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User guide for *FluvialCorridor* toolbox

Extraction of the valley bottom

Toolset name : *SPATIAL COMPONENTS*

Tool's name : *Valley bottom*

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FluvialCorridor package for ArcGIS

Version V01 - 2014

CNRS - UMR5600 Environnement Ville Société
Alpine Space Program - Sedalp

For each use of the *FluvialCorridor* GIS package leading to a publication, a report, a talk presentation or any other document, please refer to the following paper :

Roux, C., Alber, A., Bertrand, M., Vaudor, L., Piégay, H., submitted. "FluvialCorridor" : A new ArcGIS package for multiscale riverscape exploration. Geomorphology.

I. Concept and method

Within a watershed, extraction of a valley bottom related to a hydrographic network is a crucial step for the fluvial corridor characterization. Defined as the modern alluvial floodplain (Fig. 1A) by Alber and Piégay (2011), valley bottom is the deposition zone of alluvium since Holocene (Schumm, 1977) and includes both riverbed and floodplain. This valley bottom crucial fluvial unit with important water, material and biota transfers (Nanson and Croke, 1992). Valley corridor width also controls fluvial dynamics and patterns so that extracting this layer is often a preliminary step in the biogeomorphic characterization of stream networks (Notebaert et Piégay, 2013).

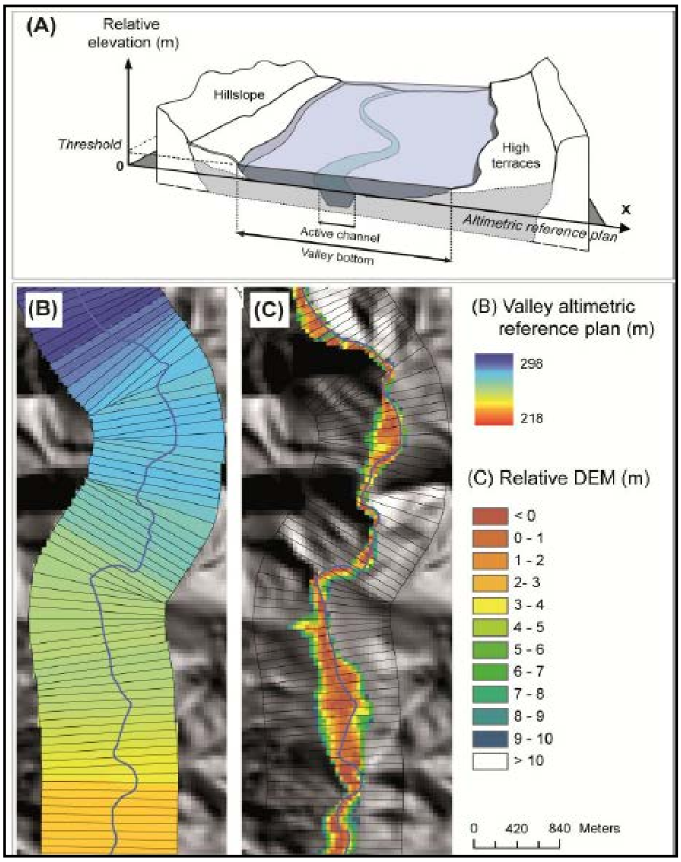


Figure 1 Topographic method for extracting the valley bottom from a DEM. (A) Definition of the valley bottom and schematization of the method. (B) Illustration of the altimetric reference plan and (C) the relative DEM, the latter being derived

Valley bottom extraction method is the one developed by Alber and Piégay (2011). This method involves a Digital Elevation Model (DEM), or any other altimetric model (e.g. LiDAR), and it is based on the creation of a detrended elevation model of the ground compared to the stream elevation :

1. During the first step, stream elevation is extracted. This elevation is assumed to be the minimal one into the valley bottom and is extracted along all the fluvial network, with a constant spatial step.
2. Then, an altimetric reference plan is created. This plan has the stream elevation values of the disaggregated network and must be quite large enough to contain the entire valley bottom (Fig. 1B).
3. The detrended DEM is then obtained by subtracting the reference plan from the original DEM (Fig. 1C).

4. A threshold, empirically defined by Alber and Piégay (2011), is then applied to the detrended DEM to keep only cells with a difference of elevation with the stream less than 10m.

This simple extraction method is not time and memory consuming. However, as mentioned by Alber and Piégay (2011), resulting valley bottom is not perfect. This is especially true for a regional use or for a study area with a high drainage density. It is therefore necessary to validate iteratively what the best elevation threshold is to map valley bottom in a given regional context and with a given DEM considering its resolution.

Implementation of this extraction method has been done with a GIS software (ArcGIS 10.0) and thanks to a DEM (BD Alti® of IGN[1]) and a vector layer of the hydrographic network (obtained with *Stream* network tool). Presented *Valley bottom* tool can be used for any area if user has a related DEM and stream network.

General algorithmic framework

Algorithmic framework developed for the *Valley bottom* tool is illustrated in Fig. 2.
Several parameters have to be provided. First ones, the original DEM and the stream network, are the material from which the valley bottom will be extracted. Others are integers and each one has a significant role during the process.

