contextual attributes by prompting the user for input.  It will then open each of the raster map layers corresponding to each map layer

attribute.  *r.binfer* then determines the values for all map layer attributes in each grid cell.  Using the conditional probability tables, the prior probabilities, and Bayes' theorem, *r.binfer* calculates the output probabilities for each inferred value and writes its probability of occurrence as a percentage.  It also determines which value is most likely to occur in that cell and writes that to the output file name.

**EXAMPLES**
The two sample scripts shown below illustrate only the use of *r.binfer* to: (1) estimate the probability that an avalanche will occur, and (2) infer the probability of finding pine mountain beetles, at each cell across a landscape, given the input map layer attributes shown below. The author makes no claims as to the correctness of using these criteria to infer either event.

Some Notes on Script Construction.

1. No Data ( or what to do with category zero).

If category zero is excluded from the ranges of any layer attribute value, it is treated as "no data" and the resulting probability and combined maps will reflect this.

Otherwise, category zero is treated just like any other cell value.

2. Category ranges for layer attributes.

The category ranges are specified using *r.reclass* rules.  For example, a value list for slope might look like this:

*(flat [0 1 thru 3], gentle [4 thru 8], moderate [9 thru 15], other [16 thru 89]).*

3. Question Attachments.

Question attachments can be supplied for and context attribute or attribute value. If names are chosen cleverly, the default menu should be sufficient.

4. Determinant List.

At this time the determinant list serves no real purpose.

Planned extensions to binfer will make use of this list, so just don't use it for now.

5. Probabilities.
The conditional probability table is very important, try to be sure of its accuracy.

```
#
# Filename:  avalanche.binfer
#
# This is a r.binfer script that infers the probability of an
# avalanche occurring, given the values of the input attributes.
#
# NOTE:  Execute r.binfer as follows:
#   r.binfer avalanche.binfer [output=name]
#   If the user does not specify an output file name,
#   the combined map will be named binfer.
#
# Script file output keywords:
#
#CombinedMap (Colortable) - assigns the combined map the given colortable.
#NoCombinedMap - only generates probability maps
# (one for each inferred attribute value).
#NoProbabilityMaps - only generates combined map.
#(Colortable) can be any of the following keywords:
#Aspect - aspect colors,
#Grey,Gray - grey scale,
#Histo - histogram stretched grey scale,
#Rainbow - rainbow colors,
#Ramp - color ramp (default),
#Random - random colors,
#RYG - red yellow green,
#Wave - color wave.
#
#
# Start layer attribute section.
#
layer:
#
# Layer attribute #1 is aspect
#
aspect:
#
#   all southern exposures = 1.
#   all eastern exposures  = 2.
#   all western exposures  = 3.
#   all northern exposures = 4.
#   all others = 0.
#
 (south[16 thru 22],east[22 23 1 thru 4],west[11 thru 15], north[5 thru 10]).
#
# Layer attribute #2 is slope
#
slope:
#
# low - 0 to 9 degrees
# moderate - 10 - 19 degrees
# steep - 20 - 29 degrees
# severe - 30 - 88 degrees
#
 (low[1 thru 10],moderate[11 thru 19],steep[20 thru 30],severe[31 thru 89]).
%
# End of layer section
```

```
#
# Start context section
#
context:
#
# Contextual attribute #1 is temperature
# NOTE: A menu will be constructed using the attribute name and
#  the names of the attribute values.
#  The user will be prompted to enter his choice.
#
temperature:
 (freezing,cold,warm,hot).
#
# Contextual attribute #2 is snowfall_amt
# NOTE: A menu will be constructed using the question attachments
#  supplied here.
#  The user will be prompted to enter his choice.
#
snowfall_amt:
 (a {question "Less than one foot."},
  b {question "Between a foot and four feet."},
  c {question "More than four feet."})
  {question "How much snow has accumulated ?"}.
%
# End of context section.

#
# Start inferred section
#
inferred:
#
# Inferred attribute is avalanche.
#
avalanche:
#
# Inferred attribute value "high".
# A colortable of Ramp will be assigned (default).
# NOTE: Prior probability, and conditional probabilities are given in
#  this section.
#
 (high <0.20>
 [0.10,0.50,0.20,0.20;
  0.05,0.15,0.20,0.60;
  0.80,0.15,0.00,0.05;
  0.05,0.35,0.60;] ,
#
# Inferred attribute value "moderate".
# A colortable of Grey will be assigned.
#
 moderate Grey <0.30>
 [0.15,0.35,0.25,0.25;
  0.10,0.20,0.20,0.50;
  0.75,0.20,0.00,0.05;
  0.05,0.35,0.60;] ,
#
# Inferred attribute value "low".
# A colortable of Rainbow will be assigned.
#
 low Rainbow <0.50>
 [0.25,0.25,0.25,0.25;
  0.25,0.25,0.25,0.25;
  0.50,0.30,0.10,0.10;
  0.10,0.40,0.50;] ).
%
# End of inferred section.
# End of avalanche.binfer script.



#
# Filename: bugs.binfer
#
# This is a r.binfer script that infers the probability of finding
# pine mountain beetles, given the input layer attributes below.
# NOTE:  Execute r.binfer as follows:
#binfer bugs.binfer [output=name]
#   if the user does not specify an output name, the combined map
#   will be named binfer.
#
# Script file output keywords:
#
#CombinedMap (Colortable) - assigns the combined map the given colortable.
#NoCombinedMap - only generates probability maps
# (one for each inferred attribute value).
#NoProbabilityMaps - only generates combined map.
#(Colortable) can be any of the following keywords:
#Aspect - aspect colors,
#Grey,Gray - grey scale,
#Histo - histogram stretched grey scale,
#Rainbow - rainbow colors,
#Ramp - color ramp (default),
#Random - random colors,
#RYG - red yellow green,
#Wave - color wave.
#
# Choose the combined map colortable to be a color wave
CombinedMap Wave
#
# Start layer attribute section.
#
layer:
#
# Layer attribute #1 is slope
#
slope:
#
#
(low[1 thru 10],moderate[11 12 13 14 thru 20],steep[21 thru 30],severe[31 thru 89]).
#
# Layer attribute #2 is aspect
#
aspect:
#
#
 (south[16 thru 22],east[22 23 1 thru 4],west[11 thru 15],
    north[5 thru 10]).
#
# Layer attribute #3 is vegcover
#
vegcover:
(other[1 thru 2],coniferous[3],deciduous[4],mixed[5],disturbed[6]).
#
# Layer attribute #4 is (forest) density
#
density:
(nonforest[1],sparse[2],moderate[3],dense[4]).
%
# End of layer section.

#
# Start inferred section
#
inferred:
#
# Inferred attribute is bugs
#
bugs:
#
# Inferred attribute value "bugs".
# A colortable of Ramp will be assigned (default).
# NOTE: Prior probability, and conditional probabilities are given in
#  this section.
#
(bugs <0.20>
 [0.124,0.416,0.371,0.090;# conditionals corresponding to slope,
  0.180,0.292,0.292,0.239;# myaspect,
  0.011,0.798,0.022,0.169,0.0; # vegcover,
  0.202,0.326,0.213,0.258;],   # and density (one per value).
#
# Inferred attribute value "nobugs".
# A colortable of Rainbow will be assigned.
#
 nobugs Rainbow <0.80>
   [0.404,0.416,0.157,0.011;
    0.225,0.281,0.281,0.225;
    0.281,0.427,0.135,0.056,0.0;
    0.584,0.112,0.202,0.112;]).
%
# End of inferred section.
# End of bugs.binfer script.
```

**SEE ALSO**
GRASS Tutorial *r.binfer*

**AUTHOR**
Kurt Buehler, Purdue University

# *r.buffer*

**NAME**
*r.buffer* - Creates a raster map layer showing buffer zones surrounding cells that contain non-zero category values.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.buffer*
*r.buffer help*
*r.buffer [-q] input=name output=name distances=value[,value,...] [units=name]*

**DESCRIPTION**
*r.buffer* creates a new raster map layer showing buffer (a.k.a., "distance" or "proximity") zones around all cells that contain non-zero category values in an existing raster map layer. The distances of buffer zones from cells with non- zero category values are user-chosen. Suppose, for example, that you want to place buffer zones around roads. This program could create the raster map layer shown below on the right based on road information contained in the raster map layer shown on the left.

```
000000000000000000000000   111122222222222222333333
111000000000000000000000   000111111111112222222222
000111111111100000000000   111000000000001111222222
000000001000011100000000   221111110111100011111111
000000001000000011111111   222222210122111100000000
000000001000000000000000   322222210122222111111111
000000001000000000000000   333332210122222222222222
000000001000000000000000   333332210122332222222222
000000001000000000000000   333332210122333333333333
Category 0: No roads  Category 0: Road location
Category 1: Roads Category 1: Buffer Zone 1 around roads
Category 2: Buffer Zone 2 around roads
Category 3: Buffer Zone 3 around roads
```

**INTERACTIVE PROGRAM USE**
The user can run the program interactively by simply typing *r.buffer* without program arguments on the command line. The program then prompts the user for parameter values.

(1) You are requested to identify the existing raster map layer from which distance-from calculations shall be based, and a name (of your choice) for the new raster map layer which will contain the results.

(2) Then, identify the units of measurement in which buffer (distance) zones are to be calculated, and the distance of each buffer zone from each non-zero cell in the input map. The user has the option of identifying up to 60 continuous zones. The zones are identified by specifying the upper limit of each desired zone (*r.buffer* assumes that 0 is the starting point). ("Continuous" is used in the sense that each category zone's lower value is the previous zone's upper value. The first buffer zone always has distance 0 as its lower bound.) Distances can be entered in one of four units: meters, kilometers, feet, and miles.

(3) Last, calculate distances from cells containing user- specified category values, using the "fromcell" method. [The "fromcell" method goes to each cell that contains a category value from which distances are to be calculated, and draws the requested distance rings around them. This method works very fast when there are few cells containing the category values of interest, but works slowly when there are numerous cells containing the category values of interest spread throughout the area.]

The *r.buffer* program now runs the process in "background" and returns keyboard control to the user. These processes can occasionally take up to an hour or more to finish; however, because they run in the background, you are free to do other things with the computer in the interim.

**NON-INTERACTIVE PROGRAM USE**
The user can run *r.buffer* specifying all parameter values on the command line, using the form:

*r.buffer* [-q] input=name output=name distances=value[,value,...] [units=name]

Flags:
-*q* Run quietly

Parameters:
*input=name* The name of an existing raster map layer whose non-zero category value cells are to be surrounded by buffer zones in the output map.

*output=name* The name assigned to the new raster map layer containing program output. The output map will contain buffer zones at the user-specified distances from non-zero category value cell in the input map.

*distances=value[,value,...]* The distance of each buffer zone from cells having non-zero category values in the input map.

*units=name* The unit of measurement in which distance zone values are to be calculated. Possible choices for name are: meters, kilometers, feet, and miles. The default units used, if unspecified by the user, are meters.

**EXAMPLE**
In the example below, the buffer zones would be (in the default units of meters): 0-10, 11-20, 21-30, 31-40 and 41-50.

Format:
*r.buffer input=name output=name distances=value[,value,...] [units=name]*

Example:
*r.buffer input=map.in output=map.out distances=10,20,30,40,50 units=meters*

**NOTES**
*r.buffer* measures distances from center of cell to center of cell using Euclidean distance measure for planimetric databases (like UTM) and using ellipsoidal geodesic distance measure for latitude/longitude databases.

*r.buffer* calculates distance zones from all cells having non-zero category values in the input map. If the user wishes to calculate distances from only selected input map layer category values, the user should run (for example) *r.reclass* prior to *r.buffer*, to reclass all categories from which distance zones are not desired to be calculated into category zero.

**SEE ALSO**
*r.region, r.mapcalc, r.reclass*

**AUTHORS**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory
James Westervelt, U.S. Army Construction Engineering Research Laboratory

## *r.cats*

**NAME**
*r.cats* **-** Prints category values and labels associated with user-specified raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.cats*
*r.cats help*
*r.cats map=name [cats=range[,range,...]][fs=character|space|tab][vals=value]*

**DESCRIPTION**
*r.cats* prints the category values and labels for the raster map layer specified by map=name to standard output.

The user can specify all needed parameters on the command line, and run the program non-interactively. If the user does not specify any categories (e.g., using the optional cats=range[,range,...] argument), then all the category values and labels for the named raster map layer that occur in the map are printed. The entire map is read, using *r.describe*, to determine which categories occur in the map. If a listing of categories is specified, then the labels for those categories only are printed. The cats may be specified as single category values, or as ranges of values. The user may also (optionally) specify that a field separator other than a space or tab be used to separate the category value from its corresponding category label in the output, by using the fs=character|space|tab option (see example below). If no field separator is specified by the user, a tab is used to separate these fields in the output, by default.

The output is sent to standard output in the form of one category per line, with the category value first on the line, then an ASCII TAB character (or whatever single character or space is specified using the fs parameter), then the label for the category.

If the user simply types *r.cats* without arguments on the command line the program prompts the user for parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

Parameter:

| | |
|---|---|
| vals=value | Comma separated value list: e.g. 1.4, 3.8, 13 |

**EXAMPLES**
*r.cats map=soils*

prints the values and labels associated with all of the categories in the soils raster map layer;

*r.cats map=soils cats=10,12,15-20*

prints only the category values and labels for soils map layer categories 10, 12, and 15 through 20; and

*r.cats map=soils cats=10,20 fs= :*

prints the values and labels for soils map layer categories 10 and 20, but uses ":" (instead of a tab) as the character separating the category values from the category values in the output.

Example output:

```
10:Dumps, mine, Cc
20:Kyle clay, KaA
```

**NOTES**
Any ASCII TAB characters which may be in the label are replaced by spaces.

The output from *r.cats* can be redirected into a file, or piped into another program.

**SEE ALSO**
UNIX Manual entries for awk and sort
*r.coin, r.describe, r.rast.what, r.support, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.circle*

**NAME**
*r.circle* – Creates a raster map containing concentric rings around a given point.

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.circle output=name coordinate=x,y [mult=value]*

**DESCRIPTION**
This module creates a raster map containing concentric rings around a given point. The cell values are increasing linear from the center point to outer rings.

**OPTIONS**
Parameters:

| | |
|---|---|
| *output=name* | Name for new raster file. |
| *coordinate=x,y* | The coordinate of the center (easting, northing) |
| *mult=value* | Multiplier |

**AUTHOR**
Bill Brown, U.S. Army Construction Engineering Research Laboratory

## *r.clump*

**NAME**
*r.clump* **-** Recategorizes data in a raster map layer by grouping cells that form physically discrete areas into unique categories.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.clump*
*r.clump help*
*r.clump [-q] input=name output=name [title="string"]*

**DESCRIPTION**
*r.clump* finds all areas of contiguous cell category values in the input raster map layer name. It assigns a unique category value to each such area ("clump") in the resulting output raster map layer name. If the user does not provide input and output map layer names on the command line, the program will prompt the user for these names, using the standard *parser* interface (see manual entry for *parser*).

Category distinctions in the input raster map layer are preserved. This means that if distinct category values are adjacent, they will NOT be clumped together. (The user can run *r.reclass* prior to *r.clump* to recategorize cells and reassign cell category values.)

**OPTIONS**
Flag:

| | |
|---|---|
| -*q* | Run quietly, without printing messages on program progress to standard output. |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing raster map layer being used for input. |
| *output=name* | Name of new raster map layer to contain program output. |
| *title="string"* | Optional title for output raster map layer, in quotes. If the user fails to assign a title for the output map layer, none will be assigned it. |

**ALGORITHM**
*r.clump* moves a 2x2 matrix over the input raster map layer. The lower right-hand corner of the matrix is grouped with the cells above it, or to the left of it. (Diagonal cells are not considered.)

**NOTES**
*r.clump* works properly with raster map layers that contain only "fat" areas (more than a single cell in width). Linear elements (lines that are a single cell wide) may or may not be clumped together depending on the direction of the line -- horizontal and vertical lines of cells are considered to be contiguous, but diagonal lines of cells are not considered to be contiguous and are broken up into separate clumps.

A random color table and other support files are generated for the output raster map layer.

**SEE ALSO**
*r.average, r.buffer, r.combine, r.grow, r.infer, r.mapcalc, r.mfilter, r.neighbors, r.poly, r.reclass, r.support, r.weight, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## ***r.cn***

**NAME**
*r.cn* **-** Generates a curve number map layer
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.cn*
*r.cn help*
*r.cn sg=name lu=name pr=name hc=name cn=name amc=value*

**DESCRIPTION**
*r.cn* generates a SCS Curve Number raster map in GRASS.

**OPTIONS**
Parameters:

| | |
|---|---|
| *sg=name* | Raster input map of hydrologic soil groups. |
| *lu=name* | Raster input map of landuse. |
| *pr=name* | Raster input map of cultural practice or management. |
| *hc=name* | Raster input map of hydrologic condition. |
| *cn=name* | Raster output map of curve numbers. |
| *amc=value* | Equivalent AMC condition number for the curve number output. |

Options: 1-3

*r.cn* uses information from the four map layers by reading the cell layer and its category files. So it is important to update the category files for all four layers and it expects the categories of the map layer exactly as shown below:

For the hydrologic soil group map (sg=), the categories may be either A, B, C or D.

For the landuse map (lu=), the categories may be either fallow, row crops, small grain, close-seeded legumes, rotation meadow, pasture, range, meadow, woods, farmsteads, roads (dirt) or hard surface.

For the cultural practice or management map layer the categories may be straight row, contoured, or contoured and terraced.

For the hydrological condition map the categories may be poor, fair, or good.

If the combination of the four layers categories does not exist in the SCS CN table, an error message is printed and the program quits.

**NOTE**
The *r.cn* program is sensitive to the current window setting. Thus the program can be used to generate a CN map of any sub-area within the full map layer. Also, *r.cn* is sensitive to any mask in effect.

**AUTHORS**

Raghavan Srinivasan, Bernie Engel, and James Darrell McCauley, Agricultural Engineering, Purdue University

# *r.coin*

**NAME**
*r.coin* **-** Tabulates the mutual occurrence (coincidence) of categories for two raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.coin*
*r.coin help*
*r.coin [-qw] map1=name map2=name units=name*

**DESCRIPTION**
*r.coin* tabulates the mutual occurrence of two raster map layers' categories with respect to one another. This analysis program respects the current geographic region and mask settings.

The user can run the program non-interactively by specifying all needed flags settings and parameter values on the command line, in the form:

*r.coin* [-qw] map1=name map2=name units=name

Flags:

| | |
|---|---|
| -*q* | Run quietly, and suppress the printing of program status messages to standard output. |
| -*w* | Print a wide report, in 132 columns (default: 80 columns) |

Parameters:

| | |
|---|---|
| *map1=name* | Name of first raster map layer. |
| *map2=name* | Name of second raster map layer. |
| *units=name* | Units of measure in which to output report results. |

Options: c, p, x, y, a, h, k, m

Alternately, the user can run *r.coin* interactively by simply typing *r.coin* without command line arguments; in this case, the user will be prompted for the names of the two raster map layers, which will be the subjects of the coincidence analysis. *r.coin* then tabulates the coincidence of category values among the two map layers and prepares the basic table from which the report is to be created. This tabulation is followed by an indication of how long the coincidence table will be. If the table is extremely long, the user may decide that viewing it is not so important after all, and may cancel the request at this point. Assuming the user continues, *r.coin* then allows the user to choose one of eight units of measure in which the report results can be given. These units are:

| | |
|---|---|
| c | cells |
| p | percent cover of region |
| x | percent of <map name> category (column) |
| y | percent of <map name> category (row) |
| a | acres |
| h | hectares |
| k | square kilometers |
| m | square miles |

Note that three of these options give results as percentage values: "p" is based on the grand total number of cells; "x" is based on only column totals; and "y" is based on only row totals. Only one unit of measure can be selected per report output. Type in just one of the letters designating a unit of measure followed by a <RETURN>. The report will be printed to the screen for review. After reviewing the report on the screen, the user is given several options. The report may be saved to a file and/or sent to a printer. If printed, it may be printed with either 80 or 132 columns. Finally, the user is given the option to rerun the coincidence tabulation using a different unit of measurement.

Below is a sample of tabular output produced by *r.coin*. Here, map output is stated in units of square miles. The report tabulates the coincidence of the Spearfish sample database's owner and road raster map layers' categories. The owner categories in this case refer to whether the land is in private hands (category 1) or is owned by the U.S. Forest Service (category 2). The roads map layer categories refer to various types of roads (with the exception of category value "0", which indicates "no data"; i.e., map locations at which no roads exist). *r.coin* does not report category labels. The user should run *r.report* or *r.cats* to obtain this information.

The body of the report is arranged in panels. The map layer with the most categories is arranged along the vertical axis of the table; the other, along the horizontal axis. Each panel has a maximum of 5 categories (9 if printed) across the top. In addition, the last two columns reflect a cross total of each column for each row. All of the categories of the map layer arranged along the vertical axis are included in each panel. There is a total at the bottom of each column representing the sum of all the rows in that column. A second total represents the sum of all the non-zero category rows. A cross total (Table Row Total) of all columns for each row appears in a separate panel.

Note how the following information may be obtained from the sample report.

In the Spearfish data base, in area not owned by the Forest Service, there are 50.63 square miles of land not used for roads. Roads make up 9.27 square miles of land in this area. Of the total 102.70 square miles in Spearfish, 42.80 square miles is owned by the Forest Service. In total, there are 14.58 square miles of roads. There are more category 2 roads outside Forest Service land (2.92 mi. sq.) than there are inside Forest land boundaries (0.72 mi. sq.).

Following is a sample report.

```
+-----------------------------------------------------------------------+
|COINCIDENCE TABULATION REPORT                                          |
|-----------------------------------------------------------------------|
|Location: spearfish    Mapset: PERMANENT   Date: Wed Jun 1  13:36:08 |
|                                                                       |
| Layer 1: owner-- Ownership                                            |
| Layer 2: roads-- Roads                                                |
| Mask:    none                                                         |
|                                                                       |
| Units:   square miles                                                 |
|-----------------------------------------------------------------------|
| Window:              North: 4928000.00                                |
|          West: 590000.00           East: 609000.00                    |
|                      South: 4914000.00                                |
+-----------------------------------------------------------------------+
```

Panel #1 of 1

```
+---------------------------------------------------------+
|        | owner  |    Panel Row Total                     |
|   cat# |    1   |    2     |   w cat 0  | w/o cat 0     |
|---------------------------------------------------------|
|r0 |50.63 |37.49 |88.12 |88.12                           |
|o1 | 1.53 | 0.68 | 2.21 | 2.21                           |
|a2 | 2.92 | 0.72 | 3.64 | 3.64                           |
|d3 | 3.97 | 2.57 | 6.54 | 6.54                           |
|s4 | 0.65 | 1.36 | 2.00 | 2.00                         |
| 5 | 0.19 | 0.00 | 0.19 | 0.19                         |
|-------------------------------------------------------|
|Total   |      |      |           |                    |
|with 0  |59.90 |42.80 |    102.70 |    102.70          |
|-------------------------------------------------------|
|w/o 0   | 9.27 | 5.32 |14.58      |14.58               |
+-------------------------------------------------------+

+-------------------------------+
|        |    Table Row Total   |
|   cat# | w cat 0 | w/o cat 0  |
|-------------------------------|
|r0      |  88.12  | 88.12      |
|o1      |   2.21  |  2.21      |
|a2      |   3.64  |  3.64      |
|d3      |   6.54  |  6.54      |
|s4      |   2.00  |  2.00      |
| 5      |   0.19  |  0.19      |
|-------------------------------|
|Total   |         |        |   |
|with 0  | 102.70  | 102.70 |
|-------------------------------|
|w/o 0   |  14.58  | 14.58      |
+-------------------------------+
```

**NOTES**

It is not a good idea to run *r.coin* on a map layer which has a monstrous number of categories (e.g., unreclassed elevation). Because *r.coin* reports information for each and every category, it is better to reclassify those categories (using reclass) into a more manageable number prior to running *r.coin* on the reclassed raster map layer.

*r.coin* calculates the coincidence of two raster map layers. Although *r.coin* allows the user to rerun the report using different units, it is not possible to simply rerun the report with different map layers. In order to choose new map layers, it is necessary to rerun *r.coin*.

**SEE ALSO**

*r.region, r.cats, r.describe, r.mask, r.reclass, r.report, r.stats*

**AUTHORS**

Michael O'Shea, U.S. Army Construction Engineering Research Laboratory
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.colors*

**NAME**
*r.colors* **-** Creates/Modifies the color table associated with a raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.colors*
*r.colors help*
*r.colors [-wq] map=name color=type*

**DESCRIPTION**
*r.colors* allows the user to create and/or modify the color table for a raster map layer. The map layer (specified on the command line by map=name) must exist in the user's current mapset search path. The color table specified by color=type must be one of the following:

| color type | description |
|---|---|
| aspect | (aspect oriented grey colors) |
| grey | (grey scale) |
| grey.eq | (histogram-equalized grey scale) |
| gyr | (green through yellow to red colors) |
| rainbow | (rainbow color table) |
| ramp | (color ramp) |
| random | (random color table) |
| ryg | (red through yellow to green colors) |
| wave | (color wave) |
| rules | (create new color table based on user-specified rules) |

If the user specifies the **-**w flag, the current color table file for the input map will not be overwritten. This means that the color table is created only if the map does not already have a color table. If this option is not specified, the color table will be created if one does not exist, or modified if it does.

If the user sets the **-**q flag, *r.colors* will run quietly, Without printing numerous messages on its progress to standard output.

Color table types aspect, grey, grey.eq (histogram-equalized grey scale), gyr (green-yellow-red), rainbow, ramp, ryg (red-yellow-green), random, and wave are pre-defined color tables that *r.colors* knows how to create without any further input.

The rules color table type will cause *r.colors* to read color table specifications from standard input (stdin) and will build the color table accordingly. Using color table type rules, there are three ways to build a color table: by color list, by category values, and by "percent" values.

Building a customized color table by color list is the simplest of the three rules methods: just list the colors you wish to appear in the color table in the order that you wish them to appear. Use the standard GRASS color names: white, black, red, green, blue, yellow, magenta, cyan, aqua, grey, gray, orange, brown, purple, violet, and indigo.

For example, to create a color table for the raster map layer elevation that assigns greens to low map category values, browns to the next larger map category values, and yellows to the still larger map category values, one would type:

*r.colors map=elevation color=rules*
*green*
*brown*
*yellow*
*end*

To build a color table by category values' indices, the user should determine the range of category values in the raster map layer with which the color table will be used. Specific category values will then be associated with specific colors. Note that a color does not have to be assigned for every valid category value because *r.colors* will interpolate a color ramp to fill in where color specification rules have been left out. The format of such a specification is as follows:

*category_value color_name*
*category_value color_name*
....
....
*category_value color_name*
*end*

Each category value must be valid for the raster map layer, category values must be in ascending order and only use standard GRASS color names (see above).

Colors can also be specified by color numbers each in the range 0-255. The format of a category value color table specification using color numbers instead of color names is as follows:

*category_value red_number green_number blue_number*
*category_value red_number green_number blue_number*
........
........
*category_value red_number green_number blue_number*
*end*

Specifying a color table by "percent" values allows one to treat a color table as if it were numbered from 0 to 100. The format of a "percent" value color table specification is the same as for a category value color specification, except that the category values are replaced by "percent" values, each from 0-100, in ascending order. The format is as follows:

*percent_value% color_name*
*percent_value% color_name*
....
....
*percent_value% color_name*
*end*

Using "percent" value color table specification rules, colors can also be specified by color numbers each in the range 0-255. The format of a percent value color table specification using color numbers instead of color names is as follows:

*percent_value% red_number green_number blue_number*
*percent_value% red_number green_number blue_number*
.....
.....
*percent_value% red_number green_number blue_number*
*end*

Note that you can also mix these three methods of color table specification; for example:

```
0 black
10% yellow
78 blue
magenta
purple
brown
100% 0 255 230
end
```

**EXAMPLES**

(1) The below example shows how you can specify colors for a three category map, assigning red to category 1, green to category 2, and blue to category 3. Start by using a text editor, like *vi*, to create the following rules specification file. Save it with the name rules.file.

```
1 red
2 green
3 blue
end
```

The color table can then by assigned to map threecats by typing the following command at the GRASS> prompt:

```
cat rules.file | r.colors map=threecats color=rules
```

(2) To create a natural looking LUT for true map layer elevation, use the following rules specification file. It will assign light green shades to the lower elevations (first 20% of the LUT), and then darker greens (next 15%, and next 20%) and light browns (next 20%) for middle elevations, and darker browns (next 15%) for higher elevations, and finally yellow for the highest peaks (last 10% of LUT).

```
0%      0 230   0
20%     0 160   0
35%     50 130   0
55%     120 100  30
75%     120 130  40
90%     170 160  50
100%  255 255 100
```

**SEE ALSO**

*d.colormode, d.colors, d.colortable, d.display, d.legend, p.colors, r.support*

**AUTHORS**

Michael Shapiro, U.S. Army Construction Engineering Research Laboratory
David Johnson, DBA Systems, Inc. supplied the idea to create this program

## *r.combine*

**NAME**
*r.combine* **-** Allows category values from several raster map layers to be combined.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.combine*
*r.combine < inputfile*

**DESCRIPTION**
*r.combine* accepts commands that are similar to those used for boolean combinations (AND, OR, NOT) in order to overlay user-selected groups of categories from different raster map layers. After the *r.combine* program is started, the users are asked if they want the graphic output to go to a color graphics monitor. If a color graphics monitor is not used, the graphic output is displayed on the terminal screen. This display is, of course, quite rough. It consists of numerals representing the various categories that result from the *r.combine* analysis. Following this question, the user will see a [1]:. This is the first prompt, and indicates that *r.combine* is ready to receive input from the user.

The following commands perform operations in *r.combine*:

| Command [Alias] | Followed by | Such as |
|---|---|---|
| NAME [name] | name for raster map output | sandstone |
| GROUP [group] [grp] | category values and a raster map | 1-40 (elevation.255) |
| AND [and] [&][&&] | expression describ-ing a raster map and categories | (grp 4 (soils)) (grp 2 (owner)) |
| OR [or] [\| ][\| \| ] | expression describ-ing a raster map and categories | (grp 4 (soils)) (grp 2 (owner)) |
| NOT [not] [~] | expression describ-ing a raster map and categories | (grp 2 3 (roads)) |
| OVER [over] [overlay] | existing raster map and color | sandstone yellow |
| COVER [cover] | existing raster map | sandstone |

*r.combine* uses the same colors for all the operating commands. This is the *r.combine* color table:

| | | | |
|---|---|---|---|
| 0 black | 4 blue | 8 grey | 12 blue/grey |
| 1 red | 5 purple | 9 red/grey | 13 purple/grey |
| 2 yellow | 6 green | 10 yellow/grey | 14 green/grey |
| 3 orange | 7 white | 11 orange/grey | 15 dark grey |

The user may enter commands either line-by-line from within *r.combine*, or by typing the commands into a file which is then read into *r.combine* using the UNIX redirection symbol < . The command format is the same for the two methods. The line-by-line method, however, does not allow as much flexibility as does use of an input file. If a line containing a syntax error is entered on the *r.combine* command line, it is cleared; the line must then be re- entered in its entirety. Input files containing mistakes, however, can easily be modified (rather than recreated). An input file is especially advantageous when a more complex series of statements is input to *r.combine*.

*r.combine* uses two types of commands: those which perform operations, and those which have some other function. *r.combine* can probably best be learned by following examples, so pay special attention to those included below with the operating command descriptions. Notice two things in particular:

1) All parentheses must be closed. A raster map layer name must often be enclosed within parentheses; each time one of the above commands is used, it and its appropriate companions must also be enclosed within parentheses.

2) Certain spaces are important. Generally, *r.combine* requires at least one space before an opening parenthesis (except when it is the first character in an expression). *r.combine* ignores extra spaces and tab characters.

**OPERATING COMMANDS**
Below is a summary of the syntax of the operating commands, a description of each command, and examples using the Spearfish sample data base.

NAME
(NAME new_map_name (Expression))
Allows graphic output to be saved in the raster map layer new_map_name, so that it is available for additional analysis or for future viewing. The results of performing the expression in parentheses are then placed into the named output raster map layer (here, new_map_name). Note that this means that *r.combine* may be used to create new raster map layers from existing ones. *r.combine* automatically creates a color table for the new raster map layers; however, the user should run the GRASS program *r.support* to fill in category assignments and history information if the new raster map layer is to be saved for future use in the mapset.

example:
(NAME sandstone (GROUP 4 (geology)))
The above command will result in the creation of a new raster map layer named sandstone, noting the locations of cells with geology category value 4. You must then run the GRASS program *r.support* in order to label the categories present in the new raster map layer. Resultant categories:

*0* **-** *black: other than sandstone*
*1* **-** *red: sandstone*

GROUP
(GROUP category_values (existing raster map layer))
Selects out categories of the desired values from the existing raster map layer, which is indicated in parentheses directly after the category grouping. It also works to select out just one category from the map layer. Any of the following are legal category groupings:

*2*
*1-18*
*1 2 5-7.*

example:
(GROUP 1-40 (elevation.255))

Depicts only the area with elevation 1187 meters or less (i.e., elevation map layer category values 1 through 40 only). Resultant categories:

*0 - black: elevation > 1187 m*
*1 - red  : elevation <= 1187 m*

example:
(NAME low.hi (GROUP 1-40 238-255 (elevation.255)))
Depicts only those areas with elevations of either 1187 meters or less, or in excess of 1787 meters (elevation categories 1-40, and 238-255). The graphic output is saved in the new raster map layer called low.hi. Resultant categories:

*0 - black : elevation > 1187 m and < 1787 m*
*1 - red   : elevation <= 1187 m and >= 1787 m*

AND
(AND (Expression A) (Expression B))
Combines two map layers and creates a new one, when BOTH of the category values associated with the same given cell location in the two combined map layers are non-zero, a category value of 1 is assigned to that cell in the new map layer. If, however, either map layer assigns a category value of zero to the same given cell location, the category value associated with this cell's location in the resultant map layer also becomes zero.

For example,

*raster map  1   2 2 0*
*2 1 0*
*0 0 0    1 0 0  results*
*AND--> 1 1 0*
*raster map  2   1 0 1    0 0 0*
*1 1 0*
*1 1 0*

example:

(AND (GROUP 4 7-9 (geology)) (GROUP 2 (owner)))
Depicts the occurrences of categories 4, 7, 8, and 9 from the map layer geology whenever they occur on U.S. Forest Service property. Results are displayed to the terminal screen. Resultant categories:

*0 - black : no data occurred in one or the other of the raster map layers*
*1 - red   : the AND condition is met*

Note that if neither map layer contained any areas of "no data", the resultant raster map layer would include only 1's.

Example:
(NAME sand (AND (GROUP 4 7-9 (geology)) (GROUP 2 (owner))))
Same as above, except the results are saved in the map layer sand.

OR
(OR (Expression A) (Expression B))
Combines two map layers and creates a new one; when EITHER of the category values associated with the same given cell location in the two combined map layers is non-zero, a category value of 1 is assigned to that cell in the new map layer. If, however, both map layers assign a category value of zero to the same

given cell location, the category value of this cell in the resultant map layer also becomes zero. Only two map layers may be combined at one time. For example:

*raster map 1 2 2 0*
*2 1 0*
*0 0 01 1 1 results*
*OR --> 1 1 0*
*raster map 2 1 0 11 1 0*
*1 1 0*
*1 1 0*

Example:

(OR (GROUP 4 7-9 (geology)) (GROUP 2 (owner)))
Depicts all occurrences of categories 4, 7, 8, and 9 from the map layer geology as well as showing all the land, which is U.S. Forest Service property. Results are displayed to the terminal screen. Resultant categories:

0 - black: this area has neither the values of 4, 7, 8, or 9 nor is it on U.S. Forest Service property
1 - red : this area meets one or the other of the conditions noted above

Note that no distinction is made between those places where conditions are met in both map layers and where they are met in only one. See the *r.combine* command OVER if it is necessary to make that distinction.

NOT(NOT (Expression))
Negates Expression in order to define a new map layer, which contains the opposite of what is defined by Expression. The new raster map layer will contain category values of either 0 or 1. 0 values would indicate that the NOT conditions were not met. Cell values of 1 would indicate that the NOT conditions were met. In order to specify the map layer in which to save the output from NOT, use the *r.combine* command NAME.

Example:
(NAME rds (NOT (GROUP 0 (roads))))
Areas containing category zero in the existing map layer roads indicate those locations within the data base where roads do not exist. Negating that expression leaves us with all other areas - i.e., those locations at which roads do exist. Here, the graphic output is saved in the raster map layer named rds. Resultant categories:

*0 - black: no roads*
*1 - red : roads*

The same results could have been obtained with: (NAME rds (GROUP 1-5 (roads))). NOT is most useful in those cases where it is simpler to define something on the basis of what it is not than on the basis of what it is.

OVER
(OVER color (Expression)) or (OVER existing_rastermap color (Expression))
Performs a transparent overlay operation. This means that when a map layer which depicts some feature in blue is overlain with one which depicts a feature in yellow, the resulting raster map layer will show areas of overlap in green; areas in the two raster map layer that do not overlap other areas maintain their original colors (i.e., yellow or blue).

OVER may be run with or without an existing map layer name. If the user does not specify an existing raster map layer name, OVER applies the color specified to the expression in parentheses and displays the results. If an existing raster map layer name is specified, OVER applies the color to the expression (just as before) and then overlays the results on top of the existing raster map layer. In order to make sense of the colors which result, use only those existing map layers created using OVER.

OVER allows the user to specify just four colors:

```
color    value
red        1
yellow     2
blue       4
grey       8
```

These four colors are then combined to form other colors. The number of progressive overlays allowed is limited to four (one for each of the basic colors above). The actual number of colors on the resultant raster map layer, however, varies depending on the distribution of the features and on the interaction of the features from the different map layers which are overlain. When two or more of these colors are overlain, new colors are created. The numerical values associated with the colors above are significant, in that the values of any additional colors created reflect the sum of two or more of the four above. These overlain color values appear on the resultant overlay as cell (category) values. The user should know what these values represent in order to know what category information is to be associated with the new map layer (entered using the GRASS *r.support* command), and to know the significance of this and subsequent analyses involving the new map layer.

Any of these colors and category values may result from OVER. Note that this is the same as the *r.combine* color table listed above.

```
0 black    4 blue     8 grey          12 blue/grey
1 red      5 purple   9 red/grey      13 purple/grey
2 yellow   6 green    10 yellow/grey  14 green/grey
3 orange   7 white    11 orange/grey  15 dark grey
```

The syntax for OVER makes no provision for a new raster map layer name. It is necessary to use the *r.combine* operator NAME to specify a new raster map layer name in which to save the graphic output generated by OVER. If the user runs OVER without specifying an output raster map layer name, output is displayed to the terminal. However, this output is available for future use only if it is saved using the NAME command.

example:
(NAME park.or.priv (OVER red (GROUP 1 (owner))))
The new raster map layer park.or.priv displays private land (i.e., category 1 of the raster map layer owner) in red, and displays U.S. Forest Service land (i.e., "no data" areas within the owner map layer) as black. Resultant categories:

*0* **-** *black: park*
*1* **-** *red : private land*

example:
(NAME roads.or.not (OVER park.or.priv yellow (GROUP 0 (roads))))
Category 0 in the map layer roads is overlain in yellow on top of the park.or.priv map layer created above. The output is placed in a new map layer named roads.or.not. Resultant categories in roads.or.not are:

*0* **-** *black : park; road*
*1* **-** *red : private; road*
*2* **-** *yellow : park; no road*

*3 - orange : private; no road*

example:
(NAME low.elev (OVER park.or.priv blue (GROUP 1-19 (elevation.255))))
The elevation categories of 1123 meters or less from the map layer elevation.255 are assigned the color blue and then overlain on park.or.priv (generated in the previous example). Resultant categories in the new map layer low.elev are:

*0 - black : park; > 1123 m*
*1 - red : private; > 1123m*
*4 - blue : park; <= 1123 m*
*5 - purple : private; <= 1123m*

Note how category 5 is the sum of red (1) + blue (4) (i.e., the intersection of areas containing low elevations and private lands with roads).

COVER
(COVER existing_map (Expression))
Performs an opaque overlay operation. This means that where the top map layer contains "holes" (cell category values of 0), the bottom map layer will show through. Where the top map layer contains information on a feature, it will cover (substitute its category value for) whatever is below it. The top map layer is that which is defined by Expression. The bottom map layer is existing_map; this map layer must already exist.

The user does not specify colors with COVER. COVER uses the default color table that is listed above with OVER. Colors are assigned starting with the lower map layer. The category values are assigned the color from the table that corresponds with that value. For example, 1 would be red; 2, yellow; 3, orange, etc. Moving to the upper map layer COVER starts wherever it left off after the lower one. If the highest value of the lower map layer was 5, then all non-zero (i.e., places where a feature exists) cells of the upper map layer would be assigned the value of 6 (green). Note that if, in this case, the upper map layer did not have any cells of value zero, then the entire resulting new map layer would be green. The upper map layer would have been assigned the value 6 and would have completely covered that which was below it.

This is what happens:

*Expression 1 1 1 0*
*(top raster map) 1 1 0 0*
*0 0 0 0 6 6 6 0 result*
*--> 6 6 2 0*
*oldmap2 5 0 0 5 5 2 2*
*(bottom raster map) 0 5 2 0*
*5 5 2 2*

As many map layers may be overlain as is desired. However, there is a practical limit on the number of map layers that can be used while still generating sensible output. That number depends on the features involved in each map layer, and how many cells within the upper (overlying) map layers contain category values of zero (holes through which underlying data can be seen).

COVER has no provision for saving graphic output. Use the *r.combine* command NAME to save output in a raster map layer.

Example:
(NAME lo.elev (COVER owner (GROUP 1-19 (elevation.255))))

The categories that indicate elevation of 1123 meters or less are placed on top of the existing map layer owner. Output is saved in lo.elev. Resultant categories:

*1 - red    : private ownership; elev > 1123 m*
*2 - yellow : park property; elev > 1123 m*
*3 - orange : park or private; elev <= 1123 m*

Example:
(NAME sand.lo (COVER lo.elev (GROUP 4 (geology))))
Category 4 of geology (sandstone) is placed on top of lo.elev, the raster map layer created in the previous example. The output is saved in sand.lo. Resultant categories:

*1 - red    : private ownership; elev > 1123 m; no sandstone*
*2 - yellow : park property; elev > 1123 m ; no sandstone*
*3 - orange : park or private; elev <= 1123 m; no sandstone*
*4 - blue   : park or private; any elev; sandstone*

**ADDITIONAL COMMANDS**
*r.combine* also contains a number of commands, which are not used for operations, but serve a variety of other functions. Additional commands:

```
Command|   Alias             | Followed By
_______|_____________________|__________________________________________
QUIT   |  quit  q  exit  bye|
CATS   |  categories  cats  |  existing raster map
EXP    |  exp  expr         |  number of an expression
!      |                    |  shell command  e.g. vi comb.1
<      |                    |  existing input file
WINDOW |  window            |  existing raster map layer
HISTORY|  history  hist     |
HELP   |  help              |  combine command for which help is needed
ERASE  |  erase             |
```

QUIT
Allows the user to exit from *r.combine* while remaining within the GRASS session.

CATS raster map
Gives user an on-line listing of categories and labels for the map layer specified.
For example:

*[1]:CATS owner*

EXPEXP expression number
During an *r.combine* session, each completed expression and command is assigned a number. This number may be used to reference the expression to which it is assigned; this means that the user can substitute the number of the expression for the expression itself.
For example:

*[4]:(GROUP 5 (geology))*
*[5]:(NAME limestone (EXP 4))*

Use the UNIX history mechanism (explained below) to determine the specific numbers associated with particular expressions in your current *r.combine* session.

!!shell command
Allows user to temporarily suspend *r.combine* and go run another command, as in the two examples below:

```
!vi input
!g.list type=rast
```

Unless otherwise specified by the user, when a file is created using a system editor (like *vi*) from within *r.combine*, this file will be placed in the user's mapset under the COMBINE directory. After the command is completed, control returns to *r.combine*.

<< input filename
Takes input from the specified filename containing *r.combine* commands. The user, of course, must previously have entered the commands into this named input file. If no pathname is given, the input file is assumed to be in the user's mapset under the COMBINE directory. For example, the user would perform the following steps to redirect input from the file comb.in into the *r.combine* program (while within *r.combine*):

First, the user would create the file:

```
!vi comb.in
```

Second, the user would direct *r.combine* to take its input from the file:

```
< comb.in
```

WINDOWWINDOW raster_map
Gives on-line geographic region (window) information about the raster map layer specified.

HISTORY
Provides a listing of all previously completed expressions used within the current *r.combine* session, and the numbers associated with the execution of these commands.

HELP command
An on-line help facility for *r.combine* commands only. Type in the name of the *r.combine* command for which help is needed, to see the entry for that command.

ERASE
Will cause the color graphics monitor to clear.

NOTES
In all of the above examples, only a single line of input was provided to *r.combine*. However, since *r.combine* conveniently ignores extra spaces and tabs, it is possible to type input to *r.combine* in the manner outlined below. Users may find this to more clearly exhibit the relationships involved and parentheses needed. This can be typed as shown below either directly at the *r.combine* command line, or redirected into *r.combine* from an already existing file.

example:

```
(NAME good.place
(AND
(OR
(GROUP 1 2 5 (geology))
(GROUP 1-5 (elevation.255))
)
(NOT
(GROUP 1-4 (landuse))
)
```

*)*
*)*

Such involved input to *r.combine* might conveniently be typed into an input file, and then input to *r.combine* using the UNIX redirection mechanism < .

**SEE ALSO**
GRASS Tutorial:, *r.combine, r.infer, r.mapcalc, r.weight*

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## *r.compress*

**NAME**
*r.compress* **-** Compresses and decompresses raster files.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.compress*
*r.compress help*
*r.compress [-u] map=name[,name,...]*

**DESCRIPTION**
The GRASS program *r.compress* can be used to compress and decompress raster map layers.

During compression, this program reformats raster files using a run-length-encoding (RLE) algorithm. Raster map layers which contain very little information (such as boundary, geology, soils and land use maps) can be greatly reduced in size. Some raster map layers are shrunk to roughly 1% of their original sizes. Raster map layers containing complex images such as elevation and photo or satellite images may increase slightly in size. GRASS uses a new compressed format, and all new raster files are now automatically stored in compressed form (see FORMATS below). GRASS programs can read both compressed and regular (uncompressed) file formats. This allows the use of whichever raster data format consumes less space.

As an example, the Spearfish data base raster map layer owner was originally a size of 26600 bytes. After it was compressed, the raster file became only 1249 bytes (25351 bytes smaller).

Raster files may be decompressed to return them to their original format, using the -u option of *r.compress*. If *r.compress* is asked to compress a raster file which is already compressed (or to decompress an already decompressed file), it simply informs the user of this and asks the user if he wishes to perform the reverse operation.

**PROGRAM OPTIONS**
*r.compress* can be run either non-interactively or interactively. In non-interactive use, the user must specify the name(s) of the raster map layer(s) to be compressed (or decompressed) on the command line, using the form map=name[,name,...] (where each name is the name of a raster map layer to be compressed or decompressed). To decompress a map, the user must include the -u option on the command line. If the -u option is not included on the command line, *r.compress* will attempt to compress the named map layer(s).

If the user simply types *r.compress* without specifying any map layer name(s) on the command line, *r.compress* will prompt the user for the names of the map layers to be compressed/decompressed, and ask whether these maps are to be compressed or decompressed. This program interface is the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:
-*u* If set, *r.compress* converts a compressed map to its uncompressed format. If not set, *r.compress* will attempt to compress the named map layer(s).

Parameters:
*map=name[name,....]* The name(s) of raster map layer(s) to be compressed or decompressed.

**FORMATS**
Conceptually, a raster data file consists of rows of cells, with each row containing the same number of cells. A cell consists of one or more bytes. The number of bytes per cell depends on the category values stored in the cell. Category values in the range 0-255 require 1 byte per cell, while category values in the range 256-65535 require 2 bytes, and category values in the range above 65535 require 3 (or more) bytes per cell.

The decompressed raster file format matches the conceptual format. For example, a raster file with 1 byte cells that is 100 rows with 200 cells per row, consists of 20,000 bytes. Running the UNIX command ls -l on this file will show a size of 20,000. If the cells were 2 byte cells, the file would require 40,000 bytes. The map layer category values start with the upper left corner cell followed by the other cells along the northern boundary. The byte following the last byte of that first row is the first cell of the second row of category values (moving from left to right). There are no end-of-row markers or other syncing codes in the raster file. A cell header file (cellhd) is used to define how this string of bytes is broken up into rows of category values.

The compressed format is not so simple, but is quite elegant in its design. It not only requires less disk space to store the raster data, but often can result in faster execution of graphic and analysis programs since there is less disk I/O. There are two compressed formats: the pre- version 3.0 format (which GRASS programs can read but no longer produce), and the version 3.0 format (which is automatically used when new raster map layers are created).

**PRE-3.0 FORMAT:**

First 3 bytes (chars) **-** These are a special code that identifies the raster data as compressed.

Address array (long) **-** array (size of the number of rows + 1) of addresses pointing to the internal start of each row. Because each row may be a different size, this array is necessary to provide a mapping of the data.

Row by row, beginning at the northern edge of the data, a series of byte groups describes the data. The number of bytes in each group is the number of bytes per cell plus one. The first byte of each group gives a count (up to 255) of the number of cells that contain the category values given by the remaining bytes of the group.

**POST-3.0 FORMAT:**

The 3 byte code is not used. Instead, a field in the cell header is used to indicate compressed format.

The address array is the same.

The RLE format is the same as the pre-3.0 RLE, except that each row of data is preceded by a single byte containing the number of bytes per cell for the row, and if run-length- encoding the row would not require less space than non-run- length-encoding, then the row is not encoded.

These improvements give better compression than the pre-3.0 format in 99% of the raster data layers. The kinds of raster data layers which get bigger are those in which each row would be larger if compressed (e.g., imagery band files). But even in this case the raster data layer would only be larger by the size of the address array and the single byte preceding each row.

**SEE ALSO**
*r.support, parser*

**AUTHORS**
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## *r.contour*

**NAME**
*r.contour* **-** Produces a GRASS binary vector map of specified contours from GRASS raster map layer.

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.contour*
*r.contour help*
*r.contour [-qn]input=name output=name [levels=value,value,...,value] [minlevel=value] [maxlevel=value] [step=value]*

**DESCRIPTION**
*r.contour* produces a contour map of user-specified levels from a raster map layer. This program works two ways:

1. Contours are produced from a user-specified list of levels.

2. Contours are produced at some regular increment from user-specified minimum level to maximum level. If no minimum or maximum level is specified, minimum or maximum data value will be used.

**OPTIONS**
*r.contour* may be run interactively or non-interactively. To run the program non-interactively, the user must specify the input and output file names, either a list of levels or a step value and, optionally, minimum and maximum levels:

*r.contour [-qn] input=name output=name [levels=value,value,...,value] [minlevel=value] [maxlevel=value] [step=value]*

To run the program interactively, the user may simply type *r.contour* at the command line and will be prompted for parameter values.

Flags:

| | |
|---|---|
| -q | Suppress progress report & min/max information |
| -*n* | Suppress single crossing error messages |

Parameters:

| | |
|---|---|
| *input=name* | Name of input raster map layer. |
| *output=name* | Name of the binary vector file created. |
| *levels=value,value,...,value* | Comma separated list of desired levels. |
| *minlevel=value* | Beginning (lowest) value to be used when stepping through contours. Default is minimum data value. |
| *maxlevel=value* | Ending (highest) value to be used when stepping through contours. Default is maximum data value. |
| *step=value* | Increment between contour levels. |

**NOTES**
*r.contour* will either step through incremental contours or produce contours from a list of levels, not both. If both a list of levels and a step are specified, the list will be produced and the step will be ignored.

Zero is treated as a valid data value by *r.contour*.

If a contour level exactly matches a category value in the raster file, the contour line may backtrack on itself, causing illegal arcs to be produced in the output GRASS vector file.

**AUTHOR**
Terry Baker, U.S. Army Construction Engineering Research Laboratory

## *r.cost*

**NAME**
*r.cost* **-** Outputs a raster map layer showing the cumulative cost of moving between different geographic locations on an input raster map layer whose cell category values represent cost.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.cost*
*r.cost help*
*r.cost [-vk] input=name output=name [coordinate=x,y[,x,y,...]] [stop_coordinate=x,y[,x,y,...]] [max_cost=value]*

**DESCRIPTION**
*r.cost* determines the cumulative cost of moving to each cell on a cost surface (the input raster map layer) from other user-specified cell(s) whose locations are specified by their geographic coordinate(s). Each cell in the original cost surface map will contain a category value, which represents the cost of traversing that cell. *r.cost* will produce an output raster map layer in which each cell contains the lowest total cost of traversing the space between each cell and the user-specified points. (Diagonal costs are multiplied by a factor that depends on the dimensions of the cell.) This program uses the current geographic region settings.

**OPTIONS**
*r.cost* can be run either non-interactively or interactively. The program will be run non-interactively if the user specifies the names of raster map layers and any desired options on the command line, using the form:

*r.cost [-vk] input=name output=name [coordinate=x,y[,x,y,...]] [stop_coordinate=x,y[,x,y,...]]*

where the input name is the name of a raster map layer representing the cost surface map, the output name is the name of a raster map layer of cumulative cost, and each x,y coordinate pair gives the geographic location of a point from which the transportation cost should be figured.

Alternately, the user can simply type *r.cost* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

*r.cost* can be run with two different methods of identifying the starting point(s). One or more points (geographic coordinate pairs) can be provided on the command line. In lieu of command line coordinates, the output map (e.g., output) is presumed to contain starting points. All non- zero cells are considered to be starting points. Beware: doing this will overwrite output with the results of the calculations. If output does exist and points are also given on the command line, the output is ignored and the coordinates given on the command line are used instead.

Flags:
-*v*	Processing is tracked verbosely. This program can run for a very long time.

-*k*	The Knight's move is used which improves the accuracy of the output. In the diagram below, the center location (O) represents a grid cell from which cumulative distances are calculated. Those neighbors marked with an X are always considered for cumulative cost updates.  With the -k option, the neighbors marked with a K are also considered.

```
    . . . . . . . . . . . . . . .
    .   .   . K .   . K .   .   .
    . . . . . . . . . . . . . . .
    .   . K . X . X . X . K .   .
    . . . . . . . . . . . . . . .
    .   .   . X . O . X .   .   .
    . . . . . . . . . . . . . . .
    .   . K . X . X . X . K .   .
    . . . . . . . . . . . . . . .
    .   .   . K .   . K .   .   .
    . . . . . . . . . . . . . . .
```

Parameters:
*input=name* Name of input raster map layer whose category values represent surface cost.

*output=name* Name of raster map layer to contain output.  Also can be used as the map layer of the input starting points.  If so used, the input starting point map will be overwritten by the output.

*coordinate=x,y[,x,y,x,y, ...]* Each x, y coordinate pair gives the easting and northing (respectively) geographic coordinates of a starting point from which to figure cumulative transportation costs for each cell.  As many points as desired can be entered by the user.

*stop_coordinate=x,y[,x,y,x,y, ...]* Each x, y coordinate pair gives the easting and northing (respectively) geographic coordinates of a stopping point.  During execution, once the cumulative cost to all stopping points has been determined, processing stops.  As many points as desired can be entered by the user.

*max_cost=value* An optional maximum cumulative cost.

**EXAMPLE**
Consider the following example:
Input:

```
    COST SURFACE
  . . . . . . . . . . . . . . .
  . 2 . 2 . 1 . 1 . 5 . 5 . 5 .
  . . . . . . . . . . . . . . .
  . 2 . 2 . 8 . 8 . 5 . 2 . 1 .
  . . . . . . . . . . . . . . .
  . 7 . 1 . 1 . 8 . 2 . 2 . 2 .
  . . . . . . . . . . . . . . .
  . 8 . 7 . 8 . 8 . 8 . 8 . 5 .
  . . . . . . . . . . _____ . .
  . 8 . 8 . 1 . 1 . 5 | 3 | 9 .
  . . . . . . . . . . |___| . .
  . 8 . 1 . 1 . 2 . 5 . 3 . 9 .
  . . . . . . . . . . . . . . .
```

Output (using -k): Output (not using -k):

```
   COST SURFACE  CUMULATIVE COST SURFACE
 . . . . . . . . . . . . . . .. . . . * * * * * . . . . . .
 . 21. 21. 20. 19. 17. 15. 14.. 22. 21* 21* 20* 17. 15. 14.
 . . . . . . . . . . . . . . .. . . . * * * * * . . . . . .
 . 20. 19. 22. 19. 15. 12. 11.. 20. 19. 22* 20* 15. 12. 11.
 . . . . . . . . . . . . . . .. . . . . . * * * * * . . . .
 . 22. 18. 17. 17. 12. 11.  9.. 22. 18. 17* 18* 13* 11.  9.
 . . . . . . . . . . . . . . .. . . . . . * * * * * . . . .
 . 21. 14. 13. 12.  8.  6.  6.. 21. 14. 13. 12.  8.  6.  6.
 . . . . . . . . . . _____ . .. . . . . . . . . . . . . . .
 . 16. 13.  8.  7.  4|  0|  6.. 16. 13.  8. 7 .  4.  0.  6.
 . . . . . . . . . . |___| . .. . . . . . . . . . . . . . . .
 . 14.  9.  8.  9.  6.  3.  8.. 14.  9.  8. 9 .  6.  3.  8.
 . . . . . . . . . . . . . . .. . . . . . . . . . . . . . . .
```

The user-provided ending location in the above example is the boxed 3 in the left-hand map. The costs in the output map represent the total cost of moving from each box ("cell") to one or more (here, only one) starting location(s). Cells surrounded by asterisks are those that are different between operations using and not using the Knight's move (-k) option. This output map can be viewed, for example, as an elevation model in which the starting location(s) is/are the lowest point(s). Outputs from *r.cost* can be used as inputs to *r.drain*, in order to trace the least-cost path given in this model between any given cell and the *r.cost* starting location(s). The two programs, when used together, generate least-cost paths or corridors between any two map locations (cells).

**NOTES**
If you submit the starting point map on the command line by specifying:

*output=start_pt_map*

the starting point map will be overwritten by the calculated output. It is wise to copy or rename (e.g., using *g.copy* or *g.rename*) the map of starting points to another name before submitting it to *r.cost*; otherwise, its contents will be overwritten.

Sometimes, when the differences among cell category values in the *r.cost* cumulative cost surface output are small, this cumulative cost output cannot accurately be used as input to *r.drain* (*r.drain* will output bad results). This problem can be circumvented by making the differences between cell category values in the cumulative cost output bigger. It is recommended that, if the output from *r.cost* is to be used as input to *r.drain*, the user multiply the input cost surface map to *r.cost* by the value of the map's cell resolution, before running *r.cost*. This can be done using *r.mapcalc* or other programs. The map resolution can be found using *g.region*.

**SEE ALSO**
*g.copy, g.region, g.rename, r.drain, r.in.ascii, r.mapcalc, r.out.ascii, parser*

**AUTHOR**
Antony Awaida, Intelligent Engineering Systems Laboratory, M.I.T.
James Westervelt, US Army Construction Engineering Research Lab

# *r.covar*

**NAME**
*r.covar* **-** Outputs a covariance/correlation matrix for user specified raster map layer(s).
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.covar*
*r.covar help*
*r.covar [-mrq] map=name[,name,...]*

**DESCRIPTION**
*r.covar* outputs a covariance/correlation matrix for user- specified raster map layer(s). The output can be printed, or (if run non-interactively) saved by redirecting output into a file.

The output is an N x N symmetric covariance (correlation) matrix, where N is the number of raster map layers specified on the command line. For example,

*r.covar map=layer.1,layer.2,layer.3*

would produce a 3x3 matrix (values are example only):

```
462.876649   480.411218   281.758307
480.411218   513.015646   278.914813
281.758307   278.914813   336.326645
```

**OPTIONS**
The program will be run non-interactively, if the user specifies the names of raster map layers and any desired options on the command line, using the form

*r.covar [-mrq] map=name[,name,...]*

where each name specifies the name of a raster map layer to be used in calculating the correlations, and the (optional) flags -*m*, -*r*, and -*q* have meanings given below. If these flags are not specified on the command line, their answers default to "no".

Flags:
-*m* Include zero values in the correlation calculations, due to the mask.

-*r* Print out the correlation matrix.

-*q* Run quietly (without comments on program progress).

Parameters:
*map=name[,name,...]* Existing raster map layer(s) to be included in the covariance/correlation matrix calculations.

Alternately, the user can simply type *r.covar* on the command line, without program arguments. In this case, the user will be prompted for flag settings and parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

**PRINCIPLE COMPONENTS**
This module can be used as the first step of a principle components transformation. The covariance matrix would be input into a system, which determines eigen values and eigen vectors. An NxN covariance matrix would result in N real eigen values and N eigen vectors (each composed of N real numbers). In the above example, the eigen values and corresponding eigen vectors for the covariance matrix are:

```
  component   eigen value       eigen vector
 1           1159.745202   <   0.691002    0.720528    0.480511   >
 2              5.970541   <   0.711939   -0.635820   -0.070394   >
 3            146.503197   <   0.226584    0.347470   -0.846873   >
```

The component corresponding to each vector can be produced using r.*mapcalc* as follows:

*r.mapcalc 'pc.1 = 0.691002*layer.1 + 0.720528*layer.2 + 0.480511*layer.3'*
*r.mapcalc 'pc.2 = 0.711939*layer.1* **-** *0.635820*layer.2* **-** *0.070394*layer.3'*
*r.mapcalc 'pc.3 = 0.226584*layer.1 + 0.347470*layer.2* **-** *0.846873*layer.3'*

Note that based on the relative sizes of the eigen values, pc.1 will contain about 88% of the variance in the data set, pc.2 will contain about 1% of the variance in the data set, and pc.3 will contain about 11% of the variance in the data set.

Also, note that the range of values produced in pc.1, pc.2, and pc.3 will not (in general) be the same as those for layer.1, layer.2, and layer.3. It may be necessary to rescale pc.1, pc.2 and pc.3 to the desired range (e.g. 0- 255). This can be done with *r.rescale*.

**NOTES**
If your system has a FORTRAN compiler, then the program *m.eigensystem* in src.contrib can be compiled and used to generate the eigen values and vectors.

**SEE ALSO**
*i.pca, m.eigensystem, r.mapcalc, r.rescale, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.cross*

**NAME**
*r.cross* **-** Creates a cross product of the category values from multiple raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.cross*
*r.cross help*
*r.cross [-qz] input=name,name[,name,...] output=name*

**DESCRIPTION**
*r.cross* creates an output raster map layer representing all unique combinations of category values in the raster input layers (input=name,name,name, ...). At least two, but not more than ten, input map layers must be specified. The user must also specify a name to be assigned to the output raster map layer created by *r.cross*.

**OPTIONS**
The program will be run non-interactively if the user specifies the names of between 2-10 raster map layers be used as input, and the name of a raster map layer to hold program output, using the form:

*r.cross [-qz] input=name,name[,name,...] output=name*

where each input name specifies the name of a raster map layer to be used in calculating the cross product, the output name specifies the name of a raster map layer to hold program output, and the options -*q* and -*z* respectively specify that the program is to run quietly and exclude zero data values.

Alternately, the user can simply type *r.cross* on the command line, without program arguments. In this case, the user will be prompted for needed input and output map names and flag settings using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:
-*q* Run quietly. Suppresses output of program percent-complete messages. If this flag is not used, these messages are printed out.

