## User's guide to GIS GRASS 7.0 for Watershed Morphology

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Technical report prepared at the Civil and Environmental Engineering Department, Colorado State University and to the Institute of International Education as a partial fulfillment to the Summer Academic Training Program.

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## Fort Collins, 2015

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## Abstract

This is a GRASS GIS 7.0 based manual which documents some of the most important and helpful tools to handle with watershed morphology data. The reader will find in this manual a description about how to execute important watershed morphology analysis such as river network extraction, watershed delineation, mean watershed slope and main channel longitudinal profile. This manual gathers necessary steps to achieve important results in watershed morphology studies, showing that those ones are feasible in a realistic analysis. The approach made here is unconventional, in the sense that it aimed to raise numerical results to the watershed morphology only from elevation GIS data, which allowed to find both: an effective way to get those results and a deep technical discussion about the maturity of GIS tools to watershed morphology analysis.

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### 1 Introduction

The field of watershed studies covered herein is part of the content of the Watershed Hydrology, which is an important knowledge for the society as a whole and especially for engineering students, since they can get started to morphology concepts, like watershed and river longitudinal profile, and at same time, to manage GIS data. The way engineers manage watershed information has been improved since engineering started to plan water facilities.

Recently, a lot of different tools has aided civil engineers and cartographic engineers to do both get data updated and get improved project data for water related studies. The GRASS GIS Software has been developed for 30 years, since its first release from NASA in the 80's, which has included all the most promising geospatial data storage and management technics and geostatistical technics as well.

The objectives of this report are to:

Use GRASS as a procedure to accomplish basic tasks at GIS softwares.

Document a procedure to accomplish simple watershed morphology analysis such as extracting river networks, obtaining watershed delineations, evaluating the mean watershed slope and plotting main channel longitudinal profiles.

The reader will find in this manual all the content organized in such a way that procedures are showed by sequels of tasks. Basic geoprocessing concepts are treated when convenient. Also, explanations about the processes themselves are provided and why their steps are needed, as well as alternative ways to solve the problems.

## 2 Basic Functions in GIS GRASS 7.0

#### 2.1 Set a Region

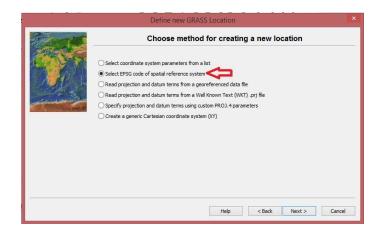
1. Open the Grass. In the initial layout you will click on "New".



2. Fill the blanks "Project Location" and "Location Title", after you will click on "Next".

a la	1	Define GRASS Database and Locati	on Name
S.M.	GIS Data Directory: Project Location:	C:\Users\User_name\Documents\grassdata	Browse
and the second second	Location Title:		~

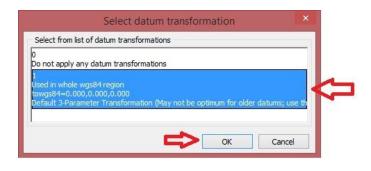
3. Select the option EPSG and click on "Next".



4. Insert the code "4326" at the blank EPSG Code and click on "Next".

CONTRACTION OF			Choose EPSG Code		
1	Path to the EPSG-	codes file:	x86)\GRASS GIS 7.0.0\share\proj\epsg	Browse	
1 10 1	EPSG code:		4326		
			Q Search		
	Code 0	Description		Parameters	^
-	2000	Anguilla 195	7 / British West Indies Grid	+proj=tmerc +lat 0=0 +l	on 0=
	2001	Antigua 194	3 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2002 0	Dominica 19	45 / British West Indies Grid	+proj=tmerc +lat 0=0 +l	on 0=
	2003 0	Grenada 19	53 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2004 1	Montserrat	1958 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2005 5	St. Kitts 195	5 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2006 9	St. Lucia 19	55 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2007 5	St. Vincent 4	15 / British West Indies Grid	+proj=tmerc +lat_0=0 +l	on_0=
	2008 1	AD27(CGQ	77) / SCoPQ zone 2 (deprecated)	+proj=tmerc +lat_0=0 +l	on_0= v
	<				>

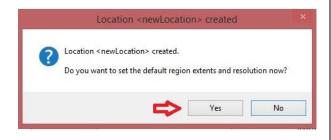
5. Confirm your selection just clicking on "OK".



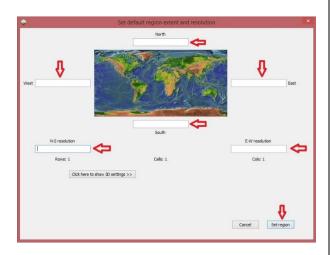
6. Check out your Summary and move on clicking on "Finish".

200		Summary	
	GRASS Database: Location Name: Location Title: Projection:	C: (Leers Documents (prosodata new.location example BPSG code 4326 (VIIGS 84)	
	PROJ.4 definition: (non-definitive)	+proj=longlat +ro_dets +#5.378135 +#f~388_257223653 +#6wg864=0.000,0.000,0.000	
		Heb < Back Finish Car	

7. You will see a message asking you to set the default region, click on "Yes".



8. Set the limits and resolution of your region filling the indicated blanks at the picture below, then click on "Set region".



Note: You can just accept the default values and set it after.

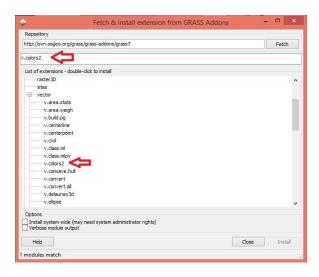
9. You will see a message asking you to create a new mapset, you must click on "Cancel".

o you want to c	reate new	mapset?	
User_name			
	ОК	Cancel	Help
		A	

#### 2.2 Installing Extensions

You will click on the main menu "Settings" >> "Addons extensions" >> "Install extension from addons".

1. As a result you will see"Fetch & install etension from GRASS Addons" window, you can search your wished addon (or extension) into the menu or type its name in the blank space below the "Repository" (e.g. v.colors2). Then, you will click on "Install".



#### 2.3 The Map Display Window

1. The window Map display shows you the content of the Vector or Raster that you imported in your "Layer Manager" display.

2. There are a lot different tool available at Map display that are important you understand, as:

3. Query raster/vector map(s): With this tool selected and the raster/vector that you are projecting to be market you are able to access the "Query results" information about each single point in your raster/vector map.

4. Note: At "Layer Manager" when you check the box referent a vector/raster you are going to project it at "Map display" and if you "mark" it clicking on the name of the raster/vector doing this to be gray colored you will be able to see the "Query results" about this raster/vector.

5. Zoom in and zoom out: Using this tool you are able to do a zoom in/out in your map just clicking on the interesting point, but you can to draw a square at the interesting area to obtain a zoom in/out too.

6. Zoom to selected map layer(s): This tool is going to show you your entire layer area at "Map display" window 7. Zoom to computational region extent: This tool is going to show you your entire computational region. To see what your computational region is you can set the dropdown box at the bottom of the "Map display" as "Show comp. extend".

8. Analyze map: Clicking on this tool you will see some extra features which are very helpful measure some aspects and parameters as distance and area. All these tool are easy to use, you can check it out to see their usability.

2.4 Change Coordinate Projection (lat/lon to UTM)

Note: If you are interesting to covert from lat/lon to UTM it is important you are in your destiny location, in this case in a UTM location.

 You will click on "Vector" >> "Develop vector map" >> "Reproject vector map from different GRASS location [v.proj]" as showed below.

le	Settings	Raster	Vector	Imagery	3D raster	Databas	se Temporal Help
	Develop ve Topology n Manage co Query vecti Feature seli Map type c Buffer vecti Lidar analy: Linear refer Nearest fea	ctor may naintena lors or map ection conversio ors [v.b sis sencing	ince ins uffer]		50 laste	> > > > >	Create new vector map Edit vector map (non-interactively) [v.edit] Convert object types [v.type] Parallel lines [v.parallel] Dissolve boundaries [v.dissolve] Create 3D vector over raster [v.drape] Extrude 3D vector map [v.extrude] Create labels [v.label]
	Network an Overlay vec Manage ca Update attr	tor map	s			;	Reposition vector map [v.transform] Rectify vector map [v.rectify] Reproject vector map from different GRASS location [v.proj] Support file maintenance [v.support]
	Generate ar Generate ar Generate gi Generate pi	reas from	n points	on [v.in.r	egion]	•	
	Reports and			Search	modules	Python s	the

Also, you can just type "v.proj" in your "Command console". You will have the same result as showed in the next chart.

File Setting	Raster				Manager Database	Tempor	al Help	
		-					ur ricip	
	1 3		6 6		í L d	5 0		
/ 🔳					🥹 🔿			
<								>
< Output wind	DW.			Comm	and prompt	-1.6		>
	w			Comm	and prompt	-1 r		>
Output wind	5	nd help, Ctr	I+Space to			-1 r-		>

2. At "Required" tab you will set the parameter "Location containing vector map" as the location name of the vector you want to convert into an UTM projection.

52 SA		Target	Optional	Command output	🚫 Manual	
location co	ontaining	input ve	ctor map:		-	(location=nam
	-				• C	
	Close		Run	Сору		Help

3. At "Source" tab you will set the parameter "Name of input vector map to re-project" as the name of the vector you want to convert into an UTM projection. Also you will set the parameter "Mapset containing input vector map" as PERMANENT if you've been using default settings or with the mapset name that you saved the vector map.