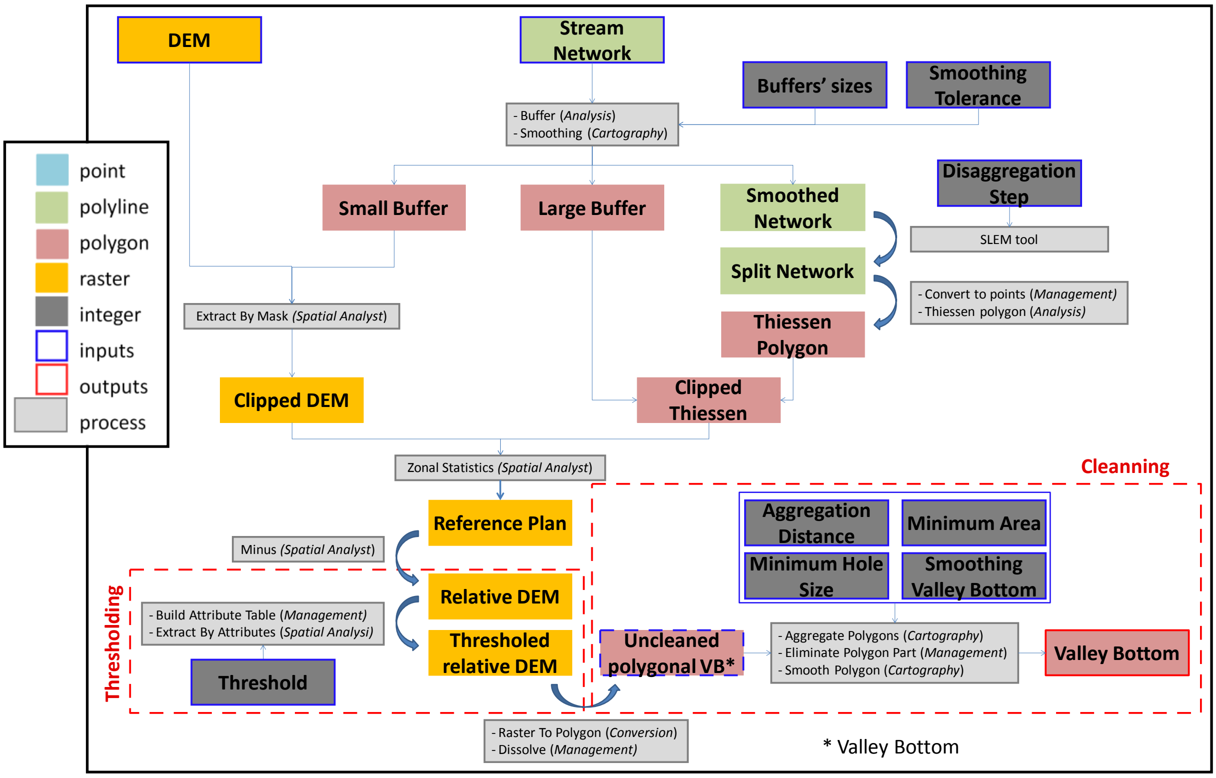


Figure 2 General algorithmic framework of the *Valley bottom* tool

They can be sorted into two groups :

– parameters used for valley bottom extraction
  - *Buffer Size* (in m) which includes both a small buffer and a large buffer (respectively *Small Buffer* and *Large Buffer*). The tool will search for the

[1] French National Geographic Institute

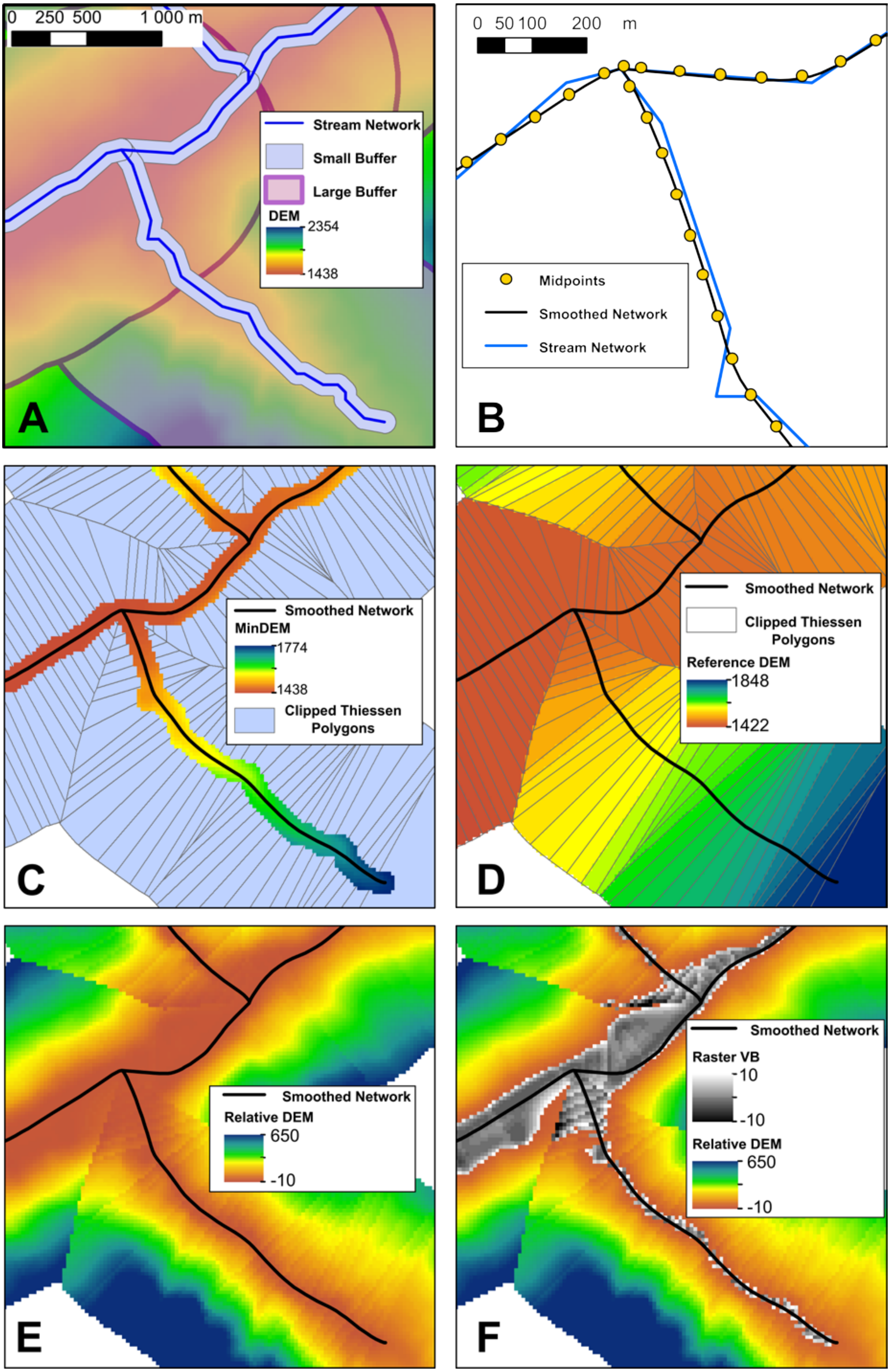
minimal elevation (i.e. stream elevation) inside the first one. The second one is the DEM extend within the valley bottom is assessed.