-*z* Do not cross zero data values. This means that if a zero category value occurs in any input data layer, the combination is assigned to category zero in the resulting map layer, even if other data layers contain non-zero data. In the example given above, use of the -z option would cause 3 categories to be generated instead of 5.

If the -*z* flag is not specified, then map layer combinations in which not all category values are zero will be assigned a unique category value in the resulting map layer.

Parameters:
*input=name,name[,name,...]* The names of between two and ten existing raster map layers to be used as input. Category values in the new output map layer will be the cross-product of the category values from these existing input map layers.

*output=name* The name assigned to the new raster map layer created by *r.cross*, containing program output.

**EXAMPLE**
For example, suppose that, using two raster map layers, the following combinations occur:

| map1 | map2 |
|---|---|
| 0 | 1 |
| 0 | 2 |
| 1 | 1 |
| 1 | 2 |
| 2 | 4 |

*r.cross* would produce a new raster map layer with 5 categories:

| map1 | map2 | output |
|---|---|---|
| 0 | 1 | 1 |
| 0 | 2 | 2 |
| 1 | 1 | 3 |
| 1 | 2 | 4 |
| 2 | 4 | 5 |

Note: The actual category value assigned to a particular combination in the result map layer is dependent on the order in which the combinations occur in the input map layer data and can be considered essentially random. The example given here is illustrative only.

**SUPPORT FILES**
The category file created for the output raster map layer describes the combinations of input map layer category values which generated each category. In the above example, the category labels would be:

| category value | category label |
|---|---|
| 1 | layer1(0) layer2(1) |
| 2 | layer1(0) layer2(2) |
| 3 | layer1(1) layer2(1) |
| 4 | layer1(1) layer2(2) |
| 5 | layer1(2) layer2(4) |

A random color table is also generated for the output map layer.

**NOTES**
When run non-interactively, *r.cross* will not protect existing files in the user's mapset. If the user specifies an output file name that already exists in his mapset, the existing file will be overwritten by the new *r.cross* output.

**SEE ALSO**
*r.corr, r.covar, r.stats, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.describe*

**NAME**
*r.describe* **-** Prints terse list of category values found in a raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.describe*
*r.describe help*
*r.describe [-1rqdi] map=name[nv=string][nsteps=value]*

**DESCRIPTION**
*r.describe* prints a terse listing of category values found in a user-specified raster map layer.

The program will be run non-interactively, if the user specifies the name of a raster map layer and any desired flags on the command line, using the form

*r.describe [-1rqdi] map=name*

where the map name is the name of a raster map layer whose categories are to be described, and the (optional) flags *-1*, *-r*, *-q*, *-d*, and *-i* have the meanings described below.

Alternately, the user can simply type *r.describe* on the command line, without program arguments. In this case, the user will be prompted for needed flag settings and the parameter value using the standard GRASS *parser* interface described in the manual entry for *parser*.

**PROGRAM USE**
The user can select one of the following two output reports from *r.describe*:

(1) RANGE. A range of category values found in the raster map layer will be printed. The range is divided into three groups: negative, positive, and zero. If negative values occur, the minimum and maximum negative values will be printed. If positive values occur, the minimum and maximum positive values will be printed. If zero occurs, this will be indicated.

(2) FULL LIST. A list of all category values that were found in the raster map layer will be printed.

The following sample output from *r.describe:*

```
0 2-4 10-13
```

means that category data values 0, 2 through 4, and 10 through 13 occurred in the named map layer. The user must choose to read the map layer in one of two ways:

(1) DIRECTLY. The current geographic region and mask are ignored and the full raster map layer is read. This method is useful if the user intends to reclassify or rescale the data, since these functions (*r.reclass* and *r.rescale*) also ignore the current geographic region and mask.

(2) REGIONED and MASKED. The map layer is read within the current geographic region, masked by the current mask.

**NON-INTERACTIVE PROGRAM USE**
*r.describe* examines a user-chosen raster map layer. If run non-interactively, the layer name must be supplied on the command line.

A compact list of category values that were found in the data layer will be printed.

Following is a sample output:

```
0 2-4 10-13
```

Flags:
-*1* Print the output one value per line, instead of the default short form. In the above example, the -*1* option would output:

```
0
2
3
4
10
11
12
13
```

-*r* Only print the range of the data. The highest and lowest positive values, and the highest and lowest negative values, are output. In the above example, the -*r* option would output:

```
0 2 13
```

If the -*1* option is also specified, the output appears with one category value per line.

-*q* Quiet. The -*q* option will tell *r.describe* to be silent while reading the raster file. If not specified, program percentage-completed messages are printed.

-*d* Use the current geographic region settings. Normally, *r.describe* will read the data layer directly, ignoring both the current region settings and mask. The -*d* option tells *r.describe* to read the map layer in the current region masked by the current mask (if any).

-*i* Read fp map as integer.

Parameters:

| | |
|---|---|
| *map=name* | Name of raster map. |
| *nv=string* | String representing no data cell value. |
| *nsteps=value* | Number of quantization steps. |

**NOTES**
The range report will generally run faster than the full list.

**SEE ALSO**
*g.region, r.mask, r.reclass, r.rescale, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.digit*

**NAME**
*r.digit* **-** Interactive tool used to draw and save vector features on a graphics monitor using a pointing device (mouse)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.digit*

**DESCRIPTION**
The GRASS tool *r.digit* provides the user with a way to draw lines, areas, and circles on a monitor screen, and to save these features in a cell file. Lines, areas, and circles are to be drawn using a pointing device (mouse). A mouse button menu indicates the consequences of pressing each mouse button. The user is requested to enter the category number associated with the line, area, or circle subsequently drawn by the user. Lines, areas, and circles are defined by the series of points marked by the user inside the map window. *r.digit* will close areas when the user has not. By drawing a series of such features, the user can repair maps, identify areas of interest, or simply draw graphics for advertisement. When drawing is completed, a raster map based on the user's instructions is generated. It is available for use as a mask, in analyses, and for display.

Digitizing is done in a "polygon" method. Each area is circumscribed completely. Two or more areas and/or lines might define a single part of a map. Each part of the map, however, is assigned only the LAST area or line which covered it.

**THE PROCESS:**
Step 1: Choose to define an area or line, quit, or finish. If you quit, the session exits with nothing created. If you choose to finish (done), you will be prompted for a new map name; the new map is then created.

Step 2: If you choose to make an area or line you must identify the category number for that area or line.

Step 3: Using the mouse trace the line or circumscribe the area; or, finish (go to Step 1).

**SEE ALSO**
*v.digit* **-** Highly, interactive tool for digitizing, editing, and labeling vector data
*d.display* **-** Tool for displaying and producing maps
*d.mapgraph* **-** Draws simple graphics on a map
*r.in.poly* **-** Tool for importing "polygon" data to raster format

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.direct*

**NAME**
*r.direct* **-** Generates a flow direction map from a given elevation layer
(GRASS Raster Program)

**GRASS VERSION**
4.x,5.x

**SYNOPSIS**
*r.direct*
*r.direct help*
*r.direct input=name output=name type=name*

**DESCRIPTION**
*r.direct* generates a flow direction map from a given elevation layer.

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=name* | elevation map |
| *output=name* | flow direction map |
| *type=name* | type of flow direction map to be created. |

Options: agnps or grass

The type is the type of format for which the user wishes to create the flow direction map. The agnps format gives category values from 1-8, with 1 facing north and increasing values in the clockwise direction. The answers format gives category values from 0-360 degrees, with 0 (360) facing east and values increasing in the counter clockwise direction at 45 degree increments. The grass format gives the same category values as the *r.slope.aspect* program.

Example

```
r.direct input=ansi.elev output=ansi.asp type=grass
```

will create a flow direction map ansi.asp for the type grass

**NOTE**
*r.direct* is sensitive to the current window setting. Thus the program can be used to generate a flow direction map for any sub-area within the full map layer. Also, *r.direct* is sensitive to any mask in effect.

**SEE ALSO**
*r.fill.dir, r.slope.aspect*

**AUTHOR**
Raghavan Srinivasan, Agricultural Engineering, Purdue University

## *r.drain*

**NAME**
*r.drain* **-** Traces a flow through an elevation model on a raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.drain*
*r.drain help*
*r.drain input=name output=name [coordinate=x,y[,x,y,...]]*

**DESCRIPTION**
*r.drain* traces a flow through a least-cost path in an  elevation model.  The elevation surface (a raster map layer input) might be the cumulative cost map generated by the *r.cost* program.  The output result (also a raster map layer) will show one or more least-cost paths between each user- provided location(s) and the low spot (low category values) in the input model.

The program will be run non-interactively, if the user specifies the names of raster map layers and any desired options on the command line, using the form

*r.drain input=name output=name [coordinate=x,y[,x,y,...]]*

where the input name is the name of a raster map layer to be used in calculating drainage, the output name is the name of the raster map layer to contain output, and each x,y coordinate pair is the geographic location of a point from which drainage is to be calculated.

Alternately, the user can simply type *r.drain* on the command line, without program arguments.  In this case, the user will be prompted for needed parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=name* | Name of raster map layer containing cell cost information. |
| *output=name* | Name of raster map layer to contain program output. |

*coordinate=x,y[,x,y,...]*     Each x,y pair is the easting and northing (respectively) of a starting point from which a least-cost corridor will be developed.  As many points as desired can be input.  (But, see BUGS below.)

**EXAMPLE**
Consider the following example:

```
Input:   Output:
   ELEVATION SURFACE  LEAST COST PATH
 . . ----- . . . . . . . . . . . . . . . . . . . . . . . . .
 . 20| 19| 17. 16. 17. 16. 16. .   . 1 . 1 . 1 .   .   .   .
 . . |___| . . . . . . . . . . . . . . . . . . . . . . . . .
 . 18. 18. 24. 18. 15. 12. 11. .   .   .   .   . 1 .   .   .
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 . 22. 16. 16. 18. 10. 10. 10. .   .   .   .   . 1 .   .   .
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 . 17. 15. 15. 15. 10. 8 . 8 . .   .   .   .   .   . 1 .   .
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 . 24. 16. 8 . 7 . 8 . 0 .12 . .   .   .   .   .   . 1 .   .
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
 . 17. 9 . 8 . 7 . 8 . 6 .12 . .   .   .   .   .   .   .   .
 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

The user-provided starting location in the above example is the boxed 19 in the left-hand map. The path in the output shows the least-cost corridor for moving from the starting box to the lowest (smallest) possible point. This is the path a raindrop would take in this landscape.

**BUGS**

Currently, *r.drain* will not actually provide output for more than one pair of input coordinates stated on the command line.

*r.drain* also currently finds only the lowest point (the cell having the smallest category value) in the input file that can be reached through directly adjacent cells that are less than or equal in value to the cell reached immediately prior to it; therefore, it will not necessarily reach the lowest point in the input file. It currently finds pits in the data, rather than the lowest point present.

Only one least-cost path is currently printed to the output file for the user.

Sometimes, when the differences among cell category values in the *r.cost* cumulative cost surface output are small, this cumulative cost output cannot accurately be used as input to *r.drain* (*r.drain* will output bad results). This problem can be circumvented by making the differences between cell category values in the cumulative cost output bigger. It is recommended that, if the output from *r.cost* is to be used as input to *r.drain*, the user multiply the input cost surface map to *r.cost* by the value of the map resolution, before running *r.cost*. This can be done using *r.mapcalc* or other programs. The map resolution can be found using *g.region*.

**SEE ALSO**

*g.region, r.cost, r.mapcalc, parser*

**AUTHOR**

Kewan Q. Khawaja, Intelligent Engineering Systems Laboratory, M.I.T.

## *r.feat.thin*

**NAME**
*r.feat.thin* **-** GRASS module that takes the feature output of *r.param.scale* and creates either a sites file or raster containing VIPs (pits, peaks and passes).

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.feat.thin [-sc] feat=name dem=name [out=name]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*s* | Create sites file output |
| -*c* | Create corner values |

Parameters:

| | |
|---|---|
| *feat=name* | Raster surface feature layer from r.param.scale |
| *dem=name* | DEM that matches feature classification |
| *out=name* | Output raster layer containing thinned surface features |

**SEE ALSO**
*r.param.scale, s.delaunay*

**AUTHOR & HISTORY**
Jo Wood, Dept. of Geography, 19th July, 1995
**-------**
Modified to include elevation in sites output (conforms with GRASS 4.2 sites API). This allows production of TIN from sites file alone.

Jo Wood, 4th September, 1996
**-------**
Modified to force output of corner cells if required.

## *r.fill.dir*

**NAME**
*r.fill.dir* **-** Filters and generates a depressionless elevation map and a flow direction map from a given elevation layer *r.fill.dir* (GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.fill.dir*
*r.fill.dir input=elev_map elevation=corrected_elev_map direction=flow_direction_map type=agnps (answers or grass)*

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=mapname* | elevation map |
| *elevation=map* | corrected elevation map |
| *direction=map* | flow direction map |
| *type=text* | type of flow direction map to be created |

**EXAMPLE**

*r.fill.dir input=ansi.elev elevation=ansi.fill.elev direction=ansi.asp type=grass*

will create a depressionless elevation map ansi.fill.elev and a flow direction map ansi.asp for the type grass

**ATTENTION**
The type is the type of format at which the user wishes to create the flow direction map. The agnps format gives category values from 1-8, with 1 facing north and increasing values in the clockwise direction. The answers format gives category values from 0-360 degrees, with 0 (360) facing east and values increasing in the counter clockwise direction at 45 degree increments. The grass format gives the same category values as the *r.slope.aspect* program.

The method adopted to filter the elevation map and rectify it is based on the paper titled "Software Tools to Extract Structure from Digital Elevation Data for Geographic Information System Analysis" by S.K. Jenson and J.O. Domingue (1988).

The procedure takes an elevation layer as input and initially fills all the depressions with one pass across the layer. Next the flow direction algorithm tries to find a unique direction for each cell. If the watershed program detects areas with potholes, it delineates this area from the rest of the area and once again the depressions are filled using the neighborhood technique used by the flow direction routine. The final output will be a depressionless elevation layer and a unique flow direction layer.

The flow direction map can be encoded in either ANSWERS (Beasley et. al, 1982) or AGNPS (Young et. al, 1985) form, so that it can be readily used as input to these
hydrologic models. The resulting depressionless elevation layer can further be manipulated for deriving slopes and other attributes required by the hydrologic models.

**NOTE**

The *r.fill.dir* program is sensitive to the current window setting. Thus the program can be used to generate a flow direction map for any sub-area within the full map layer. Also, *r.fill.dir* is sensitive to any mask in effect.

**SEE ALSO**

*r.direct*, *r.slope.aspect*

**REFERENCES**

Jenson, S.K., and J.O. Domingue. 1988. Extracting topographic structure from digital elevation model data for geographic information system analysis. Photogram. Engr. and Remote Sens. 54: 1593-1600.

Beasley, D.B. and L.F. Huggins. 1982. ANSWERS (areal nonpoint source watershed environmental response simulation): User's manual. U.S. EPA-905/9-82-001, Chicago, IL, 54 p.

Young, R.A., C.A. Onstad, D.D. Bosch and W.P. Anderson. 1985. Agricultural nonpoint surface pollution models (AGNPS) I and II model documentation. St. Paul: Minn. Pollution control Agency and Washington D.C., USDA-Agricultural Research Service.

**AUTHOR**

Raghavan Srinivasan, Agricultural Engineering Department, Purdue University

# *r.flow*

**NAME**
*r.flow* **-** construction of slope curves (flowlines), flowpath lengths, and flowline densities (upslope areas) from a raster digital elevation model (DEM).
(GRASS Raster/Vector Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.flow*
*r.flow help*
*r.flow [ -u3mMqh ] elevin = name [ aspin = name ] [ barin = name ] [ skip = val ] [ bound = val ] [ offset = val ] [ flout = name ] [ lgout = name ] [ dsout =name ]*

**DESCRIPTION**
*r.flow* generates flowlines using a combined raster-vector approach (see Mitasova and Hofierka 1993 and Mitasova et al. 1995) from an input elevation raster map elevin (integer or floating point), and optionally an input aspect raster map aspin and/or an input barrier raster map barin. There are three possible output maps, which can be produced in any combination simultaneously: a vector file flout of flowlines, a raster map lgout of flowpath lengths, and a raster map dsout of flowline densities (which are equal upslope contributed areas per unit width, when multiplied by resolution).

Aspect used for input must follow the same rules as aspect computed in other GRASS programs (*see r.slope.aspect, s.surf.rst*).

Flowline output is given in a vector map flout (flowlines generated downhill). The line segments of flowline vectors have endpoints on edges of a grid formed by drawing imaginary lines through the centers of the cells in the elevation map. Flowlines are generated from each cell downhill by default; they can be generated uphill using the flag *-u*. A flowline stops if its next segment would reverse the direction of flow (from up to down or vice-versa), cross a barrier, or arrive at a cell with undefined elevation or aspect. Another option, *skip=val*, indicates that only the flowlines from every val-th cell are to be included in flout. The default skip is max(1, <rows in elevin>/50, <cols in elevin>/50). A high skip usually speeds up processing time and often improves the readability of a visualization of flout.

Flowpath length output is given in a raster map lgout. The value in each grid cell is the sum of the planar lengths of all segments of the flowline generated from that cell. If the flag *-3* is given, elevation is taken into account in calculating the length of each segment.

Flowline density downhill or uphill output is given in a raster map dsout. The value in each grid cell is the number of flowlines that pass through that grid cell, which means the number of flowlines from the entire map which have segment endpoints within that cell.

**OPTIONS**
The program will run non-interactively if the user specifies program arguments and flag settings on the command line using the following form:

*r.flow [ -u3mMqh ] elevin = name [ aspin = name ] [ barin = name ] [ skip = val ] [ bound = val ] [ offset = val ] [ flout = name ] [ lgout = name ] [ dsout = name ]*

Alternatively, the user can simply type *r.flow* on the command line and the program will ask for parameter values and flag settings interactively, using the standard GRASS parser interface.

Flags:
-*u* Generate flowlines uphill (default generates flowlines downhill).

-*3* Compute three-dimensional lengths (default is two-dimensional).

-*m* Use less memory and compute aspect at each cell on the fly. This option incurs a performance penalty. If this flag is given, the aspect input map (if any) will be ignored.

-*M* Use a fixed size memory and utilize page-swapping to handle large input files. This option incurs a severe performance penalty but is the only way to handle arbitrarily-large data files. If this flag is given, the -*m* flag will be ignored.

-*q* Quiet operation. Do not print diagnostic messages indicating progress.

-h Display reference information.

Parameters:
*elevin=name* Use the existing raster file name with elevations as input (required).

*aspin=name* Use the existing raster file name with aspects as input.

*barin=name* Use the existing raster file name with non-zero values representing barriers as input.

*skip=val* Set the number of cells between flowlines in the flout output map to *val*.

*bound=val* Set the maximum number of segments of each flowline to *val* (default is the maximum possible).

*flout=name* Output coordinates of flowlines to a vector file named name.

*lgout=name* Output flowpath length values to a raster file named name.

*dsout=name* Output flowline density values to a raster file named name.

*offset=value* Maximum magnitude of random grid point offset.
Default: 0

**NOTES**
For best results, use input elevation maps with high precision units (e.g., centimeters) so that flowlines do not terminate prematurely in flat areas. To prevent the creation of tiny flowline segments with imperceivable changes in elevation, an endpoint which would land very close to the center of a grid cell is quantized to the exact center of that cell. The maximum distance between the intercepts along each axis of a single diagonal segment and another segment of 1/2 degree different aspect is taken to be "very close" for that axis. Note that this distance (the so-called "quantization error") is about 1-2% of the resolution on maps with square cells.

The values in length maps computed using the -*u* flag represent the distances from each cell to an upland flat or singular point. Such distances are useful in water erosion modeling for computation of the LS factor in the standard form of USLE. Uphill flowlines tend to merge on ridge lines; by redirecting the order of the flowline points in the output vector map, dispersed waterflow can be simulated. The density map can be used for the extraction of ridge lines.

Computing the flowlines downhill simulates the actual flow (also known as the raindrop method). These flowlines tend to merge in valleys; they can be used for localization of areas with waterflow accumulation and for the extraction of channels. The downslope flowline density multiplied by the resolution can be used as an approximation of the upslope contributing area, defined as the area from which water flows into a given cell, per unit contour width. This area is a measure of potential water flux for the steady state conditions and can be used in the modeling of water erosion for the computation of the unit stream power based LS factor or sediment transport capacity.

The program has been designed for modeling erosion on hillslopes and has rather strict conditions for ending flowlines. It is therefore not very suitable for the extraction of stream networks or delineation of watersheds unless a DEM without pits or flat areas is available.

If *r.flow* is invoked with the -*M* flag, it will create up to three segment files; concurrently running copies of *r.flow* using this flag will compete for the same three files. Until concurrency control is standardized in GRASS it is suggested that all concurrently running copies of *r.flow* using the -*M* flag have distinct input and output files.

**DIAGNOSTICS**
ERROR: GISRC - variable not set. The program was run outside of GRASS.

Usage: *r.flow [-uzmq] elevin=name [aspin=name] [barin=name][skip=value] [bound=value] [flout=name] [lgout=name] [dsout=name]*

Invalid options were specified on the command line.

ERROR: *r.flow*: error getting current region
ERROR: *r.flow*: cannot reset current region
"ERROR: *r.flow*: cannot find file " filename
"ERROR: *r.flow*: cannot get header for " filename
"ERROR: *r.flow*: cannot create raster\||\|vector map " filename
ERROR: *r.flow*: cannot create\||\|open\||\|read\||\|write segment "file " filename

Self-explanatory or beyond explanation.
"ERROR: *r.flow*: " input " file's resolution differs from current" region resolution. The resolutions of all input files and the current region must match. In future versions this error will be demoted to a warning.

"ERROR:*r.flow*: resolution too unbalanced (" val " x " val ")" The difference in length between the two axes of a grid cell is so great that quantization error is larger than one of the dimensions. Resample the map and try again.

**SEE ALSO**
*r.basins.fill, r.watershed, r.drain, r.slope.aspect, r.water.outlet*

**AUTHORS**
Original version of program:
Maros Zlocha and Jaroslav Hofierka, Comenius University, Bratislava, Slovakia,

The current modified version of the program (adapted for GRASS5.0):
Helena Mitasova, Mark Ruesink, and Joshua Caplan, University of Illinois at Urbana-Champaign with support from US Army CERL.

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Mitasova, H., Mitas, L., Brown, W.M., Gerdes, D.P., Kosinovsky, I., Baker, T., 1995: Modeling spatially and temporally distributed phenomena: New methods and tools for GRASS GIS. International Journal of Geographical Information Systems 9(4), 433-446.

## *r.grow*

**NAME**
*r.grow* **-** Generates an output raster map layer with contiguous areas grown by one cell (pixel).
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.grow*
*r.grow help*
*r.grow [-bq] input=name output=name*

**DESCRIPTION**
*r.grow* adds one cell around the perimeters of all areas in a user-specified raster map layer and stores the output in a new raster map layer.

An area consists of any contiguous clump of cells with non-zero category values. No distinction is made between differing category values within an area. Rather, a border is grown around the outside of each entire contiguous set of non-zero cells.

The output raster map layer will not go outside the boundaries set in the current geographic region. Thus, if a contiguous area in the input raster map layer extends to the geographic edge of the current map layer, no new border cells can be added to that side of the area.

Growth around a rectangular area in the input raster map layer will occur straight out from each edge, but not diagonally from the corners of the rectangle. Thus, the "grown" border area will contain lines along the edge of the original rectangle, but the corners of the border will not be squared off. Instead, the lines of the border that go along each side of the original rectangle will touch only at the corners of the cells at the end of each line.

**OPTIONS**
The user can run *r.grow* either interactively or non- interactively. The program is run interactively if the user types *r.grow* without specifying flag settings and parameter values on the command line. In this case, the user will be prompted for input.

Alternately, the user can run *r.grow* non-interactively, by specifying the names of an input and output map layer, and including any desired flags, on the command line.

Flags:
-*b* Output a binary raster map layer having only zero-one category values, regardless of the category values in the input map layer. In this case, all cells with a non-zero category value in the input map layer are assigned to category 1 in the output map layer. If the -b flag is not used, these cells will retain their original non-zero category values. In either case, all cells whose category value is changed from 0 during the growing process are assigned a category value of 1 in the output map.

-*q* Run quietly, suppressing printing of information about program progress to standard output.

Parameters:
*input=name* Name of an existing raster map layer in the user's current mapset search path containing areas to be "grown".

*output=name* Name of the new raster map layer to contain program output. This map will be binary if the user sets the **-***b* flag. Otherwise, input map cells having non-zero category values will retain their original values. In either case, all cells whose values changed during growth will be assigned category value 1 in the output map.

**NOTES**
The *r.grow* command can be used to represent the boundary of one or more areas. In this case, the zero-one (binary) output option should NOT be used. Then the input map layer can be subtracted from the output map layer using the *r.mapcalc* command. All original non-zero category values will be subtracted out, leaving the boundary areas only. This resulting zero-one boundary depiction can be displayed over other related raster map layers using the overlay option of *d.rast*.

If the resolution of the current geographic region does not agree with the resolution of the input raster map layer, unintended resampling of the original raster map layer may occur. The user should be sure that the current geographic region is set properly.

**SEE ALSO**
*d.rast, g.region, r.mapcalc, r.poly*

**AUTHOR**
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## *r.hydro.CASC2D*

**NAME**
*r.hydro.CASC2D* **-** GRASS raster command to execute fully integrated distributed hydrologic modeling. (GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS:**
*r.hydro.CASC2D*
*r.hydro.CASC2D help*
*r.hydro.CASC2D [-toepidbuq] elevation=mapname time_step=value tot_time=value discharge=mapname outlet_east&north&slope=east,north,bedslope rain_duration=value [watershed_mask=mapname] [initial_depth=mapname] [storage_capacity=mapname] [interception_coefficient=mapname] [roughness_map=mapname] [Manning_n=value] [conductivity=mapname] [capillary=mapname] [porosity=mapname] [moisture=mapname] [pore_index=mapname] [residual_sat=mapname] [lake_map=mapname] [lake_elev=mapname] [radar_intensity_map=mapname] [links_map=mapname] [nodes_map=mapname] [channel_input=mapname] [table_input=mapname] [dis_profile=mapname] [wat_surf_profile=mapname] [hyd_location=mapname] [r_gage_file=mapname] [unif_rain_int=value] [num_of_raingages=value] [gage_time_step=value] [radar_time_step=value] [write_time_step=value] [unit_el_conv=value] [unit_lake=value] [unit_space=value] [d_thresh=value] [dis_hyd_location=mapname] [depth_map=mapname] [inf_depth_map=mapname] [surf_moist_map=mapname] [rate_of_infil_map=mapname] [dis_rain_map=mapname]*

**NOTE**
In above, the command line arguments have been rearranged so that the required parameters (without brackets) are placed first. When doing "*r.hydro.CASC2D help*", the user will see a different sequence of parameters.

**DISCLAIMER**
Users with no background in or understanding of distributed hydrology are strongly advised against using this code in any mode, particularly in operational mode. Besides knowledge of basic hydrology, experience with typical numerical techniques used in physically-based hydrodynamic models is recommended as it will help the user grasp capabilities and limitations of this model. This manual is significantly condensed for electronic distribution and is in no way comprehensive. Users are encouraged to experiment with the model and venture in hydrology textbooks and journal papers to learn more about the topics touched upon in this manual

**HISTORY**
CASC2D originally began with the two-dimensional overland flow routing algorithm developed in APL by Prof. P.Y. Julien at Colorado State University. The overland flow routing module was converted from APL to FORTRAN by Bahram Saghafian, then at Colorado State University, with the addition of Green & Ampt infiltration and explicit channel routing (Julien and Saghafian, 1991, Saghafian, 1992, and Julien et al., 1995). The Fortran version was reformulated, significantly enhanced, and re-written in the C programming language by Bahram Saghafian at the U.S. Army Construction Engineering Research Laboratories. Implicit channel routing code was developed and added to *r.hydro.CASC2D* by Fred L. Ogden (Ogden, 1994), formerly at Colorado State University, now Asst. Professor, Department of Civil and Environmental Engineering, University of Connecticut, Storrs, Connecticut. This version became known as *r.hydro.CASC2D*, part of the GRASS GIS for hydrologic simulations (Saghafian, 1993).

**DESCRIPTION**
*r.hydro.CASC2D* is a physically-based, distributed, raster hydrologic model which simulates the hydrologic response of a watershed subject to a given rainfall field. Input rainfall is allowed to vary in space and time. Major components of the model include interception, infiltration, and surface runoff routing. Interception is a process whereby rainfall is retained by vegetation. Interception is estimated using an empirical three parameter model. Infiltration is the process whereby rainfall or surface water is pulled into the soil by capillary and gravity forces. The Green and Ampt equation with four parameters is applied to model the event-based infiltration. For continuous soil moisture accounting, redistribution of soil moisture can also be simulated whenever the non-intercepted rainfall intensity falls below the saturated hydraulic conductivity of the soil. The redistribution option requires two more soil hydraulic parameters. Excess rainfall becomes surface runoff and is routed as overland flow and subsequently as channel flow. The overland flow routing formulation is based on a two-dimensional explicit finite difference (FD) technique, while two different FD techniques, one explicit and one implicit, provide options for routing one-dimensional channel flow. Through a step function, a depression depth may be specified, below which no overland flow will be routed.

The following sections describe various aspects of the model. In executing the model, the likelihood of making a serious mistake by an inexperienced user is unfortunately very high due to complexity of input and output options. Thus the user must thoroughly read all the details of this manual and then select appropriate options for his or her needs. Since at this time GRASS is an integer GIS, all input maps are stored in integer form. This requires conversion from integer to floating point representation via a scaling factor. The scaling factor for all floating point values is fixed. Therefore, the integer maps of parameter values are created by multiplying floating point values (e.g. volumetric water content) by a multiplier.

**PARAMETERS/OPTIONS**
The following input/output parameters/options control complexity of the simulation. Map and file names in square brackets [ ] are optional. Some maps are mutually exclusive ( logical -or- ), while some maps require other maps to enable proper function ( logical -and- ). Carefully read the NOTES section.

**INPUT**
TOPOGRAPHY

*elevation=mapname* map of elevation (DEM).

*outlet_east&north&slope=value,value,value* *easting*, *northing*, and *bed slope* at the outlet
(comma delimited)

TIME

*time_step=value* computational time step duration in seconds. (typ. 1 to 30 seconds)

*tot_time=value* total simulation time in sec.

OVERLAND FLOW

*[Manning_n=value]* spatially uniform Manning's n roughness value for overland flow.

-or-

*[roughness_map=mapname]* spatially varied map of Manning's n roughness coefficient (values in 1000*Manning's n).

*[watershed_mask=mapname]* map of watershed boundary (or mask). This option is recommended, as it speeds execution greatly.

*[d_thresh=value]* threshold overland depth, in meters, below which overland routing will not be performed (i.e. average depression storage).

*[initial_depth=mapname]* map of initial overland (not lakes) depth in mm.

RAINFALL

*rain_duration=value* total rainfall duration in sec.

*[unif_rain_int=value]* spatially uniform rainfall intensity in mm/hr.

-or-

*[r_gage_file=filename]* raingage rainfall input file name (ASCII).

-and-

*[num_of_raingages=value]* number of recording raingages.

-and-

*[gage_time_step=value]* time step (temporal resolution) of recorded raingage data in sec.

-or-

*[radar_intensity_map=mapname]* prefix of time series of maps of radar- (or otherwise-) generated rainfall intensities in mm/hr.

-and-

*[radar_time_step=value]* time increment between radar- (or otherwise-) generated rainfall maps in sec.

INTERCEPTION

*[storage_capacity=mapname]* map of vegetation storage capacity in tenths of mm.

-and-

*[interception_coefficient=mapname]* map of interception coefficient (values in 1000*actual coefficient).

INFILTRATION

*[conductivity=mapname]* map of soil saturated hydraulic conductivity in tenths of mm/hr (Req'd for G&A and Redist).

*[capillary=mapname]* map of soil capillary pressure head at the wetting front in tenths of mm (Req'd for G&A and Redist).

*[porosity=mapname]* map of soil effective porosity (values in 1000*porosity) (Req'd for G&A and Redist).

*[moisture=mapname]* map of initial soil moisture (values in 1000*moisture) (Req'd for G&A and Redist).

*[pore_index=mapname]* map of soil pore-size distribution index (Brooks & Corey lambda) in 1000*index (Req'd for Redist).

*[residual_sat=mapname]* map of soil residual saturation (values in 1000*residual saturation) (Req'd for Redist).

LAKES

*[lake_map=mapname]* map of lakes categories.

*[lake_elev=mapname]* map of lakes initial water surface elevation (also see unit_lake).

CHANNEL ROUTING

*[channel_input=filename]* channel input data file name (ASCII), required for explicit (EX) and implicit (IM) channel routing methods.

*[links_map=mapname]* map of channel network link numbers. (EX & IM)

*[nodes_map=mapname]* map of channel network node numbers. (EX & IM)

*[table_input=filename]* look-up table file for links with breakpoint cross section, link type 8, (ASCII) (IM)

*[dis_profile=filename]* channel initial discharge profile file name (ASCII). (IM)

*[wat_surf_profile=filename]* channel initial water surface profile file name (ASCII). (IM)

*[hyd_location=filename]* file name containing link and node numbers of internal locations where discharge hydrographs are to be saved (ASCII).

UNITS

*[unit_el_conv=value]* unit conversion factor by which the values in elevation must be DIVIDED to convert them into meters.

*[unit_lake=value]* unit conversion factor by which the values in lake surface elevation map must be DIVIDED to convert them into meters.

*[unit_space=value]* unit conversion factor by which all region easting and northing values must be DIVIDED to convert them into meters.

**OUTPUT**
*discharge=filename* outlet hydrograph file name (ASCII).

*[dis_hyd_location=filename]* output file name for discharge hydrograph at internal locations (ASCII)

*[write_time_step=value]* time increment for writing output raster maps in seconds.

-and-

*[depth_map=mapname]* output maps of surface depth in mm.

*[inf_depth_map=mapname]* output maps of cumulative infiltration depth in tenths of mm.

*[surf_moist_map=mapname]* output maps of surface soil moisture in number of fractions of a thousand.

*[rate_of_infil_map=mapname]* output maps of infiltration rate in mm/hr.

*[dis_rain_map=mapname]* output maps of distributed rainfall intensity in mm.

**FLAGS**
There are several flags whose utility is driven by data availability and/or user's choice.

-*t* spatially interpolates raingage rainfall intensities using Thiessen polygon technique. The default technique uses inverse-distance-squared proportionality for interpolation of rainfall intensity over space.

-*o* routes edge-accumulated overland flow out of active region (ONLY when no mask is specified). Often the surface water accumulated at the edges of the current region creates severe backwater effects and may limit the use of longer computational time steps.

-*e* performs one-dimensional explicit finite difference channel routing. May be suitable for low- to medium-intensity rainstorms over small arid and semi-arid watersheds with no base flow discharge. This option often limits the computational time step to small values (<10 seconds). Channel bed smoothing is recommended to eliminate adverse slopes. No hydraulic structures, except reservoir spillways, can be simulated.

-*p* assumes uniform channel geometry in each link (requires -e option). If this option is chosen, the channel input file (channel_input) must have only one line per fluvial link rather than the default of one line per node.

-*i* performs Preissmann double sweep implicit channel routing. Particularly suitable for watersheds with some base flow to avoid dry-bed condition with channel slopes less than 1%. Supercritical slopes cannot be handled; a warning message will be printed if supercritical flow is encountered.

-*b* initializes the channel depth and discharge files (similar to -*d*, requires -*i* option) using the standard step backwater method. This option must be used with -*i* flag and replaces -*d* option to write "dis_profile" and "wat_surf_profile" files. At present, only link types 1, 2, and 8 may exist in the channel network.

-*d* performs channel initialization for implicit routing (similar to -*b*, requires -*i* option) by flooding the entire channel network with a horizontal water surface and draining down to normal depth using a y(t) outlet boundary condition (similar to -*b*). It is essential for implicit channel routing technique that a minimum initial base flow discharge exist in the channels and also the corresponding initial water surface profile at each node in the channel network have a realistic value. When the depth at the outlet reaches normal depth, the values of depth and discharge at each node is written to "dis_profile" and "wat_surf_profile" files for use in start up of actual simulations. With this option no other component of the model is executed; only the implicit channel routing is performed to create initial depth and discharge files necessary for start up of actual simulations.

*-u* writes discharges in cubic feet per second (cfs) and volumes in cubic feet in "discharge" file. The internal calculations are all in SI units regardless of this flag. The default SI unit prints the discharges in cubic meters per second (cms) and volumes in cubic meters (m3).

*-q* quietly skips printing iteration, time, and discharge values to the screen. No status report is printed.

**IMPORTANT NOTES**
The user must pay close attention to the following notes prior to any simulation:

1) watershed_mask: Although optional, preparation of this map is highly recommended as it cuts down on the memory requirements by the amount directly proportional to the ratio of mask area over the region area (also see *-o* flag). If the basin (mask) delineation has not been performed correctly, surface water may accumulate near the edges of the watershed. This excess water has no way out of the watershed and will accumulate, creating undesirable backwater effects within the watershed which eventually dictate use of shorter time step in order to accommodate such effects. It is recommended, in such instances, to re-delineate the watershed along the edges. An alternative would be to lower the elevation of the cells being flooded by excessive surface runoff near the edges such that no artificial backwater is created.

2) elevation: The elevation map in the form of Digital Elevation Model (DEM) is undoubtedly one of the most important inputs for distributed modeling. Thus the quality of the DEM plays a major role in success of distributed hydrologic simulations. DEMs almost always contain errors. Large flat areas in the DEM may be due to the limited vertical resolution of elevation data. Routing over such flat areas usually creates problems for the numerical techniques used in distributed physically-based models. Unreal pits in the DEM may be artifacts of interpolation scheme used to rasterize digitized contours, or due to coarse resolution in areas of concave topography. As a rule of thumb, the user must cross check the DEM with topographic maps of the area. One way to discover potential errors in the DEM is to run *r.hydro.CASC2D* iteratively with no other option except uniform rainfall and a relatively short time step. Writing surface depth maps should also be selected (see depth_map and write_time_step options). The simulation may terminate normally, at which case the surface depth maps must be examined in order to determine where most water accumulation occurred and whether such accumulation areas are justified by the topographic map of the area. Also, stream network may be checked for proper connectivity via depth maps. Alternatively, if the model crashed at a certain location (whose address is printed on the screen as well as at the bottom of discharge file) the user must zoom in and double check the DEM with the topographic map. Often times some manual editing of the DEM is necessary in order to impose the actual drainage trend of the topo map. Prior to editing it is recommended that the DEM be multiplied by 10 or 100, particularly if the original vertical resolution of the DEM is also a concern. To account for this multiplication factor use unit_el_conv=10 or unit_el_conv=100, whichever appropriate. Note that only the unreal pits and depressions must be removed since they most likely trap surface runoff which would have otherwise contributed to the outlet. The real lakes and reservoirs may be simulated if delineated (see lake_map). In any event, non-smoothed DEMs require short computational time steps, while properly smoothed DEMs, particularly those with coarser grid space resolution, allow use of longer time steps. Another source of concern, which was briefly mentioned in above paragraph, about the quality of the DEMs is that a nicely connected stream network cannot be derived from non-smoothed DEM. If no delineated network (in the form of a vector file, for example) is available, an approach similar to what was described before may be taken in order to edit the DEM. However where a network has been delineated independent of the DEM then the elevation of stream cells should be checked so that they are not higher than those of the surrounding cells. Otherwise the stream cells will not properly collect the surface runoff.

3) initial_depth: This is a map which contains initial overland depth values, if any. Rarely used since prior to the storm overland planes are often dry. For channel initial depth see dis_profile and wat_surf_profile options.

4) storage_capacity & interception_coefficient: In *r.hydro.CASC2D*, the interception rate (i) is expressed as:

$$i(t)=r(t) \quad \text{while } I < a$$
$$i(t)=b*r(t) \quad \text{while } I > a$$

where r(t) denotes rainfall intensity at time t; a is the storage capacity; b is the interception coefficient; and I is the cumulative interception depth. Storage capacity maps, as well as interception coefficient map, are usually a reclass of vegetation map. For table of storage capacity and interception coefficient values see Gray (1970, section 4.6) or Bras (1990) p. 233.

5) roughness_map: This map represents the spatial distribution of overland Manning roughness coefficient n. This map could be a reclass of vegetation cover map and/or the land use map. Tables of Manning's n are available in most hydrology textbooks. By using Manning resistance equation it is assumed that the overland flow over watersheds satisfies the conditions of turbulent flow over rough surfaces.

6) conductivity, capillary, porosity, & moisture: Four soil property maps are needed for modeling infiltration process using the Green-Ampt technique. These maps respectively contain saturated hydraulic conductivity, capillary suction head, effective porosity, and initial soil moisture content. The first three maps may be reclasses of soil texture map and the last one must be prepared considering antecedent soil moisture conditions. Based on soil textural classifications, tables of estimates of the first three parameters can be found in Rawls et al. (1983). Wherever reliable field measurements of such parameters are available they may be substituted for table values. Note that the saturated hydraulic conductivity map must be adjusted for the percent of rock fraction within the soil, if known. If these four maps are specified, Green & Ampt infiltration calculations are performed. If one or more of the maps is not specified, no infiltration calculations are made.

7) pore_index & residual_sat: These two maps are required when continuous soil moisture accounting is of primary interest. The model is capable of redistributing the soil moisture during periods of no- or low-intensity rainfall, over which infiltration capacity may recover for the next burst of storm intensity. The technique used herein for hiatus and post-hiatus stages is primarily based on the method by Smith el al. (1993). In this model Green-Ampt equation is used for post-hiatus stage. Tables of pore-size distribution index (Brooks & Corey lambda) and residual saturation are given by Rawls et al. (1982). As in (6), measured values should be substituted where available. When the four maps specified in (6) as well as the two maps specified here are given as command line arguments, the redistribution infiltration routine is used. All six maps must be specified to enable redistribution infiltration calculations.

8) lake_map & lake_elev: The first map is the delineated lake map with different categories corresponding to individual lakes and the second map holds the initial water surface elevation in the lakes. It is best to number the lakes categories sequentially. If a lake or reservoir connects to the implicit channel network at its outlet, then the lake must also be numbered as a link as reflected in the channel_input file. See channel_input and links_map options for more details. However isolated pond areas may be simulated as well; in fact such ponds are recommended to be delineated as part of the lake_map. Such isolated lakes should not be present in the links map since their outlet is not connected to the channel network. The routing of the lakes is performed by linear reservoir technique. Rainfall is added directly to the lake inflow. No interception or infiltration is abstracted from the lake cells.

9) radar_intensity_map: This is the common prefix of radar- or otherwise- generated rainfall maps. One possible source of this type of data could be the NEXRAD system (Crum and Albery, 1993). Alternatively, such time series of raster maps may come from the output of an interpolation software, which takes in the rainfall site data corresponding to different times and generates the time series of raster maps. For instance, where raingage rainfall data is available, one could run *s.surf.tps* of GRASS, one time for every recording time, and save the interpolated rainfall maps to be used as input for

*r.hydro.CASC2D*. In any case one must pay attention to the unit of intensity, which is in integer millimeters per hour for map values. Also see radar_time_step, and rain_duration options. Example: If one sets radar_intensity_map=rain.map and there are a total of eight maps in regular intervals of 10 minutes (radar_time_step=600 and rain_duration= 4800, both in seconds), then the actual name of the maps in the current mapset would have to be: "rain.map.1", "rain.map.2" through "rain.map.8", respectively corresponding to time periods of 0-10, 10-20 through 70-80 minutes.

10) links_map & nodes_map: A link is a channel segment, of finite length, which is comprised of two or more computational nodes placed at the center of each grid cell. Any internal boundary condition (weirs and lakes/reservoirs, for example) is also considered a link with only two nodes, one node upstream of the internal link and one downstream. Although all links and nodes must be numbered as discussed below, the link and node maps only contain trapezoidal or look-up table cross sections (link types 1 and 8). Internal boundary condition link types (e.g. weirs) do not appear in the link or node maps. The internal boundary condition link types do appear in the channel_input file (see attachment). The purpose of the link and node maps is to provide connectivity information between overland flow grid cells and channel (link,node) pairs. This information is used to pass overland flow to the 1-D channel model as lateral inflow. The nodes map must contain the node numbers corresponding to the links map. Thus nodes corresponding to internal boundary condition links are not present in the nodes map. At a cell where a link terminates and another link begins (junctions for example) the node number must comply with the downstream link; i.e. this cell is assigned a value of 1 in the nodes map. However one must note that the last node of the upstream link also lies at such junction cells. This last node number must be accounted for in the main ASCII channel data file (channel_input), in which the total number of nodes per link must be given. An exception to this rule is the most downstream link leading to the outlet. The links map essentially describes topology of the stream network and its strict conformation with the stream numbering conventions is vital. Output from the GRASS command *r.watershed* cannot be directly used in conjunction with *r.hydro.CASC2D*. The link numbers assigned by *r.watershed* must be re-numbered in accordance with the following rules. Additionally, the node map may be constructed by re-numbering the link map. The general rules for link and node numbering are:

A) The first link is numbered 1.
B) Upstream links must have smaller link numbers than downstream links.
C) Link numbers must change at junctions.
D) Link numbers may not be skipped.
E) Node numbers increase in the downstream direction.
F) Looped reaches cannot be simulated.
G) Streams may run only in x-y directions and not diagonally.
H) Link types cannot be mixed within a link.

A small example network with three links is given below:

```
         LINK MAP                          NODE MAP

0 0 0 0 0 0 0 0 0 0 0 0 0 0       0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0 0 0       0 0 0 0 1 0 0 0 0 0 0 0 0 0
0 0 0 1 1 0 0 0 0 0 0 2 0 0       0 0 0 3 2 0 0 0 0 0 0 1 0 0
0 0 0 1 0 0 0 0 0 0 2 2 0 0       0 0 0 4 0 0 0 0 0 0 3 2 0 0
0 0 0 1 1 0 0 0 0 2 2 0 0 0       0 0 0 5 6 0 0 0 0 5 4 0 0 0
0 0 0 0 1 0 0 0 2 2 0 0 0 0       0 0 0 0 7 0 0 0 7 6 0 0 0 0
0 0 0 0 1 1 3 2 0 0 0 0 0 0       0 0 0 0 8 9 1 8 0 0 0 0 0 0
0 0 0 0 0 0 3 0 0 0 0 0 0 0       0 0 0 0 0 0 2 0 0 0 0 0 0 0
0 0 0 0 0 0 3 3 0 0 0 0 0 0       0 0 0 0 0 0 3 4 0 0 0 0 0 0
0 0 0 0 0 0 0 3 0 0 0 0 0 0       0 0 0 0 0 0 0 5 0 0 0 0 0 0
```

This network has three fluvial links, link 1 has 9 nodes in the node map, while link 2 has 8 and link 3 has 5. Note that the junction of links 1 and 2 is labeled link 3. However, links 1 and 2 have hidden nodes at this junction, which must have the same bed elevation as the first node in link 3, but different cross-sections. The junction is really not the same point in space for all three links, but really represents a short distance from the confluence. In the channel_input file, link 1 really has 10 nodes and link 2 has 9. Link 3 would only have 5 nodes, because it's downstream end is not a junction, rather it is the watershed outlet. The link and node maps tell *r.hydro.CASC2D* that the overland flow in the grid cell at row 5, column 4 is passed to link 1, node 5. For more discussion of links and nodes maps, see channel_input description and the last section of this document for channel input and table file options".

11) channel_input, table_file: For a detailed description of channel data file set-up and requirements: see the last section of this document which is a modified version of the document presented at the CASC2D Workshop by F.L. Ogden, June 9-10, 1994, at the University of Memphis, Tennessee (Revision 2, 10 January 1995). Also it is recommended for the user to refer to Ogden (1994) for an overview of the implicit channel routing formulation and numerical scheme. Note that for explicit channel routing, the same channel input file may be used provided that only link types 1 and 4 are present. If explicit channel routing is used, the channel thalweg elevations are taken from the channel_input file, not from the DEM.

12) dis_profile & wat_surf_profile: These two files hold, respectively, the discharge profile and the water surface profile of all nodes within the stream network, including internal boundary condition nodes. These files are created by running *r.hydro.CASC2D* with the -*i* option AND either -*d* or -*b*. After creation, these files are used to initialize the implicit channel routing scheme for actual watershed simulations. They must be present for actual simulations. The -*d* flag creates initial discharge and depth files by flooding the entire channel network with a horizontal water surface, and draining the network using a depth vs. time relation at the watershed outlet. This draining proceeds until normal depth is reached at the outlet. At this time, the dis_profile and wat_surf_profile files are written for use in channel initialization for later simulations. The -*b* flag creates the initialization files using the standard step backwater method. Note that in dis_profile the unit of discharge is in cubic meters per second and the unit of depth in wat_surf_profile is in meters. Except for the reservoirs, the water surface profile file actually holds the flow depth values and thus is measured relative to the bed. CAUTION: The implicit channel routing routine must have good first approximation of depth and discharge at each node in the network. Inaccurate values (guesses) will surely lead to a crash. Additionally, the implicit channel routine is for SUBCRITICAL (Froude number < 1) flow only. A newly created channel input file will almost always crash when first run. It is then the task of the user to identify the location of the problem. Usually, there are regions of hydraulically steep slopes which cause supercritical flow. The channel code will warn the user of supercritical flow, including node and link number when it occurs, and then exits. The user should look at that node/link combination, and alter the data file to eliminate the reach of steep slopes. One workable solution to prevent stability problems at low flows is to use the so-called "Preissmann Slot" (see Cunge et al., 1980, for example). Be patient, as getting the channel network running is a time consuming process. There are a host of possible errors including: abrupt changes in cross-section, DEM-error, etc., which can cause problems. The implicit routing method is not applicable to steep (mountainous or upland) streams. If supercritical flow is encountered in upland (1st order) streams, they can be eliminated from the network. The user should verify the suitability of this approach on each watershed.

13) hyd_location: If a filename is specified, this input ASCII file contains the link and node numbers of the locations at which discharge hydrographs are to be written to the file named in the dis_hyd_location option. The first column in this file should contain link numbers and the second column must be filled with the corresponding node numbers. For a description of the output, see the dis_hyd_location option.

14) r_gage_file: This is an ASCII file which must be provided when raingage rainfall data is being simulated. At the top of the file, two-column lines hold the easting and the northing for each raingage. The number of such lines is determined by the total number of recording raingages (num_of_raingages). The location of any of the gages does not have to be within the current region nor within the current watershed mask as long as the easting and the northing are not specified relative to the current region, but are based on absolute values in the UTM or SP coordinates. If a gage falls outside in a different zone to the left of the active region's zone, then negative values are also acceptable. Note however that raingages well outside the watershed under analysis generally provide poor rainfall estimates. The subsequent lines

at the bottom of the raingage file must reflect temporal variation of rainfall intensity. The number of columns per line is equal to the number of raingages (specified via num_of_raingages). The columns are separated by space. The number of lines in this lower portion is equal to number of instances, separated by a constant time interval, the raingages have made a recording. As usually is the case, the unit of rainfall intensity for raingage data must be in inches per hour. Example: For three raingages, each recording rainfall intensity every 2 minutes for a total duration of, say, 10 minutes, a file called "rain.inp" may look like this:

```
205150.0    750212.0
20545.0     750104.0
205320.0    750173.0

0.0     0.0     0.55
1.75    2.25    0.80
1.00    1.80    1.50
0.65    0.90    0.70
0.0     0.50    0.30
```

In above example, the eastings and northing of the first, second, and third raingages are (205150.0,750212.0), (20545.0,750104.0), and (205320.0,750173.0) respectively. The intensities recorded by the first gage, for example, are 0.0, 1.75, 1.00, 0.65, and 0.0 inches per hour, respectively, over 0-2, 2-4, 4-6, 6-8, and 8-10 minutes, etc. For this example r_gage_file=rain.inp, num_of_raingages=3, gage_time_step=120, and rain_duration=600. For state plane (SP) coordinate system the eastings and northing will have to be in feet rather than meters.

15) outlet_east&north&slope: These three values determine the location of the outlet, in terms of its easting and northing, and the outlet bed slope. One needs to make sure that the outlet described by its easting and northing is not only within the active region but also inside watershed mask. Often times the region is not set to its original settings after zoom-in operations (*d.zoom*) are performed and this may put the outlet outside the active region thus causing the model to eventually crash. The bed slope is equal to tangent of the angle which is made between the bed profile at the outlet and horizontal plane. This slope is primarily used to calculate the outflow overland discharge at the outlet, if any, based on normal depth boundary condition, when no channel routing is performed (all surface flow treated as overland flow and channels essentially assumed wide). Normal depth is also assumed to prevail at the outlet when explicit channel routing (-*e*) has been selected.

16) Manning_n: The alternative to simulating spatially varied roughness coefficient is to provide a single value of Manning roughness coefficient n via Manning_n parameter. The user is warned if both roughness_map and Manning_n have been specified.

17) unif_rain_int: This option represents the intensity of the spatially- uniform temporally-constant (up to the rainfall duration) rainfall. Therefore this option may replace r_gage_file and radar_intensity_map options. The unit is in millimeters per hour.

18) num_of_raingages: The total number of recording raingage. If this variable is set to one, no spatial interpolation is performed and the rainfall is treated as uniform is space but could vary in time. The temporal variation will be then provided by r_gage_file. Note that when num_of_raingages is set to one, the easting and northing of the gage is irrelevant although two (arbitrary) values must still be provided at the top of raingage file (r_gage_file).

19) time_step: This represents the duration of computational time step in seconds and is a critical variable determining the total execution time for a particular simulation. There is no firm guide for the selection of the time step; it comes with experience and strongly depends on watershed and rainfall characteristics. The general rule for overland routing and explicit channel routing is that shorter time steps must be used for higher intensity storms, finer horizontal grid resolution (grid spacing), steeper watershed slopes, larger watershed areas, and smoother surfaces. Stability of explicit routing depends

upon Courant number. Unfortunately, the critical condition for Courant number limits the length of the computational time step, which must be used for the entire simulation unless variable time step algorithm is implemented in the future. Shorter time steps must be used when backwater effects are generated, mainly in flat areas which are not part of the lake map. If the time step is too long for any particular simulation the surface water depth in completely flat areas may show a checker-board pattern, i.e. oscillations are observed in the water surface level. This eventually results in a crash. As such, the time step should be decreased and the simulation repeated; or the flat areas be delineated within the lake map.

20) gage_time_step: This variable represents the time interval, in seconds, between recording instances of rainfall intensities by raingage(s). It is implied that the rainfall data has been recorded in regular intervals. See the notes under r_gage_file for an example.

21) radar_time_step: A value expressing the time interval between consecutive rainfall maps. A uniform time step is implied.

22) rain_duration: This is the total duration of rainfall in seconds. If multistorm events are simulated, the time from the beginning of the first storm to the end of the last storm constitutes the total rainfall duration. As such, selection of soil moisture redistribution capability is recommended via specifying pore index (pore_index) and residual saturation (residual_sat) maps.

23) tot_time: The total simulation time in seconds. If the falling limb of the discharge hydrograph is of particular interest the total simulation time must be set to a value greater than total rainfall duration plus the expected recession time.

24) write_time_step: This time parameter determines the frequency of writing output raster maps and is equal to the time interval, in seconds, at which output raster maps are saved. Also see depth_map, inf_depth_map, surf_moist_map, rate_of_infil_map, and dis_rain_map output options.

25) unit_el_conv: This conversion factor is used to convert elevation values in DEM (elevation) map to meters. This parameter doesn't need to be specified if the DEM is already in meters since the default is one. For DEM units in cm or ft, unit_el_conv must be respectively set to 100 or 3.281.

26) unit_lake: This conversion factor is used to convert the water surface elevation values in the lake_elev map to meters. The default is 1.0.

27) unit_space: This conversion factor is used to convert the horizontal grid spacing resolution to meters. The default is 1.0. For state plane coordinate system in ft, set unit_space equal to 3.281.

28) d_thresh: This parameter represents an average step retention storage below which the overland depth will not be routed. Another words, all depressions less than or equal to d_thresh are filled before any overland flow could begin. The unit must be in meters so for 2 mm of depression storage set d_thresh=0.002. Higher values of depression storage would reduce the total execution time of the model as the overland routing consumes most of the CPU effort.

29) discharge: The discharge hydrograph computed at the outlet will be saved in this ASCII file under the current directory. Some other information, such as peak discharge, is also printed in this file.

30) dis_hyd_location: Whenever the hyd_location option is selected, the discharge at individual node/link pairs will be saved in this file. The discharge hydrographs at the (link,node) locations specified in hyd_location file are grouped in columns. The number of lines in this file is determined by the total number of iterations equal to tot_time divided by time_step.

31) depth_map, inf_depth_map, surf_moist_map, rate_of_infil_map, & dis_rain_map: depth_map is the common filename prefix given to the time series of output raster maps containing surface depth values in

millimeters. At the channel cells the channel flow depth will be recorded in the maps. The surface depth maps, and all other output maps, are saved at regular intervals determined by write_time_step option. If write_time_step is not set, no output raster map will be saved. The first map always corresponds to the initial condition and naturally shows the water surface profile corresponding to the base flow discharge within the channel network when implicit channel routing is performed. Similarly the last depth map corresponds to the end-of-simulation time, or to the time at which the program finished abnormally, for example due to selection of a long step which generated oscillations leading to a crash. Abnormal program termination caused by oscillating depths may show negative depths in the overland plane. There is a hard-coded limit of 2000 output raster maps for each simulation. inf_depth_map and rate_of_infil_map are two options to save the output raster maps of cumulative infiltration depth, in tenth of mm, and rate of infiltration in mm/hr, respectively. These two options can only be selected when infiltration is being computed via either the Green & Ampt or redistribution methods. surf_moist_map output contains the soil moisture values at the soil surface and it may solely be selected with continuous infiltration option (pore_index and residual_sat maps are specified). dis_rain_map option saves the instantaneous rainfall intensities, in mm/hr, at write_time_step intervals and may be set for the simulations involving spatially distributed rainstorms; i.e. raingage rainfall data or radar (or other sources of rainfall raster maps) data. Example: If one sets depth_map=depth.out, tot_time=1000, and write_time_step= 100, then a total of 11 raster depth maps will be saved in a normally-terminated simulation: depth.out.00, depth.out.01, depth.out.02 through depth.out.10, respectively corresponding to times equal to 0, 100, 200, through 1000 seconds. These maps may be viewed sequentially in animation form using the GRASS animator program xganim.

**GENERAL NOTES FOR CHANNEL_INPUT AND TABLE_FILE FILE OPTIONS**

The naming convention associated with the Preissmann double-sweep 1-D implicit channel routing method is based on the concept to links and nodes. A link is a channel segment, or an internal boundary condition, which is comprised of two or more computational nodes. All internal boundary conditions contain two nodes, while fluvial reaches may be of any size greater than or equal to two nodes. The following discussion of input file format must first distinguish between different link types. A few of the possible link types are presented below in Table 1. As of August 1995, only link types 1, 2, 4, and 8 are supported. Development is continuing on link types 3 and 7.

Table 1. Link Types

| Link Type | DESCRIPTION of Link Type | Number of Parameters | Number of Nodes |
|---|---|---|---|
| 1 | Fluvial Link, Trapezoidal Cross-Section | 5 | >=2 |
| 2 | Overflow Weir | 8 | 2 |
| 3 | Culvert/Weir (not yet supported) | 8 | 2 |
| 4 | Reservoir | 5 | 2 |
| 7 | Bridge Crossing (not yet supported) | 8 | 2 |
| 8 | Fluvial Link, Look-up Table (Breakpoint) Cross-Section | 4 | >=2 |

At present the channel model formulation accepts cross-sectional input for only two different channel geometries, namely trapezoidal, and breakpoint via look-up table. Trapezoidal channel parameters, which must be provided as input at each computation node, include: Manning's n, bottom width, channel depth, side slope, and bed elevation. Look-up tables of cross sectional properties must include cross-sectional area, top width, and conveyance at equal depth intervals. Smooth transition in channel cross sectional properties within links of type 8 and between all connecting fluvial links often plays a vital role in the success of simulations. Abrupt changes in cross-sections can lead to numerical errors in mass conservation.

As far as handling the reservoirs (link type 4), flow is not routed through reservoirs in this version of the CASC2D channel routing code. Instead the linear reservoir approximation is used. Among other internal boundary conditions link types, only weirs can be simulated at present.

The channel_input file contains the channel bed elevation at each node, which constructs the longitudinal profile of channels in the drainage network. Ideally, the modeler should use surveyed cross sections and thalweg profiles of the channel network. However, extensive surveys are often impossible for the entire drainage networks on large watersheds. In lieu of an extensive survey, there are existing tools for extracting channel topology from digital elevation models (DEM). However, if the channel network is extracted from a DEM, a smoothing algorithm must be applied (e.g. Ogden et al., 1994) to produce physically realistic longitudinal profiles because of errors inherent in any DEM.

**EXAMPLE OF INPUT FILE FORMAT AND CONSTRUCTION**

NOTE: The channel_input file and table_file both follow SI unit convention. All units of length are in meters, including elevations.

In this example, a channel input data file is constructed for a fictitious watershed. Note that this particular example is merely for demonstration and has not been tried in any simulation run. The stream network will consist of trapezoidal and look-up table fluvial links, an internal reservoir, and an overflow weir. Regarding the MASK map (watershed_mask option), note that all watershed cells must be marked with 1, while all raster cells outside the watershed boundary are marked with 0. Also all the cells in the lake should carry the value 1 on the LAKE map (lake_map option). If there was another lake in this example, it would be denoted with the number 2, etc.

The channel link numbering scheme typically employed in double-sweep routing was explained in the main text. With reference to the LINK map shown below, (links_map option), assume that links 1 and 2 drain into link 3, which in-turn drains in to the lake, which is assigned link number 4. Also links 7 and 8 drain into link 9. Link 5 originates at the outlet of the reservoir. Link 5 is split into link 6 because of a change in some cross-section property. Links 6 and 9 flow into link 10, which is immediately upstream from a weir which must be considered link 11. Finally, link 12, the most downstream link, lies below the weir (link 11). Note that the LINK map contains continuous sequence of link numbers, except for the internal boundary conditions such as the weir (link 11) and lakes (link 4), which does not appear in the LINK map.

**EXAMPLE LINK MAP**

```
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0   0   0   2   0   0   0   0   0
   0   0   0   1   0   0   0   0   0   0   0   0   0   2   2   0   0   0   0   0
   0   0   0   1   1   0   0   0   0   0   0   0   2   2   0   0   0   0   0   0
   0   0   0   0   1   1   1   0   0   0   0   0   2   0   0   0   0   0   0   0
   0   0   0   0   0   0   1   1   1   0   0   0   2   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   1   0   2   2   2   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   1   1   3   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   7   7   7   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   7   7   0   0   0   0   5   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   7   7   0   0   0   5   5   0   0   0   0   0   0   0   0
   0   8   8   8   0   0   7   0   0   0   0   5   6   0   0   0   0   0   0   0
   0   0   0   8   8   8   9   9   0   0   0   0   6   6   0   0   0   0   0   0
   0   0   0   0   0   0   0   9   9   9   0   0   0   6   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   9   9   9   9  10  10  10   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  12   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  12  12  12  12   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  12   0
```

Now, refer to the NODE map (nodes_map option) shown below. In the NODE map, each link is numbered from 1 to the number of grid cells spanned by that link, with the exception of the internal boundary conditions. Conceptually, internal boundary conditions (including reservoirs) have two nodes but they are not given any node numbers in the NODE map. This is how the program recognizes internal boundary conditions. Furthermore, all links except the one leading to the watershed outlet must have an extra node to provide connectivity to the downstream link. Therefore, even though the NODE map may show link 1 to have 13 nodes, it actually has 14. This implied extra node for link 1, shared between the most downstream node of link 1 and the most upstream node of link 3, provides the connection between link 1 and link 3. The number of nodes in each link in this example are shown below in Table 2. Note that the node map entries for the lake (link 4) are 0.

**EXAMPLE NODE MAP**

```
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  1  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0  0
 0  0  0  2  0  0  0  0  0  0  0  0  0  3  2  0  0  0  0  0
 0  0  0  3  4  0  0  0  0  0  0  0  5  4  0  0  0  0  0  0
 0  0  0  0  5  6  7  0  0  0  0  0  6  0  0  0  0  0  0  0
 0  0  0  0  0  0  8  9 10  0  0  0  7  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0 11  0 10  9  8  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0 12 13  1  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  3  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  1  2  3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
 0  0  0  0  4  5  0  0  0  0  1  0  0  0  0  0  0  0  0  0
 0  0  0  0  0  6  7  0  0  0  2  3  0  0  0  0  0  0  0  0
 0  1  2  3  0  0  8  0  0  0  0  4  1  0  0  0  0  0  0  0
 0  0  0  4  5  6  1  2  0  0  0  0  2  3  0  0  0  0  0  0
 0  0  0  0  0  0  0  3  4  5  0  0  0  4  0  0  0  0  0  0
 0  0  0  0  0  0  0  0  0  6  7  8  9  1  2  3  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  2  3  4  5  0
 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  6  0
```

Table 2. Number of Nodes in each Link for Example Watershed Stream Network

| Link Number | Number of Nodes as in nodes_map | Number of Nodes in channel-input file |
|---|---|---|
| 1 | 13 | 14 |
| 2 | 10 | 11 |
| 3 | 3 | 4 |
| 4 (reservoir) | 0 | 2 |
| 5 | 4 | 5 |
| 6 | 4 | 5 |
| 7 | 8 | 9 |
| 8 | 6 | 7 |
| 9 | 9 | 10 |
| 10 | 3 | 4 |
| 11 (weir) | 0 | 2 |
| 12 (outlet link) | 6 | 6 |

The first portion of the channel input file is used to pass physical constants and simulation parameters to the model. These include the gravitational acceleration "g", kinetic energy correction factor "alpha", the friction slope weighting factor "beta", the spatial derivative weighting coefficient "theta", the length of each node "dx", the computational time step "dt" (seconds), the total simulation time "tt" (seconds), and the discharge in all first order streams "qmin" (m3/s). At present, the time step "dt" must be identical to the computational time step used in the overland flow routing portion of *r.hydro.CASC2D*. The program must be told the number of links, and the largest number of nodes in any link in the network for dynamic memory allocation. In our example problem, the number of links is 12, and the maximum number of nodes is 14 (in link 1). Remember that all links which are not at the outlet or not immediately upstream of a reservoir must have an extra node for connectivity purposes. The total number of links is called "nlinks", and the largest number of nodes in any link in the network is called "maxnodes". In this example, we will use the constants and parameters given in Table 3:

Table 3. physical constants and simulation parameters

| | |
|---|---|
| "g" | 9.81 m/s2 |
| "alpha" | 1.0 |
| "beta" | 0.5 |
| "theta" | 0.55 |
| "dx" | 100.0 m |
| "dt" | 30.0 s |
| "tt" | 3600.0 s |
| "qmin" | 0.07 cms |
| "nlinks" | 12 |
| "maxnodes" | 14 |

This data constitutes the first portion of channel_input file and is arranged into a header which must have the form (note floating point and integers):

```
9.81
1.0  0.5  0.55
100.0
30.0  3600.0
0.07
12
14
```

The second portion of the input file describes link types as well as the network topology and connectivity. This is accomplished using a line-input format, one line for each link in the network. Each line contains 6 values arranged in columns, as shown in Table 4.

Table 4. Connectivity information format

| Column | Data DESCRIPTION |
|---|---|
| 1 | Link number (INT) |
| 2 | Link type (INT) |
| 3 | Number of links upstream from this link (max. 2, min. 0) (INT) |
| 4 | Upstream link #1 (INT) (0 if no upstream links) |
| 5 | Upstream link #2 (INT) (0 if no or only one upstream link) |
| 6 | Downstream link (0 for outlet ) (INT) |

As far as link types in the current example, assume that links 1 through 9, except reservoir link 4 (link type 4), are well-described as trapezoidal (type 1), and we are  using look-up table data to describe the cross-sections of links 10 and 12  (type 8).  The weir (link 11) is of link type 2.  Thus the second portion of input file for describing link types and  connectivity looks like:

```
1   1   0   0   0   3
2   1   0   0   0   3
3   1   2   1   2   4
4   4   1   3   0   5
5   1   1   4   0   6
6   1   1   5   0  10
7   1   0   0   0   9
8   1   0   0   0   9
9   1   2   7   8  10
10  8   2   6   9  11
11  2   1  10   0  12
12  8   1  11   0   0
```

Note that only the outlet link has 0 as a downstream dependency.  It is important that this be the only link with 0 as a downstream dependency.  Also, the location and topology of internal boundary condition links (4 and 11) with respect to other links are known via above connectivity information in the channel_input file.  As an interpretation, examine link number 10 above.   It is of link type 8 (look-up table cross-section data), has 2 upstream dependencies (links 6 and 9), and flows into link 11.

The third portion of the  input  file contains the  individual  hydraulic property information for each node in the network.  Assume for now that all the trapezoidal channels in the network have the properties shown in Table 5.

Table 5. Cross-Sectional Properties of Example Trapezoidal Channels

| | |
|---|---|
| Manning roughness coefficient | varies |
| Bottom width (m) | varies |
| Channel depth (m) | 1.75 |
| Side slope H:V | varies |
| Talweg elevation | dependent upon location |

Now, build the input file section for link #1 which has 13 nodes on the NODE map, plus an extra for connectivity at the upstream end of link 3  (total of 14 nodes).  This input file section will look like:

```
1  14
0.035  2.10  1.75  2.00  264.40
0.035  2.10  1.75  2.00  263.85
0.035  2.10  1.75  2.00  263.41
0.035  2.10  1.75  2.00  262.98
0.035  2.10  1.75  2.00  262.75
0.035  2.10  1.75  2.00  262.54
0.035  2.10  1.75  2.00  262.37
0.035  2.10  1.75  2.05  262.02
0.035  2.20  1.75  2.05  261.87
0.035  2.20  1.75  2.10  261.75
0.035  2.20  1.75  2.10  261.67
0.035  2.20  1.75  2.15  261.52
0.035  2.30  1.75  2.15  261.25
0.035  2.40  1.75  2.15  261.00
```

The 1 and 14 on the first line indicate that it is link 1, with 14 nodes.  The columns represent Manning's n, bottom width, channel depth, trapezoidal side slope H/V, and thalweg elevation, respectively.

Link 2 might have an entry which looks like:

```
2  11
0.035  1.80  1.75  1.80  264.21
0.035  1.80  1.75  1.80  264.10
0.035  1.90  1.75  1.90  263.81
0.035  1.90  1.75  1.90  263.56
0.035  2.00  1.75  1.90  263.34
0.035  2.10  1.75  1.90  262.86
0.035  2.10  1.75  2.00  262.24
0.035  2.10  1.75  2.00  261.76
0.035  2.20  1.75  2.10  261.48
0.035  2.30  1.75  2.10  261.26
0.035  2.30  1.75  2.10  261.00
```

The cross-section entry for link 3 would then look like:

```
3  4
0.035  2.60  1.75  2.20  261.00
0.035  2.60  1.75  2.40  260.20
0.035  2.80  1.75  2.90  259.67
0.035  2.80  1.75  2.90  259.17
```

The elevation of the downstream end of links 1 and 2 must be equal to the bed elevation of the upstream end of link 3. It is required that the bed elevation of all channel inverts at each junction be equal. Even though they are not exactly the same points in space, they are assumed close enough to have the same elevation.