Required	Source	Target	Optional	Command output	🔇 Manual	
Name of i	nput vecto	or map to	re-project	23		(input=name
					· <	
Mapset co	ontaining i	nput vect	or map:			(mapset=name
PERMAN			-		v 🦰	
				VARM		
Path to G	steb 22AG	abace of i	nout location	00'		(dbace-nath
Path to G	RASS data	abase of i	nput locati	on:	Bro	(dbase=path
Path to G	RASS data	abase of i	nput locati	on:	Bro	(dbase=path owse
Path to G	RASS data	abase of i	nput locati	on:	Bro	
Path to G	RASS data	abase of i	nput locati	on:	Bro	
Path to G	RASS data	abase of i	nput locati			

4. At "Target" tab you will set the parameter "Name for output vector map (default: input)" as the name you want to the new map after converted. Then you will click on "Run".

equired	Source	Target	Optional	Command output	🚫 Manual		
1.000			S	ight and transform utput vector map:	if possible	(smax=	(z) =float
lame for	output ve	ctor map	(default: ir	nput):		(output=	name)
2							

- 2.5 Add a raster map by importing/exporting
- 2.5.1 Import a raster map

1. In your "Layer Manager"" you will click on "File" >> "Import raster data" >> "Common formats import".

GRASS GIS 7.0.	0 Layer N	lanager – 🗆 🗙
File     Settings     Raster     Vector     Imagery       Workspace     Map display       Import aster data       Import vector data       Import stare data       Import vector data       Export raster map       Export vector map       Export vector map       Export vector map       Export database table       Link external data       Manage maps       Georectify       [g.gui.grop]       Graphical modeler       Run model	Contraction of the second	lanager – Lana
3D image rendering [m.nviz.image] Animation tool [g.gui.animation] Bearing/distance to coordinates [m.cogo]		
Cartographic Composer [g.gui.psmap] Map Swipe [g.gui.mapswipe]		
Launch script		thon shell
Exit GUI	Ctrl+O	GDAL.

2. At "Import raster data" window you will set your preferences to import as well as "Source Type" and "Source settings", then you will click on "Import".

		Import raster data			
Settings					
Load settings:			¥ [	Save	Remove
Source type					
	ODirectory ODatabase				
Source settin	ins				
File:	3.				Browse
					Dionac
List of raster	layers - right click to (un)selec	t all			
Layer id	Layer name	Name for output GR/	ASS map (ed	litable)	
				and be y	
Extend reg Force Lat/L Override pr	ojection (use location's projec	I color names set coordinates (90N,5; 180E,W) ton)			
Keep band Extend reg Force Lat/L Override pr Allow output	ion extents based on new dat on maps to fit into geographic ojection (use location's projec t files to overwrite existing file:	i color names seet coordinates (90N,S; 180E,W) is			
Keep band Extend reg Force Lat/L Override pr Allow output	ion extents based on new data on maps to fit into geographic rojection (use location's projec t files to overwrite existing files d layers into layer tree (this m	I color names set coordinates (90N,5; 180E,W) ton)			

#### 2.5.2 Export a raster map:

3. In your "Layer Manager" you will click on "File" >> "Export raster map" >> "Common export formats".

GRASS GIS 7.0.0 Layer	Manager – 🗖 🗙
File Settings Raster Vector Imagery 3D raster Workspace Map display Import raster data Import 3D raster data	Database Temporal Help
Import database table Export raster map	Common export formats [r.out.gdal]
Export vector map Export 3D raster maps Export database table	ASCII grid export [r.out.ascii] ASCII x,y,z points export [r.out.xyz]
Link external data Manage maps	GRIDATB.FOR export [r.out.gridatb] Matlab 2D array export [r.out.mat]
Map type conversions	<ul> <li>Raw binary array export [r.out.bin]</li> <li>MPEG-1 export [r.out.mpeg]</li> </ul>
B Graphical modeler [g.gui.gmodeler] Run model	PNG export [r.out.png] PPM export [r.out.ppm]
3D image rendering [m.nviz.image] Animation tool [g.gui.animation]	PPM from RGB export [r.out.ppm3] POV-Ray export [r.out.pov] VRML export [r.out.vrml]
Bearing/distance to coordinates [m.cogo]	VTK export [r.out.vtk]
Cartographic Composer [g.gui.psmap] Map Swipe [g.gui.mapswipe]	Pack raster map [r.pack]
Launch script	thon shell
Exit GUI Ctrl+O	d formats.

4. At "r.out.gdal" window you will set your preferences to export as well as "Name of raster map", "Name for output raster map" and "file extension", then you will click on "Run".

Required	Creation	Print	Optional	Command output	🚫 Manual	
Name of r	aster map (	(or group	o) to export	*		(input=name)
						~
Name for	output rast	er file:*				(output=name)
		W/10 W/10				Browse
GTiff	ta format t				*	(format=string)
GTiff					~	

#### 2.6 Add a raster map by re-projecting

1. You will click on "File" >> "Import raster data" >> "Reproject raster map [r.proj]". Also, you can have the same result typing "r.proj" in your "Command console" line.

SRASS GIS 7.0	0.0 Layer N	Aanager – 🗆 🗙
File Settings Raster Vector Imagery	3D raster	Database Temporal Help
Workspace	•	
Map display	,	
Import raster data	•	Common formats import [r.in.gdal]
Import vector data	,	ASCII x,y,z point import and gridding [r.in.xyz]
Import 3D raster data	•	
Import database table	•	
Export raster map	,	ASCII polygons, lines, and point import [r.in.poly]
Export vector map	•	Raw binary array import [r.in.bin]
Export 3D raster maps	•	GRIDATB.FOR import [r.in.gridatb]
Export database table	•	Matlab 2D array import [r.in.mat]
Link external data	,	PNG import [r.in.png]
Manage maps	,	SPOT NDVI import [i.in.spotvgt]
Map type conversions	,	SRTM HGT import [r.in.srtm]
		Terra ASTER HDF import [r.in.aster]
茳 Georectify [g.gui.gcp]		LAS LiDAR points import [r.in.lidar]
🐉 Graphical modeler [g.gui.gmodeler]		Unpack raster map [r.unpack]
Run model		onpack faster map [f.unpack]
3D image rendering [m.nviz.image]		Reproject raster map from different GRASS location [r.proj]
Animation tool [g.gui.animation]		
Bearing/distance to coordinates [m.cogo]	]	
Cartographic Composer [g.gui.psmap]		
Map Swipe [g.gui.mapswipe]		
Launch script		thon shell
Exit GUI	Ctrl+O	current location.

Note 1: You can also click on "Raster" >> "Develop raster map" >> "Reproject raster map".

2. As a result, a new window will be showed for you, then you will set the parameter "Location containing input raster map" at tab "Required".

🖗 Re-p	orojects a	raster m	ap from g	given locatio	on to the current loc	ation.	
Required	Source	Target	Print	Optional	Command output	🔇 Manual	
Location o	ontaining	input ras	ter map	*		(location:	=name)
					~		
ſ	Close		D	1	0	Help	
L	Close		Ru	11	<u>C</u> opy	Telb	
✔ Add cre Close d	ated map ialog on fi	1.11	ayer tree	•			
	120						
proj loca	tionedro	awired					

3. At tab "Source" you will set the parameters "Name of input" and "Mapset containing input raster map".

Required	Source	Target	Print	Optional	Command output	🔇 Manual	
Name of i	input raste	r map to	re-proje	ct:	~ <	(inp	ut=name
Mapset ci	ontaining ii	nput rast	er map:			(maps	et=name
Path to G	RASS data	base of	input loca	ation:		(dba	ase=path
Path to G	RASS data	base of	input loca	ation:		(dba Browse	ase=path
Path to G	RASS data	base of	input loca	ation:			ase =pa

4. As a result you will see the layer that you are re-projecting showed in your "Map display".

Note 2: If you are re-projecting a layer from LAT-LON system to UTM you must be with a location opened corresponding to your output, in this case an UTM location.

# 2.7 Add a vector map by importing/exporting

2.7.1 Import a vector map:

1. In your "Layer Manager"" you will click on "File" >> "Import vector data" >> "Common formats import".

GRASS GIS 7.0.0 Layer File Settings Raster Vector Imagery 3D raster	
Workspace Map display	
Import raster data	
Import vector data	Common import formats [v.in.ogr]
Import 3D raster data Import database table	ASCII points or GRASS ASCII format [v.in.ascii]
Export raster map Export vector map	ASCII points as a vector lines [v.in.lines]     DXF import [v.in.dxf]
Export 3D raster maps Export database table	WFS [v.in.wfs]
Link external data	ESRI e00 import [v.in.e00] Geonames import [v.in.geonames]
Manage maps Map type conversions	Matlab array or Mapgen format import [v.in.mapgen] LAS LiDAR points import [v.in.lidar]
井 Georectify [g.gui.gcp]	Unpack vector map [v.unpack]
Graphical modeler [g.gui.gmodeler] Run model	Reproject vector map from different GRASS location [v.proj]
3D image rendering [m.nviz.image] Animation tool [g.gui.animation]	
Bearing/distance to coordinates [m.cogo]	
Cartographic Composer [g.gui.psmap] Map Swipe [g.gui.mapswipe]	
Launch script	thon shell
Exit GUI Ctrl+Q	sing OGR.

2. At "Import vector data" window you will set your preferences to import as well as "Source Type" and "Source settings", then you will click on "Import".