- *Smoothing Tolerance* (in m) aims at smoothing the initial stream network. This step is essential for a consistent Thiessen polygonization, especially if the provided stream network has been assessed from a DEM (e.g. *Stream Network* tool) and not from a digitalization.
- *Disaggregation Step* (m) relates to the constant spatial step used to split the stream network. Once the stream network is smoothed, it is split into N segments of x meters. Those segments are then converted into points and are used to create Thiessen polygons.
- *ThresholdMAX* (in m) It has been tested that an empirical threshold of 10m provides rather good results within the Rhône watershed and with the French DEM concerned (Alber and Piégay, 2011) but user can change its value after testing outputs.
- *ThresholdMIN* (in m) aims at restricting the valley bottom definition. A cell is considered as a part of the valley bottom if its value is between *ThresholdMIN* and *ThresholdMAX*. Sometimes, the *Large Buffer* into which the valley bottom is assessed is quite too large according the valley bottom width. So that unexpected cells could be taken into account. Those cells generally have strongly negative values and *ThresholdMIN* is used to exclude them.

– parameters used to clean the polygonal valley bottom
  - *Aggregation Distance, Minimum Area* and *Minimum Hole Size* are parameters from the ESRI tools *Aggregate Polygon* and *Eliminate Polygon Part*.
    - *Aggregation Distance* (m) is the distance to be satisfied between polygon boundaries for aggregation to happen.
    - *Minimum Area* (in m²) is the minimum area for an aggregated polygon to be retained.
    - *Minimum Hole Size* (in m²) is the minimum size of a polygon hole to be retained.
  - *Smoothing Valley Bottom* (in m) is used to smooth the output valley bottom.

The following points provide some details of the algorithmic framework used in the *Valley bottom* tool :

1. In a first hand, three different layers are created from the hydrographic network : (i) a small buffer in which the stream elevation is searched, (ii) a large buffer in which the valley bottom is assessed (Fig. 3A), and (iii) a set of Thiessen polygons created from the midpoints of the disaggregated network (Fig. 3B).
2. Then, Thiessen polygons are extracted according the large buffer extend and the DEM is extracted according to the small buffer extend (Fig. 3C). Each polygon is attributed with the minimal elevation value of DEM cells it overlays thanks to the *Zonal Statistics* tool (ESRI). This is the altimetric reference plan defined by Alber and Piégay (2011) (Fig. 3D).
3. This reference plan is then subtracted from the original DEM to obtain the detrended DEM (Fig. 3E). Cells included between user defined thresholds (i.e. *ThresholdMIN* and *TresholdMAX*) are extracted and converted into polygon feature. This polygon (*Uncleaned Polygonal VB*) is a raw and unusable valley bottom, without any cleaning process.
4. Finally, a set of cleaning processes are applied (Fig. 3G).


0 250 500 1 000 m
Stream Network
Small Buffer
Large Buffer
DEM
2354
1438
A
0 50 100 200 m
Midpoints
Smoothed Network
Stream Network
B
Smoothed Network
MinDEM
1774
1438
Clipped Thiessen Polygons
C
Smoothed Network
Clipped Thiessen Polygons
Reference DEM
1848
1422
D
Smoothed Network
Relative DEM
650
-10
E
Smoothed Network
Raster VB
10
-10
Relative DEM
650
-10
F