```
Flow                 Flow
   \                    /
\   \    \         /   /     /
 \   v    \       /   v     /
  \        \     /         /
   \ link 1 \   / link 2  /
    \ node 14\ / node 11 /
     \                  /
      \                /
       \              /
        \            /
         |          |
         |  link 3  |
         |  node 1  |
         |          |
```

The input for other links with trapezoidal cross section is similar to the input for link 1 (see the next section for the complete input file).

Additionally, assume that the reservoir (link 4) has a surface area of 0.498 square km, a rectangular spillway width of 12m, a spillway discharge coefficient of 0.97, an initial water surface elevation of 260.10m, and a spillway crest elevation of 260.50m. The resulting input file entry is shown below.

```
4  2
0.498  12.0  0.97  260.10  260.50
0.000   0.0  0.00    0.00    0.00
```

The number of nodes (line entries) in the channel_input file per reservoir link is two, but the numbers entered in the second row entry are for further improvements and for now their value is irrelevant. Also note that the bed elevation at the downstream limit of link 3 MUST be lower than the initial water surface elevation in the reservoir (link 4). This is mandatory at all downstream boundaries between channels flowing into the reservoirs. Reservoirs serve as downstream boundary conditions at upstream links. The elevation of reservoirs should therefore never be allowed to fall below critical depth in any channels which flow into the reservoir. If this happens, the code will crash.

The input for links 5, 6, 7, 8, and 9 will be similar to links 1, 2, and 3. See the constructed input file at the end of this text. Trapezoidal channel links are simple in terms of input. The channel depth field is intended to represent the average bank-full depth of the channel. This number is not used in the present version of the code, but will be in the future when the overland flood plane and channel flows are coupled iteratively. At present the flows are not fully coupled. Water can flow only from the overland flow plane into the channels, not from the channels back to the flood plane.

If look-up table data are used (link type 8), the look-up tables are stored in a separate file. The GRASS command line option for this look-up table file is table_file. If there is any link type 8 in the channel_input data file, the program will attempt to open the file table_file (typically called "table.dat"). If this file is not present, the program will terminate. In channel_input file, all that is needed is the table number for a particular description cross section, and the thalweg elevation. Assume that the 4 nodes in link 10 are approximated by one cross-section, which is given as table entry 1, then the channel_input file entry for link 10 would look like:

```
10  4
1  244.0 1  243.5 1  243.0 1  242.5
```

In this format, the first column represents the look-up table number for the given node, and the second column represents the bed elevation for that node. Table numbers can be mixed within a link. However, abrupt changes in cross-section should be avoided because they cause significant continuity errors in the formulation. The format of the table_file is discussed later in this document.

Link 11 is an overflow weir link. While this link has no nodes which appear in the node map for overland flow connectivity, it does have two nodes in terms of channel topology. The meaning of the columns in the weir node input section is presented in Table 6.

Table 6. Parameter description for Weirs

| Line Entry | Column | Parameter description |
|---|---|---|
| 1 | 1 | forward direction weir discharge coefficient |
| 1 | 2 | reverse direction weir discharge coefficient |
| 1 | 3 | 0.0 (reserved for future use) |
| 1 | 4 | crest length, meters |
| 1 | 5 | elevation of weir crest, meters |
| 2 | 1-4 | 0.0 (reserved for future use) |
| 2 | 5 | downstream bed elevation, meters |

The first (upstream) node represents the crest of the rectangular weir. The second (downstream) node represents the bed of the channel just downstream from the weir. Assume that this weir has a crest elevation of 244.4 m, a crest width of 8 m, a discharge coefficient in the forward direction of 0.92, a discharge coefficient for flow in the reverse direction equal to 0.85, and the channel bed elevation immediately downstream from the weir is 239.8m. The entry for this weir in the channel_input file would thus appear as:

```
11  2
0.92   0.85  0.00  8.00  244.4
0.00   0.00  0.00  0.00  239.8
```

Link 12 uses table entry 2 for the its first four nodes and entry 4 for the remaining two nodes. Note that link 12 has 6 nodes in the node map, and 6 nodes in the channel_input file. Because link 12 is the outlet link, we do not add an extra node at the downstream end for connectivity purposes. The portion of the channel_input file for link 12 looks like:

```
12  6
2  239.80
2  239.47
2  239.33
```

```
2  239.05
3  238.54
3  238.44
```

Hence, 238.44 is the thalweg elevation at the outlet of the catchment. Also notice that the upstream end of link 12 and the downstream node of link 11 have the same bed elevation.

Weirs cannot be used as the outlet boundary condition for this channel model. If your watershed has a weir at the outlet, just place a short link downstream from the weir with appropriate characteristics.

**FINAL CHANNEL FILE FORMAT**

The example channel data file (typically called chn.dat) developed for this example looks like:

```
----------------------BEGIN channel_input FILE HERE----------------------------
9.81
1.0  0.5  0.55
100.0
30.0  3600.0
0.07
12
14

1   1   0   0   0   3
2   1   0   0   0   3
3   1   2   1   2   4
4   4   1   3   0   5
5   1   1   4   0   6
6   1   1   5   0  10
7   1   0   0   0   9
8   1   0   0   0   9
9   1   2   7   8  10
10  8   2   6   9  11
11  2   1  10   0  12
12  8   1  11   0   0

1  14
0.035  2.10  1.75  2.00  264.40
0.035  2.10  1.75  2.00  263.85
0.035  2.10  1.75  2.00  263.41
0.035  2.10  1.75  2.00  262.98
0.035  2.10  1.75  2.00  262.75
0.035  2.10  1.75  2.00  262.54
0.035  2.10  1.75  2.00  262.37
0.035  2.10  1.75  2.05  262.02
0.035  2.20  1.75  2.05  261.87
0.035  2.20  1.75  2.10  261.75
0.035  2.20  1.75  2.10  261.67
0.035  2.20  1.75  2.15  261.52
0.035  2.30  1.75  2.15  261.25
0.035  2.40  1.75  2.15  261.00

2  11
0.035  1.80  1.75  1.80  264.21
0.035  1.80  1.75  1.80  264.10
0.035  1.90  1.75  1.90  263.81
0.035  1.90  1.75  1.90  263.56
0.035  2.00  1.75  1.90  263.34
0.035  2.10  1.75  1.90  262.86
0.035  2.10  1.75  2.00  262.24
0.035  2.10  1.75  2.00  261.76

0.035  2.20  1.75  2.10  261.48
0.035  2.30  1.75  2.10  261.26
0.035  2.30  1.75  2.10  261.00

3  4
0.035  2.60  1.75  2.20  261.00
0.035  2.60  1.75  2.40  260.20
0.035  2.80  1.75  2.90  259.67
0.035  2.80  1.75  2.90  259.17
```

```
4  2
0.498  12.0  0.97  260.10  260.50
0.000   0.0  0.00    0.00    0.00

5  5
0.035  2.50  1.75  2.10  249.20
0.035  2.50  1.75  2.10  248.65
0.035  2.50  1.75  2.15  247.94
0.035  2.50  1.75  2.20  247.31
0.035  2.50  1.75  2.20  246.97
0.035  2.50  1.75  2.25  246.42

6  5
0.035  2.50  1.75  2.00  246.42
0.035  2.50  1.75  2.00  245.97
0.035  2.50  1.75  2.00  245.24
0.035  2.50  1.75  2.00  244.73
0.035  2.50  1.75  2.00  244.00

7  9
0.035  1.75  1.75  2.00  254.20
0.035  1.75  1.75  2.00  253.55
0.035  1.75  1.75  2.00  252.92
0.035  1.90  1.75  2.00  252.29
0.035  1.90  1.75  2.00  251.71
0.035  1.90  1.75  2.00  251.24
0.035  2.00  1.75  2.00  250.82
0.035  2.00  1.75  2.00  250.34
0.035  2.00  1.75  2.00  250.08

8  7
0.035  1.60  1.75  2.00  253.71
0.035  1.90  1.75  2.00  253.21
0.035  1.90  1.75  2.00  252.94
0.035  2.00  1.75  2.00  252.55
0.035  2.10  1.75  2.00  251.80
0.035  2.10  1.75  2.00  251.11
0.035  2.10  1.75  2.00  250.08

9  10
0.035  3.10  1.75  2.90  250.08
0.035  3.20  1.75  2.90  249.16
0.035  3.30  1.75  3.00  248.63
0.035  3.40  1.75  3.00  248.02
0.035  3.40  1.75  3.10  247.33

0.035  3.20  1.75  3.10  246.65
0.035  3.10  1.75  3.10  246.05
0.035  3.20  1.75  3.10  245.88
0.035  3.20  1.75  3.10  245.52
0.035  3.50  1.75  3.10  245.24
0.035  3.70  1.75  3.40  244.74
0.035  3.50  1.75  3.40  244.51
0.035  3.10  1.75  3.40  244.00

10  4
1  244.00
1  243.50
1  243.00
1  242.50

11  2
0.92   0.85  0.00  8.00  244.40
0.00   0.00  0.00  0.00  239.80

12  6
2  239.80
2  239.47
2  239.33
2  239.05
3  238.54
3  238.44
--------------------- END OF channel_input FILE ---------------------------
```

**TABLE_FILE INPUT FORMAT**
If link type 8 (look-up table x-sections) is present in the channel_input file, we require a file typically called "table.dat", to store all look-up table values. This file must begin with an integer equal to the number of tables contained within the file. In our example this number is 3. Then we require 3 tables. The first line of each table is an integer equal to the table number. The second line in the table entry contains two numbers, an integer, and a floating point (real) value. The first number is equal to the number of entries (rows) in each particular table, designated by "numhts". The second number is the vertical distance between hydraulic property points, which must be a constant for each table. For instance, if you describe the variation of cross-sectional area, top width, and conveyance at 0.5 m vertical intervals, this number will be 0.5.

Each table entry must then contain "numhts" lines, each with four entries. The first line must be:

```
0.0   0.0   0.0   0.0
```

subsequent lines must contain the following:

```
height   topwidth   x-section_area  x-section_conveyance.
```

For instance, assume we know geometric variables for table entries 1, 2, and 3. The file "table.dat" (table_file option) may look like:

```
3
1 5  1.0
0.0   0.0    0.0    0.0
1.0   2.1    5.9   13.5
2.0   6.9   22.3  122.2
3.0  14.7   72.1  312.8
4.0  19.6  145.6  789.4

2 8  0.5
0.0   0.0    0.0    0.0
0.5   1.1    1.5    7.5
1.0   1.7    3.4   17.1
1.5   3.1   11.2   43.9
2.0   5.2   32.4   98.5
2.5   7.2   49.2  187.4
3.0   9.2   86.4  312.5
3.5  12.1  143.1  624.9

3 5  1.0
0.0   0.0    0.0    0.0
1.0   2.2    5.4   15.5
2.0   6.6   15.3  132.2
3.0  15.7   81.8  352.8
4.0  21.4  155.2  839.6
```

For further clarification, consider table 2 above, corresponding to cross sectional properties of the four most upstream nodes of link 12. Table 2 has 8 entries, each separated by 0.5 meter of depth. At a depth of 3.0 m, for example, the channel has a top-width of 9.2m, a cross-sectional area of 86.4 m2, and a conveyance of 312.5 m3/s. The conveyance K is used to calculate the discharge using:

*Q=K*sqrt(Slope)*

Where using Manning's equation, K is defined (in SI units) as:

*K = 1/n * (Area) * (Hydraulic_radius)^(2/3)*

These tables can be produced easily using a spreadsheet using measured channel cross-section data.

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## *r.in.agnps - aggrs_input*

**NAME**
*aggrs_input* **-** AGNPS-GRASS non-point source hydrology model input interface
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*aggrs_input*

**DESCRIPTION**
The major objective of the AGNPS-GRASS input interface is to minimize the user interaction in preparing the input data for the AGNPS model and to minimize the number of user supplied/developed IS database layers. Of the 22 different data required by the model for each cell (appendix 2), the interface will prepare the input data with only 8 (appendix 2) basic GIS database layers supplied by the user and with minimal user interaction. There are 5 (appendix 2) parameters needed for the whole watershed which will be obtained from the user.

Execute *aggrs_input* program from the shelltool window where GRASS is running. A Watershed Input menu will appear on the shelltool window requesting the following data/information from the user:

Parameters:
*Watershed description* Enter a description about the watershed. This information optional and will appear in both input and output of the AGNPS model run.

*Rainfall Amount* Enter the total amount of rainfall in inches.

*Erosivity Index Value* Enter the erosivity index value for that particular storm/rainfall event.

*Cell Size* The length of the side of a cell in meters is entered. The square of the cell size will be the area of each cell.

*File name to save in AGNPS format* Enter a file name with .dat as the extension to save the AGNPS model input file created by the AGNPS-GRASS input interface tool. This will be stored in the current working directory.

*Enter the watershed name* The name of the watershed should be entered here. All the input layers should have the same watershed name with the proper extension (as X in appendix 1). Please refer to appendix 1 for the valid extensions and valid category labels/values that are allowed for each layer.

Then hit the Esc key to continue.

**NOTES**
Error Messages: If any of the category labels/values for the input layers is not valid, an error message is printed and the program quits. Run support on the layer where the category label is wrong to correct it. The program support helps to modify the supporting files of a map, which include header, category, color, and history. The wrong/misspelled category labels can be corrected by running support on the layer to be corrected and choosing the category option. If there is any problem with the flow direction layer, error messages are printed for those cell numbers that had problems and the nature of those problems (like circularity, sinks or holes, or flow directions pointing at each other). Use Dedit on the aspect map to

correct the problems. The Dedit program helps to display and edit the aspect map with arrows on it, which should enable one to correct the flow direction on a cell by cell basis.

For each run of this input interface tool, a new temp_cell_num layer is created and stored in the current mapset. In this map, the cells are numbered from top to bottom and left to right. This is a useful layer for editing and interpreting the error messages due to conflicting flow direction for any particular cell. While using the Dedit program to correct the errors, this map allows one to locate the cell number where conflicts occur.

Once the input interface completes its run without errors, it saves the data in the AGNPS format. The AGNPS model can be executed with this data. The name of the executable file program to run the AGNPS model is agrun. Type agrun from the shelltool window where GRASS is running. The program will ask for the input file name. Enter the name of the file that was saved by running the AGNPS-GRASS input interface, with the .dat extension. The model will output the results of the run with a .nps extension. Both input and output ASCII files are needed to execute the AGNPS-GRASS output interface tool (the Visualization tool).

## Appendix 1

*Watershed boundary*
*(X.wshd)*
Should have category values greater than 0 within the watershed and 0's outside of the watershed boundary.

*Elevation*
*(X.elev)*
Elevation data in meters should be the category values for each cell. Also make sure at least 1 row and column of data around the watershed boundary exists to estimate slope and aspect at the boundary of the watershed.

*Aspect*
*(X.asp.cell_size)*
The aspect map should have values between 1-8 as category values and should not have any sinks, circularity or more than one outlet. Cell_size is the number that the user entered for question 4 in the interface input menu. For example, if the watershed is modeled for a 100 meter cell size, then the aspect map name should be X.asp.100

*Soils*
*(X.soils)*
If any of the soil attribute (K factor, clay, sand or hydrological soil group) maps do not exist, then the program looks for X.soils map to extract information from the Soils-5 data base. (currently this is not working fully).

*USLE K factor*
*(X.K)*
The USLE K factor map should contain the value of the K factor as the category label for each cell. This is obtained from the soil type map.

*Hydrological soil group*
*(X.hyg)*
The category labels allowed are either A, B, C, or D and should appear as category labels for each cell. This is obtained from the soil type map.

*Sand*
*(X.sand)*
The percentage of sand content should be the category label for each cell. This is obtained from the soil type map.

*Clay*
*(X.clay)*
The percentage of clay content should be there as a category label for each cell. This is obtained from the soil type map.

*Land use*
*(X.luse)*
The land use map category labels allowed are fallow, row crops, small grain, legumes, rotation meadow, close-seeded legumes, pasture, range, meadow, woods, woodland, grass waterway, hard surface, farmsteads, roads (dirt), water, or marsh.

*Management Practice*
*(X.mgpr)*
The management practice map category labels allowed are straight row, contoured, or contoured and terraced.

*Nutrient*
*(X.nut)*
The cell value should correspond to the level of fertilizer application, i.e. 1, 2, 3 or 0. Where 1-low, 2-medium, 3-high and 0-urban, water or marsh. (refer fertilizer level table).

*Machinery*
*(X.mach)*
This map is used to find the fertilizer availability factor for the top 1 cm depth of soil. The category labels allowed are large offset disk, moldboard plow, lister, chisel plow, disk, field cultivator, row cultivator, anhydrous applicator, rod weeder, planter, smooth, or no till. The category label for urban, water, marsh or farmsteads can be no till or smooth (refer fertilizer availability factor table).

*Channel slope*
*(X.chsl)*
A channel slope length map has to be prepared by the user. Percentage of channel slope should be the value of the category in that cell. If this layer is missing, the user has the choice to either enter the name of layer which has the channel slope values or can accept the default value of 50% of the overland slope value as the channel slope value (recommended by the AGNPS manual).

*Slope length factor*
*(X.slen)*
A slope length factor layer in feet has to be prepared by the user for each cell. The value should be the value of the category in that cell.

*USLE C factor*
*(X.C)*
The USLE C factor map should contain the value of the C factor as the category label for each cell.

Fertilization level

| Level of fertilization | Assumed fertilization (lb/acre) N | P | Input |
|---|---|---|---|
| None | 0 | 0 | 0 |
| Low | 50 | 20 | 1 |
| Medium | 100 | 40 | 2 |
| High | 200 | 80 | 3 |

Fertilizer availability factors according to tillage practice

| Tillage practice | Fertilizer availability factor (%) |
|---|---|
| Large offset disk | 40 |
| Moldboard plow | 10 |
| Lister | 20 |
| Chisel plow | 67 |
| Disk | 50 |
| Field cultivator | 70 |
| Row cultivator | 50 |
| Anhydrous applicator | 85 |
| Rod weeder | 95 |
| Planter | 85 |
| Smooth or no till | 100 |

**Appendix 2: AGNPS cell input parameters**

1. Cell number
2. Number of cell into which it drains
3. SCS curve number
4. Average slope %
5. Slope shape factor
6. Average field slope length
7. Average channel slope
8. Slope length factor
9. Mannings roughness coefficient for channel
10. Soil erodibility factor (K) from USLE
11. Cropping factor (C) from USLE
12. Practice factor (P) from USLE
13. Surface condition constant (based on land use)
14. Aspect (one of 8 directions indicating drainage from cell)
15. Soil texture (sand, silt, clay, peat)
16. Fertilization level (zero, low, medium, high)
17. Incorporation factor (% fertilizer left in top 1 cm of soil)
18. Point source indicator (indicates existence of a point source input within a cell)
19. Gully source level (estimate of amount, tons, or gully erosion in a cell)
20. Chemical oxygen demand factor
21. Impoundment factor (indicating presence of an impoundment terrace system within the cell)
22. Channel indicator (indicating existence of a defined channel within a cell)

The 8 basic input GIS layers required for extracting the data by the AGNPS-GRASS input interface tool are:

1. Soils
2. Elevation

3. Land use
4. Management practice
5. Fertilizer or nutrient inputs
6. Type of machinery used for land preparation
7. Channel slope
8. Slope length factor

Five pieces of data are required for the total watershed:

1. Watershed identification/description
2. Precipitation (inches)
3. Erosion Index (EI-value) for that storm/rainfall event
4. Area of each cell (acres)
5. Outlet cell number

An important implication of this set is that AGNPS does not accommodate non-uniform storms, i.e. it uses a lumped modeling approach for its rainfall.

For each watershed element, AGNPS requires the following 22 input data values (its distributed parameter information):

1. Cell number
2. Number of the cell into which it drains
3. SCS curve number
4. Average land slope (%)
5. Slope shape factor (uniform, convex or concave)
6. Average field slope length (feet)
7. Average channel slope (%)
8. Average channel side slope (%)
9. Mannings roughness coefficient for the channel
10. Soil erodibility factor (K) for USLE
11. Cropping factor (C) for USLE
12. Practice factor (P) for USLE
13. Surface condition constant (factor based on land use)
14. Aspect (one of 8 possible directions indicating the principal drainage direction from the cell)
15. Soil texture (sand, silt, clay, peat)
16. Fertilization level (zero, low, medium, high)
17. Incorporation factor (% fertilizer left in top 1 cm of soil)
18. Point source indicator (indicates existence of a point source input within a cell)
19. Gully source level (estimate of amount, tons, of gulley erosion in a cell)
20. Chemical oxygen demand factor
21. Impoundment factor (indicating the presence of an impoundment terrace system within the cell)
22. Channel indicator (indicating existence of a defined channel within a cell)

**AUTHOR**

Raghavan Srinivasan, TAES-Blackland Research Center, Temple, Texas

# *r.in.arc*

**NAME**
*r.in.arc* **-** Convert an ESRI ARC/INFO ASCII raster file (GRID) into a (binary) raster map layer.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.arc*
*r.in.arc help*
*r.in.arc input=name output=name [title="phrase"] [mult=multiplier]*

**DESCRIPTION**
*r.in.arc* allows a user to create a (binary) GRASS raster map layer from an ESRI ARC/INFO ASCII GRID file with (optional) title.

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=name* | Name of an existing ASCII raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |
| *title="phrase"* | Title to be assigned to resultant raster map layer. |

*mult=multiplier* Multiply all raster cell values by multiplier. multiplier is a floating point value, and has a default value of 1.0.

The input file has a header section, which describes the location and size of the data, followed by the data itself.

The header has 6 lines:

```
ncols:
nrows:
xllcorner:
yllcorner:
cellsize:
```

or alternatively (not supported in r.in.arc):

```
ncols:
nrows:
xllcenter:
yllcenter:
cellsize:
```

**NOTES**
*r.in.arc* handles floating point cell values. The *mult* option allows the number of significant figures of a floating point cell to be increased before importing. Multiples of ten are the most functional multipliers.

**SEE ALSO**
*r.out.arc*

**AUTHOR**
Unknown German author, updated by Bill Brown to floating point support.

## *r.in.ascii*

**NAME**
*r.in.ascii* **-** Convert an ASCII raster text file into a (binary) raster map layer.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.ascii*
*r.in.ascii help*
*r.in.ascii [-ifd] input=name output=name [title="phrase"] [mult=multiplier][nv=string]*

**DESCRIPTION**
*r.in.ascii* allows a user to create a (binary) GRASS raster map layer from an ASCII raster input file with (optional) title.

**OPTIONS**
Flags:

| | |
|---|---|
| -*i* | Integer values are imported. |
| -*f* | Floating point values are imported. |
| -*d* | Double floating point values are imported. |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing ASCII raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |
| *title="phrase"* | Title to be assigned to resultant raster map layer. |

*mult=multiplier* Multiply all raster cell values by multiplier. Multiplier is a floating point value, and has a default value of 1.0.

*nv=string* String representing NULL value data cells.

The input file has a header section which describes the location and size of the data, followed by the data itself.

The header has 6 lines:

```
north:   xxxxxx.xx
south:   xxxxxx.xx
east:    xxxxxx.xx
west:    xxxxxx.xx
rows:    r
cols:    c
```

The north, south, east, and west field values entered are the coordinates of the edges of the geographic region. The rows and cols field values entered describe the dimensions of the matrix of data to follow. The data which follows are r rows of c integers.

**EXAMPLE**

The following is a sample input file to *r.in.ascii:*

```
  ____________________________________
 | north:    4299000.00               |
 | south:    4247000.00               |
 | east: 528000.00                    |
 | west: 500000.00                    |
 | rows:10                            |
 | cols:15                            |
 |                                    |
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15|
 |____________________________________|
```

**NOTES**
The geographic coordinates north, south, east, and west describe the outer edges of the geographic region. They run along the edges of the cells at the edge of the geographic region and NOT through the center of the cells at the edges.

The data (which follows the header section) must contain r x c values, but it is not necessary that all the data for a row be on one line. A row may be split over many lines.

*r.in.ascii* handles floating point cell values, but truncates them into integer values. The mult option allows the number of significant figures of a floating point cell to be increased before truncation to an integer. Multiples of ten are the most functional multipliers.

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.in.erdas*

**NAME**
*r.in.erdas* **-** Creates raster files from ERDAS files.  It creates one raster file for each band, and creates color support if an ERDAS trailer file is specified.
(SCS GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.in.erdas*
*r.in.erdas help*
*r.in.erdas erdas=name [trl=name] prefix=name*

**DESCRIPTION**
This command prompts the user twice:

First the user is asked if he wishes to select a subset of the bands available in the ERDAS file for output. If unspecified by the user, all bands are used, by default.

Second, the user is asked if he wishes to select a subregion of the image available in the ERDAS file.  If unspecified by the user, the complete image is used, by default.

Note:
GRASS raster files will be named prefix.band  Remember that it is necessary to run: *r.support*: to create the histogram or change the color table and *i.group*: to associate the individual raster files as an image group.

**OPTIONS**
Parameters:

| | |
|---|---|
| *erdas=name* | Input ERDAS file name. |
| *trl=name* | Input ERDAS trailer file name. |
| *prefix=name* | Prefix of the GRASS raster files to be created. |

**AUTHOR**
M. L. Holko, USDA, SCS, NHQ-CGIS

## *r.in.gif*

**NAME**
*r.in.gif* **-** Converts a GIF87 (8bit) raster file to a GRASS raster file.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.gif [-v] input=name output=name [title=name]*

**DESCRIPTION**
This program converts a GIF raster file (8bit) to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset.

**OPTIONS**
Flag:

| | |
|---|---|
| -*v* | Verbose mode. |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing GIF raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |
| *title="phrase"* | Title to be assigned to resultant raster map layer. |

The program prompts the user to enter the name of the GIF raster file to be converted and the name to be assigned to the GRASS raster file to contain the resultant image. The user should adjust boundary coordinates stored in the cell header after import using *r.support* .

The user must, of course, first create the GIF raster file to be converted (e.g., from a scanning system that produces GIF raster file format).

**NOTE**
The GIF89 format is currently not accepted.

**SEE ALSO**
*r.support*, *parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.in.hdf*

**NAME**
*r.in.hdf* **-** Convert data in HDF format into a (binary) raster map layer.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x ,5.x

**SYNOPSIS**
*r.in.hdf*
*r.in.hdf help*
*r.in.hdf [-qal] input=name [output=name] [mult=value] [dsets=value[,value,...]]*

**DESCRIPTION**
*r.in.hdf* allows a user to create a GRASS raster map layer from a file in NCSA Hierarchical Data Format (HDF).

**OPTIONS**
Flags:

| | |
|---|---|
| -*q* | Run quietly |
| -*a* | Convert ALL data sets in the HDF file |
| -*l* | Only list the contents of the HDF file (no conversion) |

Parameters:

| | |
|---|---|
| *input* | HDF file to be converted. |
| *output* | Name of new raster file. Default: hdf.rast |
| *mult* | Floating point multiplier. (rastfile = (int)(file.hdf * multiplier)) |
| *dsets* | A list of reference numbers for datasets to be extracted. |

The raster file created will have its southwest origin at 0 East and 0 North, with resolution of 1. To view the new GRASS raster file, use *g.region rast=newfile*, then use *d.rast* as normal. You may wish to manually change the new raster's cellhd file.

NCSA HDF is a multi-object file format developed by The National Center for Supercomputing Applications at Champaign, Illinois for the transfer of graphical and floating-point data between machines. NASA Pathfinder AVHRR data is stored in HDF format. The HDF format defines both a raster type and a SDS (scientific data set) type. The later is basically a highly structured multi-dimensional array of values. A single HDF file may contain more than one SDS or raster; using the -*a* option will extract all data sets from the HDF file, creating a separate GRASS raster file from each data set and naming the raster files outputname01, outputname02, outputname03.... If the -*a* option is not specified and the HDF file contains more than one data set, only the first data set is extracted unless the user specifies specific reference numbers for desired data sets in the file using the dsets option. To see a list of reference numbers for data sets in an HDF file, use the -*l* flag. If the HDF file contains labels or descriptions of the data, these will be shown when using the -*l* flag. Labels and descriptions from the HDF file will also be written to the GRASS history file when creating the raster map. If a multiplier is given using the mult option, every file created will be the product of the input data set and the multiplier. If the

HDF file contains an SDS, it must be only two dimensional in order for *r.in.hdf* to accept it as input. If the HDF file contains an 8-bit raster image with an associated palette, a GRASS color file will be created. This program will not import 24-bit HDF raster images.

NCSA distributes the HDF library and several public domain visualization applications which use the HDF format. Some commercial applications also support HDF. For more information, use the NCSA anonymous ftp server ftp.ncsa.uiuc.edu or contact:

NCSA
152 Computing Applications Building
605 E. Springfield Ave.
Champaign, IL 61820
(217) 244-0072

**BUGS**
If a data set contains long labels and descriptions, some of it may be truncated when writing to the GRASS history file. The GRASS history structure currently allows 50 lines of 80 characters each. But when editing history using *r.support*, only 20 lines of 65 characters may be used.

**SEE ALSO**
*r.out.hdf, r.support, g.region*

**AUTHOR**
Bill Brown, U.S. Army Construction Engineering Research Laboratory

## *r.in.ll*

**NAME**
*r.in.ll* **-** Converts raster data referenced using latitude and longitude coordinates to a UTM-referenced map layer in GRASS raster format.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.ll*
*r.in.ll help*
*r.in.ll [-s] input=name output=name bpc=value corner=corner,lat,lon dimension=rows,cols res=latres, lonres spheroid=name*

**DESCRIPTION**
This program converts raster data referenced using latitude and longitude coordinates to a UTM-referenced map layer in GRASS raster format. *r.in.ll* is primarily used as the final program in converting DTED and DEM digital elevation data to GRASS raster format, but is not limited to this use. *r.in.ll* uses the user's current geographic region settings. Only data that falls within the current geographic region will appear in the final raster map layer.

*r.in.ll* requires the user to enter the following information:

**OPTIONS**
Flags:

| | |
|---|---|
| -*s* | Signed data (high bit means negative value). |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing input raster map layer. |
| *output=name* | Name to be assigned to the output raster map layer. |
| *bpc=value* | Number of bytes per cell. |

*corner=corner,lat,lon* One corner latitude and longitude of the input. Format: {nw|ne|sw|se},dd:mm:ss{N|S},ddd:mm:ss{E|W}

The latitude and longitude are specified as dd.mm.ssH where dd is degrees, mm is minutes, ss is seconds, and H is the hemisphere (N or S for latitudes, E or W for longitudes).

For example, to specify the southwest corner:

*corner=sw,46N,120W*

Note: the latitude and longitude specified are for the center of the corner cell.

| | |
|---|---|
| *dimension=rows,cols* | Number of rows and columns in the input file. |
| *res=latres,loners* | Resolution of the input (in arc seconds). |
| *spheroid=name* | Name of spheroid to be used for coordinate conversion. |

Options: *airy*, *australian*, *bessel*, *clark66*, *everest*, *grs80*, *hayford*, *international*, *krasovsky*, *wgs66*, *wgs72*, *wgs84*

**EXAMPLE**
The command line:

*r.in.ll input=rot.out output=import.out dimension=358,301 bpc=2 res=3,3 corner=sw,37:13N,103:45W spheroid=wgs72*

reads data from the file rot.out, converts the data, and stores them in the file import.out. The data to be converted are made up of 358 rows and 301 columns, and have a resolution of 3x3 arc seconds.

**NOTES**
In the conversion of DTED and DEM elevation data to raster map layer format, *r.in.ll* follows execution of the data rotation program *m.rot90*. Because the user can glean information on the number of rows and columns, the resolutions of the latitude and longitude, and the number of bytes per column from the header file produced by the tape extraction programs *m.dted.extract* and *m.dmaUSGSread*, the user should recall that *m.rot90* has rotated the files produced by the tape extraction programs 90 degrees; this means that the user should INTERCHANGE the numbers of rows and columns present in the header file for input to *r.in.ll*. The number of rows shown in the tape extract header file now become the number of columns in the *m.rot90* output file; the number of columns shown in the tape extract header file are now the number of rows present in the *m.rot90* output file.

The user should also note that the raster map layer imported into GRASS will be based on the current geographic region settings. The boundaries of this geographic region should therefore be checked before importing the raster map layer. Data outside of the geographic region will not be imported and missing data will be assigned the category value "no data".

**SEE ALSO**
*m.dmaUSGSread*, *m.dted.examine*, *m.dted.extract*, *m.rot90*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.in.miads*

**NAME**
*r.in.miads* **-** Converts a MIADS output ASCII text file into an GRASS raster import (*r.in.ascii*) formatted file.
(SCS GRASS Raster Program)

**GRASS VERSION**
4.x,5.x

**SYNOPSIS**
*r.in.miads*
*r.in.miads help*
*r.in.miads input=name output=name strip=value line=value cell=value Northing=value Easting=value size=value*

**DESCRIPTION**
*r.in.miads* allows a user to create a *r.in.ascii* formatted ASCII file from a MIADS output printer format ASCII file. The program will actively read the MIADS data file, selectively remove and process each strip, creating a individual *r.in.ascii* formatted file for each strip, and finally create one category file for all strips. The program also produces a report file summarizing all pertinent information for each strip.

The resulting *r.in.ascii* files for each strip are then used in conjunction with the GRASS commands *r.in.ascii* and *r.patch* to create a complete raster file.

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=name* | MIADS input file name. |
| *output=name* | GRASS raster data output file name. |
| *strip=value* | MIADSs strip number of reference cell. |
| *line=value* | MIADSs line number of reference cell. |
| *cell=value* | MIADS cell number of reference cell. |
| *Northing=value* | UTM Easting at the cell reference. |
| *Easting=value* | UTM Northing at the cell reference. |
| *size=value* | Cell size (length one side) in meters. |

SCS has developed scripts *run.miads*, *getstrip*, and *strip.99s*. These scripts make the MIADS to GRASS conversion easier.

*run.miads* **-** SCS macro to perform the complete conversion of a MIADS printer format data set to a GRASS raster file.

*getstrip* **-** Reads each MIADS strip file and converts it to a independent GRASS data file. Support may be run on any one of these strip files; however, there is no category information available. Each strip may be viewed at this time with *d.rast* or *d.display*.

*strip.99s* **-** Special pre-*r.in.miads* macro that removes the 99's from the MIADS data file. This effectively removes border information, replacing it with "no data" values.

**SEE ALSO**
*d.display, d.rast, r.in.ascii, r.patch, r.support*

**AUTHOR**
*r.in.miads* **-** R. L. Glenn, USDA, SCS, NHQ-CGIS
*run.miads, strip.99s* **-** Harold Kane, USDA, SCS, Oklahoma State Office

## *r.in.pbm*

**NAME**
*r.in.pbm* **-** Converts an ASCII/BINARY PPM image file to a GRASS raster file.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.pbm [-v] input=name output=name*

**DESCRIPTION**
This program converts a PPM raster file to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset.

**OPTIONS**
Flag:

| | |
|---|---|
| -*v* | Verbose mode. |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing PPM raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |

The program prompts the user to enter the name of the PPM raster file to be converted and the name to be assigned to the GRASS raster file to contain the resultant image. Currently PPM ASCII and PPM BINARY (PBM) formats are supported.

The user should adjust boundary coordinates stored in the cell header after import using *r.support* .

The user must, of course, first create the PPM raster file to be converted (e.g., from a scanning system that produces PPM raster file format).

**NOTE**
The maximum color number is limited to 32768 colors.

**SEE ALSO**
*r.support, parser*

**AUTHOR**
Bill Brown, GMS Labs, UIUC

## *r.in.poly*

**NAME**
*r.in.poly* **-** Create raster maps from ASCII polygon/line data file
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.poly*
*r.in.poly help*
*r.in.poly input=name output=name [title="phrase"] [rows=value]*

**DESCRIPTION**
*r.in.poly* allows the creation of GRASS ASCII files containing polygon and linear features.

**OPTIONS**
Parameters:
*input=name* Unix input file, in ASCII format, containing the polygon and linear features. The format of this file is described in the section INPUT FORMAT below.

*output=name* Raster output file

*title="phrase"* Title for resultant raster map (optional)

*rows* Number of rows to hold in memory (default: 512). This parameter allows users with less memory (or more) on their system to control how much memory *r.in.poly* uses.

**INPUT FORMAT**
The input format for the input file consists of sections describing either polygonal areas or linear features. The basic format is:

```
A  <for polygonal areas>
    easting northing
    .
=   cat# label
L  <for linear features>
    easting northing
    .
=   cat# label
```

The A signals the beginning of a polygon. It must appear in the first column. The L signals the beginning of a linear feature. It also must appear in the first column. The coordinates of the vertices of the polygon, or the coordinates defining the linear feature follow and must have a space in the first column and at least one space between the easting and the northing. To give meaning to the features, the = indicates that the feature currently being processed has category value cat# (which must be an integer) and a label (which may be more than one word, or which may be omitted).

**SEE ALSO**
*r.digit* **-** interactive on-screen polygon/line digitizing for raster maps
*r.colors* **-** creates color tables for raster maps

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.in.ppm*

**NAME**
*r.in.ppm* **-** Converts an ASCII/BINARY PPM image file to a GRASS raster file.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.ppm [-vb] input=name output=name [nlev=value]*

**DESCRIPTION**
This program converts a PPM raster file to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset. Optionally, the user is asked to enter the maximum number of levels for each band; the default value is 20 (= 20 x 20 x 20 = 8000 colors). If the number of colors in the PPM raster file is greater than the maximum number of colors, a quantized color table is created and each color of the PPM raster file assigned to the nearest available color. Optionally, the program creates 3 separate raster maps of the (true) red, green and blue levels. Currently PPM ASCII and PPM BINARY (PBM) formats are supported.

**OPTIONS**
Flags:

| | |
|---|---|
| -*v* | Verbose mode |
| -*b* | Create 3 separate raster maps of the (true) R/G/B levels |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing PPM raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |
| *nlev=value* | Max number of levels for R/G/B. |

Options: 1-256
Default: 20 (= 8000 colors)

**NOTES**
R/G/B levels: each output raster map layer is given a linear gray scale color table. Each output raster map layer is assigned the user-specified output with (.r, .g, .b) suffix.

The user should adjust boundary coordinates stored in the cell header after import using *r.support* and *parser*.

**SEE ALSO**
*r.in.pbm*

**AUTHOR**
Stefano Merler, ITC-irst (Italy)

## *r.in.sunrast*

**NAME**
*r.in.sunrast* **-** Converts a SUN raster file to a GRASS raster file.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.sunrast*

**DESCRIPTION**
This program converts a SUN raster file that has been created by SUN's "screendump" utility to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset.

The program prompts the user to enter the name of the SUN raster file to be converted and the name to be assigned to the GRASS raster file to contain the resultant image.

It is recommended that this program be used in an x, y database (as opposed to, for example, a UTM data base), since the cell header is created with nonsense coordinates (i.e., coordinates designed only to specify the number of rows and columns in the image). Of course, the user can adjust the cell header after import using *r.support*.

The user must, of course, first create the SUN raster file to be converted, either by running the SUN "screendump" utility (to capture a displayed image) or by some other means (e.g., from a scanning system that produces SUN raster file format).

**NOTE**
If you are using the screendump utility on a SUN workstation to create the sun rasterfile, do not use the **-***e* option. This option creates a sun rasterfile format that *r.in.sunrast* does not understand.

**SEE ALSO**
SUN screendump utility
*r.support, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.in.tiff*

**NAME**
*r.in.tiff* **-** Converts a TIFF (8bit) raster file to a GRASS raster file.
(GRASS Raster Data Import Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.in.tiff [-v] input=name output=name*

**DESCRIPTION**
This program imports a TIFF raster file (8bit) to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset.

**OPTIONS**
Flag:

| | |
|---|---|
| -*v* | Verbose mode |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing TIFF raster file to be imported. |
| *output=name* | Name to be assigned to resultant binary raster map layer. |

The program prompts the user to enter the name of the TIFF raster file to be converted and the name to be assigned to the GRASS raster file to contain the resultant image. Currently "TIFF/uncompressed", "TIFF/LZW-compression" and TIFF/PackBits-compression" formats are supported. The user should adjust boundary coordinates stored in the cell header after import using *r.support* .

The user must, of course, first create the TIFF raster file to be converted (e.g., from a scanning system that produces TIFF raster file format).

**NOTE**
The TIFF 24bit format is currently not supported.

**SEE ALSO**
*r.support, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.infer*

**NAME**
*r.infer* - Outputs a raster map layer whose category values represent the application of user-specified criteria (rules statements) to other raster map layers' category values. (GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.infer*
*r.infer help*
*r.infer [-vt] rulesfile=name*

**DESCRIPTION**
*r.infer* is an inference engine which applies a set of user- specified rules to named raster map layers. A new raster map layer named infer is created as output, whose category values reflect the ability of each cell in the named input layers to satisfy the named conditions.

*r.infer* commands (conditions and consequences) are typed into a file by the user using a system editor like *vi*, and then input to *r.infer* as the rulesfile named on the command line. The results are used to generate a new raster map layer named infer in the user's current mapset. This program performs analyses similar to *r.combine*, but uses a (possibly) more pleasing syntax and approach.

**OPTIONS**
The program will be run non-interactively if the user specifies the name of a rules file and any desired flags on the command line, using the form:

*r.infer [-vt] rulesfile=name*

where name is the name of an ASCII file containing valid input rules to *r.infer*, and the (optional) flags *-v* and *-t* have the meanings described in the OPTIONS section, below.

Alternately, the user can simply type *r.infer* on the command line, without program arguments. In this case, the user will be prompted for the needed parameter value and flag settings using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:
*-t* Allows the user to run *r.infer* in test mode. The user is questioned about the truth of each condition named in the file. *r.infer* then outputs the value that would be placed in the new layer infer for a cell meeting conditions specified by the user. When no sets of conditions stated in the input file are satisfied (based upon the user's answers), cell values of zero are output. Test mode is used to test the accuracy of the user's logic. Users are encouraged to run *r.infer* in test mode prior to actually creating map layers.

*-v* Makes *r.infer* run verbosely, giving information about each cell as it is analyzed according to the statement conditions.

Parameter:
*rulesfile=name* Allows the user to input rules to *r.infer* from an ASCII file, rather than from standard input. This rulesfile must exist in the user's current working directory or be given by its full pathname. File rules statements take the same form as those given on the command line. Examples of valid rules statements are given in the sections below.

**COMMANDS AND STATEMENTS**
The following commands are available in *r.infer*:

| Command | Aliases | Followed By | Such As |
|---|---|---|---|
| IFMAP | ANDIFMAP<br>ANDMAP | cellmap cat# | geology 2 |
| IFNOTMAP | ANDNOTMAP | cellmap cat# | geology 2 |
| THENMAPHYP | | cat# [statement] | 3 nice vacation spot |
| THEN | | statement<br>condition | No sandstone |
| IF | AND<br>ANDIF | predefined<br>statement condition | No sandstone |

These five commands may be used to formulate statements with functions ranging from a simple reclassification to a more complex expert system type application. Statements are composed of one or more conditions followed by one or more hypotheses and/or conclusions. The use of aliases is provided to allow for the use of a command which has an English meaning consistent with the logic at that point.

Following is a description of each of the five commands. The map layers used in the examples are in the Spearfish sample data base.

IFMAP
Map condition.
Map conditions are questions to each cell about the presence of specified map layer category values. *r.infer* questions each cell in the named map layer (here, geology) about its contents (i.e., category value). Cells which satisfy the named condition(s) stated by IFMAP (i.e., here, those cells which contain geology map layer category values 4 or 5) will be assigned the subsequently-stated map conclusion or hypothesis (category), in the new map layer infer. Cells which fail to satisfy named map condition(s) will continue to move down through the user's rulesfile (searching for conditions it is able to satisfy) if any additional conclusions/hypotheses are stated in the file, or will be assigned category zero in the new map layer infer (if no additional conclusions/hypotheses are possible in this rulesfile).

example: *IFMAP geology 4 5*

IFNOTMAP
Map condition.
Like IFMAP, but instead questions each cell about the absence of specified map layer categories. Cells which meet the IFNOTMAP conditions (i.e., below, those cells which do NOT include owner map layer category value 2) will be assigned the named conclusionothesis, in the new map layer infer.

example: *IFNOTMAP owner 2*

THENMAPHYP
Map conclusion.
Assigns each cell a specified category value in the new map layer infer based on the cell's ability or failure to meet conditions named above this THENMAPHYP statement in the rulesfile. The user should note that although the user can specify a uniquely-named rulesfile, *r.infer* always directs its output to a file named infer in the current mapset (overwriting whatever is currently in this file). Therefore, if the user wishes to save this file for future use, this file should be renamed before the user next runs *r.infer* (e.g., using the GRASS command *g.rename*).

It is important to realize that *r.infer* runs through the conditions stated in the named rulesfile one cell at a time, moving from the top of the raster input file to the bottom of the raster input file. As soon as the cell currently being examined by *r.infer* satisfies a set of conditions, it is assigned a category value in the new map layer infer. *r.infer* does NOT check to see if that same cell satisfies other conditions named further down in the input file, too. Instead, it moves on to the next cell, and begins anew with the conditions named at the top of the input file. Essentially, this means that conclusions made higher-up in the input file have precedence over conditions named further down in the input file.

example: *IFMAP density 1 THENMAPHYP 1 no trees*

In the above example, all cells having a category value of 1 (non-forest) in the map layer density, are assigned a category value of 1 in the resultant map layer infer. The trailing text "no trees" is entered into the category support file for category 1 in the new map layer infer.

THEN
Statement hypothesis.
At the conclusion of one or several condition statements, instead of making a map conclusion as with THENMAPHYP, the conditions are used to create a hypothesis. This may then be referenced in later statements using the IF command. The trailing text at the end of the THEN statement is used as the means with which to reference the hypothesis. An example follows the description of IF below.

IF
Statement condition.
States a condition based on an hypothesis that was created by a previous THEN statement. IF may be used only after a THEN has set up the group of statements that are to be referenced later.

example:

*IFMAP elevation.255 170-255 ANDIFMAP density 3 4 THEN high elevation with trees!*
*IF high elevation with trees ANDIFMAP owner 2 THENMAPHYP 1 this is the place*

The above example queries each cell for the presence of both elevations greater than 1580 meters (i.e., for elevation.255 category values 170-255) and a medium to high density of trees (i.e., density category values 3 4). All areas (i.e., cells) that satisfy these criteria are assigned to the hypothesis "high elevation with trees." The "!" simply tells *r.infer* to ignore whatever appears on that line (a comment statement), and is used here for readability.

The IF statement then references cells having "high elevation with trees" (i.e., those cells that satisfied both of the above conditions named by the IFMAP and ANDIFMAP statements). If a cell both has "high elevations with trees" and owner map layer category 2 (areas owned by the Forest Service), it is assigned by the THENMAPHYP statement to category 1 in the new map layer infer. The trailing text "this is the place" is automatically entered into the category support file for the new map infer. Cells failing to meet all of the conditions stated in this input file will be assigned category 0 in the new map layer infer.

**SEE ALSO**
GRASS Tutorial: *r.infer*
*g.rename, r.combine, r.mapcalc, r.weight, parser*

**AUTHOR**
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## *r.info*

**NAME**
*r.info* **-** Outputs basic information about a user-specified raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.info*
*r.info help*
*r.info map=name*

**DESCRIPTION**
*r.info* reports some basic information about a user-specified raster map layer.  This map layer must exist in the user's current mapset search path.  Information about the map's boundaries, resolution, projection, data type, category number, data base location and mapset, and history are put into a table and written to standard output.  The types of information listed can also be found in the /cats, /cellhd, and /hist directories under the mapset in which the named map is stored.

The program will be run non-interactively if the user specifies the name of a raster map layer on the command line, using the form:

*r.info map=name*

where name is the name of a raster map layer on which the user seeks information.  The user can save the tabular output to a file by using the UNIX redirection mechanism (<);  for example, the user might save a report on the soils map layer in a file called soil.rpt by typing:

*r.info map=soils > soil.rpt*

Alternately, the user can simply type *r.info* on the command line, without program arguments.  In this case, the user will be prompted for the name of a raster map layer using the standard GRASS *parser* interface described in the manual entry for *parser*.  The user is asked whether he wishes to print the report and/or save it in a file.  If saved, the report is stored in a user-named file in the user's home directory.

Below is the report produced by *r.info* for the raster map geology in the Spearfish sample data base.

```
|-------------------------------------------------------|
| Layer:    geology   Date: Mon May  4 10:00:14 1987 :   |
| Location: spearfish Login of Creator: grass            |
| Mapset:   PERMANENT                                    |
| Title:    Geology                                      |
|-------------------------------------------------------|
|   Type of Map:  rasterNumber of Categories: 9          |
|   Rows:    140                                         |
|   Columns: 190                                         |
|   Total Cells:  26600                                  |
|   Projection: UTM (zone 13)                            |
| N: 4928000.00    S: 4914000.00   Res: 100.00           |
| E:  609000.00    W:  590000.00   Res: 100.00           |
|                                                        |
|   Data Source:                                         |
|   Raster file produced by EROS Data Center             |
|                                                        |
|   Data Description:                                    |
|   Shows the geology for the map area                   |
|                                                        |
|   Comments:                                                  |
|--------------------------------------------------------------|
```

**SEE ALSO**
*g.mapsets, r.coin, r.describe, r.report, r.stats, r.support, r.what,  parser*

**AUTHOR**
Michael O'Shea, U.S. Army Construction Engineering Research Laboratory

# *r.kappa*

**NAME**
*r.kappa* **-** Calculate error matrix and kappa parameter for accuracy assessment of classification result.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.kappa*
*r.kappa help*
*r.kappa [-mwqzh] classification=name reference=name output=name [title="name"]*

**DESCRIPTION**
*r.kappa* tabulates the error matrix of classification result by crossing classified map layer with respect to reference map layer. Both overall kappa (accompanied by its variance) and conditional kappa values are calculated. This analysis program respects the current geographic region and mask settings.

**OPTIONS**
The user can run the program non-interactively by specifying all needed flag settings and parameter values on the command line, in the form:

*r.kappa [-mwqzh] classification=name reference=name output=name [title="name"]*

Flags:

| | |
|---|---|
| -*m* | Report zero values due to mask. |
| -*w* | Print a wide report, 132 columns<br>Default: 80 |
| -*q* | Run quietly. |
| -*z* | Report non-zero values only. |
| -*h* | Report without header. |

Parameters:

| | |
|---|---|
| *classification=name* | Name of classified raster map layer. |
| *reference=name* | Name of reference raster map layer. |
| *output=name* | Name of ASCII file in which to output report results. |
| *title=name* | Title of the report file which is the first line in output file.<br>Default: ACCURACY ASSESSMENT |

Alternately, the user can run *r.kappa* interactively by simply typing *r.kappa* without command line arguments; in this case, the user will be prompted for the names of classified result map and reference map, which will be the subjects of the analysis. *r.kappa* then calculates the error matrix of the two map layers and prepares the table from which the report is to be created. kappa values for overall and each classes are computed along with their variances. Also percent of commission and omission error, total correct classified result by pixel counts, total area in pixel counts and percentage of overall correctly classified pixels is tabulated.

The report will be write to an output file which is in plain text format and named by user at prompt of running the program.

The body of the report is arranged in panels. The classified result map layer categories are arranged along the vertical axis of the table, while the reference map layer categories along the horizontal axis. Each panel has a maximum of 5 categories (9 if wide format) across the top. In addition, the last column of the last panel reflects a cross total of each column for each row. All of the categories of the map layer arranged along the vertical axis, i.e., the reference map layer, are included in each panel. There is a total at the bottom of each column representing the sum of all the rows in that column.

**NOTES**

It is recommended to reclassify categories of classified result map layer into a more manageable number before running *r.kappa* on the classified raster map layer. Because *r.kappa* calculates and then reports information for each and every category.

NA's in output file mean non-applicable in case MASK exists.

**SEE ALSO**

*g.region, r.cats, r.mask, r.reclass, r.report, r.stats*

**AUTHOR**

Tao Wen, University of Illinois at Urbana-Champaign, Illinois

# *r.kineros*

**NAME**
*r.kineros* **-** A GRASS Program for Determining the Topology of Stream Networks

**GRASS VERSION**
4.x

**INTRODUCTION**
This paper presents a GRASS (geographical resource analysis support system; Shapiro et al., 1992; United States Army Corps of Engineers, 1993) program for determining the topology of stream networks. The program inputs raster files generated by the GRASS program *r.watershed*. Because it determines the relationships of tributary streams, it is called *r.tribs*. The input files required are:

*stream*: a raster map of stream segments; stream segments are labeled using integer values greater than or equal to 2,

*accumulation*: a raster map of the number of cells that drain through each cell; absolute values is the amount of overland flow that is routed through a pixel,

*drainage*: a raster map of drainage directions; if there is no flow direction, a value of **-**1 is assigned. Otherwise, the integers 1 through 8 are assigned to the compass
directions shown below:

```
5      6     7
4     -1     8
3      2     1
```

For example, a value of 2 means that the pixel drains south, a value of 5 means the pixel drains to the northwest.

Two tables are output by *r.tribs*. The first table list the tributaries associated with each stream segment. The second table list streams and tributaries in an order such that a stream and its tributaries are printed only if the tributaries have been previously listed. That is, first order streams are listed first, streams with tributaries that are first order streams are listed second, and so on. The program can also be run in debugging mode, in which more detailed information is printed.

The program *r.tribs* was written so that GRASS can be used to generate input for a runoff and erosion model called KINEROS (Smith et al., in press; Woolhiser et al., 1990). KINEROS represents a watershed as a set of related elements. Elements may be hillslopes, channels or ponds. A computational order must be specified so that boundary conditions for an element, such as the amount of water contributed by lateral hillslopes and upstream tributaries, are available. The program *r.tribs* provides KINEROS with that computational order.

**Input Files**
We assume that the program *r.watershed* has been run, and that the input files stream, accumulation and drainage are available. Assume these files are called stream.0, accum.0 and drain.0, respectively. The command-line version of *r.tribs* is:

```
GRASS 4.1 > r.tribs st=stream.0 ac=accum.0 dr=drain.0
```

Alternately, the command r.tribs can be entered on the command line:

```
GRASS 4.1 > r.tribs
```

and the user will be prompted for these files.

**Methodology and Example of Output**
This is followed by a listing of the tributaries associated with each stream. The tributaries of a stream are determined by using the following methodology.

a. The stream and accumulation files are scanned to determine the locations of pixels that are stream segments and have the lowest accumulation of runoff for that
segment. These points mark the locations of the heads of the stream segments. Locations of the head of a stream are stored for the next step.

b. Points within one pixel of the head are scanned to determine if they are part of a different stream segment and if they drain into the head of this stream. The drainage
raster file is used to determine the drainage direction. Any point meeting this criteria are listed as tributary streams.

c. All points with no tributaries are first order. Tributary values are set to zero.

d. The label of the stream and its tributaries are stored and printed to the screen.

We have used *r.tribs* to generate output for a small watershed (17.5 km2) in Idaho (Horse Creek) in which we used *r.watershed* to define a total of 50 stream segments. Note that stream segments and tributaries are labeled using even integers ranging from 2 to 102. Stream segment 2 is located at the mouth of the watershed.

The *r.tribs* program first outputs the number of rows (nrows) and columns (ncols) in the raster files. Then the maximum and minimum labels of stream segments are printed. This is followed by two tables. The first table lists streams and their tributaries. An example of this table is given below.