		Import vector of	lata		
Settings ad settings:				✓ Save	Remove
Source type	ODirectory ODatabase	0.0.1			
		e O Protocol			
Source settin	gs				
ile:					Browse
Extend regi Override da Limit import Do not crea	n polygons (not recommens on extents based on new i tracet projection (use local to the current region the attribute table um names to lowercase ch	lataset on's projection)			
Do not dea Extend regi Override da Limit import Do not crea Change coli	on extents based on new d ataset projection (use locati to the current region te attribute table	lataset on's projection) aracters			
Do not dea Extend regi Override da Limit import Do not crea Change col Allow output Add importer	on extents based on new d taset projection (use locati to the current region te attribute table umn names to lowercase ch files to overwrite existing f d layers into layer tree (this	lataset on's projection) aracters	bands)		
Do not dea Extend regi Override da Limit import Do not crea Change col Allow output	on extents based on new d taset projection (use locati to the current region te attribute table umn names to lowercase ch files to overwrite existing f d layers into layer tree (this	lataset on's projection) aracters iles	bands)		

#### 2.7.2 Export a vector map:

1. In your "Layer Manager" you will click on "File" >> "Export vector map" >> "Common export formats".

SRASS GIS 7.0.0 Layer	Manager – 🗆 🗙
File         Settings         Raster         Vector         Imagery         3D raster           Workspace         Map display         Import raster data         Import vector data         Import 3D raster data           Import database table         Import database table         Import database table         Import database table	Database Temporal Help
Export raster map Export 30 raster maps Export 30 raster maps Export database table Link external data Manage maps Map type conversions Cecretify [g.gui.gcp] Cecretify [g.gui.gcp]	Common export formats [v.out.ogr]     ASCII points or GRASS ASCII vector export [v.out.dxf]     PostGIS export [v.out.postgis]     POV-Ray export [v.out.pov]     SVG export [v.out.svg]     VTK export [v.out.vtk]     Pack vector map [v.pack]
Run model 3D image rendering [m.nviz.image] Animation tool [g.gui.animation] Bearing/distance to coordinates [m.cogo] Catographic Composer [g.gui.psmap] Map Swipe [g.gui.mapswipe]	
Launch script Exit GUI Ctrl+O	thon shell red OGR vector formats. By defaul

2. At "v.out.ogr" window you will set your preferences to export as well as "Name of vector map", "Name for output OGR datasource" and "Data format to write", then you will click on "Run".

Required	Selection	Creation	Optional	Command output	🚫 Manual			
Name of ir	nput vector	map to exp	oort:*					(input=name)
1						~		
Name of c	utput OGR	datasource	*					(output=string)
								1
	at to write:	<b>^</b>						(format=string)
Data form ESRI_Sh		•		×				(format=string)
		<u>.</u>		~				(format=string)
		•		v				(format=string)
		•		~				(format=string)
		•		v				(format=string)
		•		v				(format=string)
		•		~				(format=string)
		*		~				(format=string)

#### 2.8 Add a vector map by re-projecting

1. You will click on "File" >> "Import vector data" >> "Reproject raster map [v.proj]". Also, you can have the same result typing "v.proj" in your "Command console" line.

GRASS GIS 7.0.0 I	Layer M	tanager – 🗆 🗙
File Settings Raster Vector Imagery 3D	raster D	Database Temporal Help
Workspace Map display	*	
Import raster data	•	0
Import vector data	Þ	Common import formats [v.in.ogr]
Import 3D raster data	•	
Import database table	•	ASCII points or GRASS ASCII format [v.in.ascii]
Export raster map	•	ASCII points as a vector lines [v.in.lines]
Export vector map		DXF import [v.in.dxf]
Export 3D raster maps	•	WFS (v.in.wfs)
Export database table	•	
Link external data	۲	ESRI e00 import [v.in.e00] Geonames import [v.in.geonames]
Manage maps		Matlab array or Mapgen format import [v.in.mapgen]
Map type conversions	•	LAS LIDAR points import [v.in.lidar]
井 Georectify [g.gui.gcp]		Unpack vector map [v.unpack]
B Graphical modeler [g.gui.gmodeler] Run model		Reproject vector map from different GRASS location [v.proj]
3D image rendering [m.nviz.image] Animation tool [g.gui.animation]		
Bearing/distance to coordinates [m.cogo]		
Cartographic Composer [g.gui.psmap] Map Swipe [g.gui.mapswipe]		
Launch script		thon shell
Exit GUI C	trl+Q	current location.

Note 1: You can also click on "Vector" >> "Develop vector map" >> "Reproject vector map".

2. As a result, a new window will be showed for you, then you will set the parameter "Location containing input vector map" at tab "Required".

		Target	Optional	Command output	🔇 Manual	
ocation o	ontaining	input ve	ctor map:*			(location=name)
					× <	3
					-	
T	Close		Run	Сору		Help

3. At tab "Source" you will set the parameters "Name of input" and "Mapset containing input vector map".

nput=name
pset=name
lbase=path

4. As a result you will see the layer that you are re-projecting showed in your "Map display".

Note 2: If you are re-projecting a layer from UTM system to LAT-LON you must be with a location opened corresponding to your output, in this case a LAT-LON location.

#### 2.9 Rename a map

#### 2.9.1 Raster Map:

1. The first step you will type "g.rename" at your "Command console".

File Setting	s Raster \	ector In	agery 3	D raster	Database	Tempora	al Help	
	2 2		6 66	MM		Ċ,		
/ =								
	_							
٢	_							>
< Output wind	ow			Comma	and prompt	-1 r		>
Output wind	ow .	-	i	Comma	and prompt	11		>
Output wind	ow	d help, Ctrl-	Space to a	. r <u>.</u>				>

2. At"g.rename" window you will select the raster map you want to rename at the dropdown box called "raster map(s) to be renamed". Also, you will type at the same window the new name for this same raster separated by comma (i.e. old\_raster@PERMANENT,new\_raster). Then you will click on "Run".

Destant 10	/ector	Region	Group	Optional	Command output	😧 Manual	
aster ma	p(s) to	be renam	ied:			(ras	ster=from, to
							~ <
D raster	map(s)	) to be rer	named:			(raster	_3d=from, to
							~
						211	250

#### 2.9.2 Vector map:

1. The first step you will type "g.rename" at your "Command console".

File Setting	s Raster	Vector I	magery	3D raster	Database	Tempor	al Help	
	1 1		6	MM		(T)		
					🤫 🔾			
<								
< Output wind	ow			Comma	and prompt			
Output wind	ow			Comma	and prompt	-1 p		
the second second	ow		7	Comma	and prompt			
Output wind	<	and help, Ctr	I+Space to	1.1		11		

2. At "g.rename" window you will select the vector map you want to rename at the dropdown box called "vector map(s) to be renamed" at tab "Vector". Also, you will type at the same window the new name for this same raster separated by comma (i.e. old\_vector@PERMANENT,new\_vector). Then you will click on "Run".

aster	Vector	Region	Group	Optional	Command output	🚫 Manual	
ector	map(s) to	be renar	ned:			(veci	tor=from
							~ <b>&lt;</b>

- 2.10 Convert between vector and raster types
- 2.10.1 From vector to a raster:

1. Type the command "v.to.rast" in the command line at "Layer Manager".

File Setting:	s Raster	Vector Im	agery	3D raster	Database	Temporal	l Help	
	1 2		6 66	MM		ů,		
/ =					0.000		- 10	
	-							1
¢								
< Output wind	ow			Comma	and prompt			>
and the second	ow			Comma	and prompt	1 1		>
Output wind		nd help, Ctrl		1.		1 1		>

2. Fill the blank "input" with the map's name you want to convert, and fill the blank "output" with the map's name you want to generate. Also, set the dropdown box as "val", then click on "Run".

Required	Selection	Attributes	Optional	Command output	🔇 Manual		
Name of i	nput vector	map:				(input=	name)
						v <=	
Jama for	output rast	*				(output=	ama
vanie iui	outputrase	er map,				(output=	
1		12					
	raster valu	es:			~	(use=	string)
val				~			
	-						
	Clos	1.0	Run	Copy		lelp	

3. As a result, you will see the converted map in your "Layer Manager".

2.10.2 From raster to vector:

1. Type the command "r.to.vect" in the command line at "Layer Manager".

				.o Luyer	Manager			
File Setting	s Raster	Vector Ir	magery	3D raster	Database	Tempora	il Help	
	1 🕹		66	MM		Ċ.		
/ 🔳			2		🔅 🔿			
								1
¢								>
< Output wind	ow			Comma	nd prompt			>
	ow Car		7	Comma	nd prompt			>
Output wind		and help, Ctrl	+Space to			-1 m		>

2. Fill the blank "input" with the map's name you want to convert, and fill the blank "output" with the map's name you want to generate. Also, set the dropdown box as "area", then click on "Run".

V	verus a rasie	r map into i	a vector map.		
Required	Attributes	Optional	Command output	🔇 Manual	
Name of i	nput raster n	nap:*			(input=name)
-					~<
Name for	output vecto	r map:*			(output=name)
Output fe	ature type:				(type=string
area	atore type.			v 🧹	(type=suring)
		1 1	Dum	Сору	Help
[	Close		Run		
[	Close			=	

3. As a result, you will see the converted map in your "Layer Manager".

#### 2.11 Clip a Raster

1. You will type "r.mapcalc" in your "command console". As a result you will see the "GRASS GIS Raster Map Calculator" window.

ile Settings	Raster	Vector Ir	magery	3D raster	Database	Tempora	al Help	
	â 🛃		5 (B	M		(Å	G	
			*		<del>@</del>			
<								
< Output winds	w			Comma	and prompt			;
< Output winde	9W			Comma	and prompt	1.1		;
and the second second	w			Comma	and prompt			;
Output windo				1		-1 r		
Output winde	splay comma	nd help, Ctri	0	o autocomp				

2. At "GRASS GIS Raster Map Calculator" window you will fill the attributes "Output" with the name of your new map and "Operands" with the function "if(x,a)". In the dropdown box you will select the layer that has your crop format and the layer that you will crop as well as they must be separated per comma (i.e. if(raster\_format\_I\_want,raster\_I\_have) ). Then you will click on "Run".

perators				Output
+	-	88	11	Name for new raster map to create
*	1	&	1	
>	>=	888		Operands Insert mapcalc function
<	<=	<<	>>	if(x,a)
==	!=	>>>	1	Insert existing raster map
%	^	a?b:c	~	
xpression	\$			
	Load	Save	<u>С</u> ору	Help Run Clo
	dom seed for ra	nd0 Seed:		

Note: To understand better what expect from a crop you can see an example given at "Main canal longitudinal profile" topic of this document.