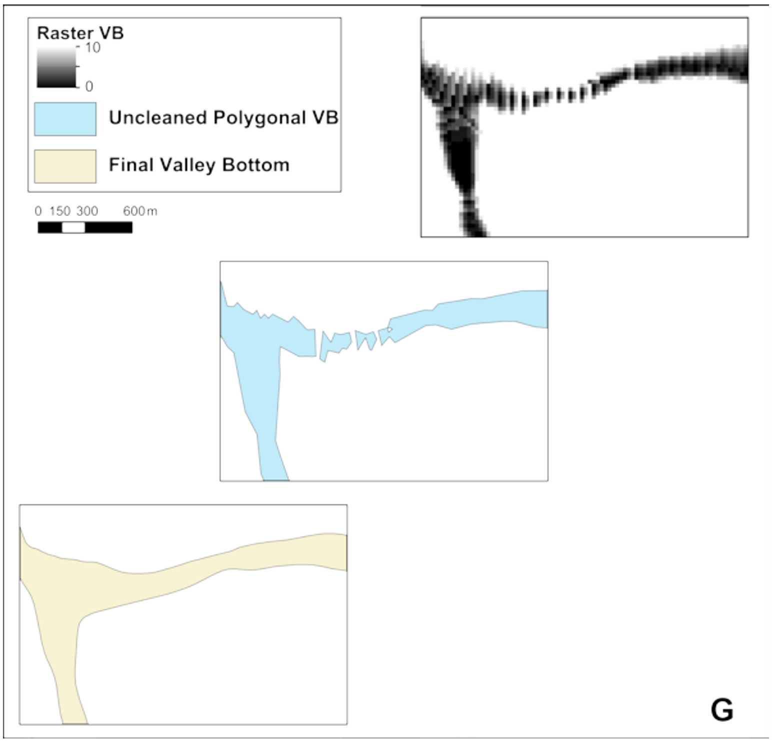


Figure 3 Main steps of the Valley Bottom tool. (A) : Creation of the small and large buffers around the stream network. (B) : Splitting of the smoothed stream network and conversion into midpoints. (C) : Extraction of the DEM thanks to the small corridor and generation of the Thiessen polygons with previous midpoints. (D) : Altimetric reference plan. (E) : Detrended DEM. (F) : Extraction of the valley bottom by thresholding the detrended DEM. (G) : Illustration of the cleaning process

Note
Valley bottom tool can be used at several scales. Cleaning parameters are not intuitive[2] and can have a very large range of values. Thus, once user has entirely run the tool and he founds the best thresholds, result can be unsatisfactory yet, despite cleaning process. That is why *Valley bottom* tool includes an option enabling to only execute cleaning steps of the process, to limit time consuming and to focus on cleaning parameter optimization. This option can be selected by checking the *Only Execute the CleanSteps of the Polygonal Valley Bottom* and requires the *Uncleaned Polygonal VB* feature created during a complete previous run.

II. Screen user interface

II.1. Start-up screen

Screen user interface provides several fields (Fig. 4). Be careful that a green mark in front of a field is not a guaranty that it is optional. Into *Valley bottom*, if a field is available this means that it is not optional and that it **must be filled**.
Firstly, user has to choose between a full run or just a cleansteps run. The second option requires a previous full run in order to correctly set *ThresholdMIN* and *ThresholdMAX* and to create the required raw valley bottom feature *Uncleaned Polygonal VB*. In that case, only concerned parameters are available and *Uncleaned Polygonal VB*, stored into the default geodatabase must be provided.

[2] They depends on several factors such as the study area extend, the drainage density and the DEM resolution.

If user wants a full run, all fields must be completed. Some fields have default values. Those indicative values can be modified (or must be modified according to the study area, the drainage density and the DEM resolution).

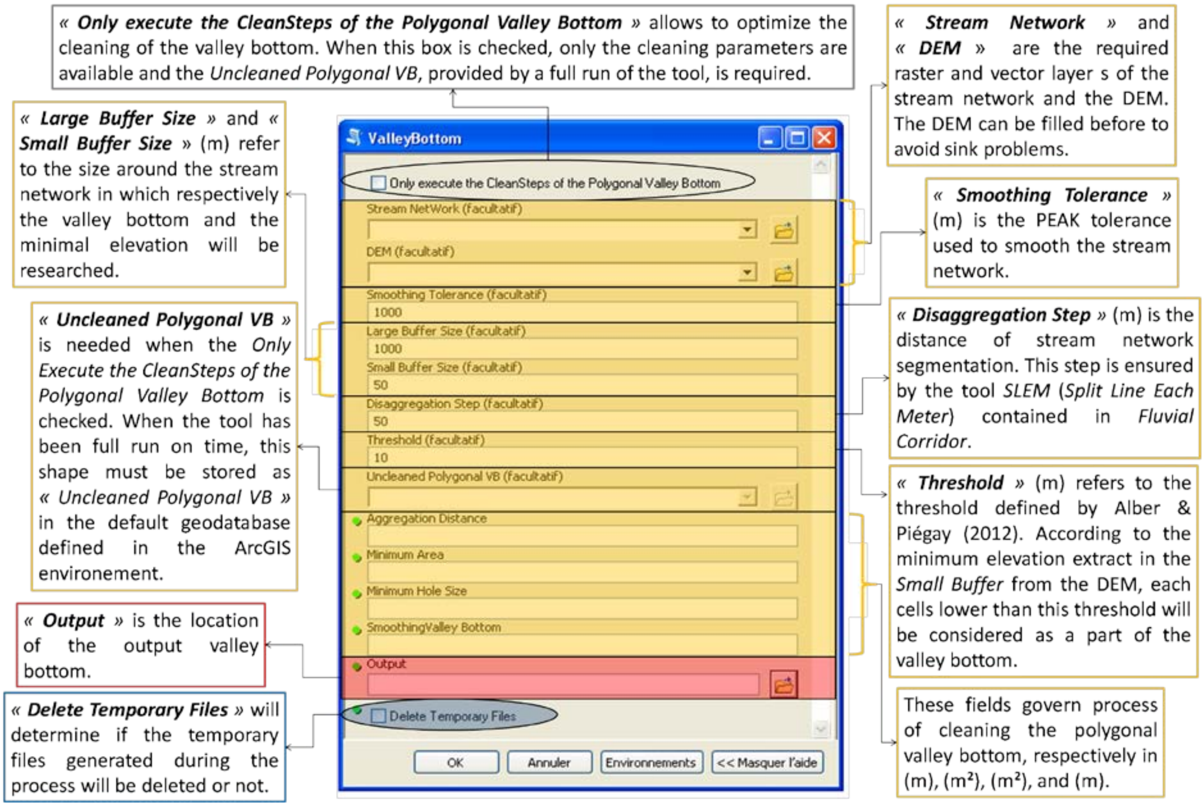


Figure 4 Screen user interface of *Valley bottom* tool

Note
To prevent some mistakes into the original DEM, it is recommended to fill it before use (*Fill* tool in ArcGIS).