```
nrows: 138
ncols: 273
Max stream index = 102
Min stream index = 2
Stream: 2 Tributary 0: 6 Tributary 1: 4
Stream: 4 Tributary 0: 0 Tributary 1: 0
Stream: 6 Tributary 0: 14 Tributary 1: 8
Stream: 8 Tributary 0: 12 Tributary 1: 10
Stream: 10 Tributary 0: 0 Tributary 1: 0
Stream: 12 Tributary 0: 0 Tributary 1: 0
Stream: 14 Tributary 0: 22 Tributary 1: 16
Stream: 16 Tributary 0: 20 Tributary 1: 18
Stream: 18 Tributary 0: 0 Tributary 1: 0
Stream: 20 Tributary 0: 0 Tributary 1: 0
Stream: 22 Tributary 0: 102 Tributary 1: 24
Stream: 24 Tributary 0: 36 Tributary 1: 26
Stream: 26 Tributary 0: 30 Tributary 1: 28
Stream: 28 Tributary 0: 0 Tributary 1: 0
Stream: 30 Tributary 0: 34 Tributary 1: 32
Stream: 32 Tributary 0: 0 Tributary 1: 0
Stream: 34 Tributary 0: 0 Tributary 1: 0
Stream: 36 Tributary 0: 100 Tributary 1: 38
Stream: 38 Tributary 0: 42 Tributary 1: 40
Stream: 40 Tributary 0: 0 Tributary 1: 0
Stream: 42 Tributary 0: 98 Tributary 1: 44
Stream: 44 Tributary 0: 96 Tributary 1: 46
Stream: 46 Tributary 0: 50 Tributary 1: 48
Stream: 48 Tributary 0: 0 Tributary 1: 0
Stream: 50 Tributary 0: 58 Tributary 1: 52
```

```
Stream: 52 Tributary 0: 56 Tributary 1: 54
Stream: 54 Tributary 0: 0 Tributary 1: 0
Stream: 56 Tributary 0: 0 Tributary 1: 0
Stream: 58 Tributary 0: 90 Tributary 1: 60
Stream: 60 Tributary 0: 88 Tributary 1: 62
Stream: 62 Tributary 0: 66 Tributary 1: 64
Stream: 64 Tributary 0: 0 Tributary 1: 0
Stream: 66 Tributary 0: 74 Tributary 1: 68
Stream: 68 Tributary 0: 72 Tributary 1: 70
Stream: 70 Tributary 0: 0 Tributary 1: 0
Stream: 72 Tributary 0: 0 Tributary 1: 0
Stream: 74 Tributary 0: 82 Tributary 1: 76
Stream: 76 Tributary 0: 80 Tributary 1: 78
Stream: 78 Tributary 0: 0 Tributary 1: 0
Stream: 80 Tributary 0: 0 Tributary 1: 0
Stream: 82 Tributary 0: 86 Tributary 1: 84
Stream: 84 Tributary 0: 0 Tributary 1: 0
Stream: 86 Tributary 0: 0 Tributary 1: 0
Stream: 88 Tributary 0: 0 Tributary 1: 0
Stream: 90 Tributary 0: 94 Tributary 1: 92
Stream: 92 Tributary 0: 0 Tributary 1: 0
Stream: 94 Tributary 0: 0 Tributary 1: 0
Stream: 96 Tributary 0: 0 Tributary 1: 0
Stream: 98 Tributary 0: 0 Tributary 1: 0
Stream: 100 Tributary 0: 0 Tributary 1: 0
Stream: 102 Tributary 0: 0 Tributary 1: 0
```

If the program is run in debugging mode, then the values of stream, accumulation and direction of the head of the stream and the surrounding 8 pixels are also printed. Set the value of DB_FIND_TRIBS (defined in the beginning of the routine find_tribs) to a value of 1 and recompile the program to activate debugging mode.

The second table that is output by *r.tribs* list the streams and their associated tributaries in their proper computational order. The program loops through the data listed above several times. First streams with no tributaries are listed (LOOP 1). Then streams with only first-order streams as tributaries are listed (LOOP 2). Then, streams with tributaries listed in previous loops are listed. The program continues until all streams have been listed. The variable "Order" is also listed, which can be interpreted as the computational order. This is the order in which programs, such as KINEROS, must consider streams in the network such that data for tributaries will be available when considering the listed stream. An example listing of the computational order of streams is given below.

Computational Order of Stream Segments:

```
LOOP: 1
Order: 0 Stream: 4 Tributary 0: 0 Tributary 1: 0
Order: 1 Stream: 10 Tributary 0: 0 Tributary 1: 0
Order: 2 Stream: 12 Tributary 0: 0 Tributary 1: 0
Order: 3 Stream: 18 Tributary 0: 0 Tributary 1: 0
Order: 4 Stream: 20 Tributary 0: 0 Tributary 1: 0
Order: 5 Stream: 28 Tributary 0: 0 Tributary 1: 0
Order: 6 Stream: 32 Tributary 0: 0 Tributary 1: 0
Order: 7 Stream: 34 Tributary 0: 0 Tributary 1: 0
Order: 8 Stream: 40 Tributary 0: 0 Tributary 1: 0
Order: 9 Stream: 48 Tributary 0: 0 Tributary 1: 0
Order: 10 Stream: 54 Tributary 0: 0 Tributary 1: 0
Order: 11 Stream: 56 Tributary 0: 0 Tributary 1: 0
Order: 12 Stream: 64 Tributary 0: 0 Tributary 1: 0
Order: 13 Stream: 70 Tributary 0: 0 Tributary 1: 0
Order: 14 Stream: 72 Tributary 0: 0 Tributary 1: 0
Order: 15 Stream: 78 Tributary 0: 0 Tributary 1: 0
Order: 16 Stream: 80 Tributary 0: 0 Tributary 1: 0
Order: 17 Stream: 84 Tributary 0: 0 Tributary 1: 0
Order: 18 Stream: 86 Tributary 0: 0 Tributary 1: 0
Order: 19 Stream: 88 Tributary 0: 0 Tributary 1: 0
Order: 20 Stream: 92 Tributary 0: 0 Tributary 1: 0
Order: 21 Stream: 94 Tributary 0: 0 Tributary 1: 0
Order: 22 Stream: 96 Tributary 0: 0 Tributary 1: 0
Order: 23 Stream: 98 Tributary 0: 0 Tributary 1: 0
```

```
Order: 24 Stream: 100 Tributary 0: 0 Tributary 1: 0
Order: 25 Stream: 102 Tributary 0: 0 Tributary 1: 0
-----------------------------------------------------------------
LOOP: 2
Order: 26 Stream: 8 Tributary 0: 12 Tributary 1: 10
Order: 27 Stream: 16 Tributary 0: 20 Tributary 1: 18
Order: 28 Stream: 30 Tributary 0: 34 Tributary 1: 32
Order: 29 Stream: 52 Tributary 0: 56 Tributary 1: 54
Order: 30 Stream: 68 Tributary 0: 72 Tributary 1: 70
Order: 31 Stream: 76 Tributary 0: 80 Tributary 1: 78
Order: 32 Stream: 82 Tributary 0: 86 Tributary 1: 84
Order: 33 Stream: 90 Tributary 0: 94 Tributary 1: 92
-----------------------------------------------------------------
LOOP: 3
Order: 34 Stream: 26 Tributary 0: 30 Tributary 1: 28
Order: 35 Stream: 74 Tributary 0: 82 Tributary 1: 76
-----------------------------------------------------------------
LOOP: 4
Order: 36 Stream: 66 Tributary 0: 74 Tributary 1: 68
-----------------------------------------------------------------
LOOP: 5
Order: 37 Stream: 62 Tributary 0: 66 Tributary 1: 64
-----------------------------------------------------------------
LOOP: 6
Order: 38 Stream: 60 Tributary 0: 88 Tributary 1: 62
-----------------------------------------------------------------
LOOP: 7
Order: 39 Stream: 58 Tributary 0: 90 Tributary 1: 60
-----------------------------------------------------------------
LOOP: 8
Order: 40 Stream: 50 Tributary 0: 58 Tributary 1: 52
-----------------------------------------------------------------
LOOP: 9
Order: 41 Stream: 46 Tributary 0: 50 Tributary 1: 48
-----------------------------------------------------------------
LOOP: 10
Order: 42 Stream: 44 Tributary 0: 96 Tributary 1: 46
-----------------------------------------------------------------
LOOP: 11
Order: 43 Stream: 42 Tributary 0: 98 Tributary 1: 44
-----------------------------------------------------------------
LOOP: 12
Order: 44 Stream: 38 Tributary 0: 42 Tributary 1: 40
-----------------------------------------------------------------
LOOP: 13
Order: 45 Stream: 36 Tributary 0: 100 Tributary 1: 38
-----------------------------------------------------------------
LOOP: 14
Order: 46 Stream: 24 Tributary 0: 36 Tributary 1: 26
-----------------------------------------------------------------
LOOP: 15
Order: 47 Stream: 22 Tributary 0: 102 Tributary 1: 24
-----------------------------------------------------------------
LOOP: 16
Order: 48 Stream: 14 Tributary 0: 22 Tributary 1: 16
-----------------------------------------------------------------
LOOP: 17
Order: 49 Stream: 6 Tributary 0: 14 Tributary 1: 8
-----------------------------------------------------------------
LOOP: 18
Order: 50 Stream: 2 Tributary 0: 6 Tributary 1: 4
```

**Obtaining *r.tribs* via FTP or email**

The C programs that are required to generate *r.tribs* are available via anonymous ftp to moon.cecer.army.mil. I have printed out the main segment of the *r.tribs* program in Appendix I. This was done to illustrate how routines in the GRASS library are used to read in raster data. Routines from the GRASS library begin with "G_". Two utility programs are also used: imatrix and ivector. These are discussed by Press and others (1989), and are used to allocate space for arrays. Comments in the code discuss the details of each routine. Appendix II lists the makefile used to compile r.tribs. Note that the variable GIS must be edited so that the proper path to the grass directory is specified.

As previously mentioned, the program can be obtained by anonymous ftp to moon.cecer.army.mil. Change to the "incoming/r.tribs" directly to get the files. The program can also be obtained by contacting the author via email (jfs5@po.cwru.edu). The code has been commented to help the user to understand the program structure.

**REFERENCES**

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T., 1989, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 735 pp.

Shapiro, M., Westervelt, J., Gerdes, D., Larson, M., and Brownfield, K.R., 1992, GRASS 4.0 Programmer's Manual, U.S. Army Construction Engineering Research Laboratory, Champaign, Illinois, 292 pp.

Smith, R.E., Goodrich, D.C., Woolhiser, D.A., and Unkrich, C.L., in press, A KINematic Runoff and EROSion Model, in: V.P. Singh (Ed.), Computer Models of Watershed Hydrology, Water Resources Pub., Highlands Ranch, Colorado

United States Army Corps of Engineers, 1993, GRASS4.1 Users's Reference Manual, U.S. Army Construction Engineering Research Laboratories, Champaign, Illinois, 556 pp.

Woolhiser, D.A., Smith, R.E., Goodrich, D.C., 1990, KINEROS, A Kinematic Runoff and Erosion Model: Documentation and Users Manual, U.S. Department of Agriculture, Agricultural Research Service, ARS-77, 130 pp.

**Appendix I: main.c code for *r.tribs***

```
#include "gis.h"
#include <stdio.h>
int **imatrix();
int *ivector();
/*
* Program to determing the topology of a stream network. A
* table is generated that reports the tributaries that are
* at the head of each stream segement. The computational order
* of streams is also determinted.
*
* Written by:
* Dr. John F. Stamm
* Department of Geological Sciences
* Case Western Reserve University
* Cleveland, OH 44106-7216
* email: jfs5@po.cwru.edu
*/
main(argc,argv)
int argc;
char *argv[];
{
/*
* Matricies
*/
int **accum;
int **chann;
int **aspect;
CELL *cell;
char *chann_name;
char *accum_name;
char *aspect_name;
char *mapset;
int col;
int fd_accum;
int fd_chann;
int fd_aspect;
int ncols;
int nrows;
int row;
struct {
```

```
struct Option *accum ;
struct Option *chann ;
struct Option *aspect ;
} parm;
/*
* Allocate memory for the Option structure and return a
* pointer to this structure. Do this for the structured
* variables parm.accum and parm.chann.
*
* Set values for parm.accum
*/
parm.accum = G_define_option() ;
parm.accum->key = "accumulation";
parm.accum->type = TYPE_STRING;
parm.accum->required = YES;
parm.accum->gisprompt = "old,cell,raster" ;
parm.accum->description= "Name of the ACCUMULATION map" ;
/*
* Set values for parm.chann
*/
parm.chann = G_define_option() ;
parm.chann->key = "stream";
parm.chann->type = TYPE_STRING;
parm.chann->required = YES;
parm.chann->gisprompt = "old,cell,raster" ;
parm.chann->description= "Name of the STREAM map" ;
/*
* Set values for parm.aspect
*/
parm.aspect = G_define_option() ;
parm.aspect->key = "drainage";
parm.aspect->type = TYPE_STRING;
parm.aspect->required = YES;
parm.aspect->gisprompt = "old,cell,raster" ;
parm.aspect->description= "Name of the DRAINAGE DIRECTION
map";
/*
* Initailize GIS library for this program
*/
G_gisinit(argv[0]);
/*
* Parse values from the command line. If this is not
* successful, then display a usage statement and exit.
*/
if (G_parser(argc, argv))
exit (-1);
accum_name = parm.accum->answer;
chann_name = parm.chann->answer;
aspect_name = parm.aspect->answer;
/*
* Find the name of mapset that we are going to use.
*/
mapset = G_find_cell2 (accum_name, "");
if (mapset == NULL) {
char msg[100];
sprintf (msg, "%s: <%s> cellfile not found\n",
G_program_name(), accum_name);
G_fatal_error (msg);
exit(1);
}
/*
* Open the cell files in "mapset".
*/
fd_accum = G_open_cell_old (accum_name, mapset);
if (fd_accum < 0)
exit(1);
fd_chann = G_open_cell_old (chann_name, mapset);
if (fd_chann < 0)
exit(1);
fd_aspect = G_open_cell_old (aspect_name, mapset);
if (fd_aspect < 0)
exit(1);
/*
* Open up a vector that is just long enough to hold one
* row of data.
```

```
*/
cell = G_allocate_cell_buf();
/*
* Determine the number of rows and columns.
*/
nrows = G_window_rows();
ncols = G_window_cols();
printf ("\n", nrows);
printf ("nrows: %d\n", nrows);
printf ("ncols: %d\n", ncols);
/*
* Allocate memory for matricies.
*/
accum = imatrix(0,nrows,0,ncols);
chann = imatrix(0,nrows,0,ncols);
aspect = imatrix(0,nrows,0,ncols);
/*
* Process DEM and Channel files.
*/
for (row=(nrows-1); row>=0; row--) {
if(G_get_map_row (fd_accum, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
accum[row][col] = (int)cell[col];
}
if(G_get_map_row (fd_chann, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
chann[row][col] = (int)cell[col];
}
if(G_get_map_row (fd_aspect, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
aspect[row][col] = (int)cell[col];
}
}
/*
* Compute the topology of the network.
*/
(void)find_tribs(nrows, ncols, accum, chann, aspect);
exit(0);
}
```

## Appendix II: Gmakefile

```
PGM = r.tribs
GIS = /GRASS4.1
HOME = .
SRC = $(GIS)/src
LIBDIR = $(SRC)/libes/LIB
GISLIB = $(LIBDIR)/libgis.a
OFILES = debug.o \
find_tribs.o \
imatrix.o \
ivector.o \
main.o \
neighbors.o \
stream_order.o
$(HOME)/$(PGM): $(OFILES) $(GISLIB)
$(CC) $(LDFLAGS) $(OFILES) $(GISLIB) -o $(PGM)
$(GISLIB): #
```

## AUTHOR

John F. Stamm
Department of Geological Sciences, Case Western Reserve University, Cleveland, OH 44106-7216, email: jfs5@po.cwru.edu

# *r.lags*

**NAME**
*r.lags* **-** GRASS module to calculate various spatial dependence measures for all possible lags within a given image. Each measure is made by comparing two cells only for each lag azimuth and distance. The whole image is read once for each cell in the image, therefore is very computationally expensive. A Sparc 2 would typically take 1 hour to calculate a 150x150 image.

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.lags [-sc] in=name out=name [measure=name]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*n* | Calculate non-zero values only |
| -*v* | Calculate semi-variogram instead |

Parameters:

| | |
|---|---|
| *in=name* | Raster surface layer to measure |
| *out=name* | Output raster containing lag map |
| *measure=name* | Spatial dependence measure (Moran's I or texture) |

Options: moran,texture
Default: moran

**AUTHOR & HISTORY**
V1.0 written 17.6.92 to calculate Moran autocorrelation statistic.

V2.0 written 18.7.92 to also calulate Haralick's grey-tone spatial  dependence textural measures.

V2.1 modified 18.9.95 to conform to standard GRASS program structure.

Future improvements could include (i) Option of faster, memory intensive option; (ii) Further lag dependent measures; (iii) Cumulative lags under some distance weighting function. (iv) Option of ignoring/including zero values in the calculation.

Jo Wood, November, 1995

## *r.le.dist*

**NAME**
*r.le.dist* **-** The *r.le.dist* program can be used to measure distances between patches and report those distances using several methods.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.dist*
*r.le.dist help*
*r.le.dist [-bntu] map=name [sam=name] [reg=name] [ski=value] [can=value] [di1=name[,name,...]] [di2=name[,name,...]] [out=name]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*b* | Run in background |
| -*n* | Output map 'num' with patch numbers |
| -*t* | Use 4 neighbor tracing instead of 8 neighbor |
| -*u* | Output maps 'units_x' with sampling units for each scale x |

Parameters:

*map* Raster map to be analyzed

*sam* Sampling method (choose only 1 method): w=whole map, u=units, m=moving window, r=regions
Options: w, u, m, r
Default: w

*reg* Name of regions map, only when sam = r; omit otherwise

*ski* Skip m boundary cells to speed up nearest neighbor search
Options: 0-10
Default: 0

*can* Use only 'can' candidate patches for faster nearest neighbor search
Options: 1-30
Default: 30

*di1* Distance methods (Choose only 1 method):
Options: m0, m1, m2, m3, m4, m5, m6, m7, m8, m9
(CC=Center-Center, EE=Edge-Edge, CE=Center-Edge):
m0 = each patch to all adjacent neighbors CC
m1 = each patch to all adjacent neighbors CE
m2 = each patch to nearest patch of same gp CC
m3 = each patch to nearest patch of same gp CE
m4 = each patch to nearest patch of same gp EE
m5 = each patch to nearest patch of any diff. gp CC
m6 = each patch to nearest patch of any diff. gp CE

m7 = patches of 1 gp to nearest of specific gp CC
m8 = patches of 1 gp to nearest of specific gp CE
m9 = patches of 1 gp to nearest of specific gp EE

*di2* Distance measures:
Options: n1, n2, n3, n4, n5, n6
n1 = mean dist.
n2 = st. dev. dist.
n3 = mean dist. by gp
n4 = st. dev. dist. by gp
n5 = no. of dist. by dist. class
n6 = no. of dist. by dist. class by gp

*out* Name of output file for individual patch measures, when sam=w, u, r; if *out=head*, then column headings will be printed

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.null*, *r.le.patch*, *r.le.pixel*, *r.le.rename*, *r.le.setup*, *r.le.trace*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.null*

**NAME**
*r.le.null* **-** The *r.le.null* program is designed to generate a neutral structure map layer. This map layer can be used as a "null hypothesis" layer for testing the statistical significance of landscape measures.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.null*
*r.le.null help*
*r.le.null map=name num=value att=value[,value,...] pro=value[,value,...]*

Parameters:

| | |
|---|---|
| *map* | Raster map, with neutral structure, to be created. |
| *num* | Number of attributes desired in the map (max = 24). |
| *att* | Attribute i (an integer) of 'num' attributes. |
| *pro* | Probability (as a % between 0-100) for attribute i of 'num' attributes. |

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.dist, r.le.patch, r.le.pixel, r.le.rename, r.le.setup, r.le.trace*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.patch*

**NAME**
*r.le.patch* **-** This program can be used to calculate attribute, patch size, core (interior) size, shape, fractal dimension, and perimeter measures for sets of patches in a landscape
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.patch*
*r.le.patch help*
*r.le.patch [-bcnptu] map=name [sam=name] [reg=name] [att=name[,name,...]] [siz=name[,name,...]] [co1=value] [co2=name[,name,...]] [sh1=name] [sh2=name[,name,...]] [fra=name] [per=name[,name,...]] [out=name]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*b* | Run in background |
| -*c* | Output map 'interior' with patch cores |
| -*n* | Output map 'num' with patch numbers |
| -*p* | Include sampling area boundary as perimeter |
| -*t* | Use 4 neighbor tracing instead of 8 neighbor |
| -*u* | Output maps 'units_x' with sampling units for each scale x |

Parameters:
*map* Raster map to be analyzed

*sam* Sampling method (choose only 1 method): w=whole map, u=units, m=moving window, r=regions
Default: w

*reg* Name of regions map, only when *sam* = *r*; omit otherwise

*att* Attribute measures:
Options: a1, a2, a3, a4, a5, a6, a7
a1 = mean pixel attribute
a2 = st. dev. pixel attribute
a3 = mean patch attribute
a4 = st. dev. patch attribute
a5 = cover by gp
a6 = density by gp
a7 = total density

*siz* Patch size measures:
Options: s1, s2, s3, s4, s5, s6
s1 = mean patch size
s2 = st. dev. patch size

s3 = mean patch size by gp
s4 = st. dev. patch size by gp
s5 = no. by size class
s6 = no. by size class by gp

*co1* Edge width in pixels (integer) for use with co2

*co2* Core size measures (required if co1 was specified):
Options: c1, c2, c3, c4, c5, c6, c7, c8, c9, c10
c1 = mean core size
c2 = st. dev. core size
c3 = mean edge size
c4 = st. dev. edge size
c5 = mean core size by gp
c6 = st. dev. core size by gp
c7 = mean edge size by gp
c8 = st. dev. edge size by gp
c9 = no. by size class
c10 = no. by size class by gp

*sh1* Shape method (choose only 1 method):
m1 = perim./area
m2 = corr. perim./area
m3 = rel. circum. circle

*sh2* Shape measures (required if sh1 was specified):
Options: h1, h2, h3, h4, h5, h6
h1 = mean patch shape
h2 = st. dev. patch shape
h3 = mean patch shape by gp
h4 = st. dev. patch shape by gp
h5 = no. by shape class
h6 = no. by shape class by gp

*fra* Fractal dimension measures:
Options: f1
f1 = perim.-area fractal dim.

*per* Perimeter measures (required if pe1 was specified):
Options: p1, p2, p3, p4, p5, p6
p1 = sum of perims.
p2 = mean perim.
p3 = st. dev. perim.
p4 = sum of perims. by gp
p5 = mean perim. by gp
p6 = st. dev. perim. by gp

*out* Name of output file for individual patch measures, when *sam=w, u, r*; if *out=head*, then column headings will be printed

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.dist, r.le.null, r.le.pixel, r.le.rename, r.le.setup, r.le.trace*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.pixel*

**NAME**
*r.le.pixel* **-** The *r.le.pixel* program contains a set of measures for attributes, diversity, texture, juxtaposition, and edge.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.pixel*
*r.le.pixel.help*
*r.le.pixel [-beuz] map=name [sam=name] [reg=name] [att=name[,name,...]] [div=name[,name,...]] [te1=name] [te2=name[,name,...]] [jux=name[,name,...]] [edg=name[,name,...]]*

**OPTIONS**
Flags:

-*b* Run in background

-*e* Output map 'edge' of edges given a '1' in *r.le.para*/edge file

-*u* Output maps 'units_x' with sampling units for each scale x

-*z* Output map 'zscores' with standardized scores

Parameters:
*map* Raster map to be analyzed

*sam* Sampling method (choose only 1 method): w=whole map, u=units, m=moving window, r=regions
Default: w

*reg* Name of regions map, only when *sam* = *r*; omit otherwise

*att* Attribute measures:
Options: b1, b2, b3, b4
b1 = mean pixel attribute
b2 = st. dev. pixel attribute
b3 = minimum pixel attribute
b4 = maximum pixel attribute

*div* Diversity measures:
Options: d1, d2, d3, d4
d1 = richness
d2 = Shannon
d3 = dominance
d4 = inverse Simpson

*te1* Texture method (choose only 1 method):
Options: m1, m2, m3, m4, m5, m6, m7
m1 = 2N-H
m2 = 2N-45
m3 = 2N-V

m4 = 2N-135
m5 = 4N-HV
m6 = 4N-DIAG
m7 = 8N

*te2* Texture measures (required if *te1* was specified):
Options: t1, t2, t3, t4, t5
t1 = contagion
t2 = ang. sec. mom.
t3 = inv. diff. mom.
t4 = entropy
t5 = contrast

*jux* Juxtaposition measures (weight file in *r.le.para* needed):
Options: j1, j2
j1 = mean juxtaposition
j2 = standard deviation of juxtaposition

*edg* Edge measures:
Options: e1, e2
e1 = sum of edges
e2 = sum of edges by type (edge file in *r.le.para* needed)

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.dist, r.le.null, r.le.patch, r.le.rename, r.le.setup, r.le.trace*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.rename*

**NAME**
*r.le.rename* **-** The *r.le.rename* program is used to either add a suffix to all the files in the *r.le.out* subdirectory, or to rename the files one by one.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.rename*
*r.le.rename help*
*r.le.rename [-a] [ext=name] [old=name[,name,...]] [new=name[,name,...]]*

**DESCRIPTION**
It is necessary to rename the files before running an *r.le program* over again, because the *r.le* program will overwrite existing files each time the program is started.

**OPTIONS**
Flag:
*-a* All files in *r.le.out* that have extension .out change their extension to parameter ext; others not affected

Parameters:

| | |
|---|---|
| *ext* | New extension with which to replace the .out extension of files in *r.le* out directory |
| *old* | Old file name i in *r.le*.out directory to be changed |
| *new* | New file name for old file name i in *r.le*.out directory |

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.dist, r.le.null, r.le.patch, r.le.pixel, r.le.setup, r.le.trace*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.setup*

**NAME**
*r.le.setup* **-** The *r.le*.setup program is used to set up the sampling and analysis framework that will be used by the other *r.le* programs.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.setup*

**DESCRIPTION**
The first menu allows the user to define a rectangular sampling frame, select how sampling will be done (regions, sampling units, moving window), setup the limits for groups and classes, and change the color table. Use the left mouse button to make your choice.

Information about the structure of the landscape is obtained by overlaying a set of sampling areas on top of a specified part (the sampling frame of a map layer, and then calculating specific structural measures for the part of the map layer that corresponds to the area in each sampling area.

To setup a ***sampling frame*** click on SAMPLING FRAME in the main menu. The program will ask "Will the sampling frame (total area within which sampling units are distributed) be the whole map? (y/n) [y]" Just hit a carriage return to accept the default, which is to use the whole map. You do not need to setup a sampling frame if you want to use the whole map, as this is the default. To setup a different sampling frame type "n" in response to this question. Then use the mouse and a rubber band box to outline a rectangular sampling frame on screen. This box will be moved to the nearest row and column of the map. You will be asked last whether you want to "Refresh the screen before choosing more setup?" If you don't like the sampling frame you just setup, answer yes to this question, then click on SAMPLING FRAME again to redo this part of the setup. This sampling frame will be used in all subsequent setup procedures unless you change it. You can change it at any time by simply clicking on SAMPLING FRAME again.

A ***sampling area*** may be one of four things. First, it is possible to treat the entire map layer as the one (and only) sampling area. Second, if the map layer can be divided into meaningful geographical regions, then it is possible to treat the regions themselves as sampling areas. The third option is that the sampling areas may be sampling units of fixed shape and size (also called scale) that are placed within the map layer as a whole. The fourth and final option is that the sampling area may be moved systematically across the map as a moving window.

If regions are to be used as the sampling areas , then the user can use *r.le.setup* to draw regions or any existing map of regions can simply be used directly. To draw regions and create a new regions map in *r.le.setup* select "REGIONS" from the first *r.le.setup* menu, and the user is asked to do the following:

```
1.  "ENTER THE NEW REGION MAP NAME:". Only a new raster map name is acceptable. The user
    can type LIST to find out the existing raster map names in this location and mapset.

2. "PLEASE OUTLINE REGION # 1". The user should move the mouse cursor into the graphic
monitor window and use the mouse buttons as instructed:
Left button: where am I.to display the current coordinates of the cursor.
Middle button: Mark start (next) point. to enter a vertex of the region boundary.
Right button: Finish region-connect to 1st point to close the region boundary by setting
the last vertex to be equal to the first one.

3. A "REGION OPTIONS:" menu is displayed and the user should use the mouse to select one
of the options:
"DRAW MORE": repeat the above process and setup another region.
```

```
"START OVER": abandon the previous setup and start all over again.
"DONE-SAVE": save the regions outlined so far and exit this procedure.
"QUIT-NO SAVE": quit the procedure without saving the regions.
```

Once the "DONE-SAVE" option is selected, the new raster map of the sampling regions is generated. It is displayed on the monitor window for several seconds, the monitor window is refreshed, the main menu is displayed again, and the program is ready for other setup work. Note that you cannot draw regions in areas outside the mask, if a mask is present (see *r.mask* command).

The user can also use the GRASS *r.digit* or *v.digit* programs to digitize circular or polygonal regions and to create a sampling regions map without using *r.le*.setup. Or, as mention above, an existing raster map can be used as a regions map.

If sampling units are to be used as the sampling areas (Fig. 2), then choose "SAMPLING UNITS" from the first *r.le.setup* menu. The program checks the *r.le*.para subdirectory for an existing "units" file from a previous setup session and allows the user to rename this file (to save it) before proceeding. The *r.le.setup* program will otherwise overwrite the "units" file. Then the following choice is displayed followed by a series of other choices:

```
Which do you want to do?
   (1) Use the keyboard to enter sampling unit parameters
   (2) Draw the sampling units with the mouse
                                            Enter 1 or 2:
```

When sampling units are defined using the keyboard, the user inputs the shape and size (scale) of the sampling units by specifying dimensions in pixels using the keyboard. When sampling units are drawn with the mouse, the user clicks the mouse to define the sampling units in the GRASS monitor window, and then actually places the sampling units for each scale onto the map. By placing the units with the mouse the user can directly determine the method of sampling unit distribution as well as the shape, size, and number of sampling units.

If the choice is made to define sampling units using the keyboard, the following series of questions must be answered:

```
How many different SCALES do you want (1-15)?
```

The user is asked to specify the number of scales that will be used. The *r.le* programs allow the user to simultaneously sample the same map with the same measures using sampling areas of different sizes. Currently there can be between 1 and 15 scales that can be sampled simultaneously. Substantial output can be produced if many scales are used.

Sampling units must be placed spatially into the landscape. There are five options for doing this :

*Random nonoverlapping*
Sampling units are placed in the landscape by randomly choosing numbers that specify the location of the upper left corner of each sampling unit, subject to the constraint that successive sampling units not overlap other sampling units or the edge of the landscape, and that they must be entirely within the area defined by the mask (see *r.mask* command) if one exists.

*Systematic contiguous*
Sampling units are placed side by side across the rows. The user will be able to enter a row and column to indicate where the upper left corner of the systematic contiguous framework should be placed. Rows are numbered from the top down beginning with row 1 of the sampling frame. Columns are numbered from left to right, beginning with column 1 of the sampling frame. A random starting location can be obtained by using a standard random number table to choose the starting row and column. The *r.le*.setup program does not avoid placing the set of sampling units over areas outside the mask. The user will have to make

sure that sampling units do not extend outside the mask by choosing a particular starting row and column or by drawing a sampling frame before placing the set of sampling units.

*Systematic noncontiguous*
The user must specify the starting row and column as in #2 above and the amount of spacing (in pixels) between sampling units. Horizontal and vertical spacing are identical. Sampling units are again placed side by side (but spaced) across the rows. As in #2 the program does not avoid placing sampling units outside the masked area; the user will have to position the set of units to avoid areas outside the mask.

*Stratified random*
The strata are rectangular areas within which single sampling units are randomly located. The user must first specify the starting row and column as in #2 above. Then the user must specify the number of strata in the horizontal and vertical directions. As in #2 the program does not avoid placing sampling units outside the masked area; the user will have to position the set of units to avoid areas outside the mask.

*Centered over sites*
The user must specify the name of a sitefile containing point locations. A single sampling unit is placed with its center over each site in the site file. This is a useful approach for determining the landscape structure around points, such as around the location of wildlife observations.

The user is prompted to enter a ratio that defines the shape of the sampling units. Sampling units may have any rectangular shape, including square as a special case of rectangular. Rectangular shapes are specified by entering the ratio of columns/rows (horizontal dimension/vertical dimension) as a real number. For example, to obtain a sampling unit 10 columns wide by 4 rows long specify the ratio as 2.5 (10/4).

```
Recommended maximum SIZE is m in x cell total area.
What size (in cells) for each sampling unit of scale n?
```

The user is then given the recommended maximum possible size for a sampling unit (in pixels) and asked to input the size of sampling units at each scale. Sampling units can be of any size, but the maximum size is the size of the landscape as a whole. All the sampling units, that make up a single sampling scale, are the same size. After specifying the size, the program determines the nearest actual number of rows and columns, and hence size, that is closest to the requested size, given the shape requested earlier.

```
The nearest size is x cells wide X y cells high = xy cells
Is this size OK?  (y/n)  [y]

Maximum NUMBER of units in scale n is p?
What NUMBER of sampling units do you want to try to use?
```

The maximum number of units that can be placed over the map, given the shape and size of the units, is then given. The user can then choose the number of sampling units to be used in the map layer. It may not always be possible to choose the maximum number, depending upon the shape of the sampling units. In the case of systematic contiguous and noncontiguous, the program will indicate how many units will fit across the columns and down the rows. The user can then specify a particular layout (e.g., 6 units could be placed as 2 rows of 3 per row or as 3 rows of 2 per row).

```
Is this set of sampling units OK?  (y/n)  [y[
```

Finally, the set of sampling units is displayed on the screen (e.g., Fig. 1) and the user is asked whether it is acceptable. If the answer is no, then the user is asked if the screen should be refreshed before redisplaying the menu for "Methods of sampling unit distribution" so that the user can try the sampling unit setup again.

The choice is made to define sampling units using the mouse, then the following menu for use with the mouse is displayed:

```
Outline the standard sampling unit of scale n.
   Left button:       Check unit size
   Middle button:     Move cursor
   Right button:      Lower right corner of unit here
```

The user can then use the mouse and the rubber band box to outline the standard sampling unit. Once it has been outlined, the number of columns and rows in the unit, the ratio of width/length and the size of the unit, in cells, will be displayed. After this first unit is outlined, then a new menu is displayed:

```
Outline more sampling units of scale n?
   Left button:       Exit
   Middle button:     Not used
   Right button:      Lower right corner of next unit here
```

The user can then place more units identical to the standard unit by simply clicking the right mouse button where the lower right corner of the unit should be placed. The rest of the rubber band box can be ignored while placing additional units. The program is set up so that units cannot be placed so they overlap one another, so they overlap the area outside the mask, or so they overlap the edge of the sampling frame. Warning messages are issued for all three of these errors and a sampling unit is simply not placed.

Using this procedure a rectangular "window" or single sampling area is moved systematically across the map to produce a new map (Fig. 2,3). This sampling procedure can only be used with the measures that produce a single value or with a single class or group when measures produce distributions of values (Table 1). The first class or group specified when defining class or group limits (section 2.3.2.) is used if distributional measures are chosen with the moving window sampling method. In this case, the user should manually edit the *r.le.para/recl_tb* file so that the desired group is listed as the first group in this file.

Sampling begins with the upper left corner of the window placed over the upper left corner of the sampling frame. It is strongly recommended that the user read the section on the GRASS mask (section 2.2.2) prior to setting up the moving window, as this mask can be used to speed up the moving window operation. The value of the chosen measure is calculated for the window area. This value is assigned to the location on the new map layer corresponding to the center pixel in the window if the window has odd (e.g. 3 X 3) dimensions. The value is assigned to the location on the new map layer corresponding to the first pixel below and to the right of the center if the window has even dimensions (e.g. 6 X 10). If this pixel has the value "0," which means "no data" in GRASS, then this pixel is skipped and a value of "0" is assigned to the corresponding location in the new map. The window is then moved to the right (across the row) by one pixel, and the process is repeated. At the end of the row, the window is moved down one pixel, and then back across the row. This option produces a new map layer, whose dimensions are smaller by approximately (m-1)/2 rows and columns, where m is the number of rows or columns in the window.

If the "MOVE-WINDOW" option in the main menu is selected, first the program checks for an existing "move_wind" file, in the *r.le*.para subdirectory, containing moving window specifications from a previous session. The user is given the option to avoid overwriting this file by entering a new file name for the old "move_wind" file. Users should be aware that moving window analyses are very slow, because a large number of sampling units are, in effect, used. See the appendix on "Time needed to complete analyses with the *r.le* programs" for some ideas about how moving window size and sampling frame area affect the needed time to complete the analyses.

The *r.le* programs *r.le.dist* and *r.le.patch* allow the attribute categories in the input map to be reclassed into several attribute groups, and reports the analysis results by each of these attribute groups. It is necessary to setup group limits for all measures that say "by gp" when typing "*r.le.dist help*" or "*r.le.patch help*" at the GRASS prompt. The same reclassing can be done with the measurement indices (e.g., size), except that each "cohort" (class) of the reclassed indices is called an index class instead of a group. It is also necessary to setup class limits for all measures that say "by class" when typing "*r.le.dist help*" or "*r.le.patch help*" at the GRASS prompt.

Group/class limits are setup by choosing "GROUP/CLASS LIMITS" from the main menu upon starting *r.le.setup*, or you can create the files manually using a text editor. The program checks for existing group/class limit files in subdirectory *r.le.para* and allows the user to rename these files prior to continuing. If the files are not renamed the program will overwrite them. The files are named recl_tb (attribute group limits), size (size class limits), shape_PA (shape index class limits for perimeter/area index), shape_CPA (shape index class limits for corrected perimeter/area index), shape_RCC (shape index class limits for related circumscribing circle index), and from_to (for the *r.le.dist* program distance methods m7-m9).

Attribute groups and index classes are defined in a different way. In the *r.le* programs attribute groups are defined as in the following example:

```
1, 3, 5, 7, 9 thru 21 = 1 (comment)
31 thru 50 = 2 (comment)
end
```

In this example, the existing categories 1, 3, 5, 7, {9, 10, ... 20, 21} are included in the new group 1, while {31, 32, 33, ..., 49, 50} are included in the new group 2. The characters in bold are the "key words" that are required in the definition. Each line is called one "reclass rule".

The GRASS reclass convention is adopted here with a little modification (see "*r.reclass*" command in the GRASS User's Manual). The difference is that *r.le* only allows one rule for each group while the GRASS *r.reclass* command allows more than one. The definition of "from" and "to" groups is simply the extension of the GRASS reclass rule. The advantage of using the GRASS reclass convention is that the user can generate a permanent reclassed map, using GRASS programs, directly from the *r.le* setup results.

The *r.le measurement* index classes are defined by the lower limits of the classes, as in the following example:

```
0.0, 10.0, 50.0, 200.0, -999
```

This means:

```
if v >= 0.0 and v < 10.0 then  v belongs to index class 1;
if v >= 10.0 and v < 50.0 then  v belongs to index class 2;
if v >= 50.0 and v < 200.0 then v belongs to index class 3;
if v >= 200.0 then v belongs to index class 4;
```

where v is the calculated index value and **-999** marks the end of the index class definition. The measurement index can be the size index, one of the three shape indices, or one of the three distance indices. The program is currently designed to allow no more than 25 attribute groups, 25 size classes, 25 shape index classes, and 25 distance index classes. As an alternative, the user may want to permanently group certain attributes prior to entering the *r.le* programs. For example, the user may want to group attributes 1-10, in a map whose attributes are ages, into a single attribute representing young patches. The user can do this using the GRASS *r.reclass* and *r.resample* commands, which will create a new map layer that can then be analyzed directly (without setting up group limits) with the *r.le* programs.

**SEE ALSO**
The *r.le* Programs Users Guide
*r.digit, r.le.dist, r.le.null, r.le.patch, r.le.pixel, r.le.rename, r.le.trace, r.reclass, r.resample, v.digit*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.le.trace*

**NAME**
*r.le.trace* **-** the *r.le.trace* program can be used to display the boundary of each patch and show how the boundary is traced, display the attribute, size, perimeter, and shape indices for each patch, and save the data in an output file.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.le.trace*
*r.le.trace help*
*r.le.*trace *[-npt] map=name [out=name]*

**DESCRIPTION**
When sampling the whole map (sam=W), the *r.le.trace* program can be used to do three things: (1) display the boundary of each patch and show how the boundary is traced, (2) display the attribute, size, perimeter, and shape indices for each patch, and (3) save these data in an output file.

Flags:

| | |
|---|---|
| -*n* | Output map 'num' with patch numbers |
| -*p* | Include sampling area boundary as perimeter |
| -*t* | Use 4 neighbor tracing instead of 8 neighbor |

Parameters:

| | |
|---|---|
| *map* | Raster map to be analyzed |
| *out* | Name of output file to store patch data |

**SEE ALSO**
The *r.le* Programs Users Guide
*r.le.dist, r.le.null, r.le.patch, r.le.pixel, r.le.rename, r.le.setup*

**AUTHOR**
William L. Baker, Department of Geography and Recreation, University of Wyoming

## *r.line*

**NAME**
*r.line* **-** Creates a new binary GRASS vector (*v.digit*) file by extracting linear features from a thinned raster file.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.line*
*r.line help*
*r.line input=name output=name [type=name]*

**DESCRIPTION**
*r.line* scans the named raster map layer (*input=name*) and extracts thinned linear features into the named vector file (*output=name*).

**OPTIONS**
The user can run this program either non-interactively or interactively. The program will be run non-interactively if the user specifies program arguments on the command line, using the form:

*r.line input=name output=name [type=name]*

If the user specifies input raster and output vector map names on the command line, any other parameter values left unspecified on the command line will be set to their default values (see below). Alternately, the user can simply type *r.line* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

Parameters:

| | |
|---|---|
| *input=name* | Name of existing raster file to be used as input. |
| *output=name* | Name of new vector file to be output. |
| *type=name* | Line type of the extracted vectors; either line or area. Specifying line will type extracted vectors as linear edges. Specifying area will type extracted vectors as area edges. |

Options: line or area.
Default: type=line

*r.line* assumes that the input map has been thinned using *r.thin*.

**NOTES**
*r.line* extracts vectors (a.k.a., "arcs") from a raster file. These arcs may represent linear features (like roads or streams), or may represent area edge features (like political boundaries, or soil mapping units). The attribute type option allows the user to establish the use of either linear or area edge attributes for all of the extracted vectors.

*r.poly* may be used to extract vectors that represent area features (like soil mapping units, elevation ranges, etc.) from a raster file.

The user must run *v.support* on the resultant vector (*v.digit*) files to build the dig_plus information.

*r.thin* and *r.line* may create excessive nodes at every junction, and may create small spurs or "dangling lines" during the thinning and vectorization process. These excessive nodes and spurs may be removed using *v.trim*.

**BUGS**
The input raster file MUST be thinned by *r.thin*; if not, *r.line* may crash.

**SEE ALSO**
*r.poly, r.thin, v.digit, v.support, v.trim, parser*

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# *r.linear.regression*

**ATTENTION:** This page is not yet properly corrected! It was taken from *r.rational.regression*. So be careful and send a better version to neteler@geog.uni-hannover.de

**NAME**
*r.linear.regression* **-** linear and nonlinear regression calculation (GRASS Image Processing Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.linear.regression*
*r.linear.regression help*
*r.linear.regression input=name output=name*

**DESCRIPTION**
The *r.linear.regression* program calculates the linear regression model. If it is used as an image processing tool, the multispectral space remote sensing data will be the regression variables (ASCII file) and the ground vegetation coverage measurements will be the response variables (also ASCII file) and this command will be useful for obtaining linear regression models from the remote-sensing data which have corresponding ground measurement and for predicting vegetation coverage using other remote-sensing data which have no corresponding ground truth records. The input file has the following format

regression valuables x1, x2, ... response variable y
channel 1 (x1) channel 2 (x2) ... coverage

For a three channel remote-sensing data the following is an example of input ASCII file

```
0.4350     0.2616       0.7016       0.98
0.4140     0.2620       0.6520       0.99
0.4940     0.3500       0.5580       0.34
0.5983     0.5350       0.5650       0.10
0.4883     0.3733       0.5533       0.88
0.4150     0.2916       0.5116       0.60
0.5566     0.5250       0.5466       0.09
0.4420     0.2820       0.6800       0.86
0.4220     0.2620       0.6260       0.88
0.4766     0.3666       0.5933       0.61
0.5180     0.4300       0.5140       0.60
0.4416     0.2700       0.7383       0.96
0.4583     0.3116       0.5133       0.76
0.4300     0.2750       0.7233       0.98
0.4320     0.2760       0.6460       1.00
0.4733     0.3566       0.5616       0.53
0.4200     0.2450       0.7966       1.00
0.4850     0.3533       0.7216       0.99
0.4360     0.2620       0.7620       0.99
0.4283     0.2650       0.6783       0.91
0.4633     0.3200       0.6750       0.94
```

The resulted regression model (coefficient numbers) and related information about the confidencial test, goodness or utility test (e.g., correlation coefficient r between observed and calculated coverage, F value and t value) are put on the output file (ASCII file also).

*r.linear.regression* will be run non-interactively if the user specifies program arguments on the command line, using the form:

*r.linear.regression input=name output=name*

But after run, the computer will prompt the user to select model number. Alternately, the user can simply type: *r.linear.regression* on the command line without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS user interface described in the manual entry for *parser*.

**SEE ALSO**
*i.rvi*, *i.ndvi*

**AUTHORS**
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Michael Shapiro, U.S. Army Construction Engineering Research Laboratory.

# *r.los*

**NAME**
*r.los* - Line-of-sight raster analysis program.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.los*
*r.los help*
*r.los input=name output=name coordinate=x,y [patt_map=name] [obs_elev=value] [max_dist=value]*

**DESCRIPTION**
*r.los* generates a raster map output in which the cells that are visible from a user-specified observer location are marked with integer values that represent the vertical angle (in degrees) required to see those cells.

The program can be run either non-interactively or interactively. To run *r.los* non-interactively, the user must specify at least an input file name, output file name, and the geographic coordinates of the user's viewing location on the command line; any remaining parameters whose values are unspecified on the command line will be set to their default values (see below). Non-interactive usage format is:

*r.los input=name output=name coordinate=x,y [patt_map=name] [obs_elev=value] [max_dist=value]*

Alternately, the user can type simply *r.los* on the command line; in this case, the program will prompt the user for parameter values using the standard GRASS interface described in the manual entry for *parser*.

Parameters:
*input=name*   Name of a raster map layer containing elevation data, used as program input.

*output=name*  Name assigned to the file in which the raster program output will be stored.

*coordinate=x,y*   Geographic coordinates (i.e., easting and northing values) identifying the desired location of the viewing point.

*patt_map=name*   Name of a binary (1/0) raster map layer in which cells within the areas of interest are assigned the category value '1', and all other cells are assigned the category value '0'. If this parameter is omitted, the analysis will be performed for the whole area within a certain distance of the viewing point inside the geographic region boundaries. Default: assign all cells that are within the max_dist and within the user's current geographic region boundaries a value of 1.

*obs_elev=value*   Height of the observer (in meters) above the viewing point's elevation. Default: 1.75 (meters)

*max_dist=value*   Maximum distance (in meters) from the viewing point inside of which the line of sight analysis will be performed. The cells outside this distance range are assigned the category value '0'. Options: 0-99999 (stated in map units) Default: 100

**NOTES**
For accurate results, the program must be run with the resolution of the geographic region set equal to the resolution of the data (see *g.region*). It is advisable to use a 'pattern layer' which identifies the areas of

interest in which the line of sight analysis is required. Such a measure will reduce the time taken by the program to run.

**SEE ALSO**
*g.region, r.pat.place, parser*

**AUTHOR**
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## *r.mapcalc*

**NAME**
*r.mapcalc* **-** Raster map layer data calculator.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.mapcalc*
*r.mapcalc [result=expression]*

**DESCRIPTION**
*r.mapcalc* performs arithmetic on raster map layers. New raster map layers can be created which are arithmetic expressions involving existing raster map layers, integer or floating point constants, and functions.

**PROGRAM USE**
If used without command line arguments, *r.mapcalc* will read its input, one line at a time, from standard input (which is the keyboard, unless redirected from a file or across a pipe). Otherwise, the expression on the command line is evaluated. *r.mapcalc* expects its input to have the form:

*result=expression*

where result is the name of a raster map layer to contain the result of the calculation and expression is any legal arithmetic expression involving existing raster map layers, integer or floating point constants, and functions known to the calculator. Parentheses are allowed in the expression and may be nested to any depth. result will be created in the user's current mapset.

The formula entered to *r.mapcalc* by the user is recorded both in the result map title (which appears in the category file for result) and in the history file for result.

Some characters have special meaning to the command shell. If the user is entering input to *r.mapcalc* on the command line, expressions should be enclosed within single quotes. See NOTES, below.

**OPERATORS AND ORDER OF PRECEDENCE**
The following operators are supported:

| Operator | Meaning | Type | Precedence |
|---|---|---|---|
| % | modulus (remainder upon division) | Arithmetic | 4 |
| / | division | Arithmetic | 4 |
| * | multiplication | Arithmetic | 4 |
| + | addition | Arithmetic | 3 |
| - | subtraction | Arithmetic | 3 |
| == | equal | Logical | 2 |
| != | not equal | Logical | 2 |
| > | greater than | Logical | 2 |
| >= | greater than or equal | Logical | 2 |
| < | less than | Logical | 2 |
| <= | less than or equal | Logical | 2 |
| && | and | Logical | 1 |
| \|\| | or | Logical | 1 |

The operators are applied from left to right, with those of higher precedence applied before those with lower precedence. Division by 0 and modulus by 0 are acceptable and give a 0 result. The logical operators give a 1 result if the comparison is true, 0 otherwise.

**RASTER MAP LAYER NAMES**
Anything in the expression which is not a number, operator, or function name is taken to be a raster map layer name. Examples:

*elevation x3 3d.his*

Most GRASS raster map layers meet this naming convention. However, if a raster map layer has a name which conflicts with the above rule, it should be quoted. For example, the expression

*x = a-b*

would be interpreted as: x equals a minus b, whereas

*x = "a-b"*

would be interpreted as: x equals the raster map layer named a-b

Also

*x = 3107*

would create x filled with the number 3107, while

*x = "3107"*

would copy the raster map layer 3107 to the raster map layer x.

Quotes are not required unless the raster map layer names look like numbers or contain operators, OR unless the program is run non-interactively. Examples given here assume the program is run interactively. See NOTES, below.

*r.mapcalc* will look for the raster map layers according to the user's current mapset search path. It is possible to override the search path and specify the mapset from which to select the raster map layer. This is done by specifying the raster map layer name in the form:

*name@mapset*

For example, the following is a legal expression:

*result = x@PERMANENT / y@SOILS*

The mapset specified does not have to be in the mapset search path. (This method of overriding the mapset search path is common to all GRASS commands, not just *r.mapcalc*.)

**THE NEIGHBORHOOD MODIFIER**
Maps and images are data base files stored in raster format, i.e., two-dimensional matrices of integer values. In *r.mapcalc*, maps may be followed by a neighborhood modifier that specifies a relative offset from the current cell being evaluated. The format is map[r,c], where r is the row offset and c is the column offset. For example, map[1,2] refers to the cell one row below and two columns to the right of the current cell, map[-2,-1] refers to the cell two rows above and one column to the left of the current cell, and map[0,1] refers to the cell one column to the right of the current cell. This syntax permits the development of neighborhood-type filters within a single map or across multiple maps.

## RASTER MAP LAYER VALUES FROM THE CATEGORY FILE

Sometimes it is desirable to use a value associated with a category's contents instead of the category value itself. If a raster map layer name is preceded by the @ operator, then the labels in the category file for the raster map layer are used in the expression instead of the category value.

For example, suppose that the raster map layer soil.ph (representing soil pH values) has a category file with labels as follows:

```
cat   label
______________
0       no data

1       1.4
2       2.4
3       3.5
4       5.8
5       7.2
6       8.8
7       9.4
```

Then the expression:

*result = @soils.ph * 10*

would produce a result with category values 0, 14, 24, 35, 58, 72, 88 and 94.

Note that this operator may only be applied to raster map layers and produces a floating point value in the expression. Also the category label must start with a valid number. Missing labels, or labels that do not start with a number will (silently) produce a 0 value for that category.

## GREY SCALE EQUIVALENTS AND COLOR SEPARATES

It is often helpful to manipulate the colors assigned to map categories. This is particularly useful when the spectral properties of cells have meaning (as with imagery data), or when the map category values represent real quantities (as when category values reflect true elevation values). Map color manipulation can also aid visual recognition, and map printing.

The # operator can be used to either convert map category values to their grey scale equivalents or to extract the red, green, or blue components of a raster map layer into separate raster map layers.

*result = #map*

converts each category value in map to a value in the range 0-255 which represents the grey scale level implied by the color for the category. If the map has a grey scale color table, then the grey level is what #map evaluates to. Otherwise, it is computed as:

*.18 * red + .81 * green + .01 * blue*

The # operator has three other forms: r#map, g#map, b#map. These extract the red, green, or blue components in the named raster map, respectively. The GRASS shell script blend.sh extracts each of these components from two raster map layers, and combines them by a user-specified percentage. These forms allow color separates to be made. For example, to extract the red component from map and store it in the new 0-255 map layer red, the user could type:

*red = r#map*

To assign this map grey colors type:

*r.colors map=red color=rules*
*black*
*white*

To assign this map red colors type:

*r.colors map=red color=rules*
*black*
*red*

**FUNCTIONS**
The functions currently supported are listed in the table below. The type of the result is indicated in the last column. F means that the functions always results in a floating point value, I means that the function gives an integer result, and * indicates that the result is float if any of the arguments to the function are floating point values and integer if all arguments are integer.

| function | description | type |
|---|---|---|
| abs(x)return | absolute value of x | * |
| atan(x) | inverse tangent of x (result is in degrees) | F |
| cos(x)cosine of x | (x is in degrees) | F |
| eval([x,y,...,]z) | evaluate values of listed expr, pass results to z | * |
| exp(x)exponential | function of x | F |
| exp(x,y) | x to the power y | F |
| float(x) | convert x to floating point | F |
| if | decision options: | * |
| if(x) 1 if x not | zero, 0 otherwise | |
| if(x,a) a if x | not zero, 0 otherwise | |
| if(x,a,b) a if x | not zero, b otherwise | |
| if(x,a,b,c)a if x | > 0, b if x is zero, c if x < 0 | |
| int(x) | convert x to integer [ truncates ] | I |
| log(x) | natural log of x | F |
| log(x,b) | log of x base b | F |
| max(x,y[,z...]) | largest value of those listed | * |
| median(x,y[,z...]) | median value of those listed | * |
| min(x,y[,z...]) | smallest value of those listed | * |
| rand(x,y) | random value between x and y | * |
| round(x) | round x to nearest integer | I |
| sin(x) | sine of x (x is in degrees) | F |
| sqrt(x) | square root of x | F |
| tan(x) | tangent of x (x is in degrees) | F |

**FLOATING POINT VALUES IN THE EXPRESSION**
Floating point numbers are allowed in the expression. A floating point number is a number which contains a decimal point:

*2.3 12. .81*

Floating point values in the expression are handled in a special way. With arithmetic and logical operators, if either operand is float, the other is converted to float and the result of the operation is float. This means, in particular that division of integers results in a (truncated) integer, while division of floats results in an accurate floating point value. With functions of type * (see table above), the result is float if any argument is float, integer otherwise.

**EXAMPLES**
To compute the average of two raster map layers a and b:
*ave = (a + b)/2*

To form a weighted average:

*ave = (5*a + 3*b)/8.0*

To produce a binary representation of the raster map layer a so that category 0 remains 0 and all other categories become 1:
*mask = a/a*

This could also be accomplished by:
*mask = if(a)*

To mask raster map layer b by raster map layer a:
*result = if(a,b)*

To represent NULL values, use the function isnull ( ):
*r.mapcalc "b=isnull (a)"*
*r.mapcalc "b=if (isnull (a),1,0)"*
*r.mapcalc "b=if (isnull (a), null (), a)"* #NO CHANGE

To make a floating point map out of an existing integer raster map:
*test_fp=1.0*test_int*

**REGION/MASK**
The user must be aware of the current geographic region and current mask settings when using *r.mapcalc*. All raster map layers are read into the current geographic region masked by the current mask. If it is desired to modify an existing raster map layer without involving other raster map layers, the geographic region should be set to agree with the cell header for the raster map layer. For example, suppose it is determined that the elevation raster map layer must have each category value increased by 10 meters. The following expression is legal and will do the job:

*new_elevation = elevation + 10*

Since a category value of 0 is used in GRASS for locations which do not exist in the raster map layer, the new raster map layer will contain the category value 10 in the locations that did not exist in the original elevation. Therefore, in this example, it is essential that the boundaries of the geographic region be set to agree with the cell header.

However, if there is a current mask, then the resultant raster map layer is masked when it is written; i.e., 0 category values in the mask force zero values in the output.

**NOTES**
Extra care must be taken if the expression is given on the command line. Some characters have special meaning to the UNIX shell. These include, among others:

** ( ) > & |*

It is advisable to put single quotes around the expression; e.g.:

*result = 'elevation * 2'*

Without the quotes, the *, which has special meaning to the UNIX shell, would be altered and *r.mapcalc* would see something other than the *.

If the input comes directly from the keyboard and the result raster map layer exists, the user will be asked if it can be overwritten. Otherwise, the result raster map layer will automatically be overwritten if it exists.

Quoting result is not allowed. However, it is never necessary to quote result since it is always taken to be a raster map layer name.

For formulas that the user enters from standard input (rather than from the command line), a line continuation feature now exists. If the user adds \ to the end of an input line, *r.mapcalc* assumes that the formula being entered by the user continues on to the next input line. There is no limit to the possible number of input lines or to the length of a formula.

If the *r.mapcalc* formula entered by the user is very long, the map title will contain only some of it, but most (if not all) of the formula will be placed into the history file for the result map.

When the user enters input to *r.mapcalc* non-interactively on the command line, the program will not warn the user not to overwrite existing map layers. Users should therefore take care to assign program outputs raster file names that do not yet exist in their current mapsets.

**BUGS**
Continuation lines must end with a and have NO trailing white space (blanks or tabs). If the user does leave white space at the end of continuation lines, the error messages produced by *r.mapcalc* will be meaningless and the equation will not work as the user intended.

Error messages produced by *r.mapcalc* are almost useless. In future, *r.mapcalc* should make some attempt to point the user to the offending section of the equation, e.g.:

*x = a * b ++ c*

*ERROR: somewhere in line 1: ... b ++ c ...*

Currently, there is no comment mechanism in *r.mapcalc*. Perhaps adding a capability that would cause the entire line to be ignored when the user inserted a # at the start of a line as if it were not present, would do the trick.

The function should require the user to type "end" or "exit" instead of simply a blank line. This would make separation of multiple scripts separable by white space.

**SEE ALSO**
*r.mapcalc*: an Angebra for GIS and Image Processing, by Michael Shapiro and Jim Westervelt, U.S. Army Construction Engineering Research Laboratory (March 1991).

Grey scale conversion is based on the C.I.E. x, y, z system where y represents luminance. See “Fundamentals of Digital Image Processing,” by Anil K. Jain (Prentice Hall, NJ, 1989; p. 67).

"GRASS Tutorial: *r.mapcalc,*"

*blend.sh, g.region, r.colors, r.combine, r.infer, r.mask, r.weight, r.xy*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.mask*

**NAME**
*r.mask* **-** Establishes or removes the current working mask.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.mask*

**DESCRIPTION**
The *r.mask* program allows the user to block out certain areas of a map from analysis, by "hiding" them from sight of other GRASS programs. This is done by establishing a mask. While a mask exists, most GRASS programs will operate only on data falling inside the masked area, and ignore any data falling outside of the mask.

Because the mask is actually only a reclass file called "MASK" that is created when the user identifies a mask using *r.mask*, it can be copied, renamed, removed, and used in analyses, just like other GRASS raster map layers. The user should be aware that a mask remains in place until a user renames it to something other than "MASK", or removes it using *r.mask* or *g.remove*.

*r.mask* provides the following options:

```
  1  Remove the current mask
  2  Identify a new mask
RETURN  Exit from program
```

The user establishes a new mask by choosing option (2). The user will be asked to name an existing raster map layer from among those available in the current mapset search path. Once done, the user is shown a listing of this map's categories, and is asked to assign a value of "1" or "0" to each map category. Areas assigned category value "1" will become part of the mask's surface, while areas assigned category value "0" will become "no data" areas in the MASK file.

If a category is not assigned category value "1" it will automatically be assigned the category value "0" in the resulting MASK file. Any cells falling in category "0" will fall outside the newly formed mask, and their presence will be ignored by GRASS programs run later on, as long as the MASK file remains in place.

**NOTES**
The above method for specifying a "mask" may seem counterintuitive. Areas inside the mask are not hidden; areas outside the mask will be ignored until the MASK file is removed. This program actually creates a raster map layer (reclass type) called MASK, which can be manipulated (renamed, removed, copied, etc.) like any other raster map layer. Somewhat similar program functions to those performed by *r.mask* can be done using *r.mapcalc*, *g.region*, and other programs.

This program can only be run interactively.

Note that some programs, like *r.stats*, have options that allow the user to see the effects of the current mask without removing the current mask. See, for example, use of the **-***m* option for *r.stats*.

**SEE ALSO**
*g.copy, g.region, g.remove, g.rename, r.combine, r.infer, r.mapcalc, r.reclass, r.stats, r.weight*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.mask.points*

**NAME**
*r.mask.points* **-**Examines and filters lists of points constituting lines to determine if they fall within current region and mask and optionally an additional raster map.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.mask.points*
*r.mask.points help*
*r.mask.points [-r] [mask=name] [input=name] [fs=name]*

**DESCRIPTION**
*r.mask.points* filters a list of points based on the current region and current mask. The point list consists of lines which have the following format

```
easting   northing   [text]
   .
   .
easting   northing   [text]
```

The eastings and northings define points in the coordinate space. Each line is examined to determine if the point falls within the current region, current mask (if any), and optionally an additional raster map that acts as a secondary mask. If the point falls outside the current region or falls in a grid cell that has value zero (either in the current mask, or the specified mask file), then the entire line is suppressed. otherwise it is printed exactly as it is input. There may be arbitrary text following the coordinate pairs and this text is output as well.

**OPTIONS**
Flags:

| | |
|---|---|
| -*r* | Coordinates are reversed: north east |

Normal input has the east first and the north second. This option allows the order of the coordinates to be north first and east next.

Parameters:

| | |
|---|---|
| *mask* | Raster map used to mask points |

This parameter is optional. If not specified, then the points are mask by the default mask (if there is one). If it is specified, then the points are mask by this layer as well as the default mask.

| | |
|---|---|
| *input* | Unix input containing point list |

If not specified it is assumed that the user will either redirect the input from a file:

```
r.mask.points < file
```

or pipe the results from some other process (e.g., a DBMS query) into *r.mask.points*