#### 2.12 Clip a vector

1. You will click on "Vector" >> "Overlay vector maps" >> "Overlay vector maps [v.overlay]". Then you will see the "v.overlay" window.

ile Settings Raster Vector Imagery 3D raste	r Database Temporal Help
Develop vector map Topology maintenance Manage colors Query vector map Feature selection Map type conversions Buffer vectors [v.buffer] Lidar analysis Linear referencing Nearest features [v.distance]	
Network analysis	•
Overlay vector maps	<ul> <li>Overlay vector maps [v.overlay]</li> </ul>
Manage categories Update attributes	Patch vector maps [v.patch]
Generate area for current region [v.in.region] Generate areas from points Generate grid [v.mkgrid] Generate points	mand prompt     Log file     Clear
Reports and statistics	•
	nlete
ress Tab to display command help, Ctrl+Space to autocor	

2. At "v.overlay" window you will set parameter as "Name of input vector map (A):" with the vector map you want to crop, "Name of input vector map (B):" with the vector that has the area of interest which will be the cut, "Operator defines features written to output vector map:" with "and", and you will fill the blank "Name for output vector map" with the name of the vector you want to generate. Then, click on "Run".

Required	Attributes	Optional	Command output	🔇 Manual	
Name of i	nput vector r	map (A): *			(ainput=name
Name of i	nput vector r	map (B):			(binput=name
					<b>-</b>
Operator	defines feat	ures writte	n to output vector n	nap:	(operator = string
and				· · <	]
Name for	output vecto	or map:*			(output=name
16	22	10			~
, Li					
		-			

Note: To understand better what expect from a crop you can see an example given at "Main canal longitudinal profile" topic of this document.

#### 2.13 Set a vector color table

1. You will click on "Vector" >> "Manage colors" >> "Color tables".

e Settings Raster Vector Imagery 3D raster Develop vector map	Database Temporal Help
Topology maintenance	
Manage colors	Color tables [v.colors]
Query vector map	<ul> <li>Manage color rules interactively</li> </ul>
Feature selection	Export color table [v.colors.out]
Map type conversions	•
Buffer vectors [v.buffer]	
Lidar analysis	•
Linear referencing	•
Nearest features [v.distance]	
Network analysis	•
Overlay vector maps	•
Manage categories	•
Update attributes	•
Generate area for current region [v.in.region]	
Generate areas from points	•
Generate grid [v.mkgrid]	
Generate points	•
Reports and statistics	•
	_
1ap layers Command console Search modules	Python shell

2. Note 1: Also, you can have the same result typing "v.colors" in your "Command console".

3. As a result, a new window will be showed to you, then you will set the parameter "Name of vector map" at tab "Required".

Required	Define	Remove	Print	Optional	Command output	🔇 Manual	
Name of ve	ector ma	ip:				(map	=name)
apiai_lito(	@PERMA	INENT.				*	
Source valu	ues: *					(use	=string)
cat					~<		

4. At tab "Define" you will set the parameter "Name of color table" as the color table that you need. After this, just click on "Run". Figure 1 depicts the result of the color table called *random* to a lithology vector map,

Required	Define	Remove	Print	Optional	Command output	🔇 Manual		
Invert	colors						(n)	^
Logari	thmic sca	ling					(g)	
Logari	thmic-abs	solute scalir	ng				(a)	
Name of o	column co	ntaining nu	imeric da	ata:		(column=n	ame)	
					~			
Name of o	olor table	e:				(color=	style)	
random							/	
		h:-h-h		able.		6		
kaster ma	ap from w	hich to cop	by color t	table:		(raster=r	ame)	
						v		

Note 2: An important tool is the dropdown box called "Vector map from which to copy color table" that can help you when you need to compare two or more different layers using them color scale.

Note 3: the colors of the color table will be applied to every categorized feature in the map; closed regions. Eventually, more than one map feature will belong to one thematic information from the map theme. For example, one geological formation might appear splitted in two or more regions, which in this case will show with two or more color and is not desirable. To apply the color table to a specific map information, one is referred to the topic *Add a RGB\_column to the vector map table* of this document.

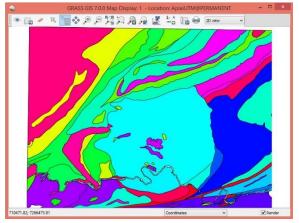


Figure 1: Result from using the *random* as the name of color table.

Note 4: If you want to remove the new color table included you should go back to the command "v.colors" and at tab "Remove" you can just check the box and click on "Run".

Required	Define	Remove	Print	Optional	Command output	🚫 Manual	
		g color tab					(r)

#### 2.14 Set a raster color table

 You will click on "Raster" >> "Manage colors" >> "Color tables".

e Settings Raster Vector Imager	ry 3D raster Database Temporal Help
Develop raster map	·LMAAA
Manage colors	Color tables [r.colors]
Query raster maps Map type conversions Raster buffers and distance	Color tables (stddev) [r.colors.stddev]     Manage color rules interactively     Export color table [r.colors.out]
Maske [rimask] Raster map calculator [rimapcalc] Neighborhood analysis	Blend 2 color rasters [r.blend] Create RGB [r.composite] RGB to HIS [r.his]
Overlay rasters Solar radiance and shadows Terrain analysis Transform features	
Hydrologic modeling Groundwater modeling Landscape patch analysis Wildfire modeling	• • •
Change category values and labels	•
Generate random cells Generate surfaces Interpolate surfaces	• •
Reports and statistics	ranmoades Python shell

2. As a result, a new window will be showed for you, then you will set the parameter "Name of raster map" at tab "Map",

[multiple] Name of raster map(s):	(map=name
Input file with one map name per line:	(file=name
	100 C
	Browse
or enter values directly:	
	4

Note 1: Also, you can have the same result typing "r.colors" in your "Command console" line.

3. At tab "Define" you will set the parameter "Name of color table" as the color table that you need. After this, just click on "Run". Figure 2 depicts the result of the color table called *rainbow* to an elevation raster map,

	Define	Remove	Print	Optional	Command output	🔇 Manual		
On	nly write ne	ew color ta	ble if it o	loes not alr	eady exist		(w)	^
In	vert colors						(n)	
Lo	garithmic s	scaling					(g)	
Lo	garithmic-a	absolute so	aling				(a)	
to an	- 5 - 3	qualization					(e)	
-	of color ta	able:				(co	lor=style)	
raint	WOW				*			
Raste	r map from	n which to	copy col	or table:		(rast	er=name)	
in a		o				07 D		
3D ras	ster map fi	rom which	to copy	color table:		(raster_3	3d=name)	
							~	
	to rules file					(m.d.	es=name)	
Pauri	to rules file					1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1	
_						Bri	owse	П
or ent	ter values	directly:						
							$\sim$	

Note 2: An important tool is the dropdown box called "Raster map from which to copy color table" that can help you when you need to compare two or more different layers using them color scale.

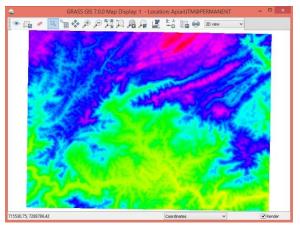


Figure 2: Result from using the *rainbow* as the name of color table.

Note 3: If you want to remove the new color table included you should go back to the command "r.colors" and at tab "Remove" you can just check the box and click on "Run".

Required	Define	Remove	Print	Optional	Command output	🔇 Manual	
Remo	ve existin	g color tab	le				(r)

## 2.15 Add a RGB\_column to the vector map table

First, you have to install the command "v.colors2" at first time you will use it. To install it you are referred to the topic "Installing add-ons" of this document.

1. With your command installed you will type "v.colors2" in your "command console". As a result you will see the "v.colors2" window

Required	Colors	8	Command output	🔇 Manual	
Name of v	@PERMA				(map=name)
	2.244.0				
lame of a	attribute o	column con	taining numeric data		(column=name)
			conting numeric date		
COD_UN			darning numeric data	~ <	
			anning namene date		

2. At tab "Required" you will fill the parameters "Name of vector map" and "Name of attribute column containing numeric data".

Note 1: The parameter "Name of attribute column containing numeric data" will be the value's column in your "attribute data" relative your map. If you need to see your "attribute data" at "Layer Manager" you will click on with the right button upon the layer of interest, then you will click on "Show attribute data". 3. Still in "v.colors2" window, at tab "colors" you will fill the attributes "Name of color column to populate with RGB values" and "Type of color table" then click on "Run".

Note 2: If you do not fill the attribute "Name of color column to populate with RGB values" it will be filled automatically as "GRASSRGB"

Required	Colors	Optional	Command output	🚫 Manual		
Invert	t colors					(r
Name of	color colu	mn to popu	late with RGB value	s:	(rgb	column=name
GRASSR	GB			V <		
2 2	7 7 11			Internet		
random	olor table	:				(color=string
random	ł.			Y <		
Name of	raster ma	p from whi	ch to copy color tab	le:		(raster=name
-						V
Name of	file contai	ning rules:				(rules=name
ritanic or					1.1	Browse
						Drowse
[	values dire	ectlv:				browse
	values dire	ectly:				browse
or enter	values dire	ectly:				browse ^
	values dire	ectly:				browse
	values dire	ectly:				browse
[	values dir	ectly:				browse

4. To apply the results in your map you will click on with the right button in the layer that you created the new column RGB and click on "Properties". As a result you will see "d.vect" window, then you will change the attribute "Colorize features according color definition column" at table "colors" to the column name that you already created in those pre steps, then click on "OK". Now you can see the results in your map. Figure 3 depicts the result of the color table called *random* to the attribute column called *COD\_UNI\_ES* in the attribute table of a lithology vector map,

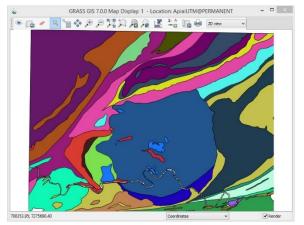


Figure 3: Result from using the *random* as the name of color table.

# 2.16 Add (set) category labels to a raster map

1. First of all you are going to type "r.category" in your "Command console". As a result you will see the "r.category" window.

<i>~</i>		GRAS:	S GIS 7.0	0.0 Layer	Manager			×
File Setting	s Raster	Vector	lmagery	3D raster	Database	Tempor	al Help	
	1 2		5 6			â		
/ 🔳			2		🔅 💮			
٢								
< Output wind	ow.			Comma	and prompt	-1 r		
	ow _			Comma	and prompt	1.1		
Output wind		and help, Ct	rl+Space t			1		

2. At tab "Required" you will set the parameter "Name of raster map" as the name of the map you want to add/set to the categories labels.