II.2. Management of temporary files

Temporary files created during the compilation are managed thanks to the ArcGIS default geodatabase (*%ScratchWorkspace%*). If the user does not modify this geodatabase in the general environment proprieties, its path looks like C:\Documents and Settings\<user>\My Documents\ArcGIS\Default.gdb. With the box "*Delete Temporary Files*", the user has the choice to keep or erase the temporary files.
For the *Valley Bottom* tool, two vector features are kept whatever the chosen option (full or partial run) : (i) final valley bottom feature, the output, and (ii) *Uncleaned Polygonal VB* feature, required for only cleansteps runs and stored into the default geodatabase.

Note
For a first run, it can be judicious to keep temporary files. A quick look of these shapefiles can help to improve required parameters such as *Buffer Sizes*, *Thresholds* or cleaning values. A non exhaustive list of mistakes due to a wrong estimation of these parameters is available into the next chapter. Annex of this guideline also provides a list of temporary files created during a run.

III. Caution for use and limitations

III.1. Results

Presented results have been obtained thanks to the *Valley bottom* tool. Study area is the watershed of the Guil river, a tributary of the Durance in the French southern Alps, in France. This watershed extends over 577 km^2. Available material is a DEM (25m,25m) from the BD Topo® (IGN) and a stream network of 182 km (extracted thanks to the *Stream network* tool). Used parameters (Table 1) have been determined empirically.

Smoothing Tolerance	$500m$
Large Buffer Size	$400m$
Small Buffer Size	$50m$
Disaggregation Step	$50m$
ThresholdMIN	$-10m$
ThresholdMAX	$10m$
Aggregation Distance	$200m$
Minimum Area	$40\ 000m^2$
Minimum Hole Size	$100\ 000m^2$
Smoothing Valley Bottom	$100m$

Tableau 1 Parameters used to extract the valley bottom.

Extracted valley bottom has been compared to a pre-existing valley bottom, extracted with the same method but manually corrected thanks to topographic map (SCAN 25® of IGN). Finally, our extracted valley bottom extends over 28.16 km^2 and the reference valley bottom over 22.44 km^2 (Fig. 5A). 75% of our extracted valley bottom is similar to the reference valley bottom and 1.33% of the reference valley bottom has not been extracted by the tool. These results lead to three conclusions. Firstly, general result provided by *Valley bottom* seems to be consistent. Then, the tool generates some wandering at the extremities of the valley bottom (Fig. 5B). And finally, links can be created between two distinct valley bottoms (Fig. 5C).

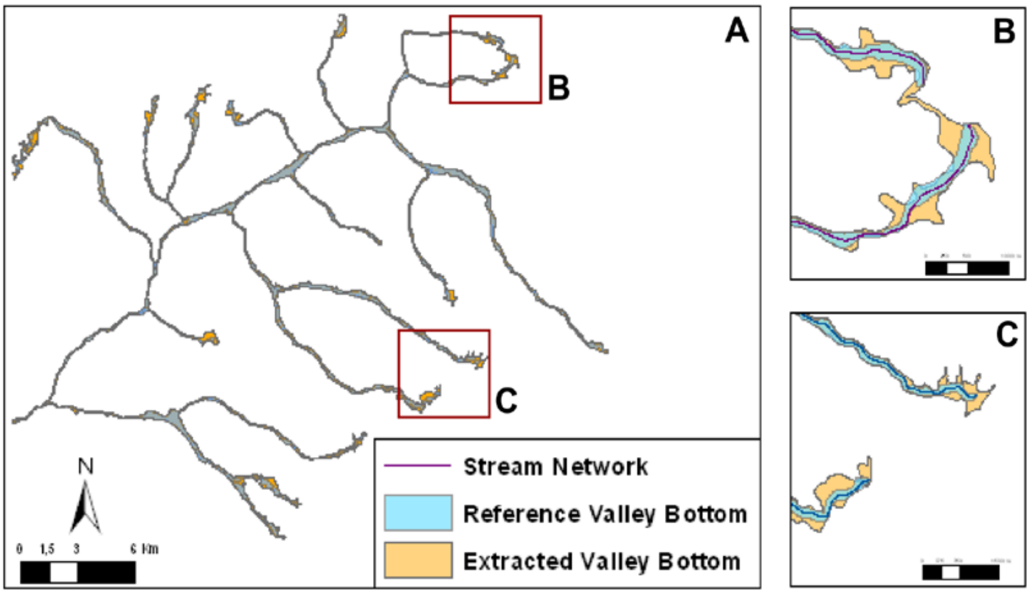
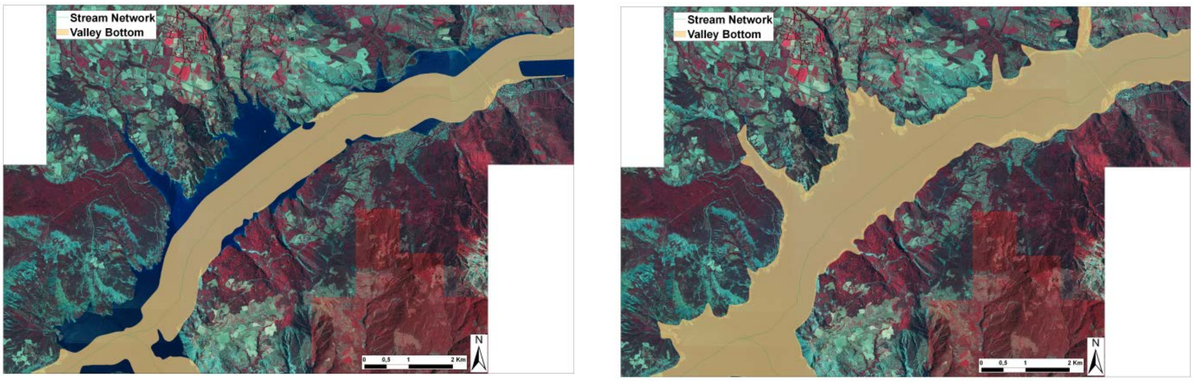