```
some_process | r.mask.points
```

*fs*   Input field separator character

If the coordinates are not separated by white space, but by some other character, this option specifies that character.  For example, if a colon is used between the east and north, then *r.mask.point* can be told this by:

*r.mask.points fs=:*

**NOTES**
Lines that make it through the filtering are output intact.  This means that if the coordinates are reversed they will remain reversed on output.  If there is a field separator, it will also be output.

**SEE ALSO**
*r.mask, s.out.ascii, s.in.ascii, d.points*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.median*

**NAME**
*r.median* **-** Finds the median of values in a cover map within areas assigned the same category value in a user-specified base map.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.median*
*r.median help*
*r.median base=name cover=name output=name*

**DESCRIPTION**
*r.median* calculates the median category of data contained in a cover raster map layer for areas assigned the same category value in the user-specified base raster map layer. These median values are stored in the new output map layer.

The output map is actually a reclass of the base map.

If the user simply types *r.median* on the command line, the user is prompted for the parameter values through the standard *parser* interface (see *parser* manual entry).

Alternately, the user can supply all needed parameter values on the command line.

Parameters:
*base=name* An existing raster map layer in the user's current mapset search path. For each group of cells assigned the same category value in the base map, the median of the values assigned these cells in the cover map will be computed.

*cover=name* An existing raster map layer containing the values to be used to compute the median within each category of the base map.

*output=name* The name of a new map layer to contain program output (a reclass of the base map). The median values will be stored in the output map.

**NOTES**
The user should use the results of *r.median* with care. Since this utility assigns a value to each cell, which is based on global information (i.e., information at spatial locations other than just the location of the cell itself), the resultant map layer is only valid if the geographic region and mask settings are the same as they were at the time that the result map was created.

Results are affected by the current region settings and mask.

**SEE ALSO**
*g.region, r.average, r.cats, r.clump, r.describe, r.mapcalc, r.mask, r.mfilter, r.mode, r.neighbors, r.reclass, r.stats, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.mfilter*

**NAME**
*r.mfilter* **-** Raster file matrix filter.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.mfilter*
*r.mfilter help*
*r.mfilter [-qpz] input=name output=name filter=name [repeat=value] [title="phrase"]*

**DESCRIPTION**
*r.mfilter* filters the raster input to produce the raster output according to the matrix filter designed by the user (see FILTERS below). The filter is applied repeat times (default value is 1). The output raster map layer can be given a title if desired. (This title should be put in quotes if it contains more than one word.)

**OPTIONS**
The program can be run either non-interactively or interactively. To run *r.mfilter* non-interactively, the user should specify desired flag settings and parameter values on the command line, using the form:

*r.mfilter [-qpz] input=name output=name filter=name [repeat=value] [title="phrase"]*

If the user specifies input, output, and filter file names on the command line, other parameters whose values are unspecified on the command line will be set to their default values (see below).

Alternately, the user can simply type *r.mfilter* on the command line, without program arguments. In this case, the user will be prompted for flag settings and parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:
-*q* *r.mfilter* will normally print messages to indicate what is doing as it proceeds. If the user specifies the -q flag, the program will run quietly.

-*z* The filter is applied only to zero category values in the input raster map layer. The non-zero category values are not changed. Note that if there is more than one filter step, this rule is applied to the intermediate raster map layer -- only zero category values which result from the first filter will be changed. In most cases this will NOT be the desired result. Hence -z should be used only with single step filters.

Parameters:
*input=name* The name of an existing raster file containing data values to be filtered.

*output=name* The name of the new raster file to contain filtered program output.

*filter=name* The name of an existing, user-created UNIX ASCII file whose contents is a matrix defining the way in which the input file will be filtered. The format of this file is described below, under FILTERS.

*repeat=value*  The number of times the filter is to be applied to the input data.
 Options: integer values
 Default: 1

*title="phrase"*  A title to be assigned to the filtered raster output map. If the title exceeds one word, it should be quoted.
 Default: (none)

FILTERS
The filter file is a normal UNIX ASCII file designed by the user. It has the following format:

```
TITLE title
MATRIXn
  .
n lines of n integers
  .
DIVISOR    d
TYPE  S/P
```

TITLEA one-line title for the filter. If a title was not specified on the command line, it can be specified here. This title would be used to construct a title for the resulting raster map layer. It should be a one-line description of the filter.

MATRIX  The matrix (n x n) follows on the next n lines. n must be an odd integer greater than or equal to 3. The matrix itself consists of n rows of n integers. The integers must be separated from each other by at least 1 blank.

DIVISOR  The filter divisor is d. If not specified, the default is 1. If the divisor is zero (0), then the divisor is dependent on the category values in the neighborhood (see HOW THE FILTER WORKS below).

TYPE The filter type. S means sequential, while P mean parallel. If not specified, the default is S.

Sequential filtering happens in place. As the filter is applied to the raster map layer, the category values that were changed in neighboring cells affect the resulting category value of the current cell being filtered.

Parallel filtering happens in such a way that the original raster map layer category values are used to produce the new category value.

More than one filter may be specified in the filter file. The additional filter(s) are described just like the first. For example, the following describes two filters:

```
EXAMPLE FILTER FILE
TITLE3x3 average, non-zero data only, followed by 5x5 average
MATRIX    3
1 1 1
1 1 1
1 1 1
DIVISOR   0
TYPE P

MATRIX    5
1 1 1 1 1
1 1 1 1 1
1 1 1 1 1
1 1 1 1 1
1 1 1 1 1
DIVISOR   25
TYPE P
```

HOW THE FILTER WORKS
The filter process produces a new category value for each cell in the input raster map layer by multiplying the category values of the cells in the n x n neighborhood around the center cell by the corresponding matrix value and adding them together.  If a divisor is specified, the sum is divided by this divisor, rounding to the nearest integer. (If a zero divisor was specified, then the divisor is computed for each cell as the sum of the MATRIX values where the corresponding input cell is non-zero.)

If more than one filter step is specified, either because the repeat value was greater than one or because the filter file contained more than one matrix, these steps are performed sequentially. This means that first one filter is applied to the entire input raster map layer to produce an intermediate result; then the next filter is applied to the intermediate result to produce another intermediate result; and so on, until the final filter is applied.  Then the output cell is written.

**NOTES**
If the resolution of the geographic region does not agree with the resolution of the raster map layer, unintended resampling of the original data may occur.  The user should be sure that the geographic region is set properly.

**SEE ALSO**
*g.region, r.clump, r.neighbors,  parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Laboratory

# *r.mode*

**NAME**
*r.mode* **-** Finds the mode of values in a cover map within areas assigned the same category value in a user-specified base map.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.mode*
*r.mode help*
*r.mode base=name cover=name output=name*

**DESCRIPTION**
*r.mode* calculates the most frequently occurring value (i.e., mode) of data contained in a cover raster map layer for areas assigned the same category value in the user-specified base raster map layer. These modes are stored in the new output map layer.

The output map is actually a reclass of the base map.

If the user simply types *r.mode* on the command line, the user is prompted for the parameter values through the standard *parser* interface (see *parser* manual entry).

Alternately, the user can supply all needed parameter values on the command line.

Parameters:
*base=name* An existing raster map layer in the user's current mapset search path. For each group of cells assigned the same category value in the base map, the mode of the values assigned these cells in the cover map will be computed.

*cover=name* An existing raster map layer containing the values to be used to compute the mode within each category of the base map.

*output=name* The name of a new map layer to contain program output (a reclass of the base map). The mode values will be stored in the output map.

**NOTES**
The user should use the results of *r.mode* with care. Since this utility assigns a value to each cell, which is based on global information (i.e., information at spatial locations other than just the location of the cell itself), the resultant map layer is only valid if the geographic region and mask settings are the same as they were at the time that the result map was created.

Results are affected by the current region settings and mask.

**SEE ALSO**
*g.region, r.average, r.cats, r.clump, r.describe, r.mapcalc, r.mask, r.median, r.mfilter, r.neighbors, r.reclass, r.stats, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## ***r.moran***

**NAME**
*r.moran* **-** GRASS module that calculates Moran's I for a raster surface and optionally creates a surface of local moran values.

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.moran [-zb] in=name [out=name] [size=value]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*z* | Exclude zeros in calculation |
| -*b* | Brief output only |

Parameters:

| | |
|---|---|
| *in* | Raster surface layer to measure. |
| *out* | Output raster layer containing local Moran measures. |
| *size* | Size of processing window (odd number only). Default: 3 |

**HISTORY**
Jo Wood 21st October, 1994
-------
Modified to give brief version of output with increased significant figures. Also reports on average local variance **-** roughness measure.
Jo Wood, 3rd April, 1995

# *r.neighbors*

**NAME**
*r.neighbors* **-** Makes each cell category value a function of the category values assigned to the cells around it, and stores new cell values in an output raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.neighbors*
*r.neighbors help*
*r.neighbors [-aq] input=name output=name method=name size=value [title="phrase"]*

**DESCRIPTION**
*r.neighbors* looks at each cell in a raster input file, and examines the category values assigned to the cells in some user-defined "neighborhood" around it. It outputs a new raster map layer in which each cell is assigned a category value that is some (user-specified) function of the values in that cell's neighborhood. For example, each cell in the output layer might be assigned a category value equal to the average of the category values appearing in its 3 x 3 cell "neighborhood" in the input layer.

The program will be run non-interactively if the user specifies program arguments (see OPTIONS) on the command line. Alternately, the user can simply type *r.neighbors* on the command line, without program arguments. In this case, the user will be prompted for flag settings and parameter values.

**OPTIONS**
The user must specify the names of the raster map layers to be used for input and output, the method used to analyze neighborhood category values (i.e., the neighborhood function or operation to be performed), and the size of the neighborhood. Optionally, the user can also specify the title to be assigned to the raster map layer output, elect to not align the resolution of the output with that of the input (the *-a* option), and elect to run *r.neighbors* quietly (the *-q* option). These options are described further below.

*Neighborhood Operation Methods*: The neighborhood operators determine what new category value a center cell in a neighborhood will have after examining category values inside its neighboring cells. Each cell in a raster map layer becomes the center cell of a neighborhood as the neighborhood window moves from cell to cell throughout the map layer. *r.neighbors* can perform the following operations:

*average* The average category value within the neighborhood. In the following example, the result would be: (7*4 + 6 + 5 + 4*3)/9 = 5.66 The result is rounded to the nearest integer (in this case 6).

*median* The category value found half-way through a list of the neighborhood's category values, when these are ranged in numerical order.

*mode* The most frequently occurring category value in the neighborhood.

*minimum* The minimum category value within the neighborhood.

*maximum* The maximum category value within the neighborhood.

```
 Raw Data       Operation     New Data
--------------------------------------------
| 7  | 7  |  5 |           |    |    |    |
|----|----|----| average   |----|----|----|
| 4  | 7  |  4 |--------->|    |  6 |    |
 |----|----|----|          |----|----|----|
 | 7  | 6  |  4 |          |    |    |    |
 |----|----|----|----------|----|----|----|
```

*stddev* The statistical standard deviation of category values within the neighborhood (rounded to the nearest integer).

*variance* The statistical variance of category values within the neighborhood (rounded to the nearest integer).

*diversity* The number of different category values within the neighborhood. In the above example, the diversity is 4.

*interspersion* The percentage of cells containing categories which differ from the category assigned to the center cell in the neighborhood, plus 1. In the above example, the interspersion is: 5/8 * 100 + 1 = 63.5 The result is rounded to the nearest integer (in this case 64).

*Neighborhood Size*: The neighborhood size specifies which cells surrounding any given cell fall into the neighborhood for that cell. The size must be an odd integer. Options are: 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, and 25. For example,

```
     _ _ _
    |_|_|_|
    3 x 3 neighborhood --->  |_|_|_|
    |_|_|_|
```

-*a* If specified, *r.neighbors* will not align the output raster map layer with that of the input raster map layer. The *r.neighbors* program works in the current geographic region. It is recommended, but not required, that the resolution of the geographic region be the same as that of the raster map layer. By default, if unspecified, *r.neighbors* will align these geographic region settings.

-*q* If specified, *r.neighbors* will run relatively quietly (i.e., without printing to standard output notes on the program's progress). If unspecified, the program will print messages to standard output by default.

**NOTES**

The *r.neighbors* program works in the current geographic region with the current mask, if any. It is recommended, but not required, that the resolution of the geographic region be the same as that of the raster map layer. By default, *r.neighbors* will align these geographic region settings. However, the user can elect to keep original input and output resolutions which are not aligned by specifying this (e.g., using the -*a* option).

*r.neighbors* copies the GRASS color files associated with the input raster map layer for those output map layers that are based on the neighborhood average, median, mode, minimum, and maximum. Because standard deviation, variance, diversity, and interspersion are indices, rather than direct correspondents to input category values, no color files are copied for these map layers. (The user should note that although the color file is copied for averaged neighborhood function output, whether or not the color file makes sense for the output will be dependent on the input data values.)

**SEE ALSO**

*g.region, r.clump, r.mapcalc, r.mask, r.mfilter, r.support*

**AUTHOR**

Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.nntool*

**NAME**
*r.nntool* **-** Neural Network classification tool for raster maps.
(GRASS Raster Command)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.nntool*

**DESCRIPTION**
*r.nntool* is a fully interactive, menu-driven GRASS routine that uses a neural network to train landuse classifications and build a classified image. *r.nntool* facilitates the use of neural networks and linear classifiers in supervised classification of raster cell files. Neural networks are composed of simple non-linear computational units called neurons that are linked together and work cooperatively to solve complex mapping problems. Neural network output is validated by the use of a controlled training dataset. For application in the GRASS framework, each input unit (equal to one satellite image pixel) to the neural network is assigned a raster map layer, and training data for the network is collected on a cell by cell basis.

Typically, a single map layer is used for selecting training sites, although this requirement can be relaxed so that output units can be assigned to more than one map layer, and the map layer used in selecting training sites need not be used as output to the neural network.

Since a maximum likelihood classifier (*i.maxlik*) already exists in GRASS, many of the utilities of *i.maxlik* in selecting and analyzing training data were used in the neural network tool. Among these utilities is the ability to visualize and, if necessary, change histograms from each training site. The program for the neural network tool is structured in such as a way that training classes selected in the neural network tool could also be used in the maximum likelihood classifier. This facilitates the implementation of *i.maxlik* within GRASS for validation of neural network output. In GRASS, the maximum likelihood classifier assumes a Gaussian distribution for the training data, which is a widely used method for satellite imagery classification. In the use of the tool, the user is asked to enter the *name of the output map layer*, the *number of output classes*, and the *names of the input map layers*. Using the *lump* option of the menu, the tool selects the "dominant" category within a specified window and generates a new map layer. The user can reset the resolution to the specified window, or retain the old resolution in which he entered the tool. In existing GRASS routines, when resolution (window) of a region is enlarged, the middle pixel of the window in the lower resolution is selected. Training areas are selected using the *define areas* option. Using the *zoom* option the user can zoom out parts of the output map in which he wishes to delineate training areas. Training areas can be delineated by clicking on points, drawing circles, or by drawing polygons. Using the *delete* function, the users can interactively select and delete polygons, with the number of samples after deletion shown in the window. Histograms of training sites can be examined and signatures saved so that the user can use *i.maxlik*.

Once the user is satisfied with the training sites selected, all input map layers are sampled for their data. At intersections of training areas with input map layers, training data for the neural network are gathered. Training data are stored as an ASCII file so that the user may examine and change it, if necessary. Input data to the network is obtained cell-wise from all areas of the input maps. The classes option of the neural network tool lets a user examine the distribution of data when two input map layers are used. For higher input dimensions, it is necessary to link the tool to a more sophisticated program such as xgobi. The user may eliminate outliers, and data conflicts by drawing rectangular boxes around data points. If necessary a whitening and diagonalization operation can be done on the data so that better class separability is achieved. Unlike in using traditional classifiers, careful preprocessing of the training data should be performed since neural networks give equal consideration to all data.

Once the user is satisfied with the class distributions, the *configure* option is selected. Here the user selects a quick propagation network , or the traditional back propagation. The quick propagation network uses gradient descent to adjust weights and assumes a parabolic shape for global minimum. Iterations of the network are performed by the number of training cycles set by the user. Back propagation uses gradient descent and converges to a root mean square error value set by the user. In *r.nntool*, performance of the network as training progresses is shown on the left half of the GRASS screen. Once training of the neural network is complete, the user propagates cell values of the input map layers through the network. The new map layer generated by the neural network can then be queried. Upon completion of network training, the user may save the neural network structure such as the number of input, hidden, and output units, and the network weights.

**NOTES**
The training site I/O data is stored in a file called *o_train* (o_ for "old" training file). This is the default file used for training the neural network.

If the *random* option is used to rearrange the training data, the network training data is stored in a file called TRAIN.

The *classes* option can only be used right now for visualization of two input vectors. The color scheme isn't all that exciting and future upgrades are working on using a better color scheme to represent the training data in each class. [Users may wish to also ftp xgobi.tar.gz, and use that tool to visualize training samples in the *o_train/TRAIN* file].

The Bayes' classifier right now can only be used if you have access to IMSL (otherwise, you'll have to wait until routines are written for diagonalizing a covariant matrix etc in C). Users will have to do a priori determine the attribute value for each class in the output map:

Ex., Say there are 5 classes. Extend the attribute values for the classes from 0 to 100. So that,

```
0 - class 1
25 - class 2
50 - class 3
75 - class 4
100 - class 5.
```

This is a limitation of GRASS since the color intensities of a map are determined by the attribute values.

The input values to the network are scaled by the highest attribute of each input. Users may wish to try other schemes such as sgn(x)(1 + ln|x|), or transform the data using a squashing function such as tahn(x). Users will have to look at the source code to do this (see nntool.c).

**SEE ALSO**
*imagery, i.maxlik, r.reclass*

**AUTHORS**
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Bruce Byars, GRASS Research Group, Baylor University

# *r.null*

**NAME**
*r.null* **-** The function of *r.null* is to explicitly create the NULL-value bitmap file.
(GRASS 5 Raster Program)

**GRASS VERSION**
5.x

**SYNOPSIS**
*r.null*
*r.null -fincr map=name [setnull=val[-val][,val[-val],...]] [null=value]*

Parameters:

| | |
|---|---|
| *map* | Raster map for which to edit null file |
| *setnull* | List of cell values to be set to NULL |
| *null* | The value to replace the null value by |

**DESCRIPTION**
The function of *r.null* is to explicitly create the NULL-value bitmap file. The intended usage is to fix "old" maps that don't have a NULL-value bitmap file (i.e. to indicate if zero is a valid value or is to be converted to NULL).

The design is flexible. Ranges of values can be set to NULL and/or the NULL value can be eliminated and replace with a specified value.

**OPTIONS**
Flags:

| | |
|---|---|
| -*f* | Only do the work if the map is floating-point. |
| -*i* | Only do the work if the map is integer. |
| -*n* | Only do the work if the map doesn't have a NULL-value bitmap file. |
| -*c* | Create NULL-value bitmap file which validates all data cells. |
| -*r* | Remove NULL-value bitmap file. |

Parameters:
*setnull=range[,range...]* The values specified in the ranges are to be set to NULL. A range is either a single value (e.g., 5.3), or a pair of values (e.g., 4.76-34.56). Existing NULL-values are left NULL, unless the null argument is requested.

*null=value* Eliminate the NULL value and replace it with value. This argument is applied only to existing NULL values, and not to the NULLs created by the setnull argument.

**NOTE**
Note that value is restricted to integer if the map is an integer map.

**SEE ALSO**
*r.support, r.quant*

**AUTHOR**
U.S. Army Construction Engineering Research Laboratory

## *r.out.agnps - vis_tool*

**NAME**
*vis_tool* **-** AGNPS-GRASS non-point source hydrology model output interface.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*vis_tool*

**DESCRIPTION**
Current NPS models including AGNPS have very limited graphics capability for visualizing and analyzing the model output. A distributed parameter model should assist in pinpointing the critical areas where one needs to pay attention for controlling NPS pollution. Even though AGNPS gives detailed output, users often can not make use of it, due to lack of proper analyzation and visualization tools. Graphical displays of the results have proven to be a more effective and efficient way of interpreting the results and in making decisions than scanning through pages and pages of numerical output in the form of tables. The following sections discuss the visualization tool in detail.

**AGNPS Output Parameters**
Various output options are available with the AGNPS model. Primary output given for watersheds being analyzed includes watershed area, cell size, storm precipitation, rainfall erosivity (EI), estimates of runoff volume, peak flow rate at the watershed outlet, area-weighted erosion, both upland and channel. Also given are estimates of the sediment delivery ratio, sediment enrichment ratio, mean sediment concentration, and total sediment yield for each of five sediment particle size classes. Also available is a nutrient analysis, which include N, P and COD mass per unit area for both soluble and sediment adsorbed nutrients, and N, P and COD concentrations in the runoff. Table 1 lists a summary of output parameters that can be obtained for each cell or all cells if desired.

**Table 1: AGNPS output parameters at the watershed outlet or any cell**

Hydrology output

```
        * Runoff volume (inches)
        * Peak runoff rate (cubic feet/second)
        * Fraction of runoff generated within the cell
```

Sediment output

```
        * Sediment yield (tons)
        * Sediment concentration (ppm)
        * Sediment particle size distribution
        * Upland erosion (tons/acre)
        * Amount of deposition (%)
        * Sediment generated within the cell (tons)
        * Enrichment ratios by particle size
        * Delivery ratios by particle size
```

Chemical output!Nitrogen

```
        * Sediment associated mass (pounds/acre)
        * Concentration of soluble material (ppm)
        * Mass of soluble material (pounds/acre)
```

Phosphorus

```
        * Sediment associated mass (pounds/acre)
        * Concentration of soluble material (ppm)
        * Mass of soluble material (pounds/acre)
```

Chemical oxygen demand (COD)

```
        * Concentration (ppm)
        * Mass (pounds/acre)
```

Initially the visualization interface generates 17 maps (Table 2) from the ASCII output files of an AGNPS run. The generated maps can be saved for future evaluation of output. All maps are generated using the reclass principle of the GRASS GIS tool, thereby minimum disk space is required. The map from which all output maps were reclassed (cell number map, filename_cell_num, where filename refers to the AGNPS ASCII input/output file without its extension) should not be removed.

**Table 2: List of AGNPS output maps created using Visualization tool**

Cell number map

Hydrology output

```
        * Runoff generated map
        * Runoff from upstream map
        * Runoff to downstream map
```

Sediment output

```
        * Erosion map
        * Deposition map
        * Sediment leaving the cell map
```

Chemical output

```
        * Nitrogen associated with Sediment (generated) map
        * Nitrogen associated with Sediment (leaving) map
        * Nitrogen associated with Runoff (generated) map
        * Nitrogen associated with Runoff (leaving) map
        * Phosphorus associated with Sediment (generated) map
        * Phosphorus associated with Sediment (leaving) map
        * Phosphorus associated with Runoff (generated) map
        * Phosphorus associated with Runoff (leaving) map
        * COD associated with Runoff (generated) map
        * COD associated with Runoff (leaving) map
```

Resize the graphics monitor to fit the full screen of the workstation and use the *d.mon* program to select the monitor. The GRASS shelltool window should be at the right hand side bottom of the screen. Execute the *vis_tool* program from the shelltool window where GRASS is running. A Visualization Tool Input menu will appear on the shelltool window requesting the following data/information from the user:

**Parameters:**
*Watershed Map name:* Enter the name of the watershed boundary map containing cell values greater than zero and zero's for cells outside the watershed boundary.

*Cell Size:* The length of the side of a cell in meters for which the model was run is entered.

*Aspect Map name:* Enter the name of the aspect map for the watershed. It should have been created for the same resolution as the cell size above.

*ASCII AGNPS file name without its extension:* Enter the ASCII AGNPS file name without its extension since the program takes the default extension of .dat and .nps for input and output of the model, respectively. These files should be in the current working directory, else give the full path with the file name.

Then hit the Esc key to continue.

**NOTES**
Always look for a message at the bottom of the ASCII screen for continuing the execution, if there is no message then hit Enter after answering the question else hit Esc to continue.

In the following text, each output screen of the visualization tool is discussed. The visualization tool splits the screen into various screens to display the output of the model. The number of windows created depends on the type of output displayed. The tool always reserves an ASCII terminal (non graphics) for interacting with the user. The first screen (Figure 1) provides various options including a watershed summary (no graphics) and spatially distributed soil loss, nutrients, runoff and feedlot movement (graphics) output of a watershed.

**Figure 1: Initial screen of the Visualization tool**

Visualization Tool Main Menu

```
Output Display Options
1. Watershed Summary including sediment (no graphics)
2. Soil Loss (graphics)
3. Nutrients Movement (graphics)
4. Feedlot Analysis (graphics)
5. Runoff Movement (graphics)
6. Analyze Different Scenarios
7. Save Output Maps
8. Exit to GRASS (to come back type 'return')
9. Quit
Enter the choice (1-9):
```

*Option 1* (Figure 1) displays the watershed summary for soil loss, runoff and nutrient movement at the watershed outlet. This output is displayed in the non-graphics window. The watershed summary can be accessed from any part of the visualization tool, providing an opportunity for decision makers/users to compare the detailed cell output with the watershed outlet output for making decisions.

*Options 2-5* (Figure 1) move to the next screen (Figure 2) where the appropriate output option maps are displayed. This screen is divided into numerous windows depending on the output option chosen. The screen is divided in half, having a series of top row windows and bottom row windows with an ASCII terminal. The top row windows display the output maps (Table 2). A scale for each of the output maps is displayed showing the color and the numerical value associated with it. The color of the output maps range from green-yellow-red, with increasing intensity of output. The right hand top corner window displays the watershed map with cell numbers by laying a grid on top of it for reference. Below this cell number map, the aspect map of the watershed with arrows pointing in the flow directions is displayed. In the bottom row, two windows display the output and input statistics for any cell. The left window shows cell inputs. The output window shows a bar chart and key features of the output option statistics for the same cell. The default cell statistics displayed in the bottom row windows are the statistics for the outlet cell of the watershed. The tool provides error checking and also explains what to do at each step.

In the next section, options 6-9 of Figure 1 are discussed.

*Analyze Different Scenarios*: This option allows the user to visualize and analyze a different simulation for the same resolution of the original run. The user is asked to enter the name of the ASCII AGNPS file name without its extension. The AGNPS run that was started with the visualization tool is called the 'current' and the simulation that was selected using this option is referred as 'selected' hereafter in this documentation. The program checks the resolutions between the 'current' and the 'selected' runs and checks for the same file names. Then the program creates the 17 output maps (Table 2) and displays the 'current' and the 'selected' output maps on the screen in the top row windows. The default output is the sediment movement maps. Bottom row windows display the output histograms of the 'current' and the 'selected' simulations. The left bottom row window corresponds to the 'current' input/output window and the right bottom row window corresponds to the 'selected' input/output.

Under this option the user has the same options (Figure 2) discussed earlier in this document. In addition to this, the user can alter the output visualization/analyzation to other model outputs such as sediment, nutrients, feedlot or runoff movement. While using options 2 and 3 (Figure 2), the user is asked to select either input or output to view in the bottom row windows.

For options 5 and 8 (Figure 2), the user is asked to select either the 'current' or the 'selected' simulation results to view in a window.  This option is one of the strongest features of the visualization tool for analyzing different scenarios simultaneously.

*Save Output Maps*: This option allows the user to save the maps created using the visualization tool. The user can save all or only those outputs of interest, which include sediment, N, P, COD, and runoff. The program asks the user to enter a map name for saving the output maps. The program attaches proper extensions depending on the type of outputs (Appendix 1).  Please refer to the appendix 1 for the extensions of different map names. It also contains reserved map names that should not exist in the current mapset. Do not remove the filename_cell_num map, since all output maps created in the visualization tool are reclassed from the created cell number map.

*Exit to GRASS* (to come back type 'return'): This option allows the user to exit to the GRASS temporarily to perform normal operations under the GRASS GIS tool. To come back to the same menu in the visualization tool, type return and hit enter.

*Quit*: This option takes the user back the GRASS prompt and exits from the visualization tool. The output maps created will be removed from the current mapset, but will not affect those maps that are saved using the *Save Output Maps* option. If you plan to use output maps at some future time, be sure to save them.

**Figure 2: Generic options screen of the visualization tool for spatially distributed output**

Cell input and output Display Options

```
1. Zoom
2. View a Cell
3. View an area output
4. Toggle between flow direction map/viewing area
5. Show the watershed summary output
6. Displayed range of output maps
7. Display user's choice map
8. Draw Cumulative and Frequency Distribution Stats
9. Restore the initial screen
10. Exit to GRASS (to come back type 'return')
11. Quit
Enter the choice (1-11):
```

Each of the options in Figure 2 is discussed below: Its usage and how this assists users or decision makers is described. These options can be used alone or in combination with other options.

*1. Zoom*: Allows users to zoom in or zoom out of any section of the watershed by choosing one of the displayed windows.  Once the zoom operation is performed, the tool automatically adjusts or redisplays all the maps in the top row windows to the same area, enabling users to take a closer look at an area of interest. This option is particularly helpful on large watersheds. Once the Zoom option is selected, the tool requests for a window to perform zoom operations. The user has to use the left mouse key to click on one of the top row windows and then click on the right mouse key to complete the selection process. Then the zoom function asks the user to use the left mouse to click on a place to define the area in the selected window, and then drag the mouse to the desired location and click on the right mouse key to complete the zoom process. Always follow the instructions displayed on the ASCII terminal. Failing to do so can cause the program to stop. Similarly, the unzoom operation can be performed.

*2. View a cell:* This option allows the user to enter a cell number of interest to display the statistics of that cell's inputs and outputs in the bottom row of windows. The displayed bar chart depends on the type of option chosen in the initial screen (Figure 1). The cell number can be either entered directly using the keyboard in the ASCII terminal or the mouse can be used to point out a cell on the graphics monitor using the left mouse key after choosing one of the top row windows. The window selection process is detailed in the Zoom section. This feature is helpful to visualize characteristics of both inputs and outputs of a critical area.

*3. View an area output*: This option allows the user to select an area from one of the top row windows and displays the average input and output statistics for that area in the bottom row windows. Here also, the user is asked to select a window from the top row windows using the selection procedure explained earlier. Then using the left mouse key, the user selects a corner of the desired area and drags the mouse to build a box. Click the right mouse key to complete the process. This information is helpful to study the statistics of the critical areas and its neighbors. Using this option, one could estimate average inputs and outputs for a field which should assist in making further decisions.

*4. Toggle between flow direction map and viewing window location*: This feature is helpful when users use Zoom to view any particular section of the watershed. After a couple of zoom operations, users may loose track of which part of the watershed is displayed. This option toggles between the flow direction map and the whole watershed map showing a box around the current viewing area.

*5. Show the watershed summary output:* The summary at the outlet of the watershed for all the outputs is displayed in the ASCII (non graphics) terminal. This option is useful to correlate cell outputs with those of watershed outputs to make decisions.

*6. Display ranges of output maps:* This option allows users to visualize output maps (Table 2) for a specified range between maximum and minimum values of the output (Figure 1) chosen. This helps users locate critical areas easily. For example, users can use this option to display problematic areas that are exceeding the soil tolerance limit (T factor). Options are available to save the displayed maps for later reference, compare various scenarios or overlay one map on another in order to make decisions.

*7. Display user's choice map:* Users have an option to display a cell map, overlay a map on another map or display a vector map. The chosen map can be displayed on one of the existing windows or users have an option to create a new window anywhere in the graphics monitor to display the map. Further, the map chosen for display can be one of the AGNPS output maps (Table 2) generated from the AGNPS output files or one of the existing maps in the database. From of the users/decision makers point of view, this option is helpful to reach conclusions about management strategies. For example, by overlaying a field boundary or property boundary on an erosion map, fields within critical limits can be located. Combinations of various outputs can be viewed simultaneously on the designed graphic windows. On selection of this option, the user is prompted for the map to be displayed. If the user selects to display the map in one of the existing windows, then the selection of the window operation is performed followed by the selection of the type of display. This could be to display a cell map, overlay a map on another map or display a vector map. Maps are listed for selection. If the user selected the option to create a new window to display a map, then the program requests a location to start the window. Using the left mouse key, drag the mouse to create a box of desired size and click the right mouse key to end the process.

*8. Draw Cumulative and Frequency Distribution Statistics:* This option allows the user to view the percentage of cumulative and frequency distribution area curves for any of the output maps (Table 2) or selective input variables for either user specified ranges of intervals/classes or for 10 equal ranges of intervals/classes between the maximum and minimum of the selected variable. This option is helpful to see how that particular variable is distributed both cumulatively and the number of occurrences in that interval. It is believed this information in combination with spatial referenced maps could be of very useful in the decision making process. The steepness of the curve shows how that variable is increasing within a corresponding range. By choosing this option, the program requests a window to display the statistical curves. Then, the program asks the user to select either an input or output variable for which to draw the curves. The user then has the option of keeping the previously selected X-axis intervals/classes or can select a new range of intervals/classes. The selection of new ranges of intervals can be done in one of two ways. Either the user can select 10 equal intervals between the maximum and minimum of the selected variable or he can enter the ranges between the maximum and minimum values. In either case, the number of intervals can't exceed 10.

*9. Restore the initial screen:* This option restores the original or initial display screen that was initiated when one of the options from Figure 1 was chosen.

*10. Exit to GRASS* (to come back type 'return'): This option allows the user to exit to the GRASS temporarily to perform normal operations under the GRASS GIS tool. To come back to the same menu in the visualization tool, type return and hit enter.

*11. Quit:* This option takes the user back to the initial screen (Figure 1). If the user has created any maps using option 6, the program asks if these are to be saved before quitting.

Appendix 1: List of AGNPS output maps and reserved map names

Hydrology output

| | | |
|---|---|---|
| Runoff generated map | ro_gen | X.ro_gen |
| Runoff from upstream map | ro_us | X.ro_us |
| Runoff to downstream map | ro_ds | X.ro_ds |

Sediment output

| | | |
|---|---|---|
| Erosion map | Sed_in | X.Sed_in |
| Deposition map | Sed_gen | X.Sed_gen |
| Sediment leaving the cell map | Sed_out | X.Sed_out |

Chemical output

| | | |
|---|---|---|
| Nitrogen associated with Sediment (generated) map | N_sed_in | X.N_sed_in |
| Nitrogen associated with Sediment (leaving) map | N_sed_out | X.N_sed_out |
| Nitrogen associated with Runoff (generated) map | N_ro_in | X.N_ro_in |
| Nitrogen associated with Runoff (leaving) map | N_ro_out | X.N_ro_out |
| Phosphorus associated with Sediment (generated) map | P_sed_in | X.P_sed_in |
| Phosphorus associated with Sediment (leaving) map | P_sed_out | X.P_sed_out |
| Phosphorus associated with Runoff (generated) map | P_ro_in | X.P_ro_in |
| Phosphorus associated with Runoff (leaving) map | P_ro_out | X.P_ro_out |
| COD associated with Runoff (generated) map | COD_ro_in | X.COD_ro_in |
| COD associated with Runoff (leaving) map | COD_ro_out | X.COD_ro_out |

*filename*: Refers to the AGNPS ASCII input/output file without its extension

X: Refers to the name supplied by the user. The maps are saved with the extension in the current mapset.

**AUTHOR**
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## ***r.out.arc***

**NAME**
*r.out.arc* **-** Converts a raster map layer into an ESRI ARCGRID file.
(GRASS Raster Data Export Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.out.arc*
*r.out.arc help*
*r.out.arc [-h] [-1] map=name [dp=value]*

**DESCRIPTION**
*r.out.arc* converts a user-specified raster map layer (map=name) into an ESRI ARCGRID ASCII file suitable for export to other computer systems. The dg=value option (where value is a number of the user's choice) can be used to request that numbers after decimal points are limited. However, to use this, the user should know the maximum number of digits that will occur in the output file. The user can find the maximum number of digits occurring in the output file by running *r.out.arc* without the dg=value option.

The GRASS program *r.in.arc* can be used to perform the reverse function, converting an ESRI ARCGRID ASCII file in suitable format to GRASS raster file format. The order of cell values in file is from lower left to upper right (reverse to GRASS).

**OPTIONS**
Flags:

| | |
|---|---|
| -*h* | Suppress printing of header information. |
| -*1* | List one entry per line. |

Parameters:

| | |
|---|---|
| *map=name* | Name of an existing raster map layer. |
| *dg=value* | The minimum number of decimals (per cell) to be printed. |

*r.out.arc* can be run either non-interactively or interactively. The program will be run non-interactively if the user specifies the name of a raster map layer and (optionally) a value for dg, using the form

```
r.out.arc map=name [dg=value]
```

where name is the name of a raster map layer to be converted to ARCGRID format, and value is the minimum number of digits (per cell) to be printed to output. The user can also the -*h* option to suppress the output of file header information.

Alternately, the user can simply type *r.out.arc* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS *parser* interface.

**NOTES**
The output from *r.out.arc* may be placed into a file by using the UNIX redirection mechanism; e.g.:

```
r.out.arc map=soils > out.grd
```

The output file out.grd can then be copied onto a magnetic tape or floppy disk for export purposes.

**SEE ALSO**
*r.in.arc, parser*

**AUTHOR**
Markus Neteler, University of Hannover, Germany, based on *r.out.ascii* from
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.out.ascii*

**NAME**
*r.out.ascii* **-** Converts a raster map layer into an ASCII text file.
(GRASS Raster Data Export Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.out.ascii*
*r.out.ascii help*
*r.out.ascii [-hi] map=name [digits=value][dp=value][null=string]*

**DESCRIPTION**
*r.out.ascii* converts a user-specified raster map layer (map=name) into an ASCII text file suitable for export to other computer systems. The digits=value option (where value is a number of the user's choice) can be used to request that numbers in the output be equally-spaced (i.e., columnar output). Each category value in the ASCII map layer will then take up value number of spaces. However, to use this, the user should know the maximum number of digits that will occur in the output file, and add one to this number (to leave a space between each column). The user can find the maximum number of digits occurring in the output file by running *r.out.ascii* without the *digits=value* option.

The GRASS program *r.in.ascii* can be used to perform the reverse function, converting an ASCII file in suitable format to GRASS raster file format.

**OPTIONS**
Flags:

| | |
|---|---|
| -*h* | Suppress printing of header information. |
| -*i* | Output integer category values, not cell values. |

Parameters:

| | |
|---|---|
| *map=name* | Name of an existing raster map layer. |
| *digits=value* | The minimum number of digits (per cell) to be printed. |
| *dp=value* | Number of decimal places. |
| *null=string* | Character string to represent no data cell. |

*r.out.ascii* can be run either non-interactively or interactively. The program will be run non-interactively if the user specifies the name of a raster map layer and (optionally) a value for digits, using the form

*r.out.ascii map=name [digits=value]*

where name is the name of a raster map layer to be converted to ASCII format, and value is the minimum number of digits (per cell) to be printed to output. The user can also the -*h* option to suppress the output of file header information.

Alternately, the user can simply type *r.out.ascii* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

**NOTES**
The output from *r.out.ascii* may be placed into a file by using the UNIX redirection mechanism;  e.g.:

```
r.out.ascii map=soils > out.file
```

The output file out.file can then be printed or copied onto a magnetic tape or floppy disk for export purposes.

**SEE ALSO**
*r.in.ascii, parser*

**AUTHOR**
Michael Shapiro, U.S. Construction Engineering Research Laboratory

## *r.out.mpeg*

**NAME**
*r.out.mpeg* - Raster File Series to MPEG Conversion Program

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.out.mpeg*
*r.out.mpeg help*
*r.out.mpeg [-qc]*
*view1=name[,name,...][view2=name[,name,...]][view3=name[,name,...]][view4=name[,name,...]]*
*[output=name] [qual=value]*

**DESCRIPTION**
*r.out.mpeg* is a tool for combining a series of GRASS raster files into a single MPEG-1 (Motion Pictures Expert Group) format file. MPEG-1 is a "lossy" video compression format, so the quality of each resulting frame of the animation will be much diminished from the original raster image. The resulting output file may then be viewed using your favorite mpeg-format viewing program.

The user may define up to four "views", or sub-windows, to animate simultaneously. e.g., View 1 could be rainfall, View 2 flooded areas, View 3 damage to bridges or levees, View 4 other economic damage, all animated as a time series. A black border 2 pixels wide is drawn around each view. There is an arbitrary limit of 100 files per view (100 animation frames). Temporary files are created in the conversion process, so lack of adequate tmp space could also limit the number of frames you are able to convert.

The environment variable GMPEG_SIZE is checked for a value to use as the dimension, in pixels, of the longest dimension of the animation image. If GMPEG_SIZE is not set, the animation size defaults to the rows & columns in the current GRASS region, scaling if necessary to a default minimum size of 200 and maximum of 500. These size defaults are overridden when using the *-c* flag (see below). The resolution of the current GRASS region is maintained, independent of image size. Playback programs have to decode the compressed data "on-the-fly", therefore smaller dimensioned animations will provide higher frame rates and smoother animations.

UNIX - style wild cards may be used with the command line version in place of a raster file name, but it must be quoted.

Example:

```
r.out.mpeg view1="rain[1-9]","rain1[0-2]" view2="temp*"
```

If the number of files differs for each view, the view with the fewest files will determine the number of frames in the animation.

**OPTIONS**
Flags:
-*q* Quiet - suppress progress report

-*c* Convert "on the fly", uses less disk space by using *r.out.ppm* with stdout option to convert frames as needed instead of converting all frames to ppm before encoding. Only use when encoding a single view. Use of this option also overrides any size defaults, using the CURRENTLY DEFINED GRASS REGION for the output size. So be careful to set region to a reasonable size prior to encoding.

Parameters:

*view1* Raster file(s) for View1

*view2* Raster file(s) for View2

*view3* Raster file(s) for View3

*view4* Raster file(s) for View4

*output* Name for MPEG output file
Default: gmovie.mpg

*qual* Quality factor (1-5)
Default: 3

A quality value of *qual=1* will yield higher quality images, but with less compression (larger MPEG file size). Compression ratios will vary depending on the number of frames in the animation, but an MPEG produced using *qual=5* will usually be about 60% the size of the MPEG produced using *qual=1*.

**BUGS**
MPEG images must be 16-pixel aligned for successful compression, so if the rows & columns of the calculated image size (scaled, with borders added) are not evenly divisible by 16, a few rows/columns will be cut off the bottom & right sides of the image. The MPEG format is optimized to recognize image MOTION, so abrupt changes from one frame to another will cause a "noisy" encoding.

**NOTES**
This program requires the program *mpeg_encode*:

MPEG-1 Video Software Encoder
(Version 1.3; March 14, 1994)

Lawrence A. Rowe, Kevin Gong, Ketan Patel, and Dan Wallach Computer Science Division-EECS, Univ. of Calif. at Berkeley

Available by anonymous ftp from: s2k-ftp.CS.Berkeley.EDU

Use of the -*c* flag also requires the program *r.out.ppm* with the *stdout* option.

**AUTHOR**
Bill Brown, U.S. Army Construction Engineering Research Laboratories

## *r.out.pov*

**NAME**
*r.out.pov* **-** Converts a raster map layer into a height-field file for POVRAY.
(GRASS Raster Data Export Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.out.pov*
*r.out.pov help*
*r.out.pov [-h] map=name tga=name [hftype=value] [bias=value] [scale=value]*

**DESCRIPTION**
*r.out.pov* converts a user-specified raster map layer (map==name) into a height-field file for POVray (tga==name). The hftype==value option (where value is either 0 or 1) specifies the height-field type. When the user enters 0 the output will be actual heights. If entered 1 the cell-values will be normalized. If hftype is 0 (actual heights) the bias==value can be used to add or subtract a value from heights. Use scale==value to scale your heights by value. The GRASS program *r.out.pov* can be used to create height-field files for Persistence of Vision (POV) raytracer. POV can use a height-field defined in Targa (.TGA) image file format where the RGB pixel values are 24 bits (3 bytes). A 16 bit unsigned integer height-field value is assigned as follows: RED = high byte, GREEN = low byte, BLUE = empty.

Parameters:

| | |
|---|---|
| *map=name* | Name of an existing raster map layer. |
| *tga=name* | Name of TARGA outputfile (one should add the extension .tga). |
| *hftype=value* | 0=actual heights, 1=normalized heights. |
| *bias=value* | Bias which is added or subtracted to heights. |
| *scale=value* | Value to stretch or shrink elevations. |

*r.out.pov* can be run either non-interactively or interactively. The program will be run non-interactively if the user specifies the name of a raster map layer and a name for tga (output), using the form

*r.out.pov map=inname tga=outname*

where inname is the name of a raster map layer to be converted to POV format, and outname is the name of the outputfile. Further optional values can be entered.

Alternately, the user can simply type *r.out.pov* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS parser interface described in the manual entry for *parser*.

*r.out.pov map=elevation tga=out.tga*

**AUTHOR**
Klaus Meyer, GEUM.tec GbR, eMail: GEUM.tec@geum.de

**NOTICE**
This program is part of the contrib section of the GRASS distribution. As such, it is externally contributed code that has not been examined or tested by the Office of GRASS Integration.

## *r.out.ppm*

**NAME**
*r.out.ppm* **-** Convert a GRASS raster file to a PPM image file
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.out.ppm [*-*qG] input=name [output=name]*

**DESCRIPTION**
This program converts a GRASS raster file to a PPM image file at the pixel resolution of the CURRENTLY DEFINED REGION. e.g., to get the resolution of the raster map, do:

*g.region rast=[mapname]*

before running *r.out.ppm*.

The PPM file created is 24bit color, rawbits storage by default. Using **-**G, you may force *r.out.ppm* to use 8bit greyscale instead. The greyscale conversion uses the NTSC conversion: Y = .30*Red + .59*Green + .11*Blue

One pixel is written for each cell value, so if *ew_res* and *ns_res* differ, the aspect ratio of the resulting image will be off.

**OPTIONS**
Flags:

| | |
|---|---|
| **-***q* | Run quietly |
| **-***G* | Output greyscale instead of color |

Parameters:

| | |
|---|---|
| *input* | Raster file to be converted. |
| *outpu*t | Name for new PPM file. (use out=**-** for stdout) default: <rasterfilename>.ppm |

**NOTE**
A few ppm file comments are written **-** the name of the GRASS raster file, resolution, etc. Although these are perfectly legal, one PD image utility that chokes on them, so if you need a commentless ppm file, use out=**-** > outfile.ppm. (When sending output to stdout, no comments are written.)

**AUTHOR**
Bill Brown, U.S. Army Construction Engineering Research Laboratories

## *r.out.tiff*

**NAME**
*r.out.tiff* **-** Converts a GRASS raster file to a 8/24bit TIFF image file at the pixel resolution of the CURRENTLY DEFINED REGION.
(GRASS Raster Data Export Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.out.tiff [-pcv] input=name output=name*

**DESCRIPTION**
This program converts a TIFF raster file (8bit) to a GRASS raster file. Output is placed in the /cell directory under the user's current GRASS mapset.

**OPTIONS**
Flags:

| | |
|---|---|
| -*p* | TIFF Palette output (8bit instead of 24bit). |
| -*c* | Compress with LZW routine. |
| -*v* | Verbose mode |

Parameters:

| | |
|---|---|
| *input=name* | Name of an existing GRASS raster file to be exported. |
| *output=name* | Name of new TIFF image file. |

The program prompts the user to enter the name of the TIFF raster file to be converted and the name to be assigned to the GRASS raster file to contain the resultant image. Currently "TIFF/uncompressed", "TIFF/LZW-compression" and TIFF/PackBits-compression" formats are supported.

The user may adjust region and resolution before export using *g.region*.

**SEE ALSO**
*g.region*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.param.scale*

**NAME**
*r.param.scale* **-** GRASS module that extracts terrain parameters from a DEM. Uses a multi-scalar approach by taking fitting quadratic parameters to any size window (via least squares).

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.param.scale [-c] in=name out=name [s_tol=value] [c_tol=value] [size=value] [param=name] [exp=value] [zscale=value]*

**OPTIONS**
Flags:

| | |
|---|---|
| -*c* | Constrain model through central window cell |

Parameters:

| | |
|---|---|
| *in* | Raster surface layer to process |
| *out* | Output raster layer containing morphometric parameter |
| *s_tol* | Slope tolerance that defines a `flat' surface (degrees)<br>Default: 1.0 |
| *c_tol* | Curvature tolerance that defines `planar' surface<br>Default: 1.0 |
| *size* | Size of processing window (odd number only)<br>Default: 3 |
| *param* | Morphometric parameter to calculate<br>Options: elev, slope, aspect, profc, planc, longc, crosc, minic, maxic, feature<br>Default: elev |
| *exp* | Exponent for distance weighting (0.0-4.0)<br>Default: 0.0 |
| *zscale* | Vertical scaling factor<br>Default: 1.0 |

***r.param.scale* can calculate the following:**

elev: Generalized elevation value.

slope: Maximum gradient at a point.

aspect: Direction of maximum gradient.

profc: Profile convexity (vertical in direction of steepest slope).

planc: Plan convexity (contour curvature).

crosc: Cross sectional convexity (tangent to contours, downslope).

longc: Longitudinal convexity (perpendicular to contours downslope).

minic: Minimum convexity.

maxic: Maximum convexity.

features: Morphometric features:
peaks, ridges, passes, channels, pits and planes.

**AUTHOR & HISTORY**
Modified to include constrained fitting.
Jo Wood, April, 1995
**-------**
Modified to include weighting matrix and double precision arithmetic.
Jo Wood, 9th May, 1995.
**-------**
Modified to include two separate tolerance values for feature detection.
Jo Wood, 23rd May, 1995.

Still to do

Fix bug when `constrain through central cell' option selected. Create color tables for all output files (presently only on features).

**SEE ALSO**
*d.param.scale*

See also Java Code in LandSerf that implements the same procedure

## *r.patch*

**NAME**
*r.patch* **-** Creates a composite raster map layer by using known category values from one (or more) map layer(s) to fill in areas of "no data" in another map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.patch*
*r.patch help*
*r.patch [-q] input=name[,name,...] output=name*

**DESCRIPTION**
The GRASS program *r.patch* allows the user to assign known data values from other raster map layers to the "no data" areas (those assigned category value 0) in another raster map layer. This program is useful for making a composite raster map layer from two or more adjacent map layers, for filling in "holes" in a raster map layer's data (e.g., in digital elevation data), or for updating an older map layer with more recent data.

The program will be run non-interactively if the user specifies program arguments on the command line, using the form

*r.patch [-q] input=name[,name,...] output=name*

where each input name is the name of a raster map layer to be patched, the output name is the name assigned to the new composite raster map layer containing the patched result, and the (optional) -*q* flag directs *r.patch* to run quietly.

The first name listed in the string *input=name,name,name, ...* is the name of the base map whose zero data values will be attempted to be filled by non-zero data values in the second through tenth input name maps listed. The second through tenth input name maps will be used to supply remaining missing (zero) data values for the first input map name, based on the order in which they are listed in the string *input=name,name,name, ...*.

Alternately, the user can simply type *r.patch* on the command line, without program arguments. In this case, the user will be prompted for the flag setting and parameter values using the standard GRASS *parser* interface described in the manual entry for *parser.*

Flag:
-*q* Directs that *r.patch* run quietly, suppressing output messages on program progress to standard output.

Parameters:
*input=name,name,...* The name(s) of between one and ten existing raster map layers to be patched together. The first of the ten maps listed will be used as a base map, and the second through tenth maps listed will be used to supply missing (zero) category values for the first map.

*output=name* The name of the new raster map to contain the resultant patched output.

**EXAMPLE**

Below, the raster map layer on the far left is patched with the middle (patching) raster map layer, to produce the composite raster map layer on the right.

```
1 1 1 0 2 2 0 0    0 0 1 1 0 0 0 0    1 1 1 1 2 2 0 0
1 1 0 2 2 2 0 0    0 0 1 1 0 0 0 0    1 1 1 2 2 2 0 0
3 3 3 3 2 2 0 0    0 0 0 0 0 0 0 0    3 3 3 3 2 2 0 0
3 3 3 3 0 0 0 0    4 4 4 4 4 4 4 4    3 3 3 3 4 4 4 4
3 3 3 0 0 0 0 0    4 4 4 4 4 4 4 4    3 3 3 4 4 4 4 4
0 0 0 0 0 0 0 0    4 4 4 4 4 4 4 4    4 4 4 4 4 4 4 4
```

Switching the patched and the patching raster map layers produces the following results:

```
0 0 1 1 0 0 0 0    1 1 1 0 2 2 0 0    1 1 1 1 2 2 0 0
0 0 1 1 0 0 0 0    1 1 0 2 2 2 0 0    1 1 1 1 2 2 0 0
0 0 0 0 0 0 0 0    3 3 3 3 2 2 0 0    3 3 3 3 2 2 0 0
4 4 4 4 4 4 4 4    3 3 3 3 0 0 0 0    4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4    3 3 3 0 0 0 0 0    4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4    0 0 0 0 0 0 0 0    4 4 4 4 4 4 4 4
```

**NOTES**

Frequently, this program is used to patch together adjacent map layers which have been digitized separately. The programs *v.mkquads* and *v.mkgrid* can be used to make adjacent maps align neatly.

The user should check the current geographic region settings before running *r.patch*, to ensure that the region boundaries encompass all of the data desired to be included in the composite map.

Use of *r.patch* is generally followed by use of the GRASS programs *g.remove* and *g.rename*; *g.remove* is used to remove the original (un-patched) raster map layers, while *g.rename* is used to then assign to the newly-created composite (patched) raster map layer the name of the original raster map layer.

*r.patch* creates support files for the patched, composite output map.

**SEE ALSO**

*g.region, g.remove, g.rename, r.mapcalc, r.support, v.mkgrid, v.mkquads, parser*

**AUTHOR**

Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.plane*

**NAME**
*r.plane* – Creates a tilted plane.

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.plane*
*r.plane help*
*r.plane [dip=value][azimuth=value][easting=value]*

**OPTIONS**
Parameters:
*dip=value* Please give the value for the dip (inclination) in degrees. The value must be between -90 and 90 from horizontal, with positive values pointing down. Real numbers are valid. No value results in dip=0 and horizontal surface.

*azimuth=value* Please give the value for the azimuth in degrees counterclockwise from north. The value must be between 0 and 360. Real numbers are valid.

*easting=value* Please enter easting, northing for one point on the plane. Real numbers are valid.

**EXAMPLE**
r.plane help - it gets the current region

```
n=5777911.25
s=5773623.75
w=3552072.25
e=3557172.25
nsres=12.5
ewres=12.5
```

# *r.poly*

**NAME**
*r.poly* **-** Extracts area edges from a raster map layer and converts data to GRASS vector format.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.poly*
*r.poly help*
*r.poly [-l] input=name output=name*

**DESCRIPTION**
*r.poly* scans the named input raster map layer, extracts area edge features from it, converts data to GRASS vector format, and smoothes vectors.

*r.poly* first traces the perimeter of each unique area in the raster map layer and creates vector data to represent it. The cell category values for the raster map layer will be used to create attribute information for the resultant vector area edge data.

A true vector tracing of the area edges might appear blocky, since the vectors outline the edges of raster data that are stored in rectangular cells. To produce a better-looking vector map, *r.poly* smoothes the corners of the vector data as they are being extracted. At each change in direction (i.e., each corner), the two midpoints of the corner cell (half the cell's height and width) are taken, and the line segment connecting them is used to outline this corner in the resultant vector file. (The cell's corner most node is ignored.) Because vectors are smoothed by this program, the resulting vector map will not be "true" to the raster map from which it was created. The user should check the resolution of the geographic region (and the original data) to estimate the possible error introduced by smoothing.

**OPTIONS**
The user can run this program either non-interactively or interactively. The program will be run non-interactively if the user specifies program arguments and flag settings on the command line using the form:

*r.poly [-l] input=name output=name*

Alternately, the user can simply type *r.poly* on the command line without program arguments. In this case, the user will be prompted for parameter values and flag settings using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flag:

| | |
|---|---|
| -*l* | Smooth corners. |

Parameters:

| | |
|---|---|
| *input=name* | Use the existing raster map name as input. |
| *output=name* | Set the new vector output file name to name. |

**NOTES**
*r.poly* extracts only area edges from the named raster input file. If the raster file contains other data (i.e., line edges, or point data) the output may be wrong.

The user must run *v.support* on the resultant file to build the needed topology information stored in the dig_plus file.

**SEE ALSO**
*v.support, parser*

**AUTHOR**
Original version of *r.poly*:
Jean Ezell, U.S. Army Construction Engineering Research Laboratory
Andrew Heekin, U.S. Army Construction Engineering Research Laboratory

Modified program for smoothed lines:
David Satnik, Central Washington University, WA

## *r.profile*

**NAME**
*r.profile* **-** Outputs the raster map layer values lying on user-defined line(s).
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.profile*
*r.profile help*
*r.profile map=name [result=type] [width=value] line=east,north,east,north[,east,north,east,north,...]*

**DESCRIPTION**
This program outputs, in ASCII, the values assigned to those cells in a raster map layer that lie along one or more lines ("profiles"). The lines are described by their starting and ending coordinates. The profiles may be single-cell wide lines, or multiple-cell wide lines. The output, for each profile, may be the category values assigned to each of the cells, or a single aggregate value (e.g., average or median value).

**OPTIONS**
Parameters:
*map=name* Raster map to be queried.

*result=type* Type of result to be output.
 Options: raw, median, average
 Default: raw

Raw results output each of the category values assigned to all cells along the profile. Median and average output a single value per profile: average outputs the average category value of all cells under the profile; median outputs the median cell category value.

*line=east,north,east,north[,east,north,east,north,...]* The geographic coordinates of the starting and ending points that define each profile line, given as easting and northing coordinate pairs. The user must state the starting and ending coordinates of at least one line, and may optionally include starting and ending coordinates of additional lines.

*width=value* Profile width, in cells (odd number).
 Default: 1

Wider profiles can be specified by setting the width to 3, 5, 7, etc. The profiles are then formed as rectangles 3, 5, 7, etc., cells wide.

**OUTPUT FORMAT**
The output from this command is printed to the standard output in ASCII. The format of the output varies slightly depending on the type of result. The first number printed is the number of cells associated with the profile. For raw output, this number is followed by the individual cell values. For average and median output, this number is followed by a single value (i.e., the average or the median value).

These examples are for the elevation.dem raster map layer in the spearfish sample data set distributed with GRASS:

Single-cell profile:

*r.profile map=elevation.dem line=593655,4917280,593726,491735*
*4 1540 1551 1557 1550*

3-cell wide profile:

*r.profile map=elevation.dem line=593655,4917280,593726,4917351 width=3*

22 1556 1538 1525 1570 1555 1540 1528 1578 1565 1551 1536 1523 1569 1557 1546 1533 1559 1550
1542 1552 1543 1548

(Output appears as multiple lines here, but is really one line)

3-cell wide profile average:

*r.profile map=elevation.dem line=593655,4917280,593726,4917351 width=3 result=average*

22 1548.363636

3-cell wide profile median:

*r.profile map=elevation.dem line=593655,4917280,593726,4917351 width=3 result=median*
*22 1549.000000*

**SEE ALSO**
*d.profile, r.transect*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.proj*

**NAME**
*r.proj* **-** projects raster maps between two projections
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.proj*
*r.proj help*
*r.proj input=name location=name [output=name] [mapset=name][dbase=name] [method=name] [res=value]*

**DESCRIPTION**
*r.proj* projects a raster map in a specified mapset of a specified location from the projection of the input location to a raster map in the current location. The projection information is taken from the momentary PROJ_INFO files.

**OPTIONS**
Parameters:

| | |
|---|---|
| *input=name* | Input raster map from source location. |
| *location=name* | Source location of input map. |
| *output=name* | Output raster map for current location. Default: Same name as input map |
| *mapset=name* | Mapset of input map. Default: Same name as current mapset |
| *dbase=name* | Database of input map. Default: Current database |
| *method=name* | Interpolation method to use. Options: nearest, bilinear, cubic Default: nearest |
| *res=value* | Resolution of output map. Default: Calculated from the number of cols in input map |

**NOTES**
If output is not specified it is set to be the same as input map name.
If dbase is not specified it is assumed to be the current database.
If mapset is not specified, its name is assumed to be the same as the current mapset's name.

*r.proj* uses three alternative resampling algorithms:

| | | |
|---|---|---|
| nearest | - | nearest neighbor |
| bilinear | - | bilinear interpolation |
| cubic | - | cubic convolution |

## DESCRIPTION

### Introduction

### Map projections

Map projections are a method of representing information from a curved surface (usually a spheroid) in two dimensions, typically to allow indexing through Cartesian coordinates. There are a wide variety of projections, with common ones divided into a number of classes, including cylindrical and pseudo-cylindrical, conic and pseudo-conic, and azimuthal methods, each of which may be conformal, equal-area, or neither.

The particular projection chosen depends on the purpose of the project, and the size, shape and location of the area of interest. For example, normal cylindrical projections are good for maps that are of greater extent east-west than north-south and in equatorial regions, while conic projections are better in mid-latitudes; transverse cylindrical projections are used for maps that are of greater extent north-south than east-west; azimuthal projections are used for polar regions. Oblique versions of any of these may also be used. Conformal projections preserve angular relationships, and better preserve arc-length, while equal-area projections are more appropriate for statistical studies and work in which the amount of material is important.

Projections are defined by precise mathematical relations, so the method of projecting coordinates from a geographic reference frame (latitude-longitude) into a projected Cartesian reference frame (e.g. meters) is governed by these equations. Inverse projections can also be achieved. The public domain Unix software package proj [1] has been designed to perform these transformations, and the user's manual contains a detailed description of over 100 useful projections. This also includes a programmer's library of the projection methods to support other software development.

Thus, converting a "vector" map - in which objects are located with arbitrary spatial precision - from one projection into another is usually accomplished by a simple two-step process: first the location of all the points in the map are converted from the source through an inverse projection into latitude-longitude, and then through a forward projection into the target. (Of course the procedure will be one-step if either the source or target is in geographic coordinates.)

Converting a "raster" map, or image, between different projections, however, involves additional considerations. A raster may be considered to represent a sampling of a process at a regular, ordered set of locations. The set of locations that lie at the intersections of a Cartesian grid in one projection will not, in general, coincide with the sample points in another projection. Thus, the conversion of raster maps involves an interpolation step in which the values of points at intermediate locations relative to the source grid are estimated.

### Projecting maps within the GRASS GIS

GIS data capture, import and transfer often requires a projection step, since the source or client will frequently be in a different projection to the working projection.

In some cases it is convenient to do the conversion outside the package, prior to import or after export, using software such as proj [1]. This is certainly the easiest method for site-lists, since there is no topology to be preserved, and proj can be used to process simple lists with a one-line command.

The format of files describing maps containing lines and arcs is generally more complex, as even in ASCII parts of the files will describe topology, and not just locations. In the GRASS GIS package a program *v.proj* is provided to convert "vector" maps, transferring topology and attributes as well as node locations. This program uses the projection definition and parameters, which are stored in the PROJ_INFO and PROJ_UNITS files in the PERMANENT mapset directory for every GRASS location.

However, although it is oriented mainly towards operations on raster maps, the standard GRASS distribution includes this *r.proj* module to convert raster maps. That is the purpose of the program described here.

**Design of *r.proj***

As discussed briefly above, the fundamental step in re-projecting a raster is resampling the source grid at locations corresponding to the intersections of a grid in the target projection. The basic procedure for accomplishing this, therefore, is as follows:

1. *r.proj* converts a map to a new geographic projection.

2. It reads a map from a different location, projects it, and writes it out to the current location.

3. The projected data is resampled with one of three different methods: nearest neighbors, bilinear, or cubic convolution.

Note that, following normal GRASS conventions, the coverage and resolution of the resulting grid is set by the current region settings, which may be adjusted using *g.region*. The target raster will be relatively unbiased for all cases if its grid has a similar resolution to the source, so that the resampling/interpolation step is only a local operation. If the resolution is changed significantly, then the behavior of the generalization or refinement will depend on the model of the process being represented. This will be very different for categorical versus numerical data. Note that three methods for the local interpolation step are provided.

The nearest option, which performs a nearest neighbor assignment is the fastest of the three resampling methods. It is primarily used for categorical data such as a land use classification, since it will not change the values of the data cells. The bilinear option determines the new value of the cell based on a weighted distance average of the 4 surrounding cells in the input map. The cubic option determines the new value of the cell based on a weighted distance average of the 16 surrounding cells in the input map.

The bilinear and cubic interpolation methods are most appropriate for continuous data and cause some smoothing. Both options shouldn't be used with categorical data, since the cell values will be altered.

If nearest neighbor assignment is used, the output map has the same raster format as the input map. If any of the both interpolations is used, the output map is written as floating point.

**BUGS**

The entire input map is read into memory. This requires a large amount of memory if large raster layers where projected.

**REFERENCES**

[1]Evenden, G.I. (1990) Cartographic projection procedures for the UNIX environment - a user's manual. USGS Open-File Report 90-284 (Also see Interim Report and 2nd Interim Report on Release 4, Evenden 1994).

Press, W.H. et al. (1992), Numerical Recipes in C, Cambridge University Press, Cambridge, 2nd edition.

Richards, John A. (1993), Remote Sensing Digital Image Analysis, Springer-Verlag, Berlin, 2nd edition.

**SEE ALSO**

*r.support, r.stats, s.sample, s.surf.idw, s.surf.tps, v.proj, m.proj, r.bilinear, r.resample*

**AUTHOR**

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Some man page text from S.J.D. Cox, AGCRC, CSIRO Exploration & Mining, Nedlands, WA

## *r.quant*

**NAME**
*r.quant* **-** This routine produces the quantization file for a floating-point map.
(GRASS 5 Raster Program)

**GRASS VERSION**
5.x

**SYNOPSIS**
*r.quant*
*r.quant [-tr] input=name[,name...] [basemap=map] [fprange=dmin,dmax] [range=min,max]*

**DESCRIPTION**
*r.quant* produces the quantization file for a floating-point map.

Flags:

-*t* Truncate floating point data.

-*r* Round floating point data.

Parameters:

*map=name* The map for which the rules be to be created. If more than one map is specified, then this implies that the floating-point range is the minimum and maximum of all the maps together, unless either basemap=map or fprange=min,max is specified.

*basemap=map* The quant rules of this map set the quantization.

*fprange=min,max* This sets the floating-point range for the quantization.

*range=min,max* This sets the integer range for the quantization. Otherwise a default of 1-255 is used.

**Quant rules**
The quant rules have to be entered interactively.

If rules are specified, the input has the form:

value1:value2:cat1:[cat2]

where value1 and value2 are floating point values and cat1 and cat2 are integers. If cat2 is missing, it is taken to be equal to cat1. All values can be "*" which means infinity.

**NOTE**
It is an error for both basemap and fprange to be specified.

**SEE ALSO**
*r.support, r.null*

**AUTHOR**
Michael Shapiro, Olga Waupotitcsh, U.S. Army Construction Engineering Research Laboratory

## *r.random*

**NAME**
*r.random* **-** Creates a raster map layer and site list file containing randomly located sites.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.random*
*r.random help*
*r.random [-qz] input=name nsites=number[%][raster_output=name] [sites_output=name]*

**DESCRIPTION**
The program *r.random* allows the user to create a raster map layer and a site list file containing geographic coordinates of points whose locations have been randomly determined. The program locates these randomly generated sites within the current geographic region and mask (if any), on non-zero category value data areas within a user-specified raster map layer. If the user sets the -z flag, sites will be randomly generated across all cells (even those assigned category value 0).

The raster_output raster map layer is created in the user's current mapset. The category values and corresponding category names already associated with the random site locations in the input map layer are assigned to these sites in the raster_output map layer.

The site_lists file created by *r.random* contains a listing of the sites' geographic coordinates; these coordinates are the center points of the randomly selected cells.

**OPTIONS**
The user may specify the quantity of random locations to be generated either as a positive integer (e.g., 10), or as a percentage of the raster map layer's total area (e.g., 10%, or 3.05%). If unspecified, the number of sites is set to '0' by default. If stated as a percentage of the raster map's total size, the number of random locations generated will be set equal to the number of cells contained within the stated percentage of the raster map layer. Options are 0-100; percentages less than one percent may be stated as decimals. The default percentage value used, if unspecified by the user, is '0'. (Note that choosing 1% of a raster map's cells frequently produces an abundance of random locations.)

*r.random* can be run interactively or non-interactively. The user may provide program arguments on the command line, specifying an input map layer name (input=name), output raster map layer name (raster_output=name), output site list file name (sites_output=name), and (optionally) give the number of sites to be randomly generated as a total number of sites (nsites=number) or as a percentage of the map's size (nsites=number%). The user can also direct that *r.random* run quietly (using the -q) option, and/or direct *r.random* to also generate random site locations against cells containing category zero (using the -z option).

Alternately, the user can simply type *r.random* on the command line without program arguments. In this case, the user will be prompted for needed inputs and option choices using the standard GRASS user interface described in the manual entry for *parser*.

Flags:
-*q* Run quietly. *r.random* will normally print output messages to standard output as it runs. The -*q* option will suppress the printing of these messages.

-*z*     Include areas assigned a category value of zero within the pool of areas within which *r.random* will randomly generate site locations. If the -*z* option is specified, sites that fall in areas assigned a category value of zero in the input map layer will be assigned to a newly-created category in the output raster map layer. If the -*z* flag is not set, cells having category value 0 in the output layer will represent the areas at which randomly- located sites were not placed.

Parameters:
*input=name*     An existing raster map layer in the user's current mapset search path. *r.random* will randomly generate sites on a user- specified portion of the cells in this input raster map.

*nsites=number* or *nsites=number%*     Allows the user to specify the quantity of sites to be randomly generated as either a positive integer, or as a percentage value of the number of cells in the input map layer. If stated as a positive integer, number is the number of sites (i.e., number of cells) to appear in the raster_output layer and/or sites_output file. Options: Non-percentage values should be given as positive integer values less than or equal to the number of cells in the input map layer. Percentage values given should be within the range 0.00 - 100.00 (decimal values are allowed).

*raster_output=name*     The new raster map layer to hold program output. This map will contain the sites randomly generated by *r.random*. If the -*z* flag is not set, all sites will be assigned whatever category values were assigned these cell locations in the input raster map layer. If the -*z* flag is set, all sites except those falling on cells assigned category value 0 in the input value will be assigned the category values assigned these cells in the input layer; sites falling on cells assigned category value 0 in the input layer will be assigned to a newly created category in the raster_output layer.

*sites_output=name*     The new GRASS site_lists file to hold program output. If no sites_output file name is given on the command line, no site_lists file will be created by *r.random*. (See raster_output parameter description, above.)

Note: Although the user need not request that *r.random* output both a raster map layer (raster_output) and a site list file (sites_output), the user must specify that at least one of these outputs be produced.

**NOTES**
To create random site locations within some, but not all, non-zero categories of the input raster map layer, the user must first create a reclassified raster map layer of the original raster map layer (e.g., using the GRASS program *r.reclass*) that contains only the desired categories, and then use the reclassed raster map layer as input to *r.random*.

**SEE ALSO**
*g.region, r.mask, r.reclass, parser*

**AUTHOR**
Dr. James Hinthorne, GIS Laboratory, Central Washington University

# *r.rational.regression*

**NAME**
*r.rational.regression* **-** linear and nonlinear regression calculation (GRASS Image Processing Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.rational.regression*
*r.rational.regression help*
*r.rational.regression input=name output=name [check="phrase"] [predict="phrase"] [plot="phrase"] [calculat="phrase"]*

**DESCRIPTION**
The *r.rational.regression* program calculates the linear or nonlinear regression model. If it is used as an image processing tool, the multispectral space remote sensing data will be the regression variables (ASCII file) and the ground vegetation coverage measurements will be the response variables (also ASCII file) and this command will be useful for obtaining linear or nonlinear regression models from the remote-sensing data which have corresponding ground measurement and for predicting vegetation coverage using other remote-sensing data which have no corresponding ground truth records. The input file has the following format

regression valuables x1, x2, ... response variable y

channel 1 (x1)   channel 2 (x2) ...  coverage

For a three channel remote-sensing data the following is an example of input ASCII file