Required	Selection	Define *	Optional	Command output	🔇 Manual	(map=name
	0@PERMAN	VENT				v lanc

3. At tab "Selection" you will set the parameter "Category values:" as the values which your categories will content or the range they are (i.e. I have a raster map showing me soils code that go from 9791 to 26425, I will fill the blank "Category values" as well as my interval: 9791-26425).

equired	Selection	Define	Optional	Command output	🚫 Manual	
	Category v	alues:			-	(cats=range)
9791-26	425			<		
multiple]	Comma sep	arated va	alue list:			(values=float)
			919(4)(4)(4)(4)			

4. At tab "Define" you will fill the blank "or enter values directly:" as a relationship between your categories that you set at tab "Selection" and the labels that you want to have for each category.

	Selection	Define	Optional	Command outp	ut 🔇 Manua	<u>[]</u>	
Raster m	ap from whic	th to copy	category	table:		(raster=na	me)
	- 65					~	
		712712 072	20 82 <b>2</b> 447		N955A		
File conta	aining catego	ry label r	ules (or "-"	to read from sto	din):	(rules=na	me)
C:\User	s\George\Do	cuments	\grassdata	/ApiaiUTM/PERM	ANENT/.tmp/uni	a Browse	
or optor	values direct	lur.	-				
		.y.					-
9791	Ferrasols						~
12959	Vertisols						
	Cambisols						
	Podzols						
	Leptosols						
26425							Y.
26425							_
26425					Load	' 'E.as	

Note 1: you will enter the values as:

"The value in your range" "Field separator" "Label name"

Using the same range at step #3 we could have this, for example:

- 9791 Ferrasols
- 12959 Acrisols
- 13817 Vertisols
- 15167 Cambisols
- 16045 Podzols
- 26425 Leptosols

Note 2: In this example the "Field separator" is the default choice (tab).

Note 3: The blank "File containing category label rules" will be different for each one according your GIS GRASS installation.

5. At tab "Optional" you can change the "Field separator" mentioned before. After all parameter filled you must click on "Run".

Quiet module output Field separator: (separator=cha tab v	erbose) (quiet)
	aracter)
Default label or format string for dynamic labeling: (format-	=string)
Dynamic label coefficients: (coefficients=mult1,offset1,mult2,c	offset2)

6. As a result now you can see the new category in your map. For example, the next picture show you an soils distribution map which was added a category label contenting the range of all the different type of soils and classifying them as Ferrasols, Acrisols, Vertisols, Cambisols, Podzols and Leptosols. As you can see, this a result from the "Cartographic is Composer" according the range. Figure 4 depicts the result of the category label rules to the raster values in a soil types raster map, The legend was added with the aid of the Cartographic Composer GRASS module, which is addressed by this document at the topic The Cartographic Composer.

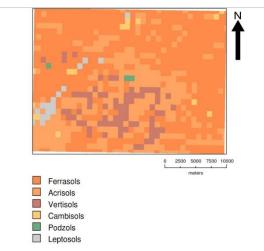


Figure 4: Result from add category label to a soil's map.

#### 2.17 The cartographic composer

1. To access the Cartographic mode you will click on "File" >> "Cartographic Compose". As a result you will see the "GRASS GIS Cartographic Composer" window.

File	Settings	Raster	Vector	Imagery	3D raster	Database	Tempor	al Help	
W	orkspace					•	(f))		
M	ap display							L-0	
Im	port raster	data				• I O I			
Im	port vecto	r data				•		4	Þ X
Im	port 3D ra	ster data				•		V	PX
Im	port datab	ase table				•			
Ex	port raster	map				•			
Ex	port vector	map				+			
Exq	port 3D ras	ter maps				•			
Exp	port datab	ase table				•			
Lir	nk external	data				•			
М	anage map	05				•			
M	ap type co	nversions				•			
🛱 Ge	eorectify [	g.gui.gcp	]						
Gr	aphical mo	odeler [c	.qui.qmc	deler]					
	in model								
30	) image rer	nderina I	m.nviz.ir	nagel					
	nimation to	1.		-					
Be	aring/dista	ance to co	oordinate	s [m.cogo	]				
- Ca	artographic	Compos	er [g.gu	i.psmap]	C				
M	ap Swipe	[g.gui.ma	pswipe]						
La	unch scrip	t				thon she	I		
-	it GUI				Ctrl+O				

2. First of all, at "GRASS GIS Cartographic Composer" window you will

click on <sup>4</sup> "Map frame".

3. At the box "Map frame settings" you will set the parameters "Map frame options" and "Map selection".

		N	lap fran	ne settir	igs		
Map frame Map frame optic	ons:						Ŷ
fit frame to ma	tch selecte	d map					
Map selection	) iraster	🔿 vector				🗹 ac	ld selected map
Map scale an Center: E: Scale: 1			N:				laurad
Map max resolu	tion (dpi):	300		•			
Border I draw border	border		1				
				0	ж	Cancel	Apply

4. Clicking on you will see a range of options as "Legend", "Map info", "Scale bar", "Text", "Image" and "North Arrow". Every those are simple to use, but there is a little trick to use the tool "Legend".

When you click on "legend" you are going to see the "Legend settings" window asking you about "Raster legend" and "Vector legend", but you are not able to add for example a vector in that window. However, if you want to include Raster and Vectors to use in your legends you have to click on twice on your "MAP FRAME" area. Then you will see options to do it, and after you can go back to the tool legend and manipulate the legends as you like.

5. After the entire process you should save your project and to do the Cartographic composer has a useful tool based on Encapsulated PostScript handled

by clicking on the button <sup>[12]</sup> (so called Generate text file with mapping instructions). Saved project is loaded by clicking on the button <add button icon>. The map can be exported to publishing formats like Portable Document File (PDF)

by clicking on 🍋 .

6. As an example you can see a result from a map created with the cartographic composer mode (Figure 5). Two layer maps were used in this example: one vector map showing a watershed area and another raster map elevations map showing the terrain elevation. The raster legend was added as depicted. Also you can see a text labeling the legend and an arrow showing the North.

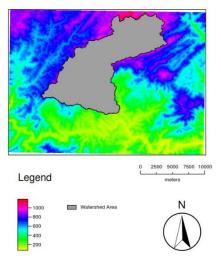


Figure 5: Result from using a raster and a vector map together at cartographic composer mode.

#### 2.18 Georeferencing images/group

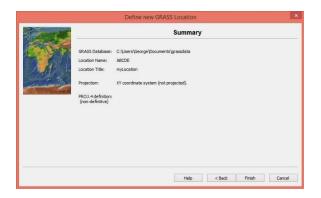
1. Open the Grass. In the initial layout you will click on "New".

2. Fill the blanks "Project Location" and "Location Title", after you will click on "Next".

3. You will select the option "Create a generic Cartesian coordinate system (XY)".



4. You will check twice your choices and click on "Finish".



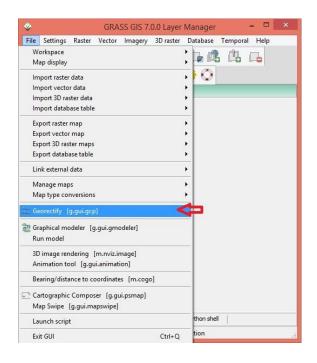
5. At "Location <Name Location> created" window you will click on "No".

6. At "Create a new mapset" window you will click on "Cancel".

7. Now you will select your just new location created and click on "Start Grass Session".

8. Use the command "r.in.gdal" (addressed by the topic "Add a raster map by importing/exporting") to import the map figure you want to georectify into the location you just created.

9. You will go to "File" >> "Georectify [g.gui.gcp]".



10. At"Setup for georectification" window you will select between "Raster" and "Vector" then you will set the parameter "Select source location". The dropdown menu "Select source mapset" will be filled automatically.

- <del>(</del> )-	Select map type	and location/m	apset	
Map type to georectify				
● raster ○ vector				
Select source location:			🗢	l.
Select source mapset:			~	

11. Either, type an extension at "Extension for output maps:" or accept the default.

Colored annual	SRutm	<b>&lt;</b>	~
Select group:		Ű,	
Create group if none exists	Create/edit group		
Extension for output maps:	_georect10484	<	
			-

Note 1: The dropdown box "Select group" will be automatically the group from the location that you're working with. If you want to georeference an image from another location, you should open such location before, then repeat these steps.

12. Now you will select the map you want to georeference at "Select source map display" set as well you will select the same map at "Select target raster map to display" set.

Select source map to display:	SR 201401122010@PERMANENT	3
Select target raster map to display:		
Select target vector map to display:		

13. At "Manage Ground Control Points"

(Manage GCP) you click on to add new GCP points.

Note 2: You must include at least 3 points and they cannot be aligned or it is going to cause an error. See example below (Figure 19).

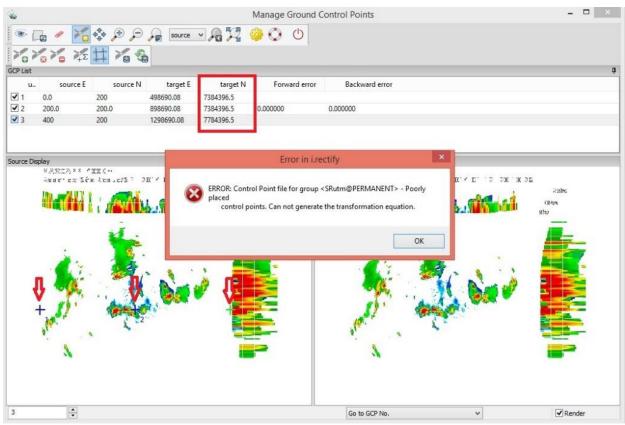


Figure 19: Result from setting three align points to georeference a map.