Figure 5 *Valley bottom* results for the Guil catchment (French southern Alps, France)

III.2. Non exhaustive list of cautions and limitations

a. Non consistent valley bottom

Incomplete valley bottom



(A) (B)

Figure 6 Impact of the Large Buffer Size parameter, under-estimation (A) and good estimation (B).

The final valley bottom shape directly depends on the *Large Buffer Size* parameter. The parameter defines the area in which the valley bottom is processed. In Figure 6, two cases are presented. In the first one (Fig. 6A), the large buffer size has been highly under-estimated (~400 m) so that lateral boundaries of the valley bottom are not validated by a photo interpretation. This case is extreme as it relates to a dam, with a very large width just upstream. Thus, to ensure a correct extraction of the valley bottom, *Valley Bottom Size* must be set at ~3000 m (Fig. 6B).

Wandering valley bottom

One of the main limitations of the *Valley bottom* tool is the accuracy at extremities. In most cases, the extracted valley bottom tends to wandering (Fig. 7). This is mainly due to the limits of the definition of valley bottom at the heads of catchments (e.g., channel versus hillslope) which is also linked to the DEM resolution. In fact and according to the DEM resolution, this can be caused by head reaches hardly identifiable and so wrongly defined.

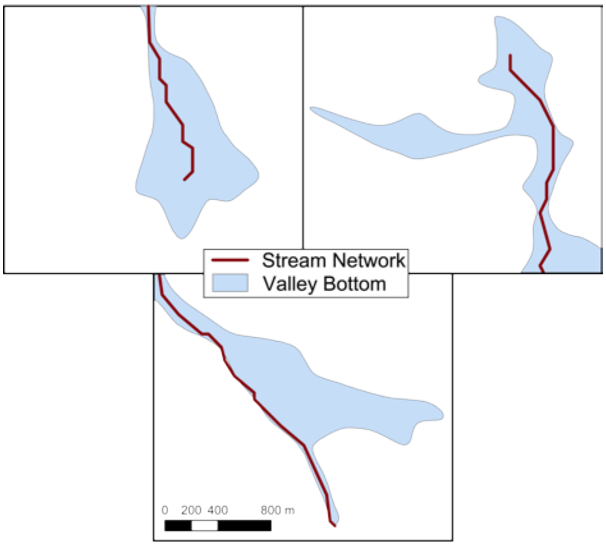
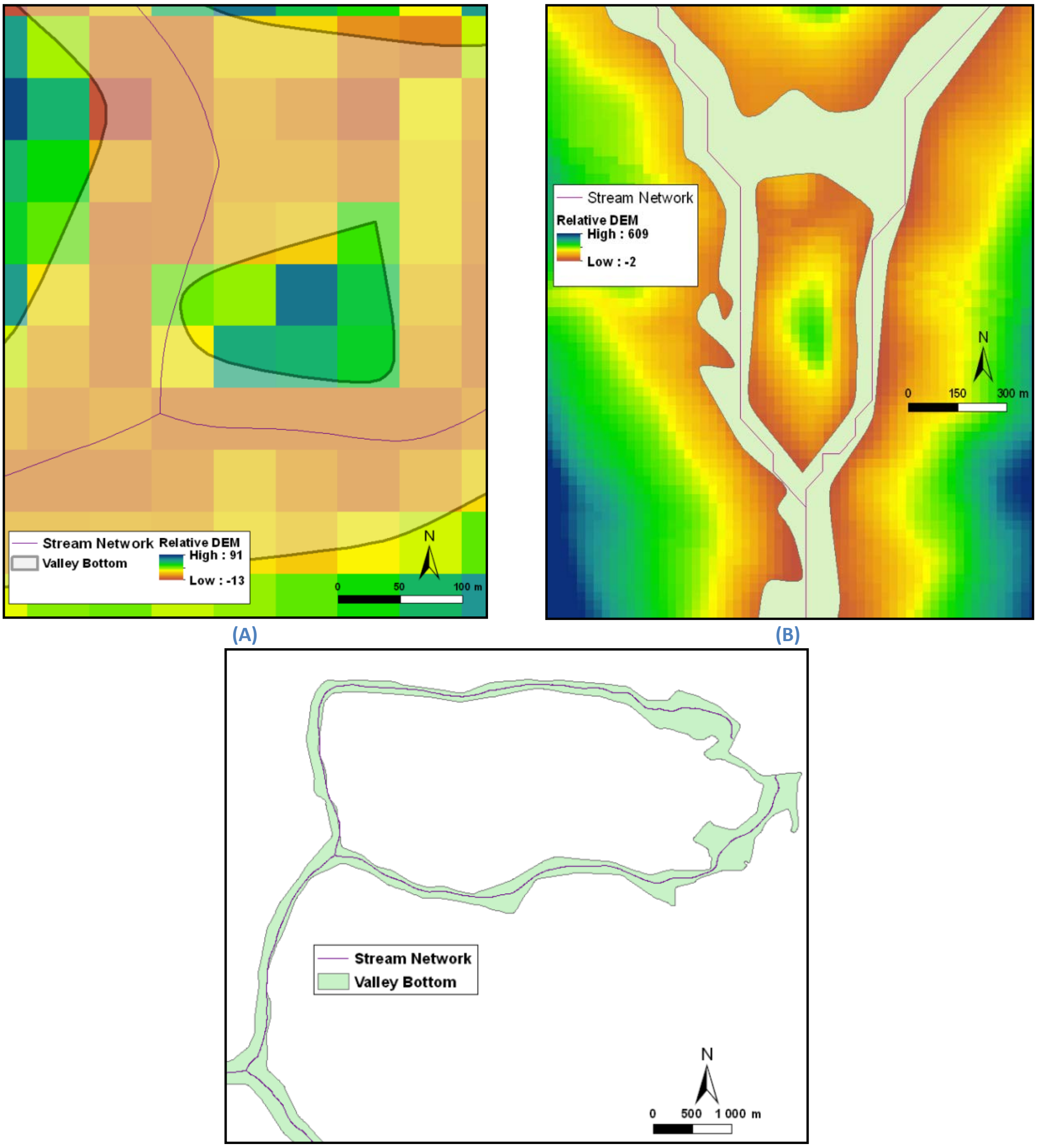