```
0.4350    0.2616      0.7016        0.98
0.4140    0.2620      0.6520        0.99
0.4940    0.3500      0.5580        0.34
0.5983    0.5350      0.5650        0.10
0.4883    0.3733      0.5533        0.88
0.4150    0.2916      0.5116        0.60
0.5566    0.5250      0.5466        0.09
0.4420    0.2820      0.6800        0.86
0.4220    0.2620      0.6260        0.88
0.4766    0.3666      0.5933        0.61
0.5180    0.4300      0.5140        0.60
0.4416    0.2700      0.7383        0.96
0.4583    0.3116      0.5133        0.76
0.4300    0.2750      0.7233        0.98
0.4320    0.2760      0.6460        1.00
0.4733    0.3566      0.5616        0.53
0.4200    0.2450      0.7966        1.00
```

```
0.4850    0.3533      0.7216        0.99

0.4360    0.2620      0.7620        0.99

0.4283    0.2650      0.6783        0.91

0.4633    0.3200      0.6750        0.94
```

The resulted regression model (coefficient numbers) and related information about the confidential test, goodness or utility test (e.g., correlation coefficient r between observed and calculated coverage, F value and t value) are put on the output file (ASCII file also).

Eight models can be chosen by user after prompted by the program. They are:

1) usual linear model:
y=a[0]x[0]+a[1],
y=a[0]x[0]+a[1]x[1]+a[2]
y=a[0]x[0]+a[1]x[1]+a[2]x[2]+a[4]

2) linear model with remote-sensing data normalized by the data in the first spectral band; normalized by x1:
y=a[0]x[1]/x[0] + a[1]
y=a[0]x[1]/x[0] + a[1]x[2]/x[0] + a[2]

3) linear model with normalization by the second band; normalized by x2:
y=a[0]x[0]/x[1] + a[1]
y=a[0]x[0]/x[1] + a[1]x[2]/x[1] + a[2]

4) NDVI (normalized differential vegetation index) model;

5) NDVI model for intensity instead of radiance;

6) NDVI model for reflectance;

7) semi-relaxation vegetation index model;

8) RVI (relaxation vegetation index) nonlinear model.

The user has three options for check: multx1, multx2, and multx3. These options check multi-colinearity of the input data. multx1 calculates $R sup 2$ for channel x1 being replaced by coverage y. multx2 for channel x2 if input data are composed of two remote-sensing channels. And multx3 for channel x3 if input data are composed of at least three channels.

The program provides three methods to conduct the nonlinear regression calculation. These methods can be invoked by the user as options of calculat. The first one is rational fraction method. If no any option of calculat is given by the user, the program will adopt the first method. If calculat = rvi_linear the linearization method is taken to conduct the nonlinear relaxation index regression. If the user set calculat = rvi_nonlinear the general nonlinear regression method is used. If calculat = all, the program will conduct nonlinear regression first using the rational fraction method and then using the obtained coefficients as initial values to conduct the second method calculation and finally using the third method to improve the results. For nonlinear regression calculation there may exist multi-minimums. We can not be in reliance on the existing usual algorithms which can find one minimum only. The computer will not scan the possible minimums in order to save computer time. The user should judge and select a least minimum during the iteration. The necessary parameters that will facilitate the judgment for each iteration are displayed in the screen and also output to the output file.

For plots of relevant features of the regression calculation the user can set option for plot. There are four options for the plot. If plot = radiance-coverage computer will send radiance data against coverage data for further plotting radiance-coverage curves or figures to show the scatter of input data. This data will be stored in ASCII files named "curve.radiance_coverage_x1y", “curve.radiance_coverage_x2y" and "curve.radiance_coverage_x3y". If plot = vegetation-soil three ASCII data files will be generated by the program for further figures. Their names are "curve.veget_soil_x1x2", "curve.veget_soil_x1x3" and "curve.veget_soil_x2x3". If the user set plot = adequacy the program will generate residual data files for plotting figures of residuals against predictors and dependent variable to show the adequacy. These files named "curve_residual_x1", "curve_residual_x2", “curve_residual_x3" and "curve_residual_y". If plot = all, the program will generate all these above mentioned data files for further plotting of different figures.

The program not only can calculate regression models but also can make prediction to new remote sensing data using the obtained model. The user can set option of predict = same to calculate regression model using part of one imagery data and predict vegetation coverage for another part of remote sensing data in the same imagery. If predict = other the program will use one imagery to get regression model and predict vegetation coverage for other imagery. If the user did not give any option for predict the program calculates model based on the whole input data and not conduct any prediction. The program still generate a set of "calculated vegetation coverage" using the obtained model and the same input data in order for the user to check the utility, goodness and confidential status of the regression. *r.rational.regression* will be run non-interactively if the user specifies program arguments on the command line, using the form:

*r.rational.regression input=name output=name [check="phrase"] [predict="phrase"] [plot="phrase"] [calculat="phrase"]*

But after run, the computer will prompt the user to select model number.
Alternately, the user can simply type:

*r.rational.regression*

on the command line without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS user interface described in the manual entry for *parser*.

**OPTIONS**
Parameters:
*check="phrase”* For check of multi-colinearity.
Options: multx1, multx2, multx3

*calculat="phrase"* Method of calculation for nonlinear regression.
Options: rvi_linear, rvi_nonlinear, all

*plot="phrase”* Name of data files generated by the program for further plotting.
Options: radiance-coverage, vegetation-soil, adequacy, all

*predict=* Fashion of prediction.
Options: same, other

**SEE ALSO**
*i.rvi*, *i.ndvi*

**AUTHORS**
Hong C. Zhuang, U.S. Army Construction Engineering Research Laboratory Department of Electrical Computer Engineering, University of Illinois at Urbana-Champaign.

Michael Shapiro, U.S. Army Construction Engineering Research Laboratory.

# *r.reclass*

**NAME**
*r.reclass* **-** Creates a new map layer whose category values mare based upon the user's reclassification of categories in an existing raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.reclass*
*r.reclass help*
*r.reclass input=name output=name [title=name]*

**DESCRIPTION**
*r.reclass* creates an output map layer based on an input raster map layer. The output map layer will be a reclassification of the input map layer based on reclass rules input to *r.reclass*, and can be treated in much the same way that raster files are treated. A title for the output map layer may be (optionally) specified by the user.

The reclass rules are read from standard input (i.e., from the keyboard, redirected from a file, or piped through another program).

The program will be run non-interactively if the user specifies the name of the raster map layer to be reclassified, the name of an output layer to hold reclass rules, and (optionally) the name of a title for the output map:

*r.reclass input=name output=name [title=name]*

After the user types in the above information on the command line, the program will (silently) prompt the user for reclass rules to be applied to the input map layer categories. The form of these rules is described in further detail in the sections on non-interactive program use reclass rules and examples, below.

Alternately, the user can simply type *r.reclass* on the command line, without program arguments. In this case, the user will be prompted for all needed inputs.

Before using *r.reclass* one must know the following:

1 The new categories desired; and, which old categories
fit into which new categories.

2 The names of the new categories.

**INTERACTIVE PROGRAM USE: EXAMPLE**
Suppose we want to reclassify the raster map layer roads, consisting of five categories, into the three new categories: paved roads, unpaved roads, and railroad tracks. The user is asked whether the reclass table is to be established with each category value initially set to 0, or with each category value initially set to its own value. A screen like that shown below then appears, listing the categories of the roads raster map layer to be reclassified and prompting the user for the new category values to be assigned them.

```
 ENTER NEW CATEGORY NUMBERS FOR THESE CATEGORIES

    OLD CATEGORY NAME  OLD   NEW   NUM   NUM
    no data  00__
    Hard Surface, 2 lanes   10__
    Loose Surface, 1 lane   20__
    Improved Dirt 30__
    Unimproved Dirt Trail   40__
    Railroad, single track  50__

    AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
   (OR <Ctrl-C> TO CANCEL)
```

In the following screen the new category values have been entered beside the appropriate old category names. Cells assigned category values 2, 3, and 4 in the old raster map layer are now assigned the new category value 2 in the reclassed map; cell data formerly assigned to category value 5 in the old raster map are now assigned the new category value 3 in the reclassed map.

```
 ENTER NEW CATEGORY NUMBERS FOR THESE CATEGORIES

    OLD CATEGORY NAME  OLD   NEW   NUM   NUM
    no data  00__
    Hard Surface, 2 lanes   11__
    Loose Surface, 1 lane   22__
    Improved Dirt 32__
    Unimproved Dirt Trail   42__
    Railroad, single track  53__

    AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
   (OR <Ctrl-C> TO CANCEL)
```

Hitting the escape key <ESC> will bring up the following screen, which prompts the user to enter a new title and category label for the newly reclassed categories.

```
  ENTER NEW CATEGORY NAMES FOR THESE CATEGORIES

  TITLE:  Roads Reclassified
   CATNEW CATEGORY NAME
   NUM
    0 no data
    1 Paved Roads
    2 Unpaved Roads
    3 Railroad, single track

  AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
 (OR <Ctrl-C> TO CANCEL)
```

Based upon the information supplied by the user in the above sample screens, the new output map, supporting category, color, history, and header files are created.

## NON-INTERACTIVE PROGRAM USE: RECLASS RULES

In non-interactive program use, the names of an input map, output map, and output map title are given on the command line. However, the reclass rules are still read from standard input (i.e., from the keyboard, redirected from a file, or piped through another program).

Once the user has specified an input raster map layer, output map layer name, and (optionally) output map layer title by typing:

*r.reclass input=name output=name* [title=name]

Each line of input must have the following format:

*input_categories=output_category  [label]* where the input lines specify the category values in the input raster map layer to be reclassified to the new output_category category value. Specification of a label to be associated with the new output map layer category is optional. If specified, it is recorded as the category label for the new category value. The equal sign = is required. The input_category(ies) may consist of single category values or a range of such values in the format "low thru high." The word "thru" must be present.

A line containing only the word end terminates the input.

NON-INTERACTIVE PROGRAM USE: EXAMPLES
The following examples may help clarify the reclass rules.

1 This example reclassifies categories 1, 3 and 5 in the input raster map layer to category 1 with category label "poor quality" in the output map layer, and reclassifies input raster map layer categories 2, 4, and 6 to category 2 with the label "good quality" in the output map layer.

```
 1 3 5   =   1   poor quality
 2 4 6   =   2   good quality
```

2 This example reclassifies input raster map layer categories 1 thru 10 to output map layer category 1, input map layer categories 11 thru 20 to output map layer category 2, and input map layer categories 21 thru 30 to output map layer category 3, all without labels.

```
  1 thru 10   =   1
 11 thru 20   =   2
 21 thru 30   =   3
```

3 Subsequent rules override previous rules. Therefore, the below example reclassifies input raster map layer categories 1 thru 19 and 51 thru 100 to category 1 in the output map layer, input raster map layer categories 20 thru 24 and 26 thru 50 to the output map layer category 2, and input raster map layer category 25 to the output category 3.

```
 1 thru 100   =   1   poor quality
 20 thru 50   =   2   medium quality
25  =   3   good quality
```

4 The previous example could also have been entered as:

```
  1 thru 19  51 thru 100   =   1   poor quality
 20 thru 24  26 thru 50    =   2   medium quality
 25    =   3   good quality

 or as:

  1 thru 19    =   1   poor quality
 51 thru 100   =   1
 20 thru 24    =   2
 26 thru 50    =   2   medium quality
25   =   3   good quality
```

The final example was given to show how the labels are handled. If a new category value appears in more than one rule (as is the case with new category values 1 and 2), the last label which was specified becomes the label for that category. In this case the labels are assigned exactly as in the two previous examples.

**NOTES**
In fact, the *r.reclass* program does not generate any new raster map layers (in the interests of disk space conservation). Instead, a reclass table is stored which will be used to reclassify the original raster map layer each time the new (reclassed) map name is requested. As far as the user (and programmer) is concerned, that raster map has been created. Also note that although the user can generate a *r.reclass* map which is based on another *r.reclass* map, the new *r.reclass* map will be stored in GRASS as a reclass of the original raster map on which the first reclassed map was based. Therefore, while GRASS allows the user to provide *r.reclass* map layer information which is based on an already reclassified map (for the user's convenience), no *r.reclass* map layer (i.e., reclass table) will ever be stored as a *r.reclass* of a *r.reclass*.

To convert a reclass map to a regular raster map layer, set your geographic region settings to match the settings in the header for the reclass map (an ASCII file found under the cellhd directory, or viewable by running *r.support*) and then run *r.resample*.

*r.mapcalc* can also be used to convert a reclass map to a regular raster map layer:

*r.mapcalc raster_map=reclass_map*

where raster_map is the name to be given to the new raster map, and reclass_map is an existing reclass map.

**BEWARE**
Because *r.reclass* generates a table referencing some original raster map layer rather than creating a reclassed raster map layer, a *r.reclass* map layer will no longer be accessible if the original raster map layer upon which it was based is later removed.

A *r.reclass* map is not a true raster map layer. Rather, it is a table of reclassification values which reference the input raster map layer. Therefore, users who wish to retain reclassified map layers must also save the original input raster map layers from which they were generated.

Category values which are not explicitly reclassified to a new value by the user will be reclassified to 0.

**SEE ALSO**
*r.resample, r.rescale*

**AUTHORS**
James Westervelt, U.S. Army Construction Engineering Research Laboratory
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.reclass.scs*

**NAME**
*r.reclass.scs* **-** Create a new raster map layer based on an existing raster map.
(SCS GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.reclass.scs*
*r.reclass.scs help*

**DESCRIPTION**
*r.reclass.scs* is an interface to the GRASS *r.reclass* program. The program will reclassify the category values in a raster map layer based on reclass instructions entered by the user. The user can enter map reclassification rules to *r.reclass.scs* either from standard input or from a file. The program then issues *r.reclass* commands to produce the new reclassified raster map layer.

Input to *r.reclass.scs* consists of a list of category names or category values that will be grouped into the same category in the output (reclassified) map. Only one category name should appear on each line of input. Input can be entered either interactively, or from a file.

A file containing these reclass rules can be created using a text editor, word-processor, DBMS, etc. It is no more than a list of category names which will have the same category value after the reclassification.

**SEE ALSO**
*r.reclass, r.resample, r.rescale*

**AUTHOR**
R. L. Glenn, USDA, SCS, NHQ-CGIS

## *r.report*

**NAME**
*r.report* **-** Reports statistics for raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.report*
*r.report help*
*r.report [-hmfqeznNCi] map=name[,name,...][units=name[,name,...]] [pl=value] [pw=value] [output=name][null=string][nsteps=value]*

**DESCRIPTION**
*r.report* allows the user to set up a series of report parameters to be applied to a raster map layer, and creates a report. If invoked with command line arguments, the report will print out to the screen only. However, output may be redirected to a file or another program using the UNIX redirection mechanism. If invoked without command line arguments, the user is given the option of printing out each report and/or saving output to a file.

The program will be run non-interactively, if the user specifies the names of raster map layers and any desired options on the command line, using the form

*r.report [-hmfqeznNCi] map=name[,name,...][units=name[,name,...]] [pl=value] [pw=value]*

where each map name is the name of a raster map layer on which to report, each unit name is a unit of measure in which results are to be reported, the pl value gives the page length, the pw value gives the page width, and the (optional) flags *-h, -e, -m, -f, -q, -z, -n, -N, -C,* and *-i* have the meanings stated below.

**OPTIONS**
Flags:
-*h* Suppress the print-out of page headers.

-*m* Report on zero values, because a mask is being used.

-*f* Use formfeeds between pages when printing report output.

-*q* Run quietly, without printing program messages to standard output.

-*e* Use scientific format for the numbers that are too long to fit in the tab table field if their decimal form is used.

-*z* Report only non-zero data values. Zero data will not be reported. However, for multiple map layers this means that if zero values occur in every map layer, they will not be reported; if non-zero category values occur in any map layer (along with zeros in others), the non- zero values along with the zero values will be reported.

-*n* Filter out all no data cells.

-*N* Filter out cells where all maps have no data.

-*C*	Report for cats fp ranges (fp maps only).

-*i*	Read fp map as integer (use map's quant rules).

Parameters:

| | |
|---|---|
| *map=name,name,...* | Names of raster map(s) on which to report. |

*units=name*	Units of measure in which results are to be reported. These units are based on the number of cells in the user's area of interest (i.e., cells within the current geographic region definition, and the current mask [if any]). These are established with the programs *g.region* and *r.mask*, respectively.
Options: Possible units of measurement are:

| | |
|---|---|
| mi | (cover measured in square miles) |
| me | (cover measured in square meters) |
| k | (cover measured in square kilometers) |
| a | (cover measured in acres) |
| h | (cover measured in hectares) |
| c | (the number of cells in the area of interest) |
| p | (the percent cover, excluding no data areas) |

*pl=value*	Page length, in lines, in which report will be output.
Default: 0 (lines)

*pw=value*	Page width, in characters, in which report will be output.
Default: 79 (characters)

*output=name*	The name of a file to store the report in. If not specified, the report is printed on the terminal screen.

*null=string*	String representing no data cell value.

*nsteps=value*	Number of fp subranges to collect stats from.

Alternately, the user can simply type *r.report* on the command line, without program arguments. In this case, the user will be prompted for program flag settings and parameter values.

The report itself consists of two parts, a header section and the main body of the report.

The header section of the report identifies the raster map layer(s) (by map layer name and title), location, mapset, report date, and the region of interest. The area of interest is described in two parts: the user's current geographic region is presented, and the mask is presented (if any is used).

The main body of the report consists of from one to three tables, which present the statistics for each category and the totals for each unit column.

Note that, unlike *r.stats*, *r.report* allows the user to select the specific units of measure in which statistics will be reported.

Following is the result of a *r.report* run on the raster map layer geology (located in the Spearfish, SD sample data base), with the units expressed in square miles and acres. Here, *r.report* output is directed into the file report.file.

**EXAMPLE**

*r.report map=geology units=miles,acres > report.file*

```
 _________________________________________________________________________
| RASTER MAP CATEGORY REPORT                                              |
| LOCATION: spearfish   Fri Sep 2 09:20:09                                |
|_________________________________________________________________________|
|          north:   4928000.00   east:   609000.00                        |
| REGION:  south:   4914000.00   west:   590000.00                        |
|          res:    100.00   res:  100.00                                  |
|_________________________________________________________________________|
| MASK:none                                                               |
|_________________________________________________________________________|
| MAP: geology in PERMANENT                                               |
|_________________________________________________________________________|
|    Category Information                      |   Acres   |   Square     |
|    #      description                        |           |   Miles      |
|______________________________________________|___________|______________|
|    0   |  no data                            |     415.13|       0.65   |
|    1   |  metamorphic                        |    2597.02|       0.46   |
|    2   |  transition                         |      32.12|       0.05   |
|    3   |  igneous                            |    8117.24|      12.68   |
|    4   |  sandstone                          |   16691.60|      26.08   |
|    5   |  limestone                          |   13681.93|      21.38   |
|    6   |  shale                              |   10304.07|      16.10   |
|    7   |  sandy shale                        |    2517.95|       3.93   |
|    8   |  claysand                           |    3229.60|       5.05   |
|    9   |  sand                               |    8141.95|      12.72   |
|______________________________________________|___________|______________|
|  TOTAL                                       |   65728.60|     102.70   |
|______________________________________________|___________|______________|
```

**NOTES**
If the user runs *r.report* interactively and saves the report output in a file, this file will be placed into the user's current working directory.

If the user runs *r.report* non-interactively, report output can be saved by redirecting it to a file or a printer using the UNIX redirection mechanism.

**SEE ALSO**
*g.region, r.coin, r.describe, r.info, r.mask, r.stats*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.resamp.rst*

**NAME**
*r.resamp.rst* **-** reinterpolates and computes topographic analysis from input raster file to a new raster file (possibly with different resolution) using regularized spline with tension and smoothing.
(GRASS Raster Program)

**GRASS VERSION**
5.x

**SYNOPSIS**
*r.resamp.rst*
*r.resamp.rst help*
*r.resamp.rst [-rdt] input = name ew_res = val ns_res = val elev = name [slope = name] [aspect = name] [pcurv = name] [tcurv = name] [mcurv = name] [smooth = name] [maskmap = name] [overlap = val] [zmult = val] [tension = val]*

**DESCRIPTION**
*r.resamp.tps*
This program reinterpolates the values from a given raster file named input to a new raster file named elev. If *-r* flag is specified, all zero elevations in input file are treated as elevations, otherwise they are ignored. Reinterpolation (resampling) is done to higher, same, or lower resolution that is specified by parameters ew_res and ns_res. All resulting raster files are created for the given region (which might be different from the header of the input raster file). As an option, simultaneously with interpolation, topographic parameters slope, aspect, profile curvature (measured in the direction of steepest slope), tangential curvature (measured in the direction of a tangent to contour line) or mean curvature are computed and saved as raster files as specified by the options slope, aspect, pcurv, tcurv, mcurv respectively. If *-d* flag is set the program outputs partial derivatives fx, fy, fxx, fxy, fyy instead of slope, aspect and curvatures.

For noisy data, it is possible to define spatially variable smoothing by providing a raster file smooth containing smoothing parameters. With the smoothing parameter set to zero (smooth is not given or contains zero data), the resulting surface passes exactly through the data points. User can define a raster file named maskmap, which will be used as a mask. The interpolation is skipped for cells that have zero value in mask. Zero values will be assigned to these cells in all output raster files. Parameter zmult allows the user to rescale the z-values (useful, e.g., for transformation of elevations given in feet to meters, so that the proper values of slopes and curvatures can be computed).

Regularized spline with tension is used for the interpolation. The tension parameter tunes the character of the resulting surface from thin plate to membrane. Higher values of tension parameter reduce the overshoots that can appear in surfaces with rapid change of gradient. The flag -t can be set to use "dnorm independent tension". The interpolation is performed for overlapping rectangular segments. The user can define the width of overlap (in number of cells) by option overlap.

**OPTIONS**
The user can run this program either interactively or non-interactively. The program will be run non-interactively if the user specifies program arguments and flag settings on the command line using the form:

*r.resamp.rst [-r] [-d] [-t] input = name ew_res = val ns_res = val elev = name [slope = name] [aspect = name] [pcurv = name] [tcurv = name] [mcurv = name] [smooth = name] [maskmap = name] [overlap = val] [ zmult = val ] [tension = val]*

Alternatively, the user can simply type *r.resamp.rst* on the command line without program arguments. In this case, the user will be prompted for parameter values and flag settings using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:

| | |
|---|---|
| *-r* | Indicates that zeroes in input map represent elevation. |
| *-d* | Output partial derivatives instead of aspect, slope and curvatures. |

Parameters:

| | |
|---|---|
| *input =name* | Use the existing site file name as input. |
| *ew_res = val* | Set desired east-west resolution to val. |
| *ns_res = val* | Set desired north-south resolution to val. |
| *elev = name* | Output elevation values to raster file named name. |
| *slope = name* | Output slope or fx values to raster file named name. |
| *aspect = name* | Output aspect or fy values to raster file named name. |
| *pcurv = name* | Output profile curvature or fxx values to raster file named name. |
| *tcurv=name* | Output tangential curvature values or fyy to raster file named name. |
| *mcurv=name* | Output mean curvature values or fxy to raster file named name. |
| *smooth=name* | 18 Set smoothing parameter from file name. |
| *maskmap=name* | Use the existing raster file name as a mask. |
| *overlap =val* | Use overlap val cells to get additional points for interpolation for a given segment. Default value is 3. |
| *zmult =val* | Convert z-values using conversion factor val. Default value is 1. |
| *tension = val* | Set tension to val. |

**NOTES**

*r.resamp.rst* uses regularized spline with tension for interpolation (as described in Mitasova and Mitas, 1993). Region is temporarily changed while writing output files with desired resolution. Topographic parameters are computed the same way as in *s.surf.rst*. (See also Mitasova and Hofierka, 1993) Raster file smooth should contain variable smoothing parameters that can be derived from errors, slope, etc. using *r.mapcalc*. The program gives warning when significant overshoots appear and higher tension should be used. However, with tension too high the resulting surface changes its behavior to membrane (rubber sheet stretched over the data points resulting in a peak or pit in each given point and everywhere else the surface goes rapidly to trend). Smoothing can also be used to reduce the overshoots. When overshoots occur the resulting elev file will have white color in the locations of overshoots since the color table for the output file is the same as colortable for raster input file. The program checks the numerical stability of the algorithm by computation of values in given points, and prints the maximum difference found into the history file of raster map elev. Increase in tension is suggested if the difference is unacceptable. For computation with smoothing set to 0 this difference should be 0. With smoothing parameter greater than zero the surface will not pass through the data points and the higher the parameter the closer the surface will be to the trend.

The program writes the values of parameters used in computation into the comment part of the history file elev as well as the following values which help to evaluate the results and choose the suitable parameters: minimum and maximum z values in the data file (zmin_data, zmax_data) and in the interpolated raster map (zmin_int, zmax_int), maximum difference between the given and interpolated z value in a given point (errtotal), rescaling parameter used for normalization (dnorm), which influences the tension. The program gives warning when the user wants to interpolate outside the region given by the header of the input raster file, zooming into the area where the points are is suggested in this case. When a mask is used, the program takes all points in the given region for interpolation, including those in the area that is masked out, to ensure proper interpolation along the border of the mask. It therefore does not mask out the data points; if this is desirable, it must be done outside *r.resamp.rst*.

**SEE ALSO**
*g.region, r.resample, r.surf.contour, s.surf.rst*

**AUTHORS**
*Original version of program (in FORTRAN):*
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Helena Mitasova, US Army CERL, Champaign, Illinois

*Modified program (translated to C, adapted for GRASS, segmentation procedure):*
Irina Kosinovsky, US Army CERL
Dave Gerdes, US Army CERL

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## *r.resample*

**NAME**
*r.resample* **-** GRASS raster map layer data resampling capability.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.resample*
*r.resample help*
*r.resample [-q] input=name output=name*

**DESCRIPTION**
*r.resample* resamples the data values in a user-specified raster input map layer name (bounded by the current geographic region and masked by the current mask), and produces a new raster output map layer name containing the results of the resampling. The category values in the new raster output map layer will be the same as those in the original, except that the resolution and extent of the new raster output map layer will match those of the current geographic region settings (see *g.region*).

The program will be run non-interactively if the user specifies program arguments on the command line, using the form

*r.resample [-q] input=name output=name*

where the input name is the name of the raster map layer whose data are to be resampled, the output name is the name of the raster map layer to store program output, and the *-q* option, if present, directs that *r.resample* run quietly (suppressing the printing of program messages to standard output).

Alternately, the user can simply type *r.resample* on the command line, without program arguments. In this case, the user will be prompted for needed inputs and option choices using the standard GRASS *parser* interface described in the manual entry for *parser*.

**NOTES**
The method by which resampling is conducted is "nearest neighbor" (see *r.neighbors*). The resulting raster map layer will have the same resolution as the resolution of the current geographic region (set using *g.region*).

The resulting raster map layer may be identical to the original raster map layer. The *r.resample* program will copy the color table and history file associated with the original raster map layer for the resulting raster map layer and will create a modified category file which contains description of only those categories which appear in resampled file.

When the user resamples a GRASS reclass file, a true raster file is created by *r.resample.*

**SEE ALSO**
*g.region, r.mapcalc, r.mask, r.mfilter, r.neighbors, r.rescale, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.rescale*

**NAME**
*r.rescale* **-** Rescales the range of category values in a raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.rescale*
*r.rescale help*
*r.rescale [-q] input=name [from=min,max] output=name [to=min,max] \ [title="phrase"]*

**DESCRIPTION**
The *r.rescale* program rescales the range of category values appearing in a raster map layer. A new raster map layer, and an appropriate category file and color table based upon the original raster map layer, are generated with category labels that reflect the original category values that produced each category. This command is useful for producing representations with a reduced number of categories from a raster map layer with a large range of category values (e.g., elevation). Rescaled map layers are appropriate for use in such GRASS programs as *r.stats*, *r.report*, and *r.coin.*

*r.rescale* will be run non-interactively if the user specifies program arguments on the command line, using the form:

*r.rescale [-q] input=name [from=min,max] output=name [to=min,max] \ [title="phrase"]*

Alternately, the user can simply type:

*r.rescale*

on the command line without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS user interface described in the manual entry for *parser*.

Flag:

| | |
|---|---|
| -*q* | Run quietly, without printing messages on program progress to the user's terminal. |

Parameters:

| | |
|---|---|
| *input=name* | The name of the raster map layer whose category values are to be rescaled. |
| *from=min,max* | The input map range to be rescaled.<br>Default: The full range of the input map layer. |
| *output=name* | The name of the new, rescaled raster map layer. |
| *to=min,max* | The output map range (after rescaling).<br>Default: 1,255 |
| *title="phrase"* | Title for new output raster map layer. |

**EXAMPLE**
To rescale an elevation raster map layer with category values ranging from 1090 meters to 1800 meters into the range 1-255, the following command line could be used:

```
r.rescale  input=elevation  from=1090,1800  output=elevation.255  to=1,255
```

**NOTES**
The rescaled category value range is actually unlimited, but the category value range 1 to 255 is frequently used due to limitations of color graphics monitors.

Category values that fall beyond the input range will become zero. This allows the user to select a subset of the full category value range for rescaling if desired. This also means that the user should know the category value range for the input raster map layer. The user can request the *r.rescale* program to determine this range, or can obtain it using the *r.describe* command. If the category value range is determined using *r.rescale*, the input raster map layer is examined, and the minimum and maximum non-zero category values are selected as the input range.

**SEE ALSO**
*r.coin, r.describe, r.mapcalc, r.reclass, r.report, r.resample, r.stats, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.rescale.inf*

**NAME**
*r.rescale.inf* **-** Generate a raster map layer in which the categories represent values in a database column which have been divided into equal interval units.
(GRASS-RDBMS Raster Interface Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.rescale.inf*
*r.rescale.inf help*
*r.rescale.inf tab=name key=name col=name cats=name input=name output=name [join=tab,tabkey,pkey]*

**DESCRIPTION**
*r.rescale.inf* creates a reclassed raster map layer by dividing the values in a numeric column in the currently selected database into equal interval units. The number of resulting categories is determined by the user via the command line parameter [cats=]. *r.rescale.inf* evaluates the range of values for the database column and subsets these values into equal interval groups of records returned by the query. For example, if the database column contains values which range from 1-1000 and the [cats] value is equal to 10 the resulting raster map layer will contain the 10 categories:1=1-100, 2=101-200 etc. In other words, each category in the new raster map layer will represent a range of 100 values from the database column used in the rescale operation. The database column being evaluated must be numeric in type. To identify the data types of columns in a database table use the *g.column.inf* command with the [-v] flag. *r.rescale.inf* does not take outlying data values into account. Therefore, if the range of values for a database column contains a limited number of extreme values the resulting rescale operation will be skewed in the direction of these values.

**OPTIONS**
Parameters:
*tab=database_table_name* Table containing a column linked to category values in an existing raster map.

*key=database_column_name* Column corresponding to category values in an existing raster map.

*col=database_column_name* Column to base rescale operation on which is numeric in type.

*cats=value* Number of categories to define in the resulting reclass map.

*input=map* Name of an existing raster file with category values linked to a column in the currently selected database.

*output=map* Name of new raster map.

*join=tab,tabkey,pkey* Tab is the table used to develop the current SQL query. Tabkey is the database column used to relate information in this table with data in the table linked to the GRASS category file. Pkey is the associated column in the table linked to the GRASS category file which is related to tabkey in the current table.

For instance, assume that stf1_main is a table containing column values associated with category values in a the GRASS raster file blkgrp.ids. In addition, assume that stf1_main is a table containing attribute data on age in the column pop100. In this example stf1_main is the table associated with the GRASS raster map and tract_blck is the column linking stf1_main to the GRASS category file. The column pop100 in stf1_main will be the basis for the rescale effort. To specify the rescale:

*r.rescale.inf tab=stf1_main key=tract_blck*
*col=pop100*
*cats=5 input=blkgrp.ids output=pop100.rescale*

Specifying these conditions would insure that all rows from table stf1_main which satisfy the query criteria would be related to the spatial features in the GRASS data layer via the GRASS category values.

**BUGS**
None known.

**NOTE**
This program requires the Informix database software.

**SEE ALSO**
*g.column.inf, g.select.inf, g.stats.inf, g.table.inf, d.rast.inf, d.site.inf, d.vect.inf, d.what.r.inf, d.what.s.inf, d.what.v.inf, r.reclass.inf, v.reclass.inf*

**AUTHOR**
James A. Farley, Wang Song and W. Fredrick Limp University of Arkansas, CAST

## *r.ros*

**NAME**
*r.ros* (for wildfire spread simulation) **-** Generates three, or four raster map layers showing 1) the base perpendicular) rate of spread (ROS), 2) the maximum (forward) ROS, 3) the direction of the maximum ROS, and optionally 4) the maximum potential spotting distance.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.ros*
*r.ros help*
*r.ros [-vs] model=name [moisture_1h=name] [moisture_10h=name] [moisture_100h=name] moisture_live=name [velocity=name] [direction=name] [slope=name] [aspect=name] [elevation=name] output=name*

**DESCRIPTION**
*r.ros* generates the base ROS value, maximum ROS value, direction of the maximum ROS, and optionally the maximum potential spotting distance of a wildfire for each raster cell in the current geographic region.

The calculation of the two ROS values for each raster cell is based on the Fortran code by Pat Andrews (1983 of the Northern Forest Fire Laboratory, USDA Forest Service.

The direction of the maximum ROS results from the vector addition of the forward ROS in wind direction and that in upslope direction.

The spotting distance, if required, will be calculated by a separate function spot_dist(), which is based on Lathrop and Xu (in preparation), Chase (1984) and Rothermel (1991).

These three or four raster map layers serve as inputs for another GRASS raster program *r.spread*. More information *on r.ros* and *r.spread* can be found in Xu (1994).

Flags:
-*v* Run verbosely, printing information about program progress to standard output.

-*s* Calculate the maximum potential spotting distance.

Parameters:
*model=name* Name of an existing raster map layer in the user's current mapset search path containing the standard fuel models defined by the USDA Forest Service. Valid values are 1-13; other numbers are recognized as barriers by *r.ros*.

*moisture_1h=name* Name of an existing raster map layer in the user's current mapset search path containing the 1-hour (<.25") fuel moisture (percentage content multiplied by 100).

*moisture_10h=name* Name of an existing raster map layer in the user's current mapset search path containing the 10-hour (.25-1") fuel moisture (percentage content multiplied by 100).

*moisture_100h=name* Name of an existing raster map layer in the user's current mapset search path containing the 100-hour (1-3") fuel moisture (percentage content multiplied by 100).

*moisture_live=name* Name of an existing raster map layer in the user's current mapset search path containing live (herbaceous) fuel moisture (percentage content multiplied by 100).

*velocity=name* Name of an existing raster map layer in the user's current mapset search path containing wind velocities at half of the average flame height (feet/minute).

*direction=name* Name of an existing raster map layer in the user's current mapset search path containing wind direction, clockwise from north (degree).

*slope=name* Name of an existing raster map layer in the user's current mapset search path containing topographic slope (degree).

*aspect=name* Name of an existing raster map layer in the user's current mapset search path containing topographic aspect, counter- clockwise from east (GRASS convention) (degree).

*elevation=name* Name of an existing raster map layer in the user's current mapset search path containing elevation (meters).

*output=name* Prefix of new raster map layers in the user's current mapset to contain 1) the base (perpendicular) ROS (cm/minute); 2) the maximum (forward) ROS (cm/minute), 3) the direction of the maximum ROS, clockwise from north (degree), and optionally 4) the maximum potential spotting distance (meters).

If 'my_ros' is given as the output name, then *r.ros* automatically assigns 'my_ros.base', 'my_ros.max', 'my_ros.maxdir', and optionally, 'my_ros.spotdist' as the names for the actual output map layers.

**OPTIONS**
*r.ros* can be run either non-interactively or interactively. The program is run interactively if the user types *r.ros* without specifying flag settings and parameter values on the command line. In this case, the user will be prompted for input.

The program will be run non-interactively if the user specifies the names of raster map layers and any desired options on the command line, using the form:

> *r.ros [-vs] model=name [moisture_1h=name] [moisture_10h=name] [moisture_100h=name] moisture_live=name [velocity=name] [direction=name] [slope=name] [aspect=name] [elevation=name] output=name*

If the options *moisture_1h=name*, *moisture_10h=name*, and *moisture_100h=name* are partially given, the program will assign values to the missing option using the formula: *moisture_100h = moisture_10h + 1 = moisture_1h + 2.*

However at least one of them should be given.

Options *velocity=name* and *direction=name* must be in pair, whether given or not. If none is given, the program will assume a no-wind condition.

Options *slope=name* and *aspect=name* must be in pair, whether given or not. If none is given, the program will assume a topographically flat condition.

Option *elevation=name* must be given if the *-s* option is used.

**EXAMPLE**
Assume we have inputs, the following generates ROSes and spotting distances:

*r.ros -vs model=fire_model moisture_1h=1hour_moisture moisture_live=live_moisture velocity=wind_speed direction=wind_direction slope=slope aspect=aspect elevation=elevation output=my_ros*

**NOTES**

1. *r.ros* is supposed to be run before running another GRASS program *r.spread*. The combination of the two forms a simulation of the spread of wildfires.

2. The inputs to *r.ros* should be in proper units.

3. The output units for the base and maximum ROSes are in cm/minute rather than ft/minute, which is due to that a possible zero ft/minute base ROS value and a positive integer ft/minute maximum ROS would result in calculation failure in the *r.spread* program.

4. The user needs to provide only ONE output name even the program actually generates THREE or FOUR map layers.

5. The rules for optional parameters must be followed.

**SEE ALSO**

*g.region r.mask r.slope.aspect, r.spread.*

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## *r.runoff*

**NAME**
*r.runoff* (G-language) Generates an SCS curve number runoff map layer. It is a command-line interface for generating the runoff map by the SCS method.

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.runoff rf=rainfall_map cn=cn_map ro=runoff_map*

**OPTIONS**
Parameters:
*rf=map* rainfall map name in mm

*cn=map* CN map name

*ro=map* output runoff map name in *100 mm

The command-line ordering can be in any form but all key words must be there to run the program.

**EXAMPLE**

```
r.runoff rf=rainfall_map cn=cn_map ro=runoff_map
```

will create a runoff map runoff_map

**NOTE**
The *r.runoff* program is sensitive to the current window setting. Thus the program can be used to generate a runoff map of any sub-area within the full map layer. Also, *r.runoff* is sensitive to any mask in effect.

**AUTHORS**
Raghavan Srinivasan and Dr. Bernie A. Engel, Agricultural Engineering Department, Purdue University

## *r.slope.aspect*

**NAME**
*r.slope.aspect* **-** Generates raster map layers of slope, aspect, curvatures, and partial derivatives from a raster map layer of true elevation values.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.slope.aspect*
*r.slope.aspect help*
*r.slope.aspect [-aqz] elevation=name [slope=name] [aspect=name] [format=name] [zfactor=value] [prec=name] [pcurv=name] [tcurv=name] [dx=name] [dy=name] [dxx=name] [dyy=name] [dxy=name] [min_slp_allowed=value]*

**DESCRIPTION**
*r.slope.aspect* generates raster map layers of slope, aspect, curvatures, and first and second order partial derivatives from a raster map layer of true elevation values. The user must specify the input elevation file name and at least one output file name to contain the slope or aspect data. The user can also specify the format for slope (degrees, percent; default=degrees), and zfactor: multiplicative factor to convert elevation units to meters; (default 1.0).

**OPTIONS**
The program will be run non-interactively if the user specifies program inputs and any desired options on the command line, using the form

*r.slope.aspect [-aq] elevation=name [slope=name] [aspect=name] [format=name] [zfactor=value] [prec=name] [pcurv=name] [tcurv=name] [dx=name] [dy=name] [dxx=name] [dyy=name] [dxy=name] [min_slp=value]*

If the user runs:
*r.slope.aspect*

without command line arguments, the program will prompt the user for flag settings and parameter values.

Flags:
-*a* Do not align the settings of the current geographic region (to which the output slope and aspect map layers will be set) to those of the elevation layer. See NOTES.

-*q* Run quietly, and suppress the printing of information on program operations during execution.

-*z* Assume that zero values in the elevation map layer represent true elevation values, not areas of "no data".

Parameters:

| | |
|---|---|
| *elevation=name* | Name of the raster map layer of true elevation values to be used as input. |
| *slope=name* | Name of a raster map layer of slope values created from the elevation map. |
| *aspect=name* | Name of a raster map layer of aspect values created from the elevation map. |

*format=name* Format for reporting the slope.
Options: degrees, percent
Default: degrees

*zfactor=value* Multiplicative factor to convert elevation units to meters.
Default: 1.0

*pcurv =name* Output profile curvature filename.

*tcurv =name* Output tangential curvature filename.

*dx=name* Output E-W slope filename.

*dy=name* Output N-S slope filename.

*dxx=name* Output partial derivative dxx filename.

*dyy=name* Output partial derivative dyy filename.

*dxy =name* Output partial derivative dxy filename.

*min_slp =value* Minimum slope value (in percent) for which aspect is computed.
Default: 0.0

*prec=name* Type of output aspect and slope maps.
Options: default, double, float, int

Resulting raster map layers of slope and aspect are named by the user and placed in the current mapset.

ELEVATION RASTER MAP
The raster elevation map layer specified by the user must contain true elevation values, not rescaled or categorized data.

ASPECT RASTER MAP
The raster aspect map layer which is created indicates the direction that slopes are facing. The aspect categories represent the number degrees of east and they increase in the counterclockwise direction: 90 = North, 180 = West, 270 = South, and 360 = East. Category and color table files are also generated for the aspect map layer.

SLOPE RASTER MAP
The resulting raster slope map layer will contain slope values, stated in degrees of inclination from the horizontal if format=degrees option (which is also default) is chosen, and in percent rise if format=percent option is chosen. The category file, but not the color table, is generated by *r.slope.aspect* for the raster slope map layer. Profile and tangential curvatures are the curvatures in the direction of steepest slope and in the direction of the contour tangent respectively.

For most applications, the user will wish to use a reclassified map layer of slope that groups slope values into ranges of slope. This can be done using *r.reclass*. An example of a useful reclassification is given below:

```
category        range      category labels
            (in degrees)     (in percent)

   1            0-1             0-2%
   2           2-3            3-5%
   3           4-5            6-10%
   4           6-8            11-15%
   5           9-11           16-20%
   6           12-14          21-25%
   7           15-90          26% and higher
```

The following color table works well with the above reclassification.

```
category       red   green   blue

   0           179    179    179
   1             0    102      0
   2             0    153      0
   3           128    153      0
   4           204    179      0
   5           128     51     51
   6           255      0      0
   7             0      0      0
```

**NOTES**
To ensure that the raster elevation map layer is not inappropriately resampled, the settings for the current region are modified slightly (for the execution of the program only): the resolution is set to match the resolution of the elevation map and the edges of the region (i.e. the north, south, east and west) are shifted, if necessary, to line up along edges of the nearest cells in the elevation map. If the user really wants the elevation map resampled to the current region resolution, the -*a* flag should be specified.

The current mask, if set, is ignored.

The algorithm used to determine slope and aspect uses a 3x3 neighborhood around each cell in the elevation file. Thus, it is not possible to determine slope and aspect for the cells adjacent to the edges in the elevation map layer. These cells are assigned a "no data" value (category 0) in both the slope and aspect raster map layers.

Because Horn's formula is used to find the derivatives in x and y directions, the aspect is biased in 0, 45, 90, 180, 225, 270, 315, and 360 directions; i.e., the distribution of aspect categories is very uneven, with peaks at 0, 45,..., 360 categories. Helena Mitasova of USACERL observed that most cells with a very small slope end up having category 0, 45,…, 360 it is sometimes possible to reduce bias in these directions by filtering out computation of aspect in areas where terrain is almost flat. The new option

*min_slp=value*

was added (minimum slope for which aspect is computed). The aspect for all cells with slope < min_slp is set to 0 (no value).

**WARNING**
The following may not be true anymore because of introduction of NULL, but it has not been tested.

Elevations of zero (as well as below sea level elevations) are valid. This means that areas assigned category value 0 may have one of two possible meanings: they may either be areas of "no data" or areas having 0 elevation. If the user wishes *r.slope.aspect* to assume that cells assigned category value zero in the elevation map layer represent true elevation values, not areas of "no data", the user should set the -*z* flag when running this program.

If the -*z* flag is not set and the raster map layer of true elevation contains areas of "no data" that are assigned to category 0, either at its edges or in its interior, incorrect (and usually quite large) slopes will result.

**SEE ALSO**
*r.mapcalc*, *r.neighbors*, *r.reclass*, *r.rescale*

**AUTHORS**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

Olga Waupotitsch, U.S. Army Construction Engineering Research Laboratory

## *r.spread*

**NAME**
*r.spread* **-** Simulates elliptically anisotropic spread on a graphics window and generates a raster map of the cumulative time of spread, given raster maps containing the rates of spread (ROS), the ROS directions and the spread origins.
(GRASS Raster/Display Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.spread*
*r.spread help*
*r.spread [-vds] max=name dir=name base=name start=name [spot_dist=name] [w_speed=name] [f_mois=name] [least_size=odds int] [comp_dens=decimal] [init_time=int (>=0)] [lag=int (>= 0)] [backdrop=name] output=name [x_output=name] [y_output=name]*

**DESCRIPTION**
Spread phenomena usually show uneven movement over space. Such unevenness is due to two reasons:
1) the uneven conditions from location to location, which can be called SPATIAL HETEROGENEITY, and 2) the uneven conditions in different directions, which can be called ANISOTROPY. The anisotropy of spread occurs when any of the determining factors have directional components. For example, wind and topography cause anisotropic spread of wildfires.

One of the simplest spatial heterogeneous and anisotropic spread is elliptical spread, in which, each local spread shape can be thought as an ellipse. In a raster setting, cell centers are foci of the spread ellipses, and the spread phenomenon moves fastest toward apogees and slowest to perigees. The sizes and shapes of spread ellipses may vary cell by cell. So the overall spread shape is commonly not an ellipse.

*r.spread* simulates elliptically anisotropic spread phenomena given three raster map layers about ROS base ROS, maximum ROS and direction of the maximum ROS plus a raster map layer showing the starting sources. These ROS layers define unique ellipses for all cell locations in the current geographic region as if each cell center was a potential spread origin. For some wildfire spread, these ROS layers can be generated by another GRASS raster program *r.ros*. The actual locations reached by a spread event are constrained by the actual spread origins and the elapsed spread time.

*r.spread* optionally produces raster maps to contain backlink UTM coordinates for each raster cell of the spread time map. The spread paths can be accurately traced based on the backlink information by another GRASS raster program *r.spreadpath*.

Part of the spotting function in *r.spread* is based on Chase (1984) and Rothermel (1983). More information on *r.spread*, *r.ros* and *r.spreadpath* can be found in Xu (1994).

Flags:
-*v* Run verbosely, printing information about program progress to standard output.

-*d* Display the "live" simulation on screen. A graphics window must be opened and selected before using this option.

-*s* For wildfires, also consider spotting.

Parameters:
*max=name* Name of an existing raster map layer in the user's current mapset search path containing the maximum ROS values (cm/minute).

*dir=name* Name of an existing raster map layer in the user's current mapset search path containing directions of the maximum ROSes, clockwise from north (degree).

*base=name* Name of an existing raster map layer in the user's current mapset search path containing the ROS values in the directions perpendicular to maximum ROSes' (cm/minute). These ROSes are also the ones without the effect of directional factors.

*start=name* Name of an existing raster map layer in the user's current mapset search path containing starting locations of the spread phenomenon. Any positive integers in this map are recognized as starting sources.

*spot_dist=name* Name of an existing raster map layer in the user's current mapset search path containing the maximum potential spotting distances (meters).

*w_speed=name* Name of an existing raster map layer in the user's current mapset search path containing wind velocities at half of the average flame height (feet/minute).

*f_mois=name* Name of an existing raster map layer in the user's current mapset search path containing the 1-hour (<.25") fuel moisture (percentage content multiplied by 100).

*least_size=odd int* An odd integer ranging 3 - 15 indicating the basic sampling window size within which all cells will be considered to see whether they will be reached by the current spread cell. The default number is 3 which means a 3x3 window.

*comp_dens=decimal* A decimal number ranging 0.0 - 1.0 indicating additional sampling cells will be considered to see whether they will be reached by the current spread cell. The closer to 1.0 the decimal number is, the longer the program will run and the higher the simulation accuracy will be. The default number is 0.5.

*init_time=int* A non-negative number specifying the initial time for the current spread simulation (minutes). This is useful when multiple phase simulation is conducted. The default time is 0.

*lag=int* A non-negative integer specifying the simulating duration time lag (minutes). The default is infinite, but the program will terminate when the current geographic region/mask has been filled. It also controls the computational time, the shorter the time lag, the faster the program will run.

*backdrop=name* Name of an existing raster map layer in the user's current mapset search path to be used as the background on which the "live" movement will be shown.

*output=name* Name of the new raster map layer to contain the results of the cumulative spread time needed for a phenomenon to reach each cell from the starting sources (minutes).

*x_output=name* Name of the new raster map layer to contain the results of backlink information in UTM easting coordinates for each cell.

*y_output=name* Name of the new raster map layer to contain the results of backlink information in UTM northing coordinates for each cell.

**OPTIONS**
The user can run *r.spread* either interactively or non-interactively. The program is run interactively if the user types *r.spread* without specifying flag settings and parameter values on the command line. In this case, the user will be prompted for input.

Alternately, the user can run *r.spread* non-interactively, by specifying the names of raster map layers and desired options on the command line, using the form:

> *r.spread [-vds] max=name dir=name base=name start=name [spot_dist=name] [w_speed=name] [f_mois=name] [least_size=odds int] [comp_dens=decimal] [init_time=int (>=0)] [lag=int (>= 0)] [backdrop=name] output=name [x_output=name] [y_output=name]*

The *-d* option can only be used after a graphics window is opened and selected.

Options *spot_dist=name*, *w_speed=name* and *f_mois=name* must all be given if the *-s* option is used.

**EXAMPLE**
Assume we have inputs, the following simulates a spotting-involved wildfire on the graphics window and generates three raster maps to contain spread time, backlink information in UTM northing and easting coordinates:

> *r.spread -ds max=my_ros.max dir=my_ros.maxdir base=my_ros.base start=fire_origin spot_dist=my_ros.spotdist w_speed=wind_speed f_mois=1hour_moisture backdrop=image_burned output=my_spread x_output=my_spread.x y_output=my_spread.y*

**NOTES**
1. *r.spread* is a specific implementation of the shortest path algorithm. *r.cost* GRASS program served as the starting point for the development of *r.spread*. One of the major differences between the two programs is that *r.cost* only simulates ISOTROPIC spread while *r.spread* can simulate ELLIPTICALLY ANISOTROPIC spread, including isotropic spread as a special case.

2. Before running *r.spread*, the user should prepare the ROS (base, max and direction) maps using appropriate models. For some wildfire spread, a separate GRASS program *r.ros* based on Rothermel's fire equation does such work. The combination of the two forms a simulation of wildfire spread.

3. The relationship of the start map and ROS maps should be logically correct, i.e. a starting source (a positive value in the start map) should not be located in a spread BARRIER (zero value in the ROS maps). Otherwise the program refuses to run.

4. *r.spread* uses the current geographic region settings. The output map layer will not go outside the boundaries set in the region, and will not be influenced by starting sources outside. So any change of the current region may influence the output. The recommendation is to use slightly larger region than needed. Refer to *g.region* to set an appropriate geographic region.

5. The inputs to *r.spread* should be in proper units.

6. *r.spread* is a computationally intensive program. The user may need to choose appropriate size of the geographic region and resolution.

7. A low and medium (i.e. <= 0.5) sampling density can improve accuracy for elliptical simulation significantly, without adding significantly extra running time. Further increasing the sample density will not gain much accuracy while requiring greatly additional running time.

**SEE ALSO**
*g.region, r.cost, r.mask, r.spreadpath, r.ros.*

**REFERENCES**

Chase, Carolyn, H., 1984, Spotting distance from wind-driven surface fires -- extensions of equations for pocket calculators, US Forest Service, Res. Note INT-346, Ogden, Utah.

Rothermel, R. C., 1983, How to predict the spread and intensity of forest and range fires. US Forest Service, Gen. Tech. Rep. INT-143. Ogden, Utah.

Xu, Jianping, 1994, Simulating the spread of wildfires using a geographic information system and remote sensing, Ph. D. Dissertation, Rutgers University, New Brunswick, New Jersey.

**AUTHOR**

Jianping Xu and Richard G. Lathrop, Jr., Center for Remote Sensing and Spatial Analysis, Rutgers University.

## *r.spreadpath*

**NAME**
*r.spreadpath* **-** Recursively traces the least cost path backwards to cells from which the cumulative cost was determined.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.spreadpath*
*r.spreadpath help*
*r.spreadpath [-v] x_input=name y_output=name [coordinate=x,y[x,y,...]] output=name*

**DESCRIPTION**
*r.spreadpath* recursively traces the least cost path backwards to the origin, given backlink information input map layers and target locations from where paths are to be traced. The backlink information map layers record each cell's backlink UTM northing (the y_input) and easting (the x_input) coordinates from which the cell's cumulative cost was determined.

The backlink inputs can be generated from another GRASS raster program *r.spread*. One of the major applications of *r.spreadpath* along with *r.spread* is to accurately find the least cost corridors and/or paths on a raster setting. More information on *r.spread* and *r.spreadpath* can be found in Xu (1994).

Flags:

| | |
|---|---|
| -*v* | Run verbosely. |

Parameters:

*x_input=name* Name of input raster map layer containing backlink UTM easting coordinates.

*y_input=name* Name of input raster map layer containing backlink UTM northing coordinates.

*coordinate=x,y[,x,y,x,y, ...]* Each x, y coordinate pair gives the easting and northing (respectively) geographic coordinates of a target point from which to backwards trace the least cost path. As many points as desired can be entered by the user.

*output=name* Name of raster map layer to contain output. Also can be used as the map layer of the input target points. If so used the input target point map will be overwritten by the output.

**OPTIONS**
The user can run *r.spread* either interactively or non- interactively. The program is run interactively if the user types *r.spreadpath* without specifying flag setting and parameter values on the command line. In this case, the user will be prompted for input.

Alternately, the user can run *r.spreadpath* non-interactively, by specifying the names of raster map layers and desired options on the command line, using the form:

*r.spreadpath [-v] x_input=name y_output=name [coordinate=x,y[x,y,...]] output=name*

**SEE ALSO**
*r.spread.*

**REFERENCE**

Xu, Jianping, 1994, Simulating the spread of wildfires using a geographic information system and remote sensing, Ph. D. Dissertation, Rutgers University, New Brunswick, New Jersey.

**AUTHOR**

Jianping Xu and Richard G. Lathrop, Jr., Center for Remote Sensing and Spatial Analysis, Rutgers University.

## *r.stage3*

**NAME**
*r.stage3* **-** NEXRAD weather radar input tool
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.stage3 [-v] input=name [output=name]*

**DESCRIPTION**
A Stage III precipitation product is a mosaic of all the Stage II precipitation estimates within the RFC (River Forecast Center) area. The Stage III products are produced by merging radar precipitation estimates (Stage I) with ground truth data provided by rain gages. In the Arkansas-red River Forecast Center (ABRFC) this includes 15 88-D radars and approximately 500 rain gages. The 13 RFC's within the United States will eventually produce Stage III products. As of 4-94 the ABRFC is the only RFC currently producing Stage III products. As more radars come on line other RFC's will begin producing this product as well. The 88-D radars have difficulty detecting precipitation when the raindrops are very small or when the precipitation is in the form of snow. Under these conditions precipitation estimates tend to be under estimated. Large Hail within a storm causes the radar to over estimate precipitation amounts. The grid cell size is approximately 4 km by 4 km. The NetCDF files containing the precipitation values in the units of 1/100 of mm can be obtained from ABRFC's gopher server. *r.stage3* program generates the GRASS raster map layers only in the Lat/Lon coordinate system. UTM is not utilized because the area being referenced is too large for a UTM zone. The region settings for the ABRFC's coverage area is:

```
__________________________________________
projection: 3 (Latitude-Longitude)
zone:  0
north: 41:16:06N
south: 32:48:28N
east:  90:53:28W
west:  107:08:03W
__________________________________________
```

You may use the clark66 spheroid and use any resolution that may be suitable as far as your other data requirements are concerned. (start with esres= nsres = 0:00:30).

This version of *r.stage3* will work only on NetCDF files created after the 6th of April 1994.

You will need the NetCDF libraries created by the Unidata Program Center. The NetCDF libraries can be obtained via anonymous ftp from unidata.ucar.edu under pub/netcdf/netcdf.tar.Z. You will the need to compile the libraries. *r.stage3* can be only run within GRASS. *r.stage3* needs both the NetCDF libraries as well as the GRASS libraries. If you have all the libraries then *r.stage3* can be compiled simply by running "gmake" (For GRASS 4.2 it is gmake4.2) in this directory.

In the above, if the output parameter is not specified then a mapname with the same name as that of the input parameter is created. The rainbow colortable is created for the resultant map. The resulting maps have a resolution of 0:02:59.

A few sample NetCDF files and the corresponding GIF files are provided in the sample directory. The vector directory contains the vector boundary output from the command *v.out.ascii* of the ABRFC basin.

To run *r.stage3* on the sample files just go into the sample directory and type:

```
r.stage3 -v in=04059418.nc
```

This will create a raster map by the name 04059418.nc. Similarly *r.stage3* can be run on other sample files. You can use the corresponding GIF files to compare them. Since the GIF files are in a different projection system, there is some distortion in between the raster maps and the GIF file. However the values in the raster are properly georeferenced.

**OPTIONS**

Flags:

| | |
|---|---|
| -*v* | Verbose |

Parameters:

| | |
|---|---|
| *input = name* | Name of the netcdf file to be converted |
| *output = name* | Name of the resultant raster map |

**AUTHORS**

Nalneesh Gaur, Arkansas Red Basin River Forecast Center
Norman L. Bingham, Arkansas Red Basin River Forecast Center

## *r.stats*

**NAME**
*r.stats* **-** Generates area statistics for raster map layers.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.stats*
*r.stats help*
*r.stats [-1aclmqzgxnNCri] input=name[,name,...] [fs=character|space] [output=name]*

**DESCRIPTION**
*r.stats* calculates the area present in each of the categories of user-selected raster map layer(s). Area statistics are given in units of square meters and/or cell counts. This analysis uses the current geographic region and mask settings. Output can be sent to a file in the user's current working directory.

The program will be run non-interactively if the user specifies the program arguments and desired options on the command line, using the form

*r.stats [-1aclmqzgxnNCri] input=name[,name,...][fs=character|space] [output=name]*

where each input name is the name of a raster map layer on which area/cell statistics are to be generated, the (optional) output name is the name of a file to contain program output (sent to the user's current working directory), the fs character or space is the field separator to be used to separate data fields in the output file (default is a space if unspecified), and the (optional) flags *-1, -a, -c, -l, -m, -q, -z, -g, -x, -n, -N, -C, -r*, and *-i* have the meanings described in the OPTIONS section.

Alternately, the user can simply type *r.stats* on the command line, without program arguments. In this case, the user will be prompted for needed inputs and option choices using the standard GRASS *parser* interface described in the manual entry for *parser*.

**OPTIONS**
Flags:
*-1* The data for each cell in the current geographic region will be output, one cell per line, rather than the totals for each distinct combination.

*-a* Print area totals in square meters.

*-c* Print total cell counts.

*-m* Report all zero values present in the input map layer(s), whether or not they fall inside or outside the current mask (see *r.mask*). When a mask is present, *r.stats* will only report zero values falling within the mask area unless the user runs *r.stats* with the *-m* option. When the user runs *r.stats* with the *-m* option, *r.stats* will report zero values falling outside the mask area, in addition to those within the mask.

*-l* Prints the category label(s) as well as the category number(s).

*-q* Run quietly, and suppress printing of percent complete messages to standard output.

*-z* Report only non-zero data values. Zero data will not be reported. However, for multiple map layers this means that if zero values occur in every map layer, they will not be reported; if non-zero category values occur in any map layer (along with zeros in others), the non-zero values along with the zero values will be reported.

*-g* Print the grid coordinates (easting and northing), for each cell. This option works only if the *-1* option is also specified.

*-x* Print the x and y (column and row) values, for each cell. This option works only if the *-1* option is also specified.

*-n* Suppress reporting of any nulls.

*-N* Suppress reporting of nulls when all values are null.

*-C* Report for cats fp ranges (fp maps only).

*-r* Print raw indexes of fp ranges (fp maps only).

*-i* Read fp map as integer (use map's quant rule).

Parameters:
*input=name* The name(s) of one or more existing raster map layer(s) whose cell counts or area statistics are to be calculated.

*fs=character* or *fs=space* The field separator (fs) to be used to separate data fields in the output file.
Options: a character or space
Default: a space

*output=name* The name to be assigned to the ASCII output file.

NON-INTERACTIVE PROGRAM USE
If users invoke program options on the command line, *r.stats* will print out area statistics for the user-specified raster map layers in a columnar format suitable for input to UNIX programs like awk and sed. Output can be saved by specifying the name of an output file on the command line.

If a single map layer is specified on the command line, a list of areas in square meters (assuming the map's coordinate system is in meters) for each category in the raster map layer will be printed. (If the *-c* option is chosen, areas will be stated in number of cells). If multiple raster map layers are specified on the command line, a cross-tabulation table of areas for each combination of categories in the map layers will be printed.

For example, if one raster map layer were specified, the output would look like:

```
1:1350000.00
2:4940000.00
3:8870000.00
```

If three raster map layers a, b, and c, were specified, the output would look like:

```
0:0:0:8027500.00
0:1:0:1152500.00
1:0:0:164227500.00
1:0:1:2177500.00
1:1:0:140092500.00
```

```
1:1:1:3355000.00
2:0:0:31277500.00
2:0:1:2490000.00
2:1:0:24207500.00
2:1:1:1752500.00
3:0:0:17140000.00
3:1:0:11270000.00
3:1:1:2500.00
```

Within each grouping, the first field represents the category value of map layer a, the second represents the category values associated with map layer b, the third represents category values for map layer c, and the last field gives the area in square meters for the particular combination of these three map layers' categories. For example, above, combination 3,1,1 covered 2500 square meters. Fields are separated by colons.

**NOTES**
*r.stats* works in the current geographic region with the current mask.

If a nicely formatted output is desired, pipe the output into a command which can create columnar output. For example, the command:

*r.stats input=a,b,c | pr -3 | cat -s*

will create a three-column output

```
1:4:4:10000.00     2:1:5:290000.00    2:4:5:2090000.00
1:4:5:1340000.00   2:2:5:350000.00    3:1:2:450000.00
2:1:1:1090000.00   2:4:1:700000.00    3:1:3:5280000.00
2:1:3:410000.00    2:4:3:10000.00     3:1:5:3140000.00
```

The output from *r.stats* on more than one map layer is sorted.

Note that the user has only the option of printing out cell statistics in terms of cell counts and/or area totals. Users wishing to use different units than are available here should use the GRASS program *r.report*.

**SEE ALSO**
*g.region, r.coin, r.describe, r.mask, r.report, parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.sun*

**NAME**
*r.sun* **-** computes solar rays incidence angle raster maps for given time and latitude, and amount of direct solar energy raster maps for given day and latitude from elevation, slope and aspect raster files. The shading effect of surrounding terrain is incorporated.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.sun*
*r.sun help*
*r.sun [-s] elevin = name [zmul=valt] aspin = name slopein = name [incidout =name] [energyout = name] latitude dej [lum_time]*

**DESCRIPTION**
The *r.sun* program computes solar rays incidence angle raster map incidout for given day *dej*, time *lum_time* and latitude and amount of direct solar energy energyout for a given day *dej* and latitude from elevation *elevin*, slope *slopein* and aspect *aspin* raster files. If elevations in the raster elevation map elevin are in different units than the mapset coordinate system, a multiplier *zmult* must be used. For instance, if elevations are in centimeters and x, y coordinates in meters, you should use *zmult = 100*. Specified day *dej* is the number where January 1 is day no.1 and December 31 is 365 (366). Time lum_time must be a local time in decimal system, e.g. 7.5 (i.e. 7h 30m). Latitude must be also in decimal system and has positive values for northern hemisphere and negative for southern one. Incidence angle is angle between normal vector of given surface and solar ray vector. Output incidence angles are in degrees. Amount of direct solar energy for given day is computed integrating the incidence angle between sunrise and sunset times. Ouput is in kW per squared meter. The incidence angle and amount of direct solar energy can be computed without shading influence of surrounding terrain by default, they can be computed incorporating this influence using the flag *-s*. In hilly areas this can lead to very different results! A declination is computed internally using Cooper's approximation for each day and energy input using solar constant 1370 kW per squared meter. It is possible to compute an amount of direct solar energy for some time interval during the year (e.g. a vegetation period). This can be done using a shell script. Elevation, aspect and slope input values should not be reclassified into coarser categories. This could lead to incorrect results.

**OPTIONS**
The user can run this program either interactively or non-interactively. The program will be run non-interactively if the user specifies program arguments and flag settings on the command line using the form:

> *r.sun [-s] elevin = name [zmult = val] aspin = name slopein = name [incidout = name] [energyout = name] latitude = val dej = val [lum_time= val]*

Alternately, the user can simply type *r.sun* on the command line without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS *parser* interface.

Flags:

| | |
|---|---|
| *[-s]* | Incorporates shading effect of terrain (default not) |

Parameters:

| | |
|---|---|
| *elevin=name* | Use the existing raster file with elevationsname as input. |

| | |
|---|---|
| *zmult=val* | Set a multiplier for elevations to val. |
| *aspin=name* | Use the existing raster file with aspectname as input. |
| *slopein=name* | Use the existing raster file with slopename as input. |
| *incidout=name* | Output solar rays incidence angle values to raster file named name. |
| *energyout=name* | Output direct solar energy values to raster file named name. |
| *latitude=val* | Set the value of latitude of given region to val. |
| *dej=val* | Set the serial number of day to val. |
| *lum_time=val* | Set the decimal value of time to val. |

**NOTES**
Solar energy is important input parameter in different models concerning landscape, vegetation, evapotranspiration, snowmelt or remote sensing. Solar rays incidence angle can be effectively used in radiometric corrections in hilly terrain where very precise investigations are performed. Incidence angle multiplied by solar constant (here is used 1370 kW per squared meter) gives irradiance which can be computed using *r.mapcalc*.

**SEE ALSO**
*s.surf.tps, r.slope.aspect*

**REFERENCES**
Mitasova, H. and Hofierka, J. (1993): Interpolation by Regularized Spline with Tension: II. Application to Terrain Modeling and Surface Geometry Analysis. Mathematical Geology (in press).
Jenco, M. (1992): Distribution of direct solar radiation on georelief and its modelling by means of complex digital model of terrain. Geograficky casopis 44, 1992, pp.342-355.(in Slovak)

**AUTHOR**
Original version of the program :
Jaroslav Hofierka and Maros Zlocha, Comenius University, Bratislava, Slovakia,

Modified program (adapted for GRASS):
Jaroslav Hofierka, Comenius University, Slovakia

# *r.support*

**NAME**
*r.support* **-** Allows the user to create and/or modify raster map layer support files.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.support*

**DESCRIPTION**
The GRASS program *r.support* allows the user to create and/or modify raster map layer support files. It may be run only on raster map layers in the user's current mapset.

No non-interactive version of this program currently exists; the user runs the program by typing *r.support*, and will be queried for inputs.

Various GRASS programs depend on one or more of the following GRASS support files:

cellhd The cell header file contains information on a map's projection, zone, regional boundaries, row and column totals, cell resolution, storage format, and compression. It describes where and how this map's raster (cell) data fits in with reference to other raster map layers' data. Without it, the raster map layer could not be displayed or analyzed properly. Using *r.support*, the user can change the # of columns, # of bytes per cell, and default geographic region settings. Generally, users would not change this information. Cell header files are stored under the cellhd directory under the user's current mapset.

stats Raster map layer statistics are saved in the form of a histogram and range of the category values which occur in the map layer. Statistics files are stored in subdirectories of the cell_misc directory under the user's current mapset.

cats A category file associates each category value in the raster map layer with a category description (label). The user may add or edit the category descriptions, alter the number of categories, and add or alter the map's title. Category files associated with raster map layers are stored under the cats directory in the user's current mapset.

colr A color file associates each category value in the raster map layer with a color. Using *r.support*, the user may assign one of eight color table types to the raster map layer. Map color table files are stored under the colr and colr2 directories under the user's current mapset.

hist Historical information about the raster map layer is stored in a history file. The user may add or edit the raster map's title, data type, data source, data description, and include comments. (Note that the specification of map data type here is somewhat archaic, and should always be set to raster.) Map history files are stored under the hist directory under the user's current mapset.

**NOTES**
The *r.support* program attempts to verify that the information in the cell header is reasonable. The data format specified in the header is verified against the raster map layer itself. This includes checking that files which the header indicates are compressed are really compressed, and that the number of rows and columns specified in the header correspond to the actual file size.

The *r.support* program can also be used to determine the number of columns and rows of data in a raster map layer, in the event that no cell header is available. This is useful, for example, for importing raster map layers created by software other than GRASS.

If the file is not compressed, the file size should be the product of the number of rows and columns. If the file is compressed, this test cannot be performed since the file size will bear no relation to the product. The number of rows can still be verified, but the number of columns cannot.

To compute or correct the stats, the cell header must be correct, since the raster map layer is read to determine the stats.

If a new cats or colr (or colr2) file is required, the stats must be correct.

The user is allowed to change the number of categories specified in the category file. This should only be done if the user knows that the maximum category value in the raster map layer is different than that which is recorded in the category file. Changing the category value in the cats file allows the user to add more category labels, or to remove labels. It does NOT change the category values in the raster map layer itself.

The color file is unique among GRASS support files. While it is necessary to protect a user's original data from being modified by users working under other mapsets, these users need to be able to create color tables for maps that are stored under mapsets other than their own. Color table files meet both these objectives.

Color table files get stored in one of two directories, both under the user's current mapset. The color files created by a user for raster maps stored under that user's current mapset get stored in the directory $LOCATION/colr and cannot be modified or removed by other users. The color table files that the user modifies/creates for raster map layers not stored under the user's current mapset get stored in a secondary color file under the user's mapset. This secondary color table is stored under $LOCATION/colr2/<mapset> where <mapset> is the name of the mapset under which the raster map data are stored. In versions of GRASS prior to 3.0, this was also the case for color tables in the user's own mapset. Now, however, if a user modifies a color table associated with a raster map layer in his own current mapset, these changes will be made to the user's original color file (i.e., the user's color changes will overwrite whatever previous color table file existed for this map under the user's $LOCATION/colr directory). No secondary color files are created for raster map layers stored in the users own mapset.

**WARNING**
In order to modify the cell header, the raster (cell) map layer under consideration must not be a reclass file. This is because the reclass file's header does not contain positional information, but rather a reference to another raster map layer. Thus it shares a cell header with the referenced raster map layer. In order to change the cell header, *r.support* must be run on the true raster file referenced.

**SEE ALSO**
For more information regarding the location and function of GRASS support files consult the GRASS Programmer's Manual chapter on GRASS Database Structure

*d.colors, r.colors, r.reclass*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.surf.contour*

**NAME**
*r.surf.contour* **-** Surface generation program.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.surf.contour*
*r.surf.contour help*
*r.surf.contour [-f] input=name output=name*

**DESCRIPTION**
*r.surf.*contour creates a raster elevation map from a rasterized contour map. Elevation values are determined using procedures similar to a manual methods. To determine the elevation of a point on a contour map, an individual might interpolate its value from those of the two nearest contour lines (uphill and downhill).

*r.surf.*contour works in a similar way. Initially, a vector map of the contour lines is made with the elevation of each line as its label (see *v.digit*). When the program *v.to.rast* is run on the vector map, continuous "lines" of rasters containing the contour line values will be the input for *r.surf.contour*. For each cell in the input map, either the cell is a contour line cell (which is given that value), or a flood fill is generated from that spot until the fill comes to two unique values. The flood fill is not allowed to cross over the rasterized contour lines, thus ensuring that an uphill and downhill contour value will be the two values chosen. *r.surf.contour* interpolates from the uphill and downhill values by the true distance.

The program will be run non-interactively if the user specifies the program parameter values and desired flag settings on the command line, using the form:

*r.surf.contour [-f] input=name output=name*

Alternately, the user can simply type *r.surf.contour* on the command line, without program arguments. In this case, the user will be prompted for needed inputs and option choices using the standard GRASS user interface described in the manual entry for *parser*.

Flag:
*-f* Invoke fast, but memory-intensive program operation.

Parameters:
*input=name* Name of an existing raster map layer that contains a set of initial category values (i.e., some cells contain known category values (denoting contours) while the rest contain zeros (0)).

*output=name* Name to be assigned to new output raster map layer that represents a smooth (e.g., elevation) surface generated from the known category values in the input raster map layer.

**NOTES**
*r.surf.contour* works well under the following circumstances:1) the contour lines extend to the edge of the current region, 2) the program is run at the same resolution as that of the input map, 3) there are no disjointed contour lines, and 4) no spot elevation data BETWEEN contour lines exist. Spot elevations at the tops of hills and the bottoms of depressions, on the other hand, improve the output greatly. Violating

these constraints will cause non-intuitive anomalies to appear in the output map.  Run *r.slope.aspect* on *r.surf.contour* results to locate potential anomalies.

The running of *r.surf.contour* is very sensitive to the resolution of rasterized vector map.  If multiple contour lines go through the same raster, slight anomalies may occur.  The speed of *r.surf.contour* is dependent on how far "apart" the contour lines are from each other (as measured in rasters).  Since a flood fill algorithm is used, the program's running time will grow exponentially with the distance between contour lines.

**SEE ALSO**
*r.surf.idw, r.surf.idw2, s.surf.idw, v.digit, v.to.rast, r.slope.aspect, parser*

**AUTHOR**
Chuck Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory

## *r.surf.fractal*

**NAME**
*r.surf.fractal* **-** GRASS module to create a fractal surface of a given fractal dimension. Uses spectral synthesis method. Can create intermediate layers showing the build up of different spectral coefficients (see Saupe, pp.106-107 for an example of this).

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.surf.fractal out=name [d=value] [n=value]*

**OPTIONS**
Parameters:

| | |
|---|---|
| *out* | Name of fractal surface raster layer to be produced |
| *d Fractal* | Dimension of surface (2 < D < 3)<br>Default: 2.05 |
| *n* | Number of intermediate images to produce<br>Default: 0 |

**SEE ALSO**
*r.mask, r.surf.contour, r.surf.idw, s.surf.idw, s.surf.tps, r.surf.gauss, r.surf.random, r.surf.idw2, v.surf.spline, parser*

**REFERENCE**
Saupe, D. (1988) Algorithms for random fractals, in Barnsley M., Devaney R., Mandelbrot B., Peitgen, H-O., Saupe D., and Voss R. (1988) The Science of Fractal Images, Ch. 2, pp.71-136. London: Springer-Verlag.

**AUTHOR**
Jo Wood

## *r.surf.gauss*

**NAME**
*r.surf.gauss* **-** GRASS module to produce a raster map layer of gaussian deviates whose mean and standard deviation can be expressed by the user. It uses a gaussian random number generator from Press, Flannery, Teukolsky and Vetterling (1988) **-** Numerical Recipes in C.

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.surf.gauss out=name [mean=value] [sigma=value]*

Parameters:
*out*    Name of fractal surface raster layer

*mean*    Distribution mean
  Default: 0.0

*sigma*    Standard deviation
  Default: 1.0

**SEE ALSO**
*r.mask, r.surf.contour, r.surf.idw, s.surf.idw, s.surf.tps, r.surf.fractal, r.surf.random, r.surf.idw2, v.surf.spline, parser*

**AUTHOR**
Jo Wood

## *r.surf.idw*

**NAME**
*r.surf.idw* **-** Surface interpolation utility for raster map layers.

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.surf.idw [-e] input=name output=name [npoints=value]*

**DESCRIPTION**
*r.surf.idw* fills a grid cell (raster) matrix with interpolated values generated from a set of input layer data points. It uses a numerical approximation technique based on distance squared weighting of the values of nearest data points. The number of nearest data points used to determine the interpolated value of a cell can be specified by the user (default: 12 nearest data points).

If there is a current working mask, it applies to the output raster file. Only those cells falling within the mask will be assigned interpolated values. The search procedure for the selection of nearest neighboring points will consider all input data, without regard to the mask.

The command line input is as follows:

Flag:
-*e*    Error analysis option that interpolates values only for those cells of the input raster map which have non-zero values and outputs the difference (see NOTES below).

Parameters:
*input=name*    Name of an input raster map layer containing an incomplete set of data values. (i.e., some grid cells contain known data values while the rest contain zero (0)).

*output=name*    Name to be assigned to new output raster map that represents the surface generated from the known data values in the input layer.

*npoints=value*    Number of nearest data points used to determine the interpolated value of an output raster cell.
  Default: 12

**NOTES**
*r.surf.idw* is a surface generation utility which uses inverse distance squared weighting (as described in Applied Geostatistics by E. H. Isaaks and R. M. Srivastava, Oxford University Press, 1989) to assign interpolated values. The implementation includes a customized data structure somewhat akin to a sparse matrix which enhances the efficiency with which nearest data points are selected. For latitude/longitude projections, distances are calculated from point to point along a geodesic.

Unlike *r.surf.idw2*, which processes all input data points in each interpolation cycle, *r.surf.idw* attempts to minimize the number of input data for which distances must be calculated. Execution speed is therefore a function of the search effort, and does not increase appreciably with the number of input data points.

*r.surf.idw* will generally outperform *r.surf.idw2* except when the input data layer contains few non-zero data, i.e. when the cost of the search exceeds the cost of the additional distance calculations performed by *r.surf.idw2*. The relative performance of these utilities will depend on the comparative speed of boolean, integer and floating point operations on a particular platform.

Worst case search performance by *r.surf.idw* occurs when the interpolated cell is located outside of the region in which input data are distributed. It therefore behooves the user to employ a mask when geographic region boundaries include large areas outside the general extent of the input data.

The degree of smoothing produced by the interpolation will increase relative to the number of nearest data points considered. The utility may be used with regularly or irregularly spaced input data. However, the output result for the former may include unacceptable nonconformities in the surface pattern.

The **-***e* flag option provides a standard surface-generation error analysis facility. It produces an output raster map of the difference of interpolated values minus input values for those cells whose input data are non-zero. For each interpolation cycle, the known value of the cell under consideration is ignored, and the remaining input values are used to interpolate a result. The output raster map may be compared to the input raster map to analyze the distribution of interpolation error. This procedure may be helpful in choosing the number of nearest neighbors considered for surface generation.

**SEE ALSO**
*r.surf.contour, r.surf.idw2, s.surf.idw, parser*

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# *r.surf.idw2*

**NAME**
*r.surf.idw2* **-** Surface generation program.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.surf.idw2 input=name output=name [npoints=count]*

**DESCRIPTION**
*r.surf.idw2* fills a raster matrix with interpolated values generated from a set of irregularly spaced data points using numerical approximation (weighted averaging) techniques. The interpolated value of a cell is determined by values of nearby data points and the distance of the cell from those input points. In comparison with other methods, numerical approximation allows representation of more complex surfaces (particularly those with anomalous features), restricts the spatial influence of any errors, and generates the interpolated surface from the data points. It is the most appropriate method to apply to most spatial data.

The program will be run non-interactively if the user specifies the values of needed program parameters and any desired optional parameter values on the command line, using the form:

*r.surf.idw2 input=name output=name [npoints=count]*

Alternately, the user can simply type *r.surf.idw2* on the command line, without program arguments. In this case, the user will be prompted for parameter values using the standard GRASS user interface described in the manual entry for *parser*.

Parameters:
*input=name* Name of an input raster map layer that contains a set of irregularly spaced data values; i.e., some cells contain known data values while the rest contain zero (0).

*output=name* Name to be assigned to the new output raster map layer containing a smooth surface generated from the known data values in the input map layer.

*npoints=count* The number of points to use for interpolation. The default is to use the 12 nearest points when interpolating the value for a particular cell.
Default: 12

**NOTES**
The amount of memory used by this program is related to the number of non-zero data values in the input map layer. If the input raster map layer is very dense (i.e., contains many non-zero data points), the program may not be able to get all the memory it needs from the system. The time required to execute increases with the number of input data points.

If the user has a mask set, then interpolation is only done for those cells that fall within the mask. However, all non-zero data points in the input layer are used even if they fall outside the mask.

This program does not work with latitude/longitude data bases. Another surface generation program, named *r.surf.idw*, should be used with latitude/longitude data bases.

The user should refer to the manual entries for *r.surf.idw*, *r.surf.contour*, and *s.surf.idw* to compare this surface generation program with others available in GRASS.

**SEE ALSO**
*r.mask*, *r.surf.contour*, *r.surf.idw*, *s.surf.idw*, *parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.surf.random*

**NAME**
*r.surf.random* **-** GRASS module to produce a raster map layer of uniform random deviates whose range can be expressed by the user. It uses the random number generator described in Press, Flannery, Teukolsky and Vetterling (1988) **-** Numerical Recipes in C.

**GRASS VERSION**
4.x,5.x

**SYNOPSIS**
*r.surf.random out=name [min=value] [max=value]*

**OPTIONS**
Parameters:

| | |
|---|---|
| *out* | Name of random surface raster layer to be produced |
| *min* | Minimum random value<br>Default: 0 |
| *max* | Maximum random value<br>Default: 100 |

**SEE ALSO**
*r.mask, r.surf.contour, r.surf.idw, s.surf.idw, s.surf.tps, r.surf.gauss, r.surf.fractal, r.surf.idw2, v.surf.spline, parser*

## *r.surf.xy*

**NAME**
*r.surf.xy* **-** GRASS module to produce two raster maps for use with *r.mapcalc*. One file contains the x-coordinates of each raster map cell, the other, the y-coordinates.

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.surf.xy x=name y=name*

**OPTIONS**
Parameters:

| | |
|---|---|
| x | Name of the new raster map layer to hold x coordinate values |
| y | Name of the new raster map layer to hold y coordinate values |

These two cell files can be used to produce mathematical functions in the form:

z = fn(x,y)

This is required as *r.mapcalc* does not provide variables that hold the current x and y coordinates of the moving window. Use these maps in calculations that are coordinate dependent.

**NOTE**
x and y values are in RELATIVE coordinates to an origin of (0,0) at the bottom left corner. To transform back to georeferenced coordinates use r.mapcalc to add the relative offset to the origin.

**SEE ALSO**
*r.mapcalc*

# *r.thin*

**NAME**
*r.thin* **-** Thins non-zero cells that denote linear features in a raster map layer.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.thin*
*r.thin help*
*r.thin input=name output=name*

**DESCRIPTION**
*r.thin* scans the named input raster map layer and thins non-zero cells that denote linear features into linear features having a single cell width.

*r.thin* will thin only the non-zero cells of the named input raster map layer within the current geographic region settings. The cell width of the thinned output raster map layer will be equal to the cell resolution of the currently set geographic region. All of the thinned linear features will have the width of a single cell.

*r.thin* will create a new output raster data file containing the thinned linear features. *r.thin* assumes that linear features are encoded with positive values on a background of 0's in the input raster data file.

Parameters:

| | |
|---|---|
| *input=name* | Name of a raster map layer containing data to be thinned. |
| *output=name* | Name of the new raster map layer to hold thinned program output. |

The user can run this program either non-interactively or interactively. The program will be run non-interactively if the user specifies program arguments on the command line, using the form:

*r.thin input=name output=name*

Alternately, the user can simply type:

*r.thin*

on the command line, without program arguments. In this case, the user will be prompted for needed parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

**NOTE**
*r.thin* only creates raster map layers. You will need to run *r.line* on the resultant raster file to create a vector (*v.digit*) map layer.

*r.thin* may create small spurs or "dangling lines" during the thinning process. These spurs may be removed (after creating a vector map layer) by *v.trim*.

*r.thin* creates a 0/1 output map.

**NOTE**
This code implements the thinning algorithm described in "Analysis of Thinning Algorithms Using Mathematical Morphology" by Ben-Kwei Jang and Ronlad T. Chin in Transactions on Pattern Analysis and Machine Intelligence, vol. 12, No. 6, June 1990. The definition Jang and Chin give of the thinning process is "successive removal of outer layers of pixels from an object while retaining any pixels whose removal would alter the connectivity or shorten the legs of the sceleton."

The sceleton is finally thinned when the thinning process converges; i.e., "no further pixels can be removed without altering the connectivity or shortening the sceleton legs" (p. 541). The authors prove that the thinning process described always converges and produces one-pixel thick sceletons. The number of iterations depends on the original thickness of the object. Each iteration peels off the outside pixels from the object. Therefore, if the object is <= n pixels thick, the algorithm should converge in <= iterations.

**SEE ALSO**
*g.region, r.line, v.digit, v.support, v.trim, parser*

**AUTHOR**
Olga Waupotitsch, U. S. Army Construction Engineering Research Laboratory

The code for finding the bounding box as well as input/output code was written by Mike Baba (DBA Systems, 1990) and Jean Ezell (USACERL, 1988).

## *r.timestamp*

**NAME**
*r.timestamp* **-** print/add/remove a timestamp for a raster map
(GRASS Raster Program)

**GRASS VERSION**
5.x

**SYNOPSIS**
*r.timestamp*
*r.timestamp help*
*r.timestamp map=name [date=timestamp],timestamp]*

**DESCRIPTION**
This command has 2 modes of operation. If no date argument is supplied, then the current timestamp for the raster map is printed. If a date argument is specified, then the timestamp for the raster map is set to the specified date(s). See EXAMPLES below.

**EXAMPLES**
*r.timestamp map=soils*
Prints the timestamp for the "soils" raster map. If there is no timestamp for soils, nothing is printed. If there is a timestamp, one or two lines are printed, depending on if the timestamp for the map consists of a single date or two dates (i.e. start and end dates).

*r.timestamp map=soils date='15 sep 1987'*
Sets the timestamp for "soils" to the single date "15 sep 1987"

*r.timestamp map=soils date='15 sep 1987,20 feb 1988'*
Sets the timestamp for "soils" to have the start date "15 sep 1987" and the end date "20 feb 1988"

*r.timestamp map=soils date=none*
Removes the timestamp for the "soils" raster map

**COMMAND LINE OPTIONS**
Parameters:

| | |
|---|---|
| *map* | Raster map name |
| *date* | Date/time stamp or date1,date2 range |

**TIMESTAMP FORMAT**
The timestamp values must use the format as described in the GRASS datetime library. The source tree for this library should have a description of the format. For convenience, the formats as of Feb, 1996 are reproduced here:

There are two types of datetime values: absolute and relative. Absolute values specify exact dates and/or times. Relative values specify a span of time. Some examples will help clarify:

**Absolute**
The general format for absolute values is

```
day month year [bc] hour:minute:seconds timezone

day is 1-31
```

```
month is jan,feb,...,dec
year is 4 digit year
[bc] if present, indicates dates is BC
hour is 0-23 (24 hour clock)
minute is 0-59
second is 0-59.9999 (fractions of second allowed)
timezone is +hhmm or -hhmm (e.g., -0600)
```

parts can be missing

```
1994 [bc]
Jan 1994 [bc]
15 jan 1000 [bc]
15 jan 1994 [bc] 10 [+0000]
15 jan 1994 [bc] 10:00 [+0100]
15 jan 1994 [bc] 10:00:23.34 [-0500]
```

**Relative**
There are two types of relative datetime values, year- month and day-second. The formats are:

```
[-] # years # months
[-] # days # hours # minutes # seconds
```

The words years, months, days, hours, minutes, seconds are literal words, and the # are the numeric values.
Examples:

```
2 years
5 months
2 years 5 months
100 days
15 hours 25 minutes 35.34 seconds
100 days 25 minutes
1000 hours 35.34 seconds
```

The following are illegal because it mixes year-month and day-second (because the number of days in a month or in a year vary):

```
3 months 15 days
3 years 10 days
```

**BUGS**
Spaces in the timestamp value are required.

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

## *r.to.gnuplot*

**NAME**
*r.to.gnuplot* **-** outputs a raster map in GNUPLOT format
(GRASS Shell Script)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.to.gnuplot help*
*r.to.gnuplot name*

**DESCRIPTION**
*r.to.gnuplot* is a Bourne shell script that converts a raster map into a format suitable for plotting with *g.gnuplot.html* and writes the results to standard output.

**OPTIONS**
This program runs non-interactively; the user must state all parameter values on the command line.

Parameter:

| | |
|---|---|
| *name* | Name of a raster map layer. |

**EXAMPLE**
Typing the following at the command line:

```
r.to.gnuplot elevation > elev.dat
```

will write the raster data to elev.dat. After staring the GRASS graphics monitor, the following dialogue:

```
g.gnuplot
gnuplot> set parametric
gnuplot> set contour base
gnuplot> set nosurface
gnuplot> set view 180,0
gnuplot> splot 'elev.dat' notitle with lines
```

will plot a contour map of elevation.

**NOTES**
Similar procedures may be used to plot wire-mesh surfaces.

*g.gnuplot* may be used to simultaneously plot surfaces and contours from multiple raster maps.

Output may be saved as PostScript, FrameMaker, TeX, etc (approximately 2 dozen output formats).

**FILES**

$GISBASE/scripts/r.to.gnuplot.

**SEE ALSO**
*r.stats, v.to.gnuplot, g.gnuplot*

**AUTHOR**
James Darrell McCauley, Agricultural Engineering, Purdue University

## *r.traj*

**NAME**
*r.traj* **-** Ballistic trajectory modeling program.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.traj*
*r.traj help*
*r.traj input=name output=name weapon=name coordinate=x,y elevation=value ammunition=name left.azimuth=name right.azimuth=name*

**DESCRIPTION**
*r.traj* generates a raster map layer showing cells that can be hit from a firing point by shells from a user-specified weapon. Cells are marked with integer values that represent the muzzle firing angles required to hit them.

**OPTIONS**
Parameters:
*input=name* Name of the elevation raster map.

*output=name* Name of new raster map containing results.

*weapon=name* Type of weapon used for firing. A list of weapon types and their associated attributes are kept in the file
$GISBASE/weapon_data/weapons.

*coordinate=x,y* The coordinates of the firing point (east, north).

*elevation=value* Maximum weapon muzzle elevation.

*ammunition=name* Type of ammunition. A list of ammunition types and their associated attributes are kept in the file
$GISBASE/weapon_data/ammunition.

*left.azimuth=name* Far left edge of allowable firing azimuth. The angle will be in the form of:

[NS]0-90[EW]

For example, S60E indicates the angle is 60 degrees East of true South.

right.azimuth=name Far right edge of allowable firing azimuth, stated in same form as left.azimuth.

Category values in the output raster map layer will program results. Category values between -89 and 89 indicate the gun elevation angle in degrees needed to hit that cell. A category value of 90 is assigned to the weapon's firing point. A category value of -90 is assigned to those points unhittable by the weapon.

**EXAMPLE**
*r.traj input=elevation output=name weapon=M1 coordinate=600000.0,4920000.0 elevation=2.5 ammunition=M392 left.azimuth=S30E right.azimuth=S25W*

**WEAPON AND AMMUNITION TYPES**
Weapon types and their attribute types are listed below. These can be listed by running the program *r.traj.data*.

```
 ____________
| Weapon Type|
|____________|
| M48 19   -9|
| M1  20   -9|
| M10166   -5|
| M10275   -5|
|____________|
```

Ammunition types and their attributes are listed below. These can be displayed by running the program *r.traj.data*.

```
 ____________________________
| Ammo Type                  |
|____________________________|
| M392   105   18.60   1458 |
| M392A2 105   18.60   1458 |
| M728   105   18.95   1426 |
| M735   105   23.05   1501 |
| M735A1 105   17.24   1508 |
| M774   105   17.23   1508 |
| M494   105   24.98     21 |
| M456   105   21.78   1173 |
| M416   105   20.68    737 |
| M467   105   20.42    730 |
| M490   105   20.41   1170 |
| M724   105   14.51   1507 |
| M724A1 105   14.51   1539 |
| M737   105    9.44   1539 |
| M393   105   20.41    732 |
|____________________________|
```

**SEE ALSO**
See $GISBASE/etc/weapon_data/weapons for a list of weapon types. See, $GISBASE/etc/weapon_data/ammunition, for a list of ammunition types.
*d.rast.arrow, r.los, r.slope.aspect, r.surf.contour, r.surf.idw r.surf.idw2, r.traj.data, range.place, parser*

**AUTHORS**
Chuck Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory
Kewan Q. Khawaja, Intelligent Engineering Systems Laboratory, M.I.T.

## *r.traj.data*

**NAME**
*r.traj.data* **-** Reviews the ammunition and weapon data base used by *r.traj*.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.traj.data*
*r.traj.data help*
*r.traj.data [-aw]*

**DESCRIPTION**
*r.traj* uses ammunition and weapon information that can be displayed with this program.  Program flags are listed below.

Flags:

| | |
|---|---|
| -*a* | Prints list of ammunition types usable by *r.traj*. |
| -*w* | Prints list of weapons usable by *r.traj*. |

**SEE ALSO**
*r.traj*, *parser*

**AUTHOR**
James Westervelt, Construction Engineering Research Laboratory

## *r.transect*

**NAME**
*r.transect* **-** Outputs raster map layer values lying along user defined transect line(s).
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.transect*
*r.transect help*
*r.transect map=name [result=type] [width=value] line=east,north,azimuth,distance[,east, north,azimuth,distance,...]*

**DESCRIPTION**
This program outputs, in ASCII, the values in a raster map which lie along one or more user-defined transect lines. The transects are described by their starting coordinates, azimuth, and distance. The transects may be single-cell wide lines, or multiple-cell wide lines. The output, for each transect, may be the values at each of the cells, or a single aggregate value (e.g., average or median value).

**OPTIONS**
Parameters:
*map=name* Name of an existing raster map layer to be queried.

*result=type* Type of results to be output.
Options: raw, median, average
Default: raw

If raw results are output, each of the category values assigned to cells falling along the transect are output. Median and average results output a single value per transect: average outputs the average category value of all cells along the transect; median outputs the median category value of these cells.

*line=east,north,azimuth,distance[,east,north,azimuth,distance,...]* A definition of (each) transect line, specified by the geographic coordinates of its starting point (easting, northing), the angle and direction of its travel (azimuth), and its distance (distance).

The azimuth is an angle, in degrees, measured to the east of north. The distance is in map units (meters for a metered database, like UTM).

*width=value* Profile width, in cells (odd number).
Default: 1

Wider transects can be specified by setting the width to 3, 5, 7, etc. The transects are then formed as rectangles 3, 5, 7, etc., cells wide.

OUTPUT FORMAT
The output from this command is printed to standard output in ASCII. The format of the output varies slightly depending on the type of result requested. The first number printed is the number of cells associated with the transect. For raw output, this number is followed by the individual cell values. For average and median output, this number is followed by a single value (i.e., the average or the median value).

The following examples use the elevation.dem raster map layer in the spearfish sample data set distributed with GRASS 4.0. (To reproduce these examples, first set the geographic region as shown:

```
g.region rast=elevation.dem
```

Single-cell transect:

```
r.transect map=elevation.dem
line=593655,4917280,45,100
```

```
4 1540 1551 1557 1550
```

3-cell wide transect:

```
r.transect map=elevation.dem
line=593655,4917280,45,100 width=3
```

```
22 1556 1538 1525 1570 1555 1540 1528 1578 1565
1551 1536 1523 1569 1557 1546 1533 1559 1550 1542
1552 1543 1548
```

(Output appears as multiple lines here, but is really one line)

3-cell wide transect average:

```
r.transect map=elevation.dem line=593655,4917280,45,100 width=3 result=average
```

```
22 1548.363636
```

3-cell wide transect median:

```
r.transect map=elevation.dem
line=593655,4917280,45,100 width=3 result=median
```

```
22 1549.000000
```

**NOTES**
This program is a front-end to the *r.profile* program. It simply converts the azimuth and distance to an ending coordinate and then runs *r.profile*.

**SEE ALSO**
*r.profile*, *parser*

**AUTHOR**
Michael Shapiro, U.S. Army Construction Engineering Research Laboratory

# *r.tribs*

**NAME**
*r.tribs* **-** A GRASS program for determining the topology of stream networks.

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.tribs*
*r.tribs st=name ac=name dr=name*

**DESCRIPTION**
This paper presents a GRASS (geographical resource analysis support system; Shapiro et al., 1992; United States Army Corps of Engineers, 1993) program for determining the topology of stream networks. The program inputs raster files generated by the GRASS program *r.watershed*. Because it determines the relationships of tributary streams, it is called *r.tribs*. The input files required are:

Parameters:
*st=name* A raster map of stream segments; stream segments are labeled using integer values greater than or equal to 2. Stream file from *r.watershed*.

*ac=name* A raster map of the number of cells that drain through each cell; absolute values is the amount of overland flow that is routed through a pixel. Accumulation file from *r.watershed*.

*dr=name* Drainage file from *r.watershed*. A raster map of drainage directions; if there is no flow direction, a value of -1 is assigned. Otherwise, the integers 1 through 8 are assigned to the compass directions shown below:

5 6 7
4 **-**1 8
3 2 1.

For example, a value of 2 means that the pixel drains south, a value of 5 means the pixel drains to the northwest. Two tables are output by *r.tribs*. The first table lists the tributaries associated with each stream segment. The second table lists streams and tributaries in an order such that a stream and its tributaries are printed only if the tributaries have been previously listed. That is, first order streams are listed first, streams with tributaries that are first order streams are listed second, and so on. The program can also be run in debugging mode, in which more detailed information is printed.

The program *r.tribs* was written so that GRASS can be used to generate input for a runoff and erosion model called KINEROS (Smith et al., in press; Woolhiser et al., 1990). KINEROS represents a watershed as a set of related elements. Elements may be hillslopes, channels or ponds. A computational order must be specified so that boundary conditions for an element, such as the amount of water contributed by lateral hillslopes and upstream tributaries, are available. The program *r.tribs* provides KINEROS with that computational order. We are developing a program called *r.kineros* which will output a file that can be read by KINEROS.

**Input Files**
We assume that the program *r.watershed* has been run and that the input files: stream, accumulation and drainage, are available. Assume these files are called stream.0, accum.0 and drain.0, respectively. The command-line version of *r.tribs* is:

```
GRASS 4.1 > r.tribs st=stream.0 ac=accum.0 dr=drain.0
```

Alternately, the command *r.tribs* can be entered on the command line:

```
GRASS 4.1 > r.tribs
```

and the user will be prompted for these files.

**Methodology and Example of Output**

Output of *r.tribs* is a listing of the tributaries associated with each stream. The tributaries of a stream are determined by using the following methodology.

a. The stream and accumulation files are scanned to determine the locations of pixels that are stream segments and have the lowest accumulation of runoff for that segment. These points mark the locations of the heads of the stream segments. Locations of the head of a stream are stored for the next step.

b. Points within one pixel of the head are scanned to determine if they are part of a different stream segment and if they drain into the head of this stream. The drainage raster file is used to determine the drainage direction. Any point meeting this criteria are listed as tributary streams.

c. All points with no tributaries are first order. Tributary values are set to zero.

d. The label of the stream and its tributaries are stored and printed to the screen.

We have used *r.tribs* to generate output for a small watershed (17.5 km2) in Idaho (Horse Creek) in which we used *r.watershed* to define a total of 50 stream segments. Note that stream segments and tributaries are labeled using even integers ranging from 2 to 102. Stream segment 2 is located at the mouth of the watershed.

The *r.tribs* program first outputs the number of rows (nrows) and columns (ncols) in the raster files. Then the maximum and minimum labels of stream segments are printed. This is followed by two tables. The first table lists streams and their tributaries. An example of this table is given below.

```
nrows: 138
ncols: 273
Max stream index = 102
Min stream index = 2
Stream: 2 Tributary 0: 6 Tributary 1: 4
Stream: 4 Tributary 0: 0 Tributary 1: 0
Stream: 6 Tributary 0: 14 Tributary 1: 8
Stream: 8 Tributary 0: 12 Tributary 1: 10
Stream: 10 Tributary 0: 0 Tributary 1: 0
Stream: 12 Tributary 0: 0 Tributary 1: 0
Stream: 14 Tributary 0: 22 Tributary 1: 16
Stream: 16 Tributary 0: 20 Tributary 1: 18
Stream: 18 Tributary 0: 0 Tributary 1: 0
Stream: 20 Tributary 0: 0 Tributary 1: 0
Stream: 22 Tributary 0: 102 Tributary 1: 24
Stream: 24 Tributary 0: 36 Tributary 1: 26
Stream: 26 Tributary 0: 30 Tributary 1: 28
Stream: 28 Tributary 0: 0 Tributary 1: 0
Stream: 30 Tributary 0: 34 Tributary 1: 32
Stream: 32 Tributary 0: 0 Tributary 1: 0
Stream: 34 Tributary 0: 0 Tributary 1: 0
Stream: 36 Tributary 0: 100 Tributary 1: 38
Stream: 38 Tributary 0: 42 Tributary 1: 40
Stream: 40 Tributary 0: 0 Tributary 1: 0
Stream: 42 Tributary 0: 98 Tributary 1: 44
Stream: 44 Tributary 0: 96 Tributary 1: 46
Stream: 46 Tributary 0: 50 Tributary 1: 48
Stream: 48 Tributary 0: 0 Tributary 1: 0
Stream: 50 Tributary 0: 58 Tributary 1: 52
Stream: 52 Tributary 0: 56 Tributary 1: 54
```

```
Stream: 54 Tributary 0: 0 Tributary 1: 0
Stream: 56 Tributary 0: 0 Tributary 1: 0
Stream: 58 Tributary 0: 90 Tributary 1: 60
Stream: 60 Tributary 0: 88 Tributary 1: 62
Stream: 62 Tributary 0: 66 Tributary 1: 64
Stream: 64 Tributary 0: 0 Tributary 1: 0
Stream: 66 Tributary 0: 74 Tributary 1: 68
Stream: 68 Tributary 0: 72 Tributary 1: 70
Stream: 70 Tributary 0: 0 Tributary 1: 0
Stream: 72 Tributary 0: 0 Tributary 1: 0
Stream: 74 Tributary 0: 82 Tributary 1: 76
Stream: 76 Tributary 0: 80 Tributary 1: 78
Stream: 78 Tributary 0: 0 Tributary 1: 0
Stream: 80 Tributary 0: 0 Tributary 1: 0
Stream: 82 Tributary 0: 86 Tributary 1: 84
Stream: 84 Tributary 0: 0 Tributary 1: 0
Stream: 86 Tributary 0: 0 Tributary 1: 0
Stream: 88 Tributary 0: 0 Tributary 1: 0
Stream: 90 Tributary 0: 94 Tributary 1: 92
Stream: 92 Tributary 0: 0 Tributary 1: 0
Stream: 94 Tributary 0: 0 Tributary 1: 0
Stream: 96 Tributary 0: 0 Tributary 1: 0
Stream: 98 Tributary 0: 0 Tributary 1: 0
Stream: 100 Tributary 0: 0 Tributary 1: 0
Stream: 102 Tributary 0: 0 Tributary 1: 0
```

If the program is run in debugging mode, then the values of stream, accumulation and direction of the head of the stream and the surrounding 8 pixels are also printed. Set the value of DB_FIND_TRIBS (defined in the beginning of the routine find_tribs) to a value of 1 and recompile the program to activate debugging mode.

The second table that is output by *r.tribs* list the streams and their associated tributaries in their proper computational order. The program loops through the data listed above several times. First streams with no tributaries are listed (LOOP 1). Then streams with only first-order streams as tributaries are listed (LOOP 2). Then, streams with tributaries listed in previous loops are listed. The program continues until all streams have been listed. The variable Order is also listed, which can be interpreted as the computational order. This is the order in which programs, such as KINEROS, must consider streams in the network such that data for tributaries will be available when considering the listed stream. An example listing of the computational order of streams is given below.

```
Computational Order of Stream Segments:

LOOP: 1
Order: 0 Stream: 4 Tributary 0: 0 Tributary 1: 0
Order: 1 Stream: 10 Tributary 0: 0 Tributary 1: 0
Order: 2 Stream: 12 Tributary 0: 0 Tributary 1: 0
Order: 3 Stream: 18 Tributary 0: 0 Tributary 1: 0
Order: 4 Stream: 20 Tributary 0: 0 Tributary 1: 0
Order: 5 Stream: 28 Tributary 0: 0 Tributary 1: 0
Order: 6 Stream: 32 Tributary 0: 0 Tributary 1: 0
Order: 7 Stream: 34 Tributary 0: 0 Tributary 1: 0
Order: 8 Stream: 40 Tributary 0: 0 Tributary 1: 0
Order: 9 Stream: 48 Tributary 0: 0 Tributary 1: 0
Order: 10 Stream: 54 Tributary 0: 0 Tributary 1: 0
Order: 11 Stream: 56 Tributary 0: 0 Tributary 1: 0
Order: 12 Stream: 64 Tributary 0: 0 Tributary 1: 0
Order: 13 Stream: 70 Tributary 0: 0 Tributary 1: 0
Order: 14 Stream: 72 Tributary 0: 0 Tributary 1: 0
Order: 15 Stream: 78 Tributary 0: 0 Tributary 1: 0
Order: 16 Stream: 80 Tributary 0: 0 Tributary 1: 0
Order: 17 Stream: 84 Tributary 0: 0 Tributary 1: 0
Order: 18 Stream: 86 Tributary 0: 0 Tributary 1: 0
Order: 19 Stream: 88 Tributary 0: 0 Tributary 1: 0
Order: 20 Stream: 92 Tributary 0: 0 Tributary 1: 0
Order: 21 Stream: 94 Tributary 0: 0 Tributary 1: 0
Order: 22 Stream: 96 Tributary 0: 0 Tributary 1: 0
Order: 23 Stream: 98 Tributary 0: 0 Tributary 1: 0
Order: 24 Stream: 100 Tributary 0: 0 Tributary 1: 0
Order: 25 Stream: 102 Tributary 0: 0 Tributary 1: 0
```

```
----------------------------------------------------------------
LOOP: 2
Order: 26 Stream: 8 Tributary 0: 12 Tributary 1: 10
Order: 27 Stream: 16 Tributary 0: 20 Tributary 1: 18
Order: 28 Stream: 30 Tributary 0: 34 Tributary 1: 32
Order: 29 Stream: 52 Tributary 0: 56 Tributary 1: 54
Order: 30 Stream: 68 Tributary 0: 72 Tributary 1: 70
Order: 31 Stream: 76 Tributary 0: 80 Tributary 1: 78
Order: 32 Stream: 82 Tributary 0: 86 Tributary 1: 84
Order: 33 Stream: 90 Tributary 0: 94 Tributary 1: 92
----------------------------------------------------------------
LOOP: 3
Order: 34 Stream: 26 Tributary 0: 30 Tributary 1: 28
Order: 35 Stream: 74 Tributary 0: 82 Tributary 1: 76
----------------------------------------------------------------
LOOP: 4
Order: 36 Stream: 66 Tributary 0: 74 Tributary 1: 68
----------------------------------------------------------------
LOOP: 5
Order: 37 Stream: 62 Tributary 0: 66 Tributary 1: 64
----------------------------------------------------------------
LOOP: 6
Order: 38 Stream: 60 Tributary 0: 88 Tributary 1: 62
----------------------------------------------------------------
LOOP: 7
Order: 39 Stream: 58 Tributary 0: 90 Tributary 1: 60
----------------------------------------------------------------
LOOP: 8
Order: 40 Stream: 50 Tributary 0: 58 Tributary 1: 52
----------------------------------------------------------------
LOOP: 9
Order: 41 Stream: 46 Tributary 0: 50 Tributary 1: 48
----------------------------------------------------------------
LOOP: 10
Order: 42 Stream: 44 Tributary 0: 96 Tributary 1: 46
----------------------------------------------------------------
LOOP: 11
Order: 43 Stream: 42 Tributary 0: 98 Tributary 1: 44
----------------------------------------------------------------
LOOP: 12
Order: 44 Stream: 38 Tributary 0: 42 Tributary 1: 40
----------------------------------------------------------------
LOOP: 13
Order: 45 Stream: 36 Tributary 0: 100 Tributary 1: 38
----------------------------------------------------------------
LOOP: 14
Order: 46 Stream: 24 Tributary 0: 36 Tributary 1: 26
----------------------------------------------------------------
LOOP: 15
Order: 47 Stream: 22 Tributary 0: 102 Tributary 1: 24
----------------------------------------------------------------
LOOP: 16
Order: 48 Stream: 14 Tributary 0: 22 Tributary 1: 16
----------------------------------------------------------------
LOOP: 17
Order: 49 Stream: 6 Tributary 0: 14 Tributary 1: 8
----------------------------------------------------------------
LOOP: 18
Order: 50 Stream: 2 Tributary 0: 6 Tributary 1: 4
```

**Obtaining *r.tribs* via FTP or email**

The C programs that are required to generate *r.tribs* are available via anonymous ftp to moon.cecer.army.mil. I have printed out the main segment of the *r.tribs* program in Appendix I. This was done to illustrate how routines in the GRASS library are used to read in raster data. Routines from the GRASS library begin with G_. Two utility programs are also used: imatrix and ivector. These are discussed by Press and others (1989), and are used to allocate space for arrays. Comments in the code discuss the details of each routine. Appendix II lists the makefile used to compile *r.tribs*. Note that the variable GIS must be edited so that the proper path to the grass directory is specified.

As previously mentioned, the program can be obtained by anonymous ftp to moon.cecer.army.mil. Change to the incoming/r.tribs directly to get the files. The program can also be obtained by contacting the author via email (jfs5@po.cwru.edu). The code has been commented to help the user to understand the program structure. Also, a developmental version of *r.kineros* is in the incoming/r.kineros directory on moon.cecer.army.mil.

**REFERENCES**

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T., 1989, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 735 pp.

Shapiro, M., Westervelt, J., Gerdes, D., Larson, M., and Brownfield, K.R., 1992, GRASS 4.0 Programmers Manual, U.S. Army Construction Engineering Research Laboratory, Champaign, Illinois, 292 pp.

Smith, R.E., Goodrich, D.C., Woolhiser, D.A., and Unkrich, C.L., in press, A KINematic Runoff and EROSion Model, in: V.P. Singh (Ed.), Computer Models of Watershed Hydrology, Water Resources Pub., Highlands Ranch, Colorado

United States Army Corps of Engineers, 1993, GRASS4.1 Users Reference Manual, U.S. Army Construction Engineering Research Laboratories, Champaign, Illinois, 556 pp.

Woolhiser, D.A., Smith, R.E., Goodrich, D.C., 1990, KINEROS, A Kinematic Runoff and Erosion Model: Documentation and Users Manual, U.S. Department of Agriculture, Agricultural Research Service, ARS-77, 130 pp.

**Appendix I: main.c code for r.tribs**

```
#include "/GRASS4.1/src/include/gis.h"
#include <stdio.h>
int **imatrix();
int *ivector();
/*
* Program to determing the topology of a stream network. A
* table is generated that reports the tributaries that are
* at the head of each stream segement. The computational order
* of streams is also determinted.
*
* Written by:
* Dr. John F. Stamm
* Department of Geological Sciences
* Case Western Reserve University
* Cleveland, OH 44106-7216
* email: jfs5@po.cwru.edu
*/
main(argc,argv)
int argc;
char *argv[];
{
/*
* Matricies
*/
int **accum;
int **chann;
int **aspect;
CELL *cell;
```

```
char *chann_name;
char *accum_name;
char *aspect_name;
char *mapset;
int col;
int fd_accum;
int fd_chann;
int fd_aspect;
int ncols;
int nrows;
int row;
struct {
struct Option *accum ;
struct Option *chann ;
struct Option *aspect ;
} parm;
/*
* Allocate memory for the Option structure and return a
* pointer to this structure. Do this for the structured
* variables parm.accum and parm.chann.
*
* Set values for parm.accum
*/
parm.accum = G_define_option() ;
parm.accum->key = "accumulation";
parm.accum->type = TYPE_STRING;
parm.accum->required = YES;
parm.accum->gisprompt = "old,cell,raster" ;
parm.accum->description= "Name of the ACCUMULATION map" ;
/*
* Set values for parm.chann
*/
parm.chann = G_define_option() ;
parm.chann->key = "stream";
parm.chann->type = TYPE_STRING;
parm.chann->required = YES;
parm.chann->gisprompt = "old,cell,raster" ;
parm.chann->description= "Name of the STREAM map" ;
/*
* Set values for parm.aspect
*/
parm.aspect = G_define_option() ;
parm.aspect->key = "drainage";
parm.aspect->type = TYPE_STRING;
parm.aspect->required = YES;
parm.aspect->gisprompt = "old,cell,raster" ;
parm.aspect->description= "Name of the DRAINAGE DIRECTION map";
/*
* Initailize GIS library for this program
*/
G_gisinit(argv[0]);
/*
* Parse values from the command line. If this is not
* successful, then display a usage statement and exit.
```

```
*/
if (G_parser(argc, argv))
exit (-1);
accum_name = parm.accum->answer;
chann_name = parm.chann->answer;
aspect_name = parm.aspect->answer;
/*
* Find the name of mapset that we are going to use.
*/
mapset = G_find_cell2 (accum_name, "");
if (mapset == NULL) {
char msg[100];
sprintf (msg, "%s: <%s> cellfile not found\n",
G_program_name(), accum_name);
G_fatal_error (msg);
exit(1);
}
/*
* Open the cell files in "mapset".
*/
fd_accum = G_open_cell_old (accum_name, mapset);
if (fd_accum < 0)
exit(1);
fd_chann = G_open_cell_old (chann_name, mapset);
if (fd_chann < 0)
exit(1);
fd_aspect = G_open_cell_old (aspect_name, mapset);
if (fd_aspect < 0)
exit(1);
/*
* Open up a vector that is just long enough to hold one
* row of data.
*/
cell = G_allocate_cell_buf();
/*
* Determine the number of rows and columns.
*/
nrows = G_window_rows();
ncols = G_window_cols();
printf ("\n", nrows);
printf ("nrows: %d\n", nrows);
printf ("ncols: %d\n", ncols);
/*
* Allocate memory for matricies.
*/
accum = imatrix(0,nrows,0,ncols);
chann = imatrix(0,nrows,0,ncols);
aspect = imatrix(0,nrows,0,ncols);
/*
* Process DEM and Channel files.
*/
for (row=(nrows-1); row>=0; row--) {
if(G_get_map_row (fd_accum, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
accum[row][col] = (int)cell[col];
}
if(G_get_map_row (fd_chann, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
chann[row][col] = (int)cell[col];
}
if(G_get_map_row (fd_aspect, cell, row) < 0)
exit(1);
for (col = 0; col < ncols; col++) {
aspect[row][col] = (int)cell[col];
}
}
/*
* Compute the topology of the network.
*/
(void)find_tribs(nrows, ncols, accum, chann, aspect);
exit(0);
}
```

**Appendix II: makefile**

```
PGM = r.tribs
GIS = /GRASS4.1
HOME = .
SRC = $(GIS)/src
LIBDIR = $(SRC)/libes/LIB
GISLIB = $(LIBDIR)/libgis.a
OFILES = debug.o \
find_tribs.o \
imatrix.o \
ivector.o \
main.o \
neighbors.o \
stream_order.o
$(HOME)/$(PGM): $(OFILES) $(GISLIB)
$(CC) $(LDFLAGS) $(OFILES) $(GISLIB) -o $(PGM)
$(GISLIB): #
```

**AUTHOR**

John F. Stamm, Department of Geological Sciences, Case Western Reserve University, Cleveland, OH 44106-7216, email: jfs5@po.cwru.edu

## *r.univar*

**NAME**
*r.univar* **-** Univariate statistics for a GRASS raster map.
(GRASS Script)

**GRASS VERSION**
5.x

**SYNOPSIS**
*r.univar*
*r.univar help*
*r.univar name*

**DESCRIPTION**
*r.univar* calculates univariate statistics of a raster map. This includes the number of cells counted, minimum and maximum cell values, range, arithmetic mean, variance, standard deviation and coefficient of variation.

Parameter:

| | |
|---|---|
| *name* | Name of an existing raster map. |

**SEE ALSO**
*s.univar*

**AUTHOR**
Markus Neteler
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## *r.volume*

**NAME**
*r.volume* **-** Calculates the volume of data "clumps", and (optionally) produces a GRASS site_lists file containing the calculated centroids of these clumps.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.volume*
*r.volume help*
*r.volume [-fq] data=name [clump=name] [site_list=name]*

**DESCRIPTION**
This program computes the cubic volume of data contained in user-defined clumps. *r.volume* outputs:

(1) The category value assigned to each clump formed by the clump map layer. This value is stored under the "Cat Number" column (field 1) in the output table.
(2) The average category value of the cells found in a data map that fall within the boundaries of each clump in a clump map. The table stores this value under the "Average in Clump" column (field 2).
(3) The summed total value of the category values assigned to the cells falling within each of these clumps. This value is output under the "Data Total" column (field 3).
(4) The number of cells from the data map that fall within the boundaries of each clump formed by the clump map layer. This cell count is stored under the "# Cells in Clump" column (field 4) in the output table.
(5,6) The centroid (easting and northing) of each clump. These values are output under the "Centroid Easting" and "Centroid Northing" columns (fields 5 and 6) in the output.
(7) The total "volume" of each clump. For each clump, the volume is calculated by multiplying the area of each cell by its category value, and taking the sum of this value for all cells within the clump. Since, in GRASS, each cell in the data map will have the same cell dimensions (i.e., the same area), this is equivalent to multiplying the area of one cell by the "Data Total" column (field 3). (The area of each cell is equal to the product of its east-west resolution by its north-south resolution. See *g.region*.)

Results are sent to standard output in the form of a table. If the user sets the *-f* flag, this table will be output in a form suitable for input to such UNIX programs as awk and sed; the table's columns are stored as colon-separated fields. The user can also (optionally) elect to store clump centroids in a GRASS site_lists file. A sample output report is shown below.

*r.volume* works with the current geographic region definitions and respects the current MASK.

The user can run *r.volume* non-interactively by specifying parameter values on the command line. If the user omits parameter values from the command line, the program will prompt the user for input using the standard interface described in the manual entry for *parser*.

**OPTIONS**
Flags:
*-f* Generate unformatted output. Output is in a form suitable for input to UNIX programs like awk; each column in the output is separated by a colon. Results are sent to standard output.

*-q* Run quietly, suppressing the printing of debugging messages to standard output.

Parameters:

*data* Name of an existing raster map layer containing the category values to be summed. The cell resolution (area) of the data map will also be used.

*clump* Name of an existing raster map layer that defines the boundaries of each clump. Preferably, this map should be the output of *r.clump*. If the user has imposed a mask, the program uses this mask as the clump map layer if no other clump layer is specified by the user.

site_list The name to be assigned to a new GRASS site_lists file, in which clump centroids can be stored.

**EXAMPLE OF REPORT**

The following report might be generated by the command:

*r.volume d=elevation c=fields.only s=field.centers*

```
   Cat    Average    Data       # Cells          Centroid             Total
  Number  in clump   Total     in clump      Easting     Northing      Volume
    1     1181.09   75590 64   595500.00   4927700.00   755900000.00
    2     1163.50   69810 60   597100.00   4927700.00   698100000.00
    3     1146.83   34405 30   598300.00   4927700.00   344050000.00
    4     1193.20  366311307   599400.00   4927300.00  3663110000.00
  .....
  .....
   60     1260.08  351563279   603100.00   4921000.00  3515630000.00
   61     1213.93   35204 29   603700.00   4921500.00   352040000.00
   62     1207.71   33816 28   604100.00   4921500.00   338160000.00
   Total Volume = 67226740000.00
```

For ease of example, it is assumed that each clump in the fields.only map layer is a field, that cell category values in the elevation map layer represent actual elevation values in meters, and that the data base is a UTM data base (in meters). This means that field #1 (clump #1) contains 64 cells; the average elevation in field #1 is 1181.09 meters. The sum of all of the elevation values assigned to cells within field #1 is 75590 meters. The volume (x*y*z) of space in field #1 is equal to 755900000 cubic meters.

The "Data Total" column is the sum of the cell category values appearing in the elevation map layer, within each field of the fields.only map layer. The Total Volume is the sum multiplied by the e-w resolution times the n-s resolution.

CENTROIDS

The coordinates of the clump centroids are the same as those stored in the GRASS site_lists file (if one was requested). They are guaranteed to fall on a cell of the appropriate category; thus, they are not always the true, mathematical centroids. However, they will always fall at a cell center.

FORMAT OF SITE LIST

For each line of above table the GRASS site_lists file reads:

*easting|northing|#cat v=volume a=average t=sum n=count*

This can be converted directly to a raster map layer in which each point is assigned to a separate category.

**APPLICATIONS**

By preprocessing the elevation map layer with *r.mapcalc* and using suitable masking or clump maps, very interesting applications can be done with *r.volume*. For instance, one can calculate: the volume of rock in a potential quarry; cut/fill volumes for roads; and, water volumes in potential reservoirs. Data layers of other measures of real values can also be used.

**NOTES**
The output is sent to the terminal screen. The user can capture the output in a file using the UNIX redirection mechanism, as in the following example:

```
r.volume d=data_map c=clump_map s=site_list > table.out
```

Output can also be sent directly to the printer, as shown
below:

```
r.volume d=data_map c=clump_map s=site_list | lpr
```

The user should be aware of what units of measurement the cell e-w and n-s resolution are in, and in what units the data map's cell category values are stated (since these three values will be multiplied together to produce the volume).

This program respects the current mask, and uses this mask as the clump map layer if none is specified by the user.

**SEE ALSO**
*g.region, r.clump, r.mapcalc, r.mask, s.db.rim, s.menu, parser*

**AUTHOR**
Dr. James Hinthorne, Central Washington University GIS Laboratory

# *r.water.fea*

**NAME**
*r.water.fea* **-** Finite element analysis program for hydrologic simulations.
(GRASS Raster Program)

**GRASS VERSION**
4.x,5.x

**SYNOPSIS**
*r.water.fea*

**OVERVIEW**
*r.water.fea* is an interactive program that allows the user to simulate storm water runoff analysis using the finite element numerical technique. Infiltration is calculated using the Green and Ampt formulation. *r.water.fea* computes and draws hydrographs for every basin as well as at stream junctions in an analysis area. It also draws animation maps at the basin level.

**DATA REQUIREMENTS**
The maps required by *r.water.fea* are:

1) Basin map
2) Stream map
3) Drainage map
4) Accumulation map
5) Slope map

The other data requirements of *r.water.fea* are the parameters needed to calculate infiltration and the channel roughness parameter. Model parameters may be provided either in the form of maps or as values:

1) Manning roughness coefficient map or basin value
2) Saturated hydraulic conductivity map or basin value
3) Suction head at wetting front map or basin value
4) Effective porosity map or basin value
5) Degree of saturation basin value

**DESCRIPTION**
On running *r.water.fea* for the first time, the directory "*r.water.fea*" is created under $LOCATION. When the user runs *r.water.fea*, the program will prompt the user for the project name. The project name refers to the directory that is created under the " *r.water.fea*" directory. All files (not maps) related to the analysis carried out by *r.water.fea* are stored under this directory. If the project does not exist then the user is further requested for the input maps. If the project already exists, then the program looks for the proper project related files to proceed with stopped work.

Configuration

The user is asked for the following configuration modes:
I) Rainfall mode:
The rainfall mode is defined as follows:

1 = spatially uniform and constant in time
2 = spatially uniform but varying in time

If the user decides to use mode 2, then a mechanism is provided to allow creation of a rainfall rate file (described in step 4).

II) Basin-level hydrographs: This configuration mode allows the user to view intermediate hydrographs for every basin. The hydrographs will be displayed on the graphics monitor. Each basin is considered to be independent of every other basin in the analysis area.

III) Basin-level animation maps: This configuration mode allows the user to create time-series maps for later animation of flow depth for all the basins that have been analyzed. All animation maps use a multiplication factor of 1000. The map cell value divided by the multiplication factor yields the actual value of flow depth in meters. The user will require enough file space in the GRASS database for this configuration. All animation map names have the following naming scheme:

*fea.<project_name>.#*

Here '#' represents the time step. One time step refers to 1/40th of the total monitoring time. Twenty maps are created at every other time step.

Program flow

The basin and stream maps are displayed on the monitor when the user starts working on a project. The entire analysis is divided into a number of steps. The user is presented with a menu to proceed through the set of steps to facilitate easy changes to the simulation for a given analysis area or to stop analysis between menu steps and continue at a more convenient time.

The main menu is shown below:

Choose from the menu:

```
        * 1. Process steps without breaks.
        *-> 2. Select basins for simulation.
        X 3. Extract topographical data.
        X 4. Select hydraulic parameters and simulation time.
        X 5. Basin simulation.
        X 6. Simulate any particular basin.
        X 7. Channel routing of basin hydrographs.
        * 8. Stop.
```

You are starting from the beginning.

Choice:

The "X", "*", and "*->" above have the following meaning.

*    The user can select this part from the menu.
*->    This is the step that the user must select in order to proceed in a sequence.
*X*    The user can not select these parts of the menu (until previous steps have been executed).

Throughout the program the symbols described above change as the user moves from step to step. The message just above the Choice prompt signals the status of the program, and guides the user as to what should be the next step.

*"1. Process steps without breaks." 8*
This part of the menu will not prompt for steps 2-5, 7 and will carry out all the analysis. The user will find it advantageous to use this step when analyzing a small area or a few basins.

*"2. Select basins for simulation." 8*
This part of the menu draws the basin and stream maps for the user to select the area of analysis. The mouse is then activated to provide a point and click environment for the user to select basins in the area of analysis. Upon successfully selecting the basins the user is given the choice of deleting basins from the selected area. The basin topology is then determined and information on basin statistics is gathered. The information on connectivity between basins is stored in the "input.basin" file and the information on basin statistics is stored in the "basin_info" file. Two reclass maps describing the analysis area are also created. The maps have the following naming scheme:

*"fea.stream.<project_name>"*
*"fea.basin.<project_name>"*

The user should avoid using these names to create other maps. Once these maps are created the user should not destroy them, if the user wishes to continue working on the project.

*"3. Extract topographical data." 8*
This part of the menu generates information about the connectivity between cells and boundary conditions. This information is stored in the "input.file" file in the project directory. If the animation configuration has been set then another file called "coordinates" is created in the project directory. This file contains information on the coordinates of every cell in the analysis area.

*"4. Select hydraulic parameters and simulation time." 8*
This part of the menu carries out two tasks. The first task involves querying the user for simulation parameters. The simulation parameters include duration of rainfall, maximum intensity, time step for simulation, monitoring time and names of simulation maps if any. The second task involves querying channel characteristics assuming the channels as trapezoidal cross-sections. The user is required to provide channel side slope, channel bottom width and the channel roughness coefficient values for every stream category.

The program creates a file "timedata" in the project directory to store information from this part of the menu. If the user has selected the "Spatially uniform and time varying rainfall" mode (mode = 2), then the user is queried for the name of a time file. If the file does not exist then a screen like the one shown below appears:

```
------------------------------------------------------------------
 Rainfall data
 -------------
[The time column must be filled in increasing order.]