14. The next step is to fill in correctly the ground points. To do so you must click on twice upon each record of the GDP list and fill in the pixel's coordinates and fill the

		Edit GCP	>
Ground Co	ontrol Point No. 1		
source E:	0.0	target E:	498690.08
source N:	0.0	target N:	6984396.5
UT	M		coordinates.
15 of		ou will just	finish the process on at 井 .

## 3 Main Watershed Applications

#### 3.1 River network extraction

1. First step you will type the command "r.watershed" at your "Command console".

<b>*</b>		0	GRASS C	GIS 7.0.0 I	ayer Man	ager		-		×
File Setting	s Raster	Vector	Imagery	3D raster	Database	Tempor	al Help			
	<b>î</b> 🖢		6	Mi		3 03				
/ 🗉			<b>2</b>		۵ 🍪					
٢										>
< Output wind	DW				Command pr	ompt				>
		]	Save		Command pr			Clear	•	*
Output wind		]	Save					Clear	*	*
Output wind	ar	and helo. C		to autocom	Log			Clear		>

2. At "r.watershed" window you will set the parameters "(elevation=name)" with the raster layer that you have containing terrain elevations. Also, you will fill the blank "(threshold=integer)" with the value of the minimum watershed area that you expect, then you must dived it per your resolution's layer (i.e. 62 = $500000m^2/(90x90m^2)$ ).

Inputs	Outputs	Optional	Command output	🚫 Manual		
Name o	f input elev	vation rast	er map: *		(elevatio	n=name)
ASTER	dem@PER	MANENT				~
Name o	f input dep	pressions ra	aster map:		(depressio	on=name)
						~
Name o	f input ras	ter <mark>r</mark> eprese	nting amount of ov	erland flow per c	ell: (flo	w=name)
						~
Name o	f input ras	ter map pe	rcent of disturbed la	and:	(disturbed_lar	nd=name)
						~
Name o	finput ras	ter map blo	cking overland surf	ace flow:	(blockin	ng=name)
						~
11.551.6	n size of ex	cterior wat	ershed basin:		(threshold	=integer)
62						
	Close	e	Run	Сору	Help	

3. Next you will change to the tab "Outputs", then you will fill the blank "stream". Then you will click on "Run".

nputs	Outputs	Optional	Command output	🔇 Manual		
Name f	or output a	accumulatio	n raster map:		(accumulation=name)	1
					*	
Topogr	aphic index	n(a / tan	(b)):		(tci=name)	
					~	
Name f	or output o	drainage dir	ection raster map:		(drainage=name)	
					~	
Name f	or basins r	aster map:			(basin=name)	
					*	
Name f	or output s	tream segr	ments raster map:		(stream=name)	
river_	network				v <	
Name f	o <mark>r o</mark> utput h	half basins i	raster map:		(half_basin=name)	
					~	
						2
	Clos	e	Run	Copy	Help	

4. The expected result in going to be as the picture below (Figure 6).

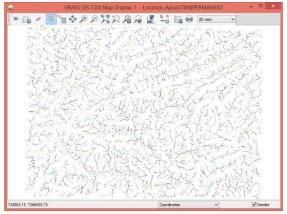
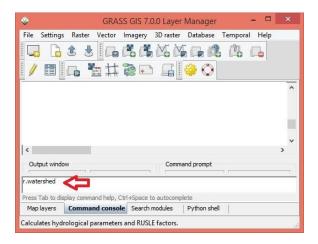


Figure 6: Obtained result from the topic "River network extraction" using a raster map with the ground elevations.

#### 3.2 Watershed delineation

1. First of all, you should know that exist a third part (add on) module to accomplish this task so called "r.basin", which is accessed only from the "command console". The module "r.basin"it is a simple command and you can try it before these steps, if the result is not the wanted you can try the next steps.

2. You will type "r.watershed" at "Command console".



3. You will fill the blank "elevation" with the raster layer name that you have elevations included. Also, you will fill the blank "threshold" with the value of the minimum watershed area that you expect, then you must dived it per your resolution's layer (i.e. 62 = 500000m<sup>2</sup>/(90x90m<sup>2</sup>)).

Inputs	Outputs	Optional	Command output	🚫 Manual			
Name o	f input elev	vation rast	er map:		(elevatio	on=name)	^
ASTER	dem@PER	MANENT				~ <	
Name o	f input dep	pressions ra	ster map:		(depressio	on=name)	
					200000000000000000000000000000000000000	~	
Name o	f input rasi	ter represe	nting amount of ov	erland flow per d	ell: (flo	w=name)	
					0.00	~	
Name o	f input ras	ter map pe	rcent of disturbed la	and:	(disturbed lar	nd=name)	
	1000000			84556	( <u>-</u>	~	
Name o	finnutrae	ter man blo	cking overland surf	ace flow:	hlockir	ng=name)	
Nume o	i inpucius	cer map bio	ching overland sam	acc now.	(DIOCIAI		
Minimur 62	n size of ex	cterior wat	ershed basin:		(threshold	l=integer)	~
	Close	e	Run	Сору	Help		

4. Now, change to the tab "Outputs", then you will fill the blanks "drainage" and "stream". After on "Run".

Inputs	Outputs	Optional	Command outpu	it 🔇 Manual		
Name f	or output a	ccumulation	raster map:		(accumulation=r	name)
					¥	
Topogr	aphic index	: ln(a / tan(b	)):		(tci=r	name)
					~	
Name f	or output d	lrainage dire	ction raster map	:	(drainage=r	name)
					*	4
Name f	or basins ra	aster map:			(basin=r	name)
					*	
Name f	or output s	tream segm	ents raster map:		(stream=r	name)
					~	4
Name f	or output h	alf basins ra	ster map:		(half_basin=r	name)
					~	
16	-	(*				
	Close	e	Run	Copy	Help	

5. The expected result to the output "stream" we already know from the step "River network extraction", and the expected result to the "drainage" output is going to be as the picture below (Figure 7).

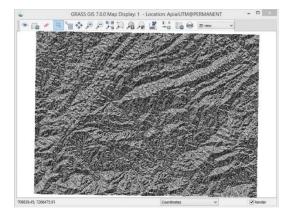
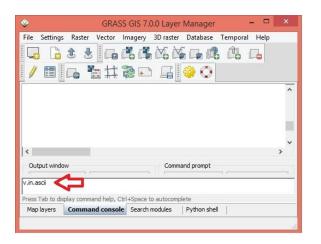


Figure 7: Result from using a raster map with the ground elevations to create a drainage map.

6. The next step is to verify the outlet position in your raster stream map (note: the coordinates to your outlet should be upon whatever pixel to the raster stream).

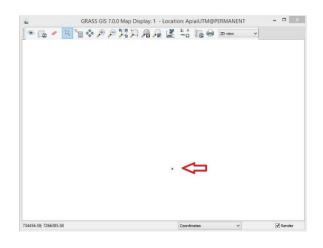
7. To do it, you will type the command "v.in.ascii" at "console command".



8. You will type the outlet's coordinates in the blank "enter values directly" as well as 718826.83092 | 7272803.04057. Then, give a name to the output map at blank "output". After, click on "Run".

Required	Input format	Points Opti	onal Co	mmand output	🚫 Manua	1
Name of i	nput file to be i	mported:				(input=name)
C:\Users	George Docur	nents\grassdat	a/ApiaiU1	M/PERMANEN	/.tmp/unki	Browse
or enter v	alues directly:					
					Load	Save as
Name for	output vector r	nap:*				Save as (output=name)

9. The expected result to the "v.in.asc" command is going to be as the picture below.



10. Now, you will type "r.water.outlet" at command console.

File Setting	s Raster	Vector	Imagery	3D raster	Database	Tempora	al Help	
	£ 3	2	C. C.	MM		Ċ,		
/ =					10 202			
								^
<								~
and the second	0144			Comm	and promot			~
< Output wind	ow			Comm	and prompt			>
and the second	-		1	Comm	and prompt	1 r		<b>`</b>
Output wind	4	mand help, C	rl+Space to	1. r		7. F		* *

11. You will add the coordinate of your outlet in the blank "coordinates". Also, you will fill the blanks "input" and "output". After, you will click on "Run".

	Optional Comma	nd output 🚫 Manual	
ame of inp	out drainage direct	tion map:	(input=name
drainage_i	map@PERMANEN	г	v 🤇
ame for ou	utput watershed b	basin map:*	(output=name
watershed	l_map		v <->
oordinates	s of outlet point:*		(coordinates=east,north
718826.83	3092, 7272803.04	057	R
	Close	Run Copy	Help

12. As a result you will have a new layer with the area of the watershed (Figure 8).

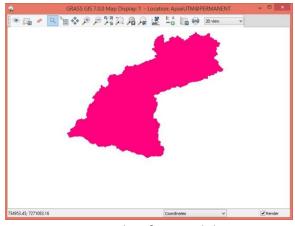
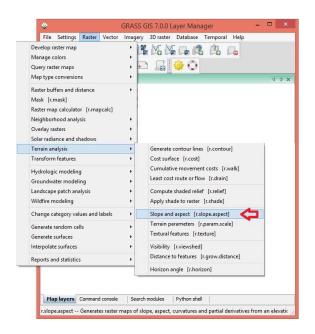


Figure 8: Result from delineating a watershed area a raster map.

#### 3.3 Mean watershed slope

1. You will click on "Raster" >> "Terrain Analysis" >> "Slope and aspects".



2. At tab "Required" in the "r.slope.aspect" you will set the parameter "Name of input elevation raster map" as a name's map that you have containing the elevations value.