Figure 7 Valley bottom wandering at the upper ends of stream branches

b. heterogeneous in valley bottom spatial coverage

The second most common type of problems is heterogeneities in spatial coverage. Holes can come from a variety of causes. Firstly, they can be induced by a low DEM resolution or by a wrong setting of *Thresholds*. In that case, two distinct valley bottoms can be joined (Fig. 8A). So that holes are clearly topologic mistakes and must be deleted. Secondly, they can be natural if they are related to a real ground level raising (Fig. 8B).

In both cases, if user wishes to continue the geomorphic characterization of its network using *FluvialCorridor* toolbox (e.g. *Centerline*), such a valley bottom will induce problems so that it must be correctly filled at this step. Sometimes, link between two separate valley bottoms can be very unrealistic (Fig. 8C). So it is highly recommended to perform a visual verification of *Valley bottom* output feature.

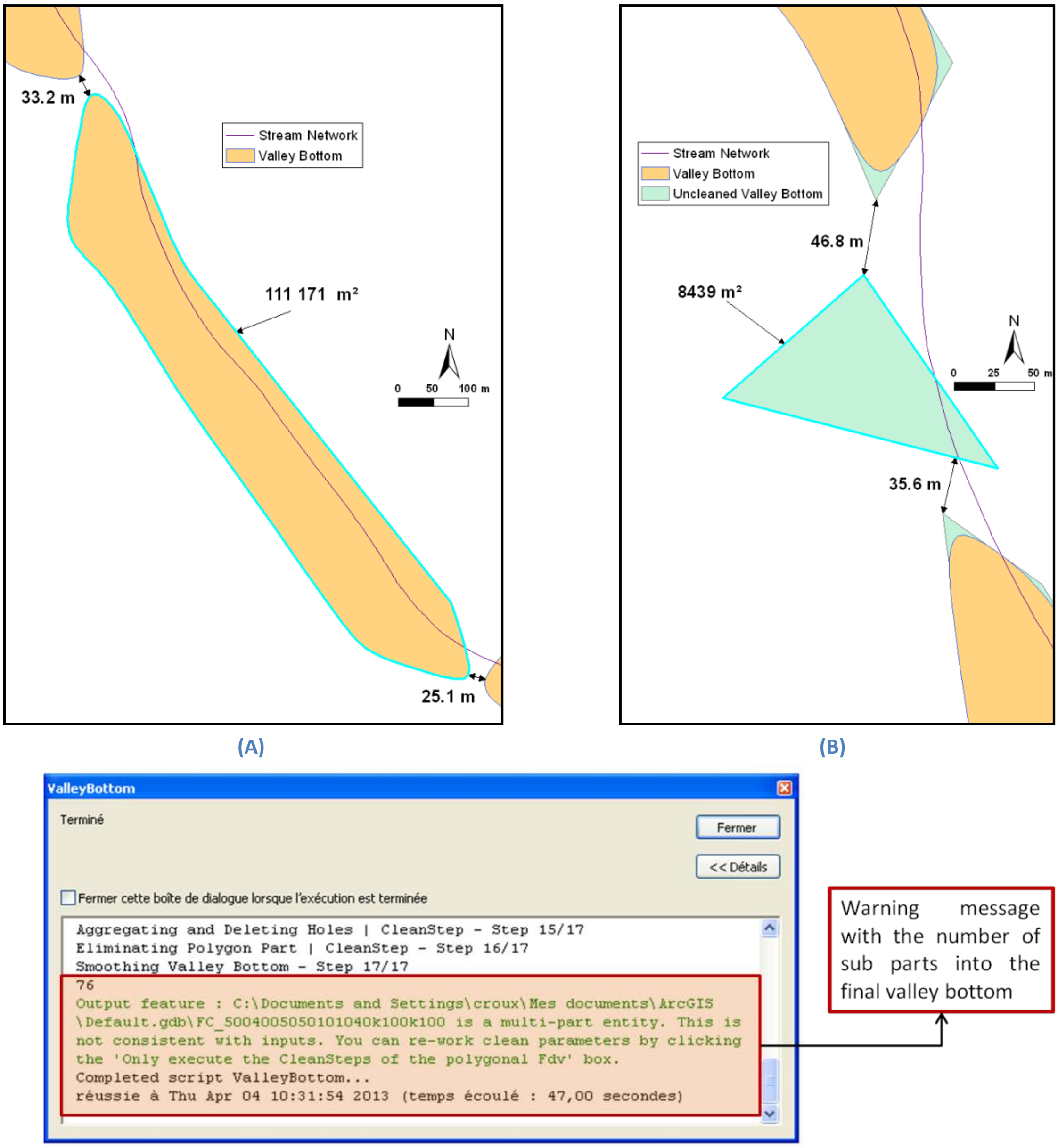


(C)

Figure 8 Holes in the extracted valley bottom. (A) Non consistent hole due to the junction between two different valley bottoms. (B) Natural hole due to a ground rising. Extreme case of junction (C).

c. Discontinuous valley bottom

In order to characterize fluvial corridor along an entire continuum, it absolutely necessary for the extracted valley bottom to be continuous. This requirement is ensured by the parameter *Aggregation Distance* of the vectorization and cleaning steps of the valley bottom. If its value is not correctly set, polygonal output valley bottom will be composed by several parts (Fig. 9A). Moreover, if one of those multi-parts is smaller than the user-specified *Minimum Area*, it will be deleted from the final output, so that information will be lost (Fig. 9B).
To prevent discontinuity problems, user will be notified of the number of parts composing the output valley bottom by a warning message at the end of the process (Fig. 9C).



(C)

Figure 9 Wrong values of *Aggregation Distance* and *Minimum Area* during the aggregation and elimination of the small residual polygons on the *Uncleaned Polygonal VB*. (A) : Typical case of an under-estimation of the *Aggregation Distance* parameter (10m). (B) : A similar case but with a polygon with an area lower than the one specified in the *Minimum Area* parameter and consequently, a loss of information. (C) : The warning message about the number of multi-parts composing the final valley bottom feature.

IV. References

Alber, A. and Piégay, H., 2011. Spatial disaggregation and aggregation procedures for characterizing fluvial features at the network-scale: Application to the Rhône basin (France). Geomorphology, Vol.125, No.3, pp.343-360