 Time[minutes]   Intensity[cm/hr]

    1______    ______
    2______    ______
    3______    ______
    4______    ______
    5______    ______
    6______    ______
    7______    ______
    8______    ______
    9______    ______
   10______    ______
   11______    ______
   12______    ______
   13______    ______
   14______    ______
   15______    ______
c s s s
c s s s
l l l l.
AFTER COMPLETING ALL ANSWERS, HIT <ESC> TO CONTINUE
(OR <Ctrl-C> TO CANCEL)
```

```
----------------------------------------------------------------
```

It is important to note that the values in the time column should be in an increasing order. It is also not necessary to fill all the rows and the user can stop after filling only a few rows. The number of lines are limited to fifteen. If more than fifteen lines are required then the user will have to create the file using an editor. In that case the user should just type the time since commencement of rainfall (minutes) in the first column followed by the rainfall intensity (cm/hr) in the second column as shown below:

```
l l
l c.
10 2.54
30 4.52
60 5.62
```

*"5. Basin simulation." 8*
This part of the menu carries out the simulation for each basin in the area of analysis. Every basin is analyzed as independent of every other basin. The user is shown the independent basin hydrograph for every basin on the graphics monitor. The file "disch.basin" is created towards the end of simulation of all the basins. This file contains columns of discharge for each basin. The column number corresponds to the basin category value in the legend. If the animation configuration mode was set then a file is created in the project directory called "disch_file". This file holds basin discharge values at every point in every basin of the analysis area.

*"6. Simulate any particular basin." 8*
This part of the menu provides the facility of changing basin characteristics such as the Manning roughness coefficient and other infiltration parameters. This choice can be used only after the successful completion of choice 5. If the user has provided maps for the parameters then the user should select "stop" from the menu to make changes to the parameter maps provided to the model.

*"7. Channel routing of basin hydrographs." 8*
This part of the menu connects the basins that were considered independent in the previous step. Routing of the basin-level hydrographs is done based on the connectivity between basins. This can generate hydrographs only for seven stream junctions. If there are more than seven stream junctions then the first seven stream junction hydrographs are shown. The process of drawing individual basin animation maps follows the drawing of the hydrographs at stream junctions. After completing this choice a file "disch.junction" is created. This file contains discharge values at different steps for every stream junction.

*"8. Stop." 8*
This part of the menu is available to the user at any time between the different choices described in the menu and exits the user out of the program.

**LIMITATIONS**

1.) Negative values of drainage direction inside basins maps cannot be accepted. Negative values are generated as a result of incomplete information regarding the basin drainage pattern (e.g., *r.watershed* produces negative values as a result of outflowing drainage basins).

2.) The drainage map should route the water and not form pits, lakes, or ponds. Note that this does not imply that the DEM by itself should not have any pits.

3) Interstorm modeling, interflow, or baseflow are not considered.

4) Backwater effects are not considered.

5) The kinematic wave analogy is appropriate where the land surface slope and channel slope are large. This may not be true in flat, marshy terrain and in slow, meandering river channels.

**OUTPUT FILES OF INTEREST**
These are ASCII files that can be found in the "$LOCATION/ *r.water.fea*/<project_name>" directory. The files have a format such that it can be imported to various analysis packages.

*disch.basin 8*
This file contains multiple columns which contain the individual basin discharge values in order of first column containing the discharge values for basin one and the second for basin two and so on.

*disch.junction 8*
This file contains the results of the discharge values at stream junctions specified by the icons. The first column in this file shows the time step in minutes. The remaining columns specify the discharge values. The first row specifies the stream junction icon numbers.

**NOTES**
1. *r.water.fea* alters the region in the WIND file. This is done by making a systems call to *g.region align=name* just when the program *r.water.fea* is run.

2. A small watershed can be analyzed by providing values of model parameters. However it is advisable to provide maps of various model parameters if there are many basins in the watershed. In the former case the value provided by the user shall be constant for the entire basin for which the value is queried. The user shall create the infiltration maps using the following set of rules. The map value divided by the multiplication factor yields the actual value in the described units:

Parameter:
Multiplication factor

Soil saturated hydraulic conductivity map (meters/sec):10,000,000

Manning roughness coefficient:1000

Soil suction at wetting front (m):1000

Soil porosity map (m3/m3):1000

3. If the user has provided a slope map that has zero slope value anywhere in the map, then a slope value of 5% is assumed for that cell.

4. It is preferred that none of the basins in the analysis area has more than 750 cells, as this will increase the computation time drastically. The number of cells in a basin can be controlled by setting the threshold value to small values when running *r.watershed*.

5. Using larger cells can speed up the analysis process significantly. It is important to note that *r.watershed* should be run for the resolution at which the user desires to run the *r.water.fea* analysis.

**FILES**
All the files listed below are ASCII files. None of these files should be
deleted if the user wishes to continue working on the same project.

$LOCATION/ r.water.fea/<project_name>/input.basin 8
This file contains information on connectivity between different basins in the analysis area.

$LOCATION/ r.water.fea/<project_name>/input.file 8
This file contains information on connectivity between different cells for every basin in the analysis area.

$LOCATION/ r.water.fea/<project_name>/disch.basin 8
This file contains discharge values for every basin in the analysis area.

$LOCATION/ r.water.fea/<project_name>/disch.junction 8
This file contains discharge values at every stream junction in the analysis area.

$LOCATION/ r.water.fea/<project_name>/timedata 8
This file contains the response queried from the user in choice 4 of the menu.

$LOCATION/ r.water.fea/<project_name>/basin_info 8
This file contains information on statistics of the basins in the analysis area.

$LOCATION/ r.water.fea/<project_name>/coordinates 8
This file contains information on coordinates of every cell in the analysis area.

$LOCATION/ r.water.fea/<project_name>/control 8
This file contains information on map names, configuration modes, and stopped choice in the menu.

$LOCATION/ r.water.fea/<project_name>/disch_file 8
This file contains the discharge values at every point in the analysis area.

$LOCATION/ r.water.fea/<project_name>/timefiles/<file_name> 8
This file contains the spatially constant and time variant rainfall mode file.

## SEE ALSO
*r.slope.aspect, r.watershed, r.mask, r.reclass, r.stats, r.colors*

## REFERENCES
Vieux, B. E., Bralts, V. F., Segerlind, L. J., Wallace, R. B., (1990), "FINITE ELEMENT WATERSHED MODELING: ONE-DIMENSIONAL ELEMENTS", J. of Water Resources Planning and Management, Vol. 116, No. 6, p803-819.

## AUTHORS
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## *r.water.outlet*

**NAME**
*r.water.outlet* **-** Watershed basin creation program.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.water.outlet*
*r.water.outlet help*
*r.water.outlet drainage=name basin=name easting=value northing=value*

**DESCRIPTION**
*r.water.outlet* generates a watershed basin from a drainage direction map (from *r.watershed* or *r.water.aspect*) and a set of coordinates representing the outlet point of watershed.

**OPTIONS**
Parameters:
*drainage* Input map: drainage direction. Indicates the "aspect" for each cell. Multiplying positive values by 45 will give the direction in degrees that the surface runoff will travel from that cell. The value -1 indicates that the cell is a depression area. Other negative values indicate that surface runoff is leaving the boundaries of the current geographic region. The absolute value of these negative cells indicates the direction of flow. This map is generated from either *r.watershed* or *r.water.aspect.*

*basin* Output map: Values of one (1) indicate the watershed basin. Values of zero are not in the watershed basin.

*easting* Input value: Easting value of outlet point.

*northing* Input value: Northing value of outlet point.

**NOTES**
In the context of this program, a watershed basin is the region upstream of an outlet point. Thus, if the user chooses an outlet point on a hill slope, the resulting map will be a thin silver of land representing the overland slope uphill of the point.

It is usually a good idea for the user to "find" the stream channel of the desired basin. If the user runs *r.water.accum, r.water.swale* with a small swale threshold, and *d.where* on the resulting map, the user can pinpoint the exact location of the outlet point with ease.

**SEE ALSO**
*r.watershed, r.water.aspect, r.water.accum, r.water.swale, r.water.basin, d.where*

**AUTHOR**
Charles Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory

## *r.watershed*

**NAME**
*r.watershed* **-** Watershed basin analysis program.
(GRASS Raster Program)

**GRASS VERSION**
4.x,5.x

**SYNOPSIS**
*r.watershed*
*r.watershed help*
*r.watershed [-m4] elevation=name [depression=name] [flow=name] [disturbed.land=name|value] [blocking=name] [threshold=value] [max.slope.length=value] [accumulation=name] [drainage=name] [basin=name] [stream=name] [half.basin=name] [visual=name] [length.slope=name] [slope.steepness=name]*

**DESCRIPTION**
*r.watershed* generates a set of maps indicating: 1) the location of watershed basins, and 2) the LS and S factors of the Revised Universal Soil Loss Equation (RUSLE).

*r.watershed* can be run either interactively or non-interactively. If the user types

*r.watershed*

on the command line without program arguments, the program will prompt the user with a verbose description of the input maps. The interactive version of *r.watershed* can prepare inputs to lumped-parameter hydrologic models. After a verbose interactive session, *r.watershed* will query the user for a number of map layers. Each map layer's values will be tabulated by watershed basin and sent to an output file. This output file is organized to ease data entry into a lumped-parameter hydrologic model program. The non- interactive version of *r.watershed* cannot create this file.

The user can run the program non-interactively, by specifying input map names on the command line. Parameter names may be specified by their full names, or by any initial string that distinguish them from other parameter names. In *r.watershed*'s case, the first two letters of each name sufficiently distinguishes parameter names. For example, the two expressions below are equivalent inputs to *r.watershed*:

*r.watershed el=elev.map th=100 st=stream.map ba=basin.map*

*r.watershed elevation=elev.map threshold=100 stream=stream.map basin=basin.map*

**OPTIONS**
Flags:
-*m* Without this flag set, the entire analysis is run in memory maintained by the operating system. This can be limiting, but is relatively fast. Setting the flag causes the program to manage memory on disk which allows larger maps to be processes but is considerably slower.

-*4* Allow only horizontal and vertical flow of water. Stream and slope lengths are approximately the same as outputs from default surface flow (allows horizontal, vertical, and diagonal flow of water). This flag will also make the drainage basins look more homogeneous.

Parameters:
*elevation* Input map: Elevation on which entire analysis is based.

*depression* Input map: Map layer of actual depressions in the landscape that are large enough to slow and store surface runoff from a storm event. Any non-zero values indicate depressions.

*flow* Input map: amount of overland flow per cell. This map indicates the amount of overland flow units that each cell will contribute to the watershed basin model. Overland flow units represent the amount of overland flow each cell contributes to surface flow. If omitted, a value of one (1) is assumed.

*disturbed.land* Raster map input layer or value containing the percent of disturbed land (i.e., croplands, and construction sites) where the raster or input value of 17 equals 17%. If no map or value is given, *r.watershed* assumes no disturbed land. This input is used for the RUSLE calculations.

*blocking* Input map: terrain that will block overland surface flow. Terrain that will block overland surface flow and restart the slope length for the RUSLE. Any non-zero values indicate blocking terrain.

*threshold* The minimum size of an exterior watershed basin in cells, or overland flow units.

*max.slope.length* Input value indicating the maximum length of overland surface flow in meters. If overland flow travels greater than the maximum length, the program assumes the maximum length (it assumes that landscape characteristics not discernible in the digital elevation model exist that maximize the slope length). This input is used for the RUSLE calculations and is a sensitive parameter.

*accumulation* Output map: number of cells that drain through each cell. The absolute value of each cell in this output map layer is the amount of overland flow that traverses the cell. This value will be the number of upland cells plus one if no overland flow map is given. If the overland flow map is given, the value will be in overland flow units. Negative numbers indicate that those cells possibly have surface runoff from outside of the current geographic region. Thus, any cells with negative values cannot have their surface runoff and sedimentation yields calculated accurately.

*drainage* Output map: drainage direction. Provides the "aspect" for each cell. Multiplying positive values by 45 will give the direction in degrees that the surface runoff will travel from that cell. The value -1 indicates that the cell is a depression area (defined by the depression input map). Other negative values indicate that surface runoff is leaving the boundaries of the current geographic region. The absolute value of these negative cells indicates the direction of flow.

*basin* Output map: Unique label for each watershed basin. Each basin will be given a unique positive even integer. Areas along edges may not be large enough to create an exterior watershed basin. 0 values indicate that the cell is not part of a complete watershed basin in the current geographic region.

*stream* Output map: stream segments. Values correspond to the watershed basin values.

*half.basin* Output map: each half-basin is given a unique value. Watershed basins are divided into left and right sides. The right-hand side cell of the watershed basin (looking upstream) are given even values corresponding to the watershed basin values. The left-hand side cells of the watershed basin are given odd values which are one less than the value of the watershed basin.

*visual* Output map: useful for visual display of results. Surface runoff accumulation with the values modified to provide for easy display. All negative accumulation values are changed to zero. All positive values above the basin threshold are given the value of the basin threshold.

*length.slope* Output map: slope length and steepness (LS) factor. Contains the LS factor for the Revised Universal Soil Loss Equation. Equations taken from Revised Universal Soil Loss Equation for

Western Rangelands (see SEE ALSO section). Since the LS factor is a small number, it is multiplied by 100 for the GRASS output map.

*slope.steepness* Output map: slope steepness (S) factor for RUSLE. Contains the revised S factor for the Universal Soil Loss Equation. Equations taken from article entitled Revised Slope Steepness Factor for the Universal Soil Loss Equation (see SEE ALSO section). Since the S factor is a small number (usually less than one), it is multiplied by 100 for the GRASS output map layer.

**NOTES**

There are two versions of this program: *ram* and *seg*. Which is run by *r.watershed* depends on whether the -*m* flag is set. *ram* uses virtual memory managed by the operating system to store all the data structures and is faster than *seg*; *seg* uses the GRASS segment library which manages data in disk files. *seg* allows other processes to operate on the same CPU, even when the current geographic region is huge. Due to memory requirements of both programs, it will be quite easy to run out of memory. If *ram* runs out of memory and the resolution size of the current geographic region cannot be increased, either more memory needs to be added to the computer, or the swap space size needs to be increased. If *seg* runs out of memory, additional disk space needs to be freed up for the program to run.

*seg* uses the $A^T$ least-cost search algorithm to determine the flow of water over the landscape (see SEE ALSO section). The algorithm produces results similar to those obtained when running *r.cost* and *r.drain* on every cell on the map.

In many situations, the elevation data will be too finely detailed for the amount of time or memory available. Running *r.watershed* will require use of a coarser resolution. To make the results more closely resemble the finer terrain data, create a map layer containing the lowest elevation values at the coarser resolution. This is done by: 1) Setting the current geographic region equal to the elevation map layer, and 2) Using the neighborhood command to find the lowest value for an area equal in size to the desired resolution. For example, if the resolution of the elevation data is 30 meters and the resolution of the geographic region for *r.watershed* will be 90 meters: use the minimum function for a 3 by 3 neighborhood. After going to the resolution at which *r.watershed* will be run, *r.watershed* will be taking values from the neighborhood output map layer that represents the minimum elevation within the region of the coarser cell.

The minimum size of drainage basins is only relevant for those basins that have no basins draining into them (they are called exterior basins). An interior drainage basin has the area that flows into an interior stream segment. Thus, interior drainage basins can be of any size.

The *r.watershed* program does not require the user to have the current geographic region filled with elevation values. Areas without elevation data MUST be masked out using the *r.mask* command. Areas masked out will be treated as if they are off the edge of the region. Masks will reduce the memory necessary to run the program. Masking out unimportant areas can significantly reduce processing time if the watersheds of interest occupies a small percentage of the overall area.

Zero data values will be treated as elevation data (not no_data). If there are zero data along the edges of the current region, that edge will not be able to propagate negative accumulation data to the rest of the map. This might give users a false sense of security about the quality of their data. If there are incomplete data in the elevation map layer, users should mask out those areas.

**SEE ALSO**

The $A^T$ least-cost search algorithm used by *r.watershed* is described in Using the $A^T$ Search Algorithm to Develop Hydrologic Modelsfrom Digital Elevation Data, in Proceedings of International Geographic Information Systems Symposium '89. pp, 275-281, (Baltimore, MD, 18-19, March 1989 by, Charles Ehlschlaeger, U.S. Army Construction Engineering, Research Laboratory.

Length slope and steepness (length.slope) factor equations were taken from Revised Universal Soil Loss Equation for Western Rangelands, presented at the U.S.A./Mexico Symposium of Strategies for Classification and Management of Native Vegetation for Food Production In Arid Zones (Tucson, AZ, 12-16 Oct 1987), by M. A. Weltz, K. G. Renard, and J. R. Simanton.

The slope steepness (slope.steepness) factor contains the revised slope steepness factor for the Universal Soil Loss Equation.  Equations were taken from article entitled Revised Slope Steepness Factor for the Universal Soil Loss Equation, in Transactions of the ASAE (Vol 30(5), Sept-Oct 1987), by McCool et al.

*r.cost, r.drain, r.mask*

**AUTHOR**
Charles Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory

## *r.watershed4.0*

**NAME**
*r.watershed4.0* **-** Watershed basin analysis program.
(GRASS 4.0 Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.watershed4.0*
*r.watershed4.0 help*
*r.watershed4.0 [-m4] elevation=name [depression=name] [flow=name] [disturbed.land=name|value] [blocking=name] [threshold=value] [max.slope.length=value] [accumulation=name] [drainage=name] [basin=name] [stream=name] [half.basin=name] [visual=name] [length.slope=name] [slope.steepness=name] [armsed=name*]

**DESCRIPTION**
This is the GRASS 4.0 version of this program; the GRASS 4.1 version is available as *r.watershed*. Note also that the armsed sedimentation calculation facility is not available.

*r.watershed4.0* generates a set of maps indicating: 1) the location of watershed basins, 2) information to interface with ARMSED, a storm-water runoff and sedimentation yield model, and 3) the LS and S factors of the Revised Universal Soil Loss Equation (RUSLE).

*r.watershed4.0* can be run either interactively or non-interactively. If the user types

*r.watershed4.0*

on the command line without program arguments, the program will prompt the user with a verbose description of the input maps. The interactive version of *r.watershed4.0* can prepare inputs to lumped-parameter hydrologic models. After a verbose interactive session, *r.watershed4.0* will query the user for a number of map layers. Each map layer's values will be tabulated by watershed basin and sent to an output file. This output file is organized to ease data entry into a lumped-parameter hydrologic model program. The non- interactive version of *r.watershed4.0* cannot create this
file.

The user can run the program non-interactively, by specifying input map names on the command line. Parameter names may be specified by their full names, or by any initial string that distinguish them from other parameter names. In *r.watershed4.0*'s case, the first two letters of each name sufficiently distinguishes parameter names. For example, the two expressions below are equivalent inputs to *r.watershed4.0*:

```
  r.watershed4.0 el=elev.map th=100 st=stream.map
  ba=basin.map
r.watershed4.0 elevation=elev.map threshold=100
  stream=stream.map basin=basin.map
```

**OPTIONS**
Flags:
-*m* Without this flag set, the entire analysis is run in memory maintained by the operating system. This can be limiting, but is relatively fast. Setting the flag causes the program to manage memory on disk which allows larger maps to be processes but is considerably slower.

*-4* Allow only horizontal and vertical flow of water. Stream and slope lengths are approximately the same as outputs from default surface flow (allows horizontal, vertical, and diagonal flow of water). This flag will also make the drainage basins look more homogeneous.

Parameters:
*elevation* Input map: Elevation on which entire analysis is based.

*depression* Input map: Map layer of actual depressions in the landscape that are large enough to slow and store surface runoff from a storm event. Any non-zero values indicate depressions.

*flow* Input map: amount of overland flow per cell. This map indicates the amount of overland flow units that each cell will contribute to the watershed basin model. Overland flow units represent the amount of overland flow each cell contributes to surface flow. If omitted, a value of one (1) is assumed.

*disturbed.land* Raster map input layer or value containing the percent of disturbed land (i.e., croplands, and construction sites) where the raster or input value of 17 equals 17%. If no map or value is given, *r.watershed4.0* assumes no disturbed land. This input is used for the RUSLE calculations.

*blocking* Input map: terrain that will block overland surface flow. Terrain that will block overland surface flow and restart the slope length for the RUSLE. Any non-zero values indicate blocking terrain.

*threshold* The minimum size of an exterior watershed basin in cells, or overland flow units.

*max.slope.length* Input value indicating the maximum length of overland surface flow in meters. If overland flow travels greater than the maximum length, the program assumes the maximum length (it assumes that landscape characteristics not discernable in the digital elevation model exist that maximize the slope length). This input is used for the RUSLE calculations and is a sensitive parameter.

*accumulation* Output map: number of cells that drain through each cell. The absolute value of each cell in this output map layer is the amount of overland flow that traverses the cell. This value will be the number of upland cells plus one if no overland flow map is given. If the overland flow map is given, the value will be in overland flow units. Negative numbers indicate that those cells possibly have surface runoff from outside of the current geographic region. Thus, any cells with negative values cannot have their surface runoff and sedimentation yields calculated accurately.

*drainage* Output map: drainage direction. Provides the "aspect" for each cell. Multiplying positive values by 45 will give the direction in degrees that the surface runoff will travel from that cell. The value -1 indicates that the cell is a depression area (defined by the depression input map). Other negative values indicate that surface runoff is leaving the boundaries of the current geographic region. The absolute value of these negative cells indicates the direction of flow.

*basin* Output map: Unique label for each watershed basin. Each basin will be given a unique positive even integer. Areas along edges may not be large enough to create an exterior watershed basin. 0 values indicate that the cell is not part of a complete watershed basin in the current geographic region.

*stream* Output map: stream segments. Values correspond to the watershed basin values.

*half.basin* Output map: each half-basin is given a unique value. Watershed basins are divided into left and right sides. The right-hand side cell of the watershed basin (looking upstream) are given even values corresponding to the watershed basin values. The left-hand side cells of the watershed basin are given odd values which are one less than the value of the watershed basin.

*visual* Output map: useful for visual display of results. Surface runoff accumulation with the values modified to provide for easy display. All negative accumulation values are changed to zero. All positive values above the basin threshold are given the value of the basin threshold.

*length.slope* Output map: slope length and steepness (LS) factor. Contains the LS factor for the Revised Universal Soil Loss Equation. Equations taken from Revised Universal Soil Loss Equation for Western Rangelands (see SEE ALSO section). Since the LS factor is a small number, it is multiplied by 100 for the GRASS output map.

*slope.steepness* Output map: slope steepness (S) factor for RUSLE. Contains the revised S factor for the Universal Soil Loss Equation. Equations taken from article entitled Revised Slope Steepness Factor for the Universal Soil Loss Equation (see SEE ALSO section). Since the S factor is a small number (usually less than one), it is multiplied by 100 for the GRASS output map layer.

**NOTES**

There are two versions of this program: *ram* and *seg*. Which is run by *r.watershed4.0* depends on whether the *-m* flag is set. ram uses virtual memory managed by the operating system to store all the data structures and is faster than *seg*; *seg* uses the GRASS segment library which manages data in disk files. *seg* allows other processes to operate on the same CPU, even when the current geographic region is huge. Due to memory requirements of both programs, it will be quite easy to run out of memory. If *ram* runs out of memory and the resolution size of the current geographic region cannot be increased, either more memory needs to be added to the computer, or the swap space size needs to be increased. If *seg* runs out of memory, additional disk space needs to be freed up for the program to run.

seg uses the $A^T$ least-cost search algorithm to determine the flow of water over the landscape (see SEE ALSO section). The algorithm produces results similar to those obtained when running *r.cost* and *r.drain* on every cell on the map.

In many situations, the elevation data will be too finely detailed for the amount of time or memory available. Running *r.watershed4.0* will require use of a coarser resolution. To make the results more closely resemble the finer terrain data, create a map layer containing the lowest elevation values at the coarser resolution. This is done by: 1) Setting the current geographic region equal to the elevation map layer, and 2) Using the neighborhood command to find the lowest value for an area equal in size to the desired resolution. For example, if the resolution of the elevation data is 30 meters and the resolution of the geographic region for *r.watershed4.0* will be 90 meters: use the minimum function for a 3 by 3 neighborhood. After going to the resolution at which *r.watershed4.0* will be run, *r.watershed4.0* will be taking values from the neighborhood output map layer that represents the minimum elevation within the region of the coarser cell.

The minimum size of drainage basins is only relevant for those basins that have no basins draining into them (they are called exterior basins). An interior drainage basin has the area that flows into an interior stream segment. Thus, interior drainage basins can be of any size.

The *r.watershed4.0* program does not require the user to have the current geographic region filled with elevation values. Areas without elevation data MUST be masked out using the *r.mask* command. Areas masked out will be treated as if they are off the edge of the region. Masks will reduce the memory necessary to run the program. Masking out unimportant areas can significantly reduce processing time if the watersheds of interest occupies a small percentage of the overall area.

Zero data values will be treated as elevation data (not no_data). If there are zero data along the edges of the current region, that edge will not be able to propagate negative accumulation data to the rest of the map. This might give users a false sense of security about the quality of their data. If there are incomplete data in the elevation map layer, users should mask out those areas.

**SEE ALSO**
The $A^T$ least-cost search algorithm used by *r.watershed4.0*, is described in Using $A^T$ Search Algorithm to Develop Hydrologic Models from Digital Elevation Data. *in* Proceedings of International Information Systems (IGIS) Symposium, '89, pp, 275-281, (Baltimore, MD, 18-19 1989), by Charles Ehlschlaeger U.S. Army Construction Engineering Research Laboratory.

Length slope and steepness (length.slope) factor equations were taken from Revised Universal Soil Loss Equation for Western Rangelands, presented at the U.S.A./Mexico Symposium of Strategies for Classification and Management of Native Vegetation for Food Production In Arid Zones (Tucson, AZ, 12-16 Oct 1987), by M. A. Weltz, K. G. Renard, and J. R. Simanton.

The slope steepness (slope.steepness) factor contains the revised slope steepness factor for the Universal Soil Loss Equation. Equations were taken from the article entitled Revised Slope Steepness Factor for the Universal Soil Loss Equation, in Transactions of the ASAE (Vol 30(5), Sept-Oct 1987), by McCool et al.

*r.cost, r.drain, r.grass.armsed, r.mask*

**AUTHOR**
Charles Ehlschlaeger, U.S. Army Construction Engineering Research Laboratory

## *r.weight*

**NAME**
*r.weight* **-** Raster map overlay program.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.weight*

**DESCRIPTION**
*r.weight* is a language driven raster map overlay program. It provides a means for performing geographical analyses using several raster maps. *r.weight* asks the user to weight (assign numeric values to) the raster map categories of interest. The assignment of weighted values requires that the user intimately understand the analysis being undertaken. How important is the slope of the land in comparison with the current land use, or the depth to bedrock? The assignment of values to the land's characteristics allows *r.weight* to mix and compare apples and oranges, such as slopes and land uses, and soil types and vegetation.

*r.weight* is a language-driven analysis tool. It responds to worded commands typed at the terminal. Help is always available via the one word command: help. Commands available in *r.weight* are listed below.

Note that raster map names appear in parentheses. The use of parentheses is now optional in *r.weight*.

*list maps* List available raster maps

*list categories (name)* List categories for raster map (name)

*list save* List saved analyses

*list analysis* Display current analysis request

*print analysis* Send current analysis request to printer

*choose (name)* Choose raster map (name) for analysis

*assign (name)* Interactive way to assign weights for raster map (name)

*assign (name) (cat) (val)* Assign weight (val) to category (cat) for raster map (name) assign (name) (cat) (cat) (val) Assign weight (val) to categories (cat) (cat) for raster map (name)

*save* Save the current analysis

*recover* Recover old analysis

*add* Request that weights be added (this is the default)

*mult* Request that weights be multiplied

*execute* Run analysis

| | |
|---|---|
| *erase* | Erase the screen |
| *color grey* | Set the graphics monitor colors to a grey scale (this is the default) |
| *color wave* | Set the graphics monitor colors to a color wave. |
| *color ramp* | Set the graphics monitor colors to a color ramp. |
| *quit* | Leave *r.weight* |

A more detailed explanation of a command can be obtained by typing:

*help (command)*

**SUGGESTED APPROACH**

In order for *r.weight* to generate raster maps useful for analysis, the user must make a reasonable and defensible request. While much more powerful than *r.combine, r.weight* is also more dangerous. The user provides the necessary value judgments which are registered as weights. Only well-conceived value judgments will result in defensible results. We suggest the following approach to a weighted overlay analysis:

B

a) Define the question to be answered. e.g., "Locate sites suitable for building apartments."
b) Determine what mapped information is useful for answering the question. e.g., geology, soils, land_use, flood_potential.
c) Based on professional judgement, statistical inference, and engineering principals, assign weights to the categories in the chosen raster maps.

STEP 2: CHOOSE CELL MAPS
In r.weight, use the command choose to identify up to six raster maps of interest.

STEP 3: ASSIGN WEIGHTS
Using the r.weight command assign, assign specific weights to raster map categories.

STEP 4: SAVE ANALYSIS
Use the save command to save a copy of the analysis requested for later use.

STEP 5: RUN ANALYSIS
Use execute to run the analysis.

STEP 6: EVALUATE RESULTS
To modify an existing analysis request, use the recover command to retrieve the analysis and then go to STEP 3.

**SEE ALSO**

GRASS Tutorial: *r.weight, r.infer, r.combine, r.mapcalc*

**AUTHOR**

James Westervelt, U.S. Army Construction Engineering Research Laboratory

## *r.weight2*

**NAME**
*r.weight2* **-** Weighted overlay raster map layer analysis program.
(GRASS Raster Program)

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.weight2 [output] [action] [color]*
*r.weight2 [output=option] [action=option] [color=option]*

**DESCRIPTION**
*r.weight2* is the non-interactive version of *r.weight*. Both programs allow the user to assign numeric values (i.e., "weights") to individual category values within raster map layers. These weights are then distributed locationally throughout a raster map layer based on the distribution of the categories with which they are associated. The user can weight the categories of several raster map layers in a data base. Such weighted raster map layers can then be overlain. *r.weight2* will combine weights in the overlain map layers by cell location.

A resulting output raster map layer depicts the combination of map layer weights across a landscape. These values represent a hierarchy of suitability for some user-defined purpose. To obtain a more detailed description, see the manual entry for *r.weight.*

Output raster map must be specified (no default) Action must be either (add or mult) (default: add) Color table for the new raster map (grey | wave | ramp) (default: grey)

Once the *r.weight2* command line is entered, the user will need to enter a raster map layer name and assign numeric values to its categories. Values can be assigned to the categories of up to six raster map layers within *r.weight2* in a single analysis. Help is available to the user by typing *r.weight2* help.

EXAMPLE
The following is the format in which data should be entered to *r.weight2*:
Raster_layer1
[Reclass rule 1a]
[Reclass rule 1b]
Raster_layer2
[Reclass rule 2a]
etc.
end

Raster_layer: raster_map OR "raster_map in mapset"
Reclass rule: (example) 1 = 5 OR 20 thru 50 = 10 (must leave spaces between the category, =, and value entries)

Example: (the prompts are shown in bold)

```
>  r.weight2 sites add wave
>  soils

soils>  1 thru 20 = 5
soils>  21 thru 30 = 10
soils>  landcover
```

```
landcover>  1 = 2
landcover>  2 = 4
landcover>  3 thru 8 = 6
landcover>  end
```

**NOTES**
The user must be knowledgeable about *r.weight* to run *r.weight2*. *r.weight2* does not provide the user with a listing of raster map layers or map layer categories. Users unsure about raster map layer names should run the GRASS program *g.list*. To obtain a listing of the categories for a raster map layer run *r.report*.

The user can create an input file containing the data needed to run *r.weight2*. This file must list the raster map layer and reclass rules in the format shown in the above example. The prompts must not be included in the file. This file can be directed into *r.weight2* at the command line by typing *r.weight2* output action color < input_file

**BUGS**
When entering data for the reclass rules, if the user does not include spaces between the category, =, and value, the program will assume that the entry is a raster map layer.

**SEE ALSO**
*g.list, r.combine, r.infer, r.report, r.weight*

**AUTHOR**
David Gerdes, U.S. Army Construction Engineering Research Laboratory

## *r.weighted.cn*

**NAME**
*r.weighted.cn*(G-language) **-** Generates a weighted SCS curve number map layer

**GRASS VERSION**
4.x

**SYNOPSIS**
*r.weighted.cn input=cn_map output=weighted_cn_map*

Parameters:

| | |
|---|---|
| *input=map* | curve number map name |
| *output=map* | weighted curve number map name |

The command-line ordering can be in any form but all key words must be there to run the program.

**NOTE**
The *r.weighted.cn* program is sensitive to the current window settings. Thus the program can be used to generate a weighted CN map of any sub-area within the full map layer. Also, *r.weighted.cn* is sensitive to any mask in effect.

**AUTHORS**
Raghavan Srinivasan and Dr. Bernie A. Engel, Agricultural Engineering Department, Purdue University

## *r.what*

**NAME**
*r.what* **-** Queries raster map layers on their category values and category labels.
(GRASS Raster Program)

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*r.what*
*r.what help*
*r.what [-fci] input=name[,name,...][cache=value][null=string]*
*r.what [-fci] input=name[,name,...] [< inputfile][cache=value][null=string]*

**DESCRIPTION**
*r.what* outputs the category values and (optionally) the category labels associated with user-specified locations on raster input map(s). Locations are specified as geographic x, y coordinate pairs (i.e., pair of eastings and northings); the user can also (optionally) associate a label with each location.

The program will be run non-interactively if the user specifies the program parameter values and (optionally) the flag setting on the command line, using the form:

*r.what [-f] input=name[,name,...]*

where each input name is the name of a raster map layer whose category values are to be queried, and the (optional) flag *-f* directs *r.what* to also output category labels. The user can also redirect a user-created ASCII input file containing a list of geographic coordinate pairs and (optionally) user-named labels, into *r.what* using the form:

*r.what [-f] input=name[,name,...] [< inputfile]*

If the user does not redirect an input file containing these coordinates into the program, the program will query the user for point locations and labels.

Alternately, the user can simply type:

*r.what*

on the command line, without program arguments. In this case, the user will be prompted for the flag setting and parameter values using the standard GRASS *parser* interface described in the manual entry for *parser*.

Flags:

| | |
|---|---|
| -*f* | Also output the category label(s) associated with the cell(s) at the user-specified location(s). |
| -*c* | Turn on cache reporting. |
| -*i* | Output integer category values, not cell values. |

Parameters:

| | |
|---|---|
| *input=name[,name,name,...]* | The name(s) of one or more existing raster map layers to be queried. |

|  |  |
|---|---|
| *cache=value* | Size of point cache. |
| *null=string* | Character string to represent no data cell. |

**EXAMPLES**
The contents of the ASCII inputfile to *r.what* can be typed in at the keyboard, redirected from a file, or piped from another program (like *d.where*). Each line of the input consists of an easting, a northing, and an optional label, which are separated by spaces. The word end is typed to end input of coordinates to *r.what*. For example:

```
635342.21 7654321.09 site 1
653324.88 7563412.42 site 2
end
```

*r.what* output consists of the input geographic location and label, and, for each user-named raster map layer, the category value, and (if *-f* is specified) the category label associated with the cell(s) at this geographic location. Sample input (in Times text) to and output (in plain text) from *r.what* are given below.

```
r.what input=soils,aspect
635342.21 7654321.09 site 1
653324.88 7563412.42 site 2
end

635342.21|7654321.09|site 1|45|21
653324.88|7563412.42|site 2|44|20

r.what -f input=soils,aspect
635342.21 7654321.09 site 1
653324.88 7563412.42 site 2
end

635342.21|7654321.09|site 1|45|NaC|21|30 degrees NW
653324.88|7563412.42|site 2|44|NdC|20|15 degrees NW
```

**NOTES**
The maximum number of raster map layers that can be queried at one time is 14.

**SEE ALSO**
*d.sites, d.where, r.cats, r.report, r.stats, sites, parser*

**AUTHOR**
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# *r.wrat*

**NAME**
*r.wrat* **-** Water Resource Assessment Tool

**GRASS VERSION**
4.x

**USAGE**
This module must be used interactively.

**INPUT MAP CODES**

| | |
|---|---|
| *elevation* | meters, as well as cell resolution |
| *rainfall maps* | 100ths of an inch |
| *K factor* | K factor times 100 K of .35 = 35 |

**Introduction**
The Water Resource Assessment Tool is a collection of programs run within the GRASS GIS. These programs are an aid in understanding the nature of runoff in a study area based on information typically available for a GIS. The programs analyze the terrain to define drainage direction and areas, simulate runoff and peak runoff and model nonpoint source pollution and map contaminant source areas and contaminant pathways. This users guide outlines the typical analytical sequence, describes input data requirements and possible output. Some suggestions for interpreting output are included. It is assumed the user is familiar with the basics of GRASS.

**Input**
Map layers required: digital elevation model, land cover, soil maps of hydrologic soil group, soil texture, and erodibility factor (K factor). Optional maps describe best management practices for sediment, nitrogen phosphorous and chemical oxygen demand (COD).

**Typical Analysis**
Three interrelated areas of analysis are available: terrain analysis, hydrology and pollution (see figure X1). Because these areas are not distinct, analysis should proceed in a logical order since some portions build on previous results. Terrain analysis and runoff generation must proceed routing peak discharge, which in turn must proceed contaminant routing. The following steps provide a natural sequence of analysis through all of the tools. However, a great deal of valuable information may be gained executing only a portion of the available programs. This is a tool kit, not a prescription for studying every area.

```
Terrain Analysis        Hydrology               Pollution
_________________       _________________       _________________
|               |       |               |       |               |
| Elevation     |       | Land Cover    |       | Land Cover    |
| Model         |       |               |       |               |
--------+--------       | Hydrologic    |       | Soils         |
        |               | Soil Group    |       | K factor      |
________V________       --------+--------       | Texture       |
|               |               |               --------+--------
| Idealized     |               |                       |
| Elevation     |               |                       |
| Model         |               |                       |
|               |               |                       |
| Drainage      |               |                       |
| Direction     |               |                       |
|               |               |                       |
| Drainage      |       ________V________               |
| Accumulation  |       |               |               |
|               |       | Runoff Map    |               |
| Slope         |       -+------+--------               |
--------+--------        |      |                       |
        |            +----      |                       |
        --------+----(--------->|<-----------------------
                |    |  ________V________       _________________
                |<---+  |               |       |               |
                |       | Contaminant   |       | Best          |
                |       | Source Areas  |       | Management    |
                |       --------+--------       | Practices     |
        ________V________       |               --------+--------
        |               |       |                       |
        | Peak          |       ------------+------------
        | Discharge     |                   |
        -----------------           ________V________
                                    |               |
                                    | Contaminant   |
                                    | Routing       |
                                    -----------------
```

figure X1.

**Defining the study area**

GRASS looks at the world through a rectangular "window". The window should be set to include the entire area of interest with several cells to spare in all directions. Because of difficulty interpreting terrain at the edge of the window, the analysis moves in from the window edge. The extra area is particularly important if the top of a watershed of interest is not marked by a steep decline into the adjacent watershed.

Routing routines assume that the entire watershed is within the current window. This is not always true or even practical. For instance, an analysis along the side of a long river will provide valuable information about local contributions to the larger resource. However, calculations in the long river itself can not take into account upstream effects outside the current window and are thus invalid. Yet those local contributions may be of considerable interest. Great care must be taken interpreting results of watersheds only partially contained within the operating window.

Cell resolution, the size of each cell, should be set as large as is appropriate for your purposes. In no case should the resolution be smaller than the spatial resolution of your best input layer. Doubling the cell length and width will cut computation times by 3/4s! The east-west resolution need not match the north-south resolution. However, large deviations from square cells will distort some of the neighbor concepts used by some algorithms to "feel their way" across the terrain.

Once the analysis is begun, the same window, including cell resolution, must be maintained throughout the project. The interface program tries to insure this. Changing the boundaries invalidates the drainage accumulation maps. Changing the cell resolution can have disastrous effects on the drainage direction map, such as creating dead end and circular drainages. The idealized elevation model will lose its "ideal" character if resampled. If the window must be changed, start the analysis from the beginning.

Some of the output maps may be resampled to a smaller window or different cell size after the analysis is finished. Contaminant source area maps are produced in units of mass per unit area and may be resampled. This may be useful for presentation of results or incorporation within another GIS analysis.

**Temporal scale**

Hydrologic simulations are based on single storms, presumably one day events. Actual or design storms may be employed.

**Terrain analysis**

The actual analysis may begin using the digital elevation model to produce an idealized elevation model. Real data has, for a number of reasons, sections that are difficult to drain. The idealized elevation model has no cells that can not drain to the edge of the window. This assumes complete surface drainage is possible. This condition is never completely true and in some regions, such as those with karst topography, so far from the case as to invalidate the peak discharge and contaminant routing results.

The idealized elevation model is used to determine the direction in which each cell will drain. This is done by searching the edge of the window for the lowest point and draining the watershed that leads there. Then the next lowest outlet is found and its watershed drained, and so on until the entire area is drained.

The drainage direction map is used to produce a drainage accumulation map. The values in a drainage accumulation map are the total number of cells including that cell, which drains through that cell. If multiplied by the area of a cell, the drainage accumulation map will yield the area of the watershed above and including each cell.

**Hydrology**
Two programs contribute to the hydrology section: runoff and peak discharge. The runoff section is based on the Soil Conservation Services Curve number method (Soil Conservation Service, USDA, 1971). Curve numbers, from 0 to 100, describe the potential for runoff. Curve numbers are inferred from the land cover map and the map of hydrologic soil groups. A depth of precipitation for a design storm or a rainfall map is required to produce a runoff map.

To this point the terrain analysis and the hydrology could progress independently. From this point on the distinctions between terrain analysis, hydrology and pollution, as separate lines of analysis begin to fade. Actually pollution analysis will always be dependent to some extent on hydrology but that will be dealt with in a later section. Peak discharge combines the results of the terrain analysis and runoff sections.

Peak discharge, the volume of water passing out of a cell per unit time, is calculated with an empirical relationship developed by Smith and Williams (1980) and employed in CREAMS and AGNPS. Watershed characteristics are interpreted from several all of the results from the terrain analysis. The resulting map of peak discharge, significant by itself, is also used in the routing of contaminants.

**Pollution**
Contaminant sources are mapped as the contaminant originating per unit area. Sediment, nitrogen, phosphorous and COD may be modeled. The algorithms used to predict contaminant mobilization depend on the landcover of the cell involved. The universal soil loss equation and adaptations from AGNPS and CREAMS are employed for rural, agricultural and open lands. An algorithm from SWMM is adopted for urban areas. Land cover, soil texture and erodibility factors, rainfall, runoff and peak discharge maps are the required inputs for this section.

The final part of the analysis routes contaminants. It requires the results of the preceding sections. Sediment, nitrogen and phosphorous nutrients and COD may be modeled. The routing is done as a mass balance accounting for imports of contaminants into a cell, contaminants originating within the cell, losses to infiltration and deposition and exports to the next cell. Figure X2 is a schematic representation.

```
                       rainfall with
                       contaminants
                             |
                       ______________
imports from          /             /       Surface exports
up gradient      -   /             /  -    down gradient
                    /_____________/

                           |

                   losses to infiltration
                   and deposition

                                  figure X2.
```

**Some practical considerations:**
GRASS only stores integers, assuming values less then one to be equal to zero. Therefore small units of measure have been employed. Rainfall and runoff are described in hundredths of inches, while quantities of sediment are in kilograms with nutrients in grams. Flows are measured in cubic feet per second. The mixing of English and metric units employs those units in common usage in the U.S. Maps may be converted to any appropriate set of units using *r.mapcalc* to multiply the map by the appropriate conversion factor.

**Preparing map layers**
GRASS associates numeric values with cells as their attributes. Sometimes these numbers have real meanings, as in an elevation model in which the cell's value is its elevation. Some are more arbitrary codes representing qualitative categories, such as landcover. The following tables provide guides to units and codes used in the water resource assessment tools. The GRASS tool *r.reclass* allows speedy recoding of map layers to these codes.

**Input layers and data**

**Elevation**
Values in the digital elevation model represent the altitude above mean sea level expressed in meters.

**Rainfall**
Rainfall maps should be rainfall for a single day, measured in hundredths of an inch. Thus a one and a quarter inch rainfall would be represented as 125. The GRASS command "Gsurface" can be used to interpolate a rainfall map between observation stations, however, Gsurface does not understand the effects of terrain on rainfall and will make significant mistakes in hilly country and for thunderstorms passing through a widely scattered set of observation points. A design storm may be preferable for assessment purposes.

**Soil, texture**
Values are a code for the dominant texture.

```
1 = clay soils
2 = silt soils
3 = sandy soils
4 = peat
5 = water
```

**Soil, hydrologic soil group**
Hydrologic soil group is primarily dependent on the soil texture. However depth to bed rock and depth to water table may strongly influence a soil's classification.

```
1 = hydrologic soil group A
2 = hydrologic soil group B
3 = hydrologic soil group C
4 = hydrologic soil group D
5 = water
```

**Soil, erodibility K factor**
K factors are a decimal value greater then zero and typically less then .5. Formally they represent the soil loss rate per unit of per erosion index unit for a specified test plot. (Agriculture Handbook Number 537 "Predicting Rainfall Erosion Losses", USDA 1978) Information about local soils should be available from your local Soil Conservation Service office. Because GRASS uses only integer values, multiply K factors by 100. Thus a K factor of .37 would be coded as 37. Use a code of 100 for water.

**Landcover**
The landcover map must be coded so the water resource assessment tools can recognize the landcovers indicated. The following table illustrates the 15 landcover category codes expected. When attempting to make the best fit of available data to this encoding scheme, remember to think of the areas both in terms of their ability to slow runoff and their contributions to water quality. Some creative lies may be useful for special purposes. For instance, a development built to the performance standard that peak discharge is not to exceed a field in good condition could be coded as an old field for hydrologic analysis and built up for pollution analysis.

```
1 = corn
2 = rye
3 = oats
4 = soybeans
5 = hay
6 = grass
7 = old field (grass)
8 = old field (shrub)
9 = pasture
10 = forest
11 = wetlands
12 = fens
13 = water
14 = built up
15 = barren
```

**Output Map layers**
Many maps can be produced with the water resource assessment tools. The following sections outline how these maps are prepared, the units of measure and codes employed along with some notes as to how they should and should not be used. More complete information is available in the model documentation. The source code is also provided and contains a great deal of internal documentation. Output maps are presented in the approximate order in which they would be produced.

The idealized elevation file is a digital elevation file. Cell values represent elevation in meters. This elevation model will differ from the input DEM provided by the user, in that depressions in the data are filled in so that water landing anywhere on the idealized surface can flow to the edge. Although useful for analyzing terrain, and employed for slope measurements, the idealized elevation model is probably further removed from reality then the original data upon which it is based. The idealized elevation data may not be resampled to a different cell resolution and retain its desired "idealized" characteristics.

**Drainage Direction**
Cells in the drainage direction map are coded to indicate the neighboring cell into which they drain. The eight nearest neighbors are represented by the integers 1 through 8 as depicted in figure X3.

```
4 3 2
5   1
6 7 8

figure X3.
```

Drainage direction is similar to aspect. However they are not exactly the same thing. In an aspect map, the cells at the bottom of a V shaped valley may face each other without draining into each other. This map is produced by searching the border of the window for the lowest cell and draining all cells in that drainage. The algorithm moves up through the drainage one unit of elevation at a time until all adjacent cells of that elevation are drained, trying to assign the most direct drainage direction. Then the next lowest undrained border cell is found and that watershed is drained until the entire map is drained. The routine sometimes has difficulty at the top of watersheds if the next valley does not clearly drop away.

**Drainage Accumulation**
Values in the drainage accumulation map represent the number of cells, including the cell with the value that drains through the cell. Thus the minimum drainage accumulation is one, while the maximum is the number of cells in the largest watershed in the study area. The drainage accumulation map is used to find the watershed area for each cell in the study area and to guide a search up the watershed to find the length of the longest stream. The drainage accumulation map can be used to define the stream networks by reclassifying the cells below a minimum accumulated drainage to zero. The remainder represents the streams. Drainage accumulation is drainage area represented in cells. Multiplying a drainage accumulation by the area of a cell yields the drainage area above that cell.

**Runoff**
The values in the runoff map represent the depth of water expected to run off that cell, from the input rainfall, based on the soil and landcover maps specified. Values could range between zero and the amount of rain that fell on that cell. Runoff, like rainfall, is measured in hundredths of inches. A value of 75 represents .75 inches of runoff. Runoff values can be multiplied by the area of each cell to give a volume of runoff. However, care should be taken when converting units because cell sizes in GRASS are defined in meters. Upgradient values in the runoff map are summed during the peak discharge calculations and used in the contaminant source area and routing calculations.

**Peak Discharge**
Peak discharge is the maximum rate at which water passes through a cell measured in cubic feet per second. These estimates are based on an empirical relationship that describes the entire upstream portion of the watershed. If the entire upstream portion of the watershed is not within the current window, the model assumes the upstream edge is the top of the watershed. This is wrong and estimates of peak discharge in streams which enter the window are meaningless as are routings of contaminants based on peak discharge. The calculations are retained so that local contributions from side streams and slopes may be modeled. These local effects may be of substantial importance to those involved in the local area regardless of distant conditions.

**Contaminant Source Areas**
Sediment, nitrogen and phosphorus nutrients and COD can be simulated. The algorithms used to predict contaminant mobilization are dependent on the contaminant and the landcover class. In non urban areas sediment production is based on the universal soil loss equation. Nitrogen and phosphorous are modeled both in solution and associated with sediment in rural areas and only as a function of sediment in urban areas. COD is assumed to be soluble and is calculated by loading factors.

Sediment loadings are expressed as kilograms per hectare. Nutrients and COD loadings are expressed as grams per hectare.

These loadings are a function of the rainfall, the soil, slope and landcover. They do not represent the natural scatter found in natural events. Results may be used as a relative indicator of contaminant generation. As such these maps may highlight those areas in a watershed that would benefit most from conservation efforts. Subtracting two source area maps generated for different scenarios would help locate the areas of greatest change.

**Routing of Contaminants**
Contaminants are routed down stream assuming total conservation unless a best management practice map for the particular contaminant is used. If a best management practice map is used contaminants flux across a BMP is reduced by the percentage indicated.

The output maps indicate the total mass of contaminant passing through a cell. These maps can be used as indicators of the contaminants delivered to any point down stream. Similar analysis for varying land cover regimes could be subtracted with *r.mapcalc* to find areas of greatest positive and negative change resulting from the changes in scenarios. Again these numbers represent relative indicators.

**Interface Program**
The Water resources assessment tool is run through an interface program invoked from the grass environment at any GRASS prompt by typing wrat. Work is organized in projects, which should represent the investigation of a geographic area. The user interface is a series of menus that guide the user through the program. A project file is created which keeps track of the options used and input and output map names. The project file also creates a database window based on the active window at the time a project is started. The active window is returned to this active window for subsequent work sessions on the project.

**First Menu**
At this menu the user can:

1 start a new project
2 start a project based on an existing project
3 work on an existing project
4 remove project files
5 exit

The user is prompted for needed information such as the name of the project to work on with the option of listing project files if needed. Once a project is selected the second menu is offered. The User may do:

1 Terrain Analysis
2 Runoff Analysis
3 Contaminant Analysis
4 return to main menu

Choices 1, 2 or 3 lead to menus for each of those analysis.

In the Terrain Analysis the options are:

1 Create an idealized elevation model
2 Create a drainage direction map
3 Create a drainage accumulation map
4 Create a slope map
5 Return to the previous menu

In each case except option 5 the user is prompted for needed information. where appropriate the likely choices are supplied if not insisted upon. The drainage direction map must be based on the idealized elevation map. The drainage accumulation map needs a drainage direction map, which should be the output map from option 2. In this way the user is guided along.

In the runoff analysis section there are only three options:

1 Create a runoff map
2 Simulate peak discharge
3 Return to the previous menu

In this section the options are not as straight forward and the user is coached along. The user must provide the names of several input maps and can obtain a listing by entering list instead of a map name where requested. The user must also choose between a design storm and rainfall map. The most difficult information requested of the user is the antecedent moisture condition. This is a number between 1 and 3 inclusively which describes the amount of moisture already in the soil, which effects the amount of rain that can be absorbed during the current storm. 1 represents extremely dry conditions and 3 extremely wet conditions. The concept comes from the Soil Conservation Service curve number method of predicting runoff. The basic guidance from the SCS is offered with the request and a value of 2 neither wet or dry is the default. Peak discharge is quite sensitive to thee antecedent moisture condition so some care should be taken here.

The contaminant section has only three options as well:

1 Model Contaminant source areas
2 Rout contaminants through the watershed
3 Return to the previous menu

When modeling contaminant source areas the user may model just sediment or sediment and any combination of nitrogen, phosphorus and COD. Because nutrients are associated with sediment predictions are required for nutrient modeling. Most input for this section is straight forward except the number of days since the last significant rain. The amount of dirt available to wash off of urban areas accumulates between rainstorms. Rain storms wash urban areas clean. a default of 7 days is suggested because this puts urban and rural areas on roughly even footings for comparison. To complicate the issue street sweeping also removes contaminants from road ways and so if the study area has a regular street cleaning program that should be reflected by entering fewer dry days. Several minor rain storms, especially short hard rains will accomplish the same cleaning as a long large rain. SWMM assumes that a half inch of rain removes half of the available dirt and the next half inch removes half of what is left an so on. A worst case for urban areas is a rain after an extended dry period. However the goal is to compare watersheds or source areas. Agricultural areas contribute the most pollution with an antecedent moisture condition of 3 since that is when the most runoff and erosion takes place.

**Summary**
The tools presented here run within the GRASS GIS. A flow chart of input and analysis (figure X1) can be used as a guide for the order of analysis. The system of units and means for encoding qualitative information are supplied for both input and output map layers. Careful preparation of input maps is strongly encouraged since this effort will likely save time and trouble later in the analysis.

The ultimate utility of analyses performed with these water resource assessment tools is dependent on the interpretation of the user. Always keep in mind that these results are based on empirical relationships that represent expectations over a long term average. For this reason numerical results should be used only for comparison of areas and scenarios. Employing the entire set of tools from the tool kit may be inappropriate, and or redundant information.

You can't hurt the model by running it! So feel free to experiment!

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# *xganim*

**NAME**
*xganim* **-** Raster File Animation Program

**GRASS VERSION**
4.x, 5.x

**SYNOPSIS**
*xganim*
*xganim help*
*xganim view1=name[,name,...][view2=name[,name,...] [view3=name[,name,...]] [view4=name[,name,...]]*

**DESCRIPTION**
*xganim* is a tool for animating a series of GRASS raster files. At startup, a graphics window is opened containing VCR-like button controls for: rewind, reverse play, step back, stop, step forward, forward play, loop, swing, slower, faster, show filenames, current frame no., and Exit. The image is displayed above or to the left of the controls. Each raster file is read into memory, then the animation is played once beginning to end. The user may then replay the series or play continuous animation by using the buttons.

The user may define up to four "views", or sub-windows, to animate simultaneously. e.g., View 1 could be rainfall, View 2 flooded areas, View 3 damage to bridges or levees, View 4 other economic damage, all animated as a time series. There is an arbitrary limit of 100 files per view (100 animation frames), but the practical limit may be less depending on the window size and amount of available RAM.

The environment variable XGANIM_SIZE is checked for a value to use as the dimension, in pixels, of the longest dimension of the animation window. If XGANIM_SIZE is not set, the animation size defaults to the rows & columns in the current GRASS region, scaling if necessary to a default minimum size of 600 and maximum of 900. The resolution of the current GRASS region is maintained, independent of window size. Resizing the window after the program is running will have no effect on the animation size. UNIX - style wild cards may be used in the command line version in place of a raster name, but it must be quoted.

Example:

```
xganim view1="rain[1-9]","rain1[0-2]" view2="temp*"
```

If the number of files differs for each view, the view with the fewest files will determine the number of frames in the animation.

**OPTIONS**
Parameters:

| | |
|---|---|
| *view1* | Raster file(s) for View1 |
| *view2* | Raster file(s) for View2 |
| *view3* | Raster file(s) for View3 |
| *view4* | Raster file(s) for View4 |

**BUGS**
On some displays that need to use private color maps, the interface buttons may become difficult to see.

**AUTHOR**
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