Required	Outputs	Settings	Optional	Command output	🔇 Manual	
Name of i	nput elevat	tion raster	map: *		(ele	vation=name)
ASTERde	em@PERMA	ANENT				~

3. At tab "Outputs" you will set the parameter "Name for output slope raster map" as the name the map you want get it.

Name for output slope raster map:	(slope=name)
Name for output aspect raster map:	
Name for output aspect raster map:	22 D
	(aspect=name)
	~
Name for output profile curvature raster map:	(pcurvature=name)
	~
Name for output tangential curvature raster map:	(tcurvature=name)
	~

4. At tab "Settings" you will set the dropdown box "Format for reporting the slope" as you prefer. Then you will click on "Run".

				ect, curvatures and t is calculated count	partial derivatives erclockwise from ea	st.
Required	Outputs	Settings	Optional	Command output	🔇 Manual	
	align the o	-		aster elevation map	-	(a) (format=string)
degrees percent FCELL				,	~	(precision=string)
Multiplicat	ive factor i	to convert	elevation u	inits to horizontal ur	its:	(zscale=float
Minimum s	lone value	(in nercen	t) for which	aspect is computed	1:	(min slope=float
0.0						
	ated map(			tun C	opy H	elp

5. The next pictures (Figure 9 and 10) show you the elevation map and the terrain slope map resulting from these steps.

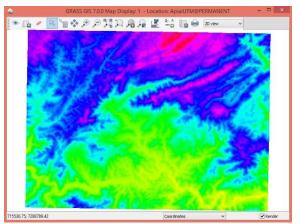


Figure 9: Shows the original elevations map which is going to origin the "Terrain Slope map".

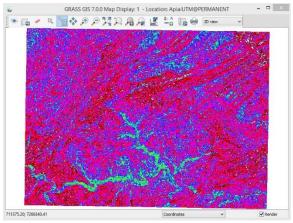


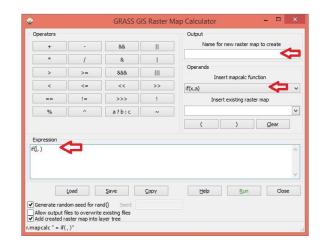
Figure 10: Result from using an elevations map to create a slope map.

6. The next step will make a crop between the Watershed area and the Slope map. To do it you will type "r.mapcalc" at

our		U	///////	and			conse	
<b>\$</b>		GRASS	GIS 7.0	.0 Layer	Manager			×
File Setting	s Raster	Vector I	magery	3D raster	Database	Tempor	al Help	
	1 2		66	MG M	i R d	â	<b>G</b>	
/ 🔳			2		0 🍪			
¢								>
< Output winc	ow			Comm	and prompt =	-1.1		>
Output wind	ow			Comm	and prompt	-1.4		,
	<b>\$</b>	nd belo. Cit						>

7. In the new open window you will fill the attributes "Output" with the name of your new map and "Operands" with the function "if(x,a)". In the dropdown box you will select the layer that has the watershed shape and the map which has the slope data set as well as they must be separated per comma (i.e.

if(raster\_format\_I\_want,raster\_I\_have))
Then you will click on "Run".



8. The next picture (Figure 11) show you the watershed area with the ground slope as a result from these steps

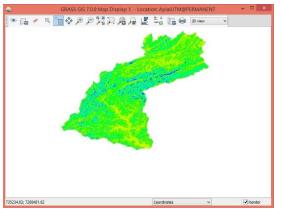


Figure 11: Result of cropping the slope map to the watershed shape.

9. Now, you will check and select the layer resulted from the crop, and at your "Map display" window you will click on

(Analyze map) and select the tool "Create a histogram of raster map".

10. At "Histogramming Tool" window you will click on  $\Sigma$  (Plot statistics).

11. At "Statistics" window you will see some different information and the average slope at the watershed will be the "mean of absolute values:".

12. At Figure 12 you can see the results from these steps as well as the average slope resulted from a test.

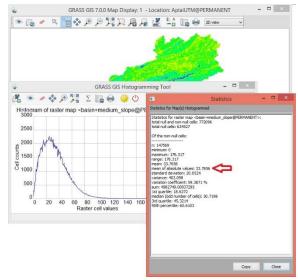


Figure 12: Result of the mean slope at the watershed area.

### 3.4 Main channel longitudinal profile

First of all, you should know that exist a third part (add on) module to accomplish this task so called "r.basin", which is accessed only from the "command console" However, sometimes this command can give you back the longest canal and not the deepest one, as a main canal is supposed to be. The command "r.basin" it is a simple command and you can try it before these steps, if the result is not the wanted you can try the next steps.

1. At the first step you will need to obtain the stream network map. This map is obtained from the terrain elevation raster map.

2. The stream network is addressed by the River network extraction topic of this document. Now you will type "r.mapcalc" in your "command console".

File Setting:	s Raster	Vector	Imagery	3D raster	Database	Tempora	al Help	
<b>G</b>	1 2		66	MA		ů.	6	
/ =					🥹 🔿			
٢								>
< Output wind	DW			Comm	and prompt			>
Output wind	ow			Comm	and prompt	-1 F		>
Output wind	<b>\$</b>			1.		1.0		>
	splay comma	and help, Ct	0	o autocomp		-1 p		>

3. In the Raster Map Calculator Window you will fill in the attributes "Output" with the name of your new map and choose "Operands" dropdown menu to the function "if(x,a)". In the Insert existing raster map dropdown menu you will select one layer to your crop boundary (in this case, your watershed map) first. Then, another raster map to crop (in this case, your stream network map). The names of the existing maps you pick shows in the Expression text box. You need to edit the text box in order the raster names show separated by a comma (i.e. if(raster\_boundary\_I\_want,

existing\_raster\_I\_have) ). Then you will click on "Run".

Operators				Output
+		8.8.		Name for new raster map to create
*	1	8	1	Watershed+river_network
>	>=	888	i	Operands Insert mapcalc function
<	<=	<<	>>	if(x,a)
	!=	>>>	1	Insert existing raster map
%	^	a?b:c	~	
Expression		NT , river NETW		
in ( water sined_in	аренскимис	NI , IVE_NEIW	ORNERUNA	
	Load	Save	<u>С</u> ору	Help Run Close
	dom seed for ra	nd() Seed:		

4. Since the checkbox "Add the generated raster map into layer tree" is checked, the resulting stream network will be shown with its name in the layer tree as well as into the Map Display window with the watershed shape as depicted in the Figure 13.

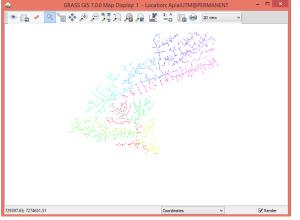


Figure 13: Result from making a crop between the watershed area and the river network.

5. Now you will take note of the codes within the main channel. To do so you will select the stream network watershed clip raster (clicking on it at the layer tree; it will be marked as gray). At the "Map display"

click on at button to query ID code values in the watershed stream network raster. Find every single code represent only the pixels which belongs to the main channel. Write down each code either in a piece of paper or a simple text editor (e.g. notepad).

6. Make another crop, now to the elevation heights with the watershed stream network shape.

7. You will again type "r.mapcalc" at your "Command console".

8. Fill in the blank "Output" with the name of your at watershed stream elevation clip map and "Operands" with the function "if(x,a)". In the dropdown menu you will select the layer that has your crop

shape (in this case, the stream network map as the watershed shape). Scroll the dropdown menu again to the layer that you will crop (in this case, your elevation map). At the text box, the two maps must be shown separated by a comma (i.e. if(raster\_shape, raster\_map\_to\_crop) ). Then you will click on "Run". The generated map is going to be shown both in the layer tree and in the Map Display window. It looks like the previous clip except by the values attributed to each pixel, which are no longer ID codes, they are elevation heights.

Operators				Output
+	-	8.8.	11	Name for new raster map to create
*	1	&	1	Watershed+river_network+elevations
>	>=	888	III	Operands Insert mapcalc function
<	<=	<<	>>	if(x,a)
	!=	>>>	1	Insert existing raster map
%	~	a?b:c	~	
				( ) <u>C</u> lear
Expression				
f(Watershed+r	iver_network@	PERMANENT , AST	ERdem@PERN	IANENT)
	Load	Save	<u>С</u> ору	Help Run Close

9. Then you will export the raster map into a (ASCII) text file and import it into a spreadsheet editor. To do it you will click on "File" >> "Export raster map" >> "[r.out.zyx]". At "r.out.xyz" you will fill the blank "Name of input raster map(s)" by typing the two raster crops just made separated by comma.

lequired	Optional	Command output	t 💟 Manual	
multiple]	Name of in	put raster map(s):	*	(input=name)
1				~

10. At tab "Optional" you will set the parameter "Name for output file" as the file path you want to be saved (including the map's name with the extension you wish, e.g. txt). Also you will set the parameter "Field separator" as you prefer.

Required	Optional	Command output	🚫 Manua	4		
Allow	output files	to overwrite existin	g files			(overwrite)
Verbo	se module o	output				(verbose)
Quiet	module out	put				(quiet)
Name for	output file	(if omitted or "-" ou	tput to stdou	it):	(ou	itput=name)
				<		Browse
Field sepa	arator:				(separator	=character)
pipe						~ <b>&lt;</b>
[	Close	Run		Сору	Help	

11. The XYZ text file exported from GRASS has no header. At a spreadsheet editor import such XYZ file. Your XYZ file should have 4 columns (UTM E, UTM N, ID and elevations). Now add headers to each column. Use the names we described such columns just above if you want. Then select all the filled cells and add an automatic filter. With the aid of the code list you wrote/typed down on step 5, open the

column ID's filter and keep selected just the codes which belongs to your main channel As depicted in the snapshot (Figure 14).

24	A		В		С		D
1	UTM E		UTM N	× 1	ł	▼ ID	
2	72356 A	<u>S</u> oi	rt Smallest f	to Large	st		
3	72359 Z	So	rt Largest to	Smalle	st		
4	72362		rt by Color				Þ
5	72401						
6	72365		ar Filter Fro	m "ID"			
7	72401	Filt	er by Color	5			*
8	72368	Nu	mber <u>F</u> ilter	s			+
9	72401	0	50 F.C				0
10	72524	1000	arch				2
11	72371	Ĩ	(Select	AII)			^
12	72401		🗹 5462 ✔ 5464				
13	72527		5466				
14	7237		5468				
15	72401		5470				
16	72527		🗹 5472 🗹 5474				
17	71927		5476				
18	72311		5478				~
19	72314		Celeton .				
20	72377			OK		Car	ncel
21	72401			-			
22	725306.4	631	728779	2.021	9	21	6774
23	719274.4	064	728776	2.008	9	26	6488
24	723175.7	366	728776	2.008	10	31	6718
25	723745.	931	728776	2.008	9	53	6760
26	723986.0	129	728776	2 008	9	42	6758

Figure 14: Result from to export a data set to a spreadsheet editor.