Nanson, G.C. and Croke, J.C., 1992. A genetic classification of flooplains. Geomorphology, Vol.4, pp.459-486

Notebaert, B. et Piégay, H., 2013. Multi-scale factors controlling the pattern of floodplain width at a network scale : The case of the Rhône basin, France. Geomorphology. http://dx.doi.org/10.1016/j.geomorph.2013.03.014

Schumm, S.A., 1977. The fluvial system. Wiley-Intersciences, New-York, 338p.

ANNEX 1

List of temporary files created during the *Valley bottom* tool

Name	Description
ProcessDEM	The provided DEM is converted into a usable format (the used *Extract By Attribute* tool of *Spatial Analyst* requires an attributed raster and *Built Raster Attribute Table* of *Management* needs an integer raster). If the provided raster is already into a correct format, it is just copied in the default geodatabase with the name *ProcessDEM*.
SmoothedNetwork	Hydrographic network smoothed with the user-defined *Smooth Tolerance*.
LargeBuffer	Large buffer polygon around the stream network.
SmallBuffer	Small buffer polygon around the stream network.
SplitNetwork	Segmented network with the constant user-defined step of disaggregation. Further details on this file (creation and its attribute table into the *SLEM* (*Split Line Each Meter*) guideline.
SplitNetworkToPoints	Converted *SplitNetwork* into a set of midpoints
ThiessenPolygons	Thiessen polygons created from *SplitNetworkToPoints*.
ClippedThiessenPolygons	Thiessen polygons extracted according the *LargeBuffer* extend.
MinDEM	DEM extraction according to the *SmallBuffer* extend.
ReferenceDEM	Raster of the reference altimetric plan.
RelativeDEM	Raster of the detrended DEM.
RasterVB	Extracted cells of the *RelativeDEM* contained into *ThresholdMIN* and *ThresholdMAX*. This is the raw raster valley bottom.
VBminusVB	Convert the *RasterVB* into a polygon is quite faster if all cells have the same value. So we substract *RasterVB* by itself so that all cells are 0 and valley bottom shape is preserved.
RasterVBToPolygon	First polygon of the valley bottom. The number of polygons is equal to the number of cells into *RasterVB*.
UncleanedPolygonalVB	Raw polygon of the valley bottom, ready to be cleaned. All micro polygons have been aggregated.
AggregatedVB	Cleaning of the valley bottom with the *Aggregate*

	Polygon Part tool (*Cartography*) and related user-defined parameters (i.e. *Aggregation Distance*, *Minimum Area* et *Minimum Hole Size*).
EliminatedVB	Filling the remnant holes by the *Eliminate Polygon Part* tool (*Management*) and the related user-defined parameter (i.e. *Minimum Hole Size*).
Output	Final output shapefile of the valley bottom after smoothing.