Note 1: From this point is already possible to plot the main channel chart. However, the values comes in disorder making noise at the chart as the next picture (Figure 15).

Note 2: To avoid this problem we should either follow the next steps or manually sort the table according to the coordinate sort describes the main channel geometry. To manually resort the coordinates, resort all coordinates according to either east coordinates or north coordinates with respect to the channel longitudinal geometry. Select small ranges of coordinate pairs still with inconsistency and apply the sort trying to lead them aligned to the expected meandering. If this is your choice

### skip to the step 20 after manually resorting.



Figure 15: Result from plotting a

12. After you identify and select all the main channel codes the next step is to export the spreadsheet file. To do it you will copy and paste the entire table in a new spreadsheet tab or file, because you cannot export a dynamic table (if you do this you will export the entire data set and not only the filter). So, after you copy and paste you will click on "File" >> "Export" >> "Text (Tab delimited)".

13. After you export the data set from a spreadsheet editor you will import back the file into the GRASS. To do it you will click on

chart with the data set as exported. "File" >> "Import raster data" >> "[r.in.xyz]".

14. In the next open box you will set the directory of your exported spreadsheet file (.txt). Also you have to type an output name to the file at tab "Required" in "(output=name)".

15. Browse to the text file you just created in the spreadsheet editor. Also you have to type an output name to the map at tab "Required" in "(output=name)".

Required	Statistic	Input	Advanced Input	Optional	Command output	it 🔇 Manual
ASCII file	containing	input da	ta (or "-" to read fi	rom stdin):		(input=name)
						Browse
or enter v	alues direc	:tly:			-	
						A
						~
			2		Load	Save as
Name for	output ras	ter map:	*		Load	Save as (output=name)
Name for	output ras	ter map:			Load	
Name for	output ras	ter map:	* Rim	Сору		(output=name)

16. Set the parameter "Field separator" as the character used to separate the columns when you exported the text file from the spreadsheet editor. Also you might set the parameters "(x=integer)" as the UTM E coordinates, "(y=integer)" as the UTM N coordinates and "(z=integer)" as the height coordinates. Then you will click on "Run".

Required	Statistic	Input	Advanced Input	Optional	Command output	🔇 Manual
Field sepa	rator:				(separat	or=character)
pipe						
Column nu 1	umber of x	coordina	ates in input file (fir	st <mark>colum</mark> n is	1):	(x=integer)
Column nu 2	umber <mark>of</mark> y	coordina	ates in input file:			(y=integer)
Column nu	umber of d	ata value	es in input file:			(z=integer)
3						
Number o 0	f header lir		p at top of input fil	e:		(skip=integer)
[	Close		Run	Сору	Help	

17. The expected result from this importation is going to be shown as the picture below (Figure 16).

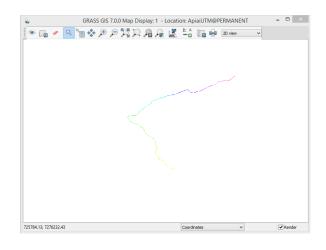
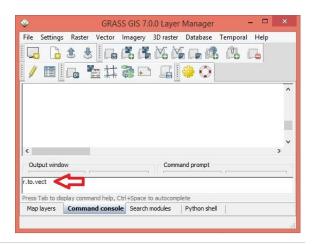


Figure 16: Result from importing the data set already filtered in a spreadsheet editor.

18. The next step is to convert the raster map into a vector map in order to obtain the canal coordinates sorted accordingly to the canal's longitudinal geometry. However, the raster value will not be attributed to the vector map in each node and we will have to import such sorted coordinates back to the spreadsheet editor to link them to the elevations. To do so you will type the command "r.to.vect" in the command console.



19. Fill the blank "input" with the map's name you want to convert, and fill the blank "output" with the map's name you want to get. Also, set the dropdown box as "area", then click on "Run".

V			a vector map.		
Required	Attributes	Optional	Command outp	ut 🔇 Manual	
Name of i	input raster n	ap:*			(input=name)
					~ <->
Name for	output vecto	r map:*			(output=name)
0.10.16					(huma athing)
line	eature type:			v 🦯	(type=string)
				~~~~	2
[	Close	1	Run	Сору	Help

20. As a result, you will see the converted map in your "Layer Manager" (Figure 17).

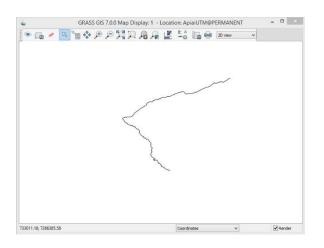


Figure 17: Result from converting the mainchannel raster file to a vector.

21. Now you will export the vector map and open it in a spreadsheet editor. To do so you will click on "File" >> "Export vector map" >> "[v.out.ascll]". 22. At tab "Required" you will set the parameter "(input=name)" and the parameter "(format=string)" as "standard".

STATE OF THE OWNER		t Points	Optional	Command output	Manual
Name of input	vector map:				(input=nar
	8				16
Output format: standard				v 🧹	(format=stri
5 tantaara				<	

23. At tab "Output" you will fill the blank "(output=name)" with the path to your new file.

24. The file comes organized by values into categories. You should to re-sort only such categories now. The result will be the correct main channel geometry.

25. Note that the XYZ file you just imported does not have the elevations informed and we have to attach them to the sorted coordinates now. To plot the canal longitudinal profile you will make some extra columns in your table. One will be the difference between values of X (UTM E), another will be the difference between values of Y (UTM N). Also, a column with the result of a hypotenuse from these two differences (X and Y). Then, a column content the cumulative sum of the hypotenuse that will represent the distance.

Note: The cumulative sum should be equal the total length of the main channel. The Canal longitudinal profile chart is going to be the chart between the distance and the height in each point.

Note: You must attach the elevation (available at the XYZ text file exported from the watershed stream network elevation clip) to the coordinate sort found. Remember, every pair of coordinates are unique, then you should link a pair of coordinates that have an elevation value with an equal pair of coordinates. To do so, you will need to create a unique key to every pair of coordinates, for example, by using the function Concatenate at a spreadsheet editor (i.e.=CONCATENATE(TEXT(B3," 0") TEXT(C2 " 0")) where B represents

0"),TEXT(C3," 0")) ) where B represents UTM E and C represents UTM N. This function will create a unique phrase or key with these two coordinates in UTM E and UTM N. You will make the same in both tables. After, you can use the spreadsheet function Vertical Lookup (i.e =VLOOKUP(B2,C2:D1568,2,FALSE) ) where B2 represents the key value, C2:F1568 represents the column to search such key value, 2 (two) represents how many columns aside (right side) you will look up and FALSE says whether the search column is sorted or not.

Now you are able to plot the canal longitudinal profile. Do it using the chart tool of your spreadsheet editor. You could notice that the chart will present a lot of ups. It happens sometimes because the pixel of the used radar is sometimes smaller than the channel width (the water surface width). Hence, the pixel will storage an averaged elevation, which is a wrong elevation between the river overbank and the water surface elevation in these cases.

To handle problems like that, one can make a correction at the longitudinal profile using the function IF in a spreadsheet editor. If the profile is oriented downstream to the right, use this "=IF(K2>E3,E3,K2)", where K2 is the height corrected and E2 is the original height value. The formula says if some K elevation is bigger than the previous one, use the previous one

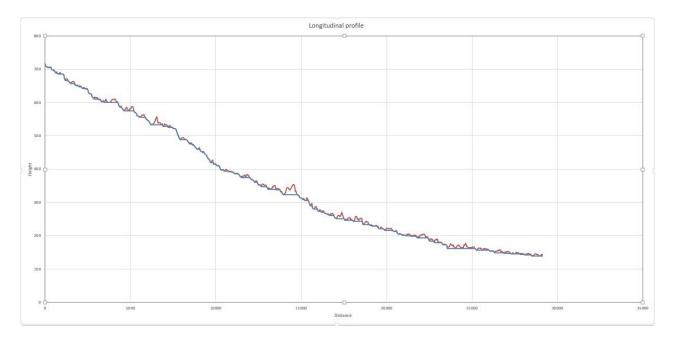


Figure 18: Result from plotting the original and the corrected data set of the mainchannel.

# 4 Conclusion

This manual gathers necessary steps to achieve important results in watershed morphology studies, showing that those ones are feasible in a realistic analysis.

The main channel longitudinal profile analysis allowed one to notice that an additional software (spreadsheet editor) is needed to complement the GIS GRASS tools in doing so.

Since the river longitudinal profiles are supposed to be downhill, the results obtained with 1-sec resolution elevation data showing jumps up are inconsistent. That occurs because 1-sec resolution is not high enough to accurate river longitudinal profiles in small watersheds.

Finally, the software GIS GRASS 7.0 shows a very useful tool to help one to develop a watershed morphology analysis. In some sense, it makes easier to students, engineers and researches to accomplish watershed morphology studies because of the worldwide availability of digital data and their treatability.

## 5 Acknowledgments

I would like to express my appreciation to all those whose assistance proved to be a milestone in the accomplishment of my summer research.

To my sponsors CNPq and CAPES for my scholarship in the context of BSMP (Brazilian Science Mobility Program).

In Brazil, I would like to pay my regards to my Tutor Professor Mauricio Dai Prá for his vital support and assistance.

I really would like to express my deepest thank to all those who provided me the possibility to carry out this report such as the Civil and Environmental Engineering Department in the Colorado State University, especially Professor Dr. Pierre Y. Julien whose advises turned my research a success.

A special thankfulness I give to my project supervisor, Dr. José Anderson Batista, whose contribution in stimulating suggestions and encouragement, helped me to develop my project, especially in writing this report.

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