ARMINES / ECOLE DES MINES DE PARIS

Tutorial FLUMY 1.4

may 2011

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1 Installation of Flumy

Download the zip file. In the explorer window, double click on the corresponding icon and extract the contents of the archive in a directory of yours or in C:\Program Files. A new directory mcrc should be created.

You will find a program named mcrc\bin\flumy (or mcrc\bin\flumy.exe depending of your Explorer settings). Double-click on it to start the program. You may also create a shortcut to this program on your desktop.

Under mcrc\doc, you will find Flumy usersguide for more details.

Under mcrc\data, you will find some data files that can be used.

This tutorial has been written for Flumy 1.4 version. Screenshots and parameters could be different in newer versions.

2 Migration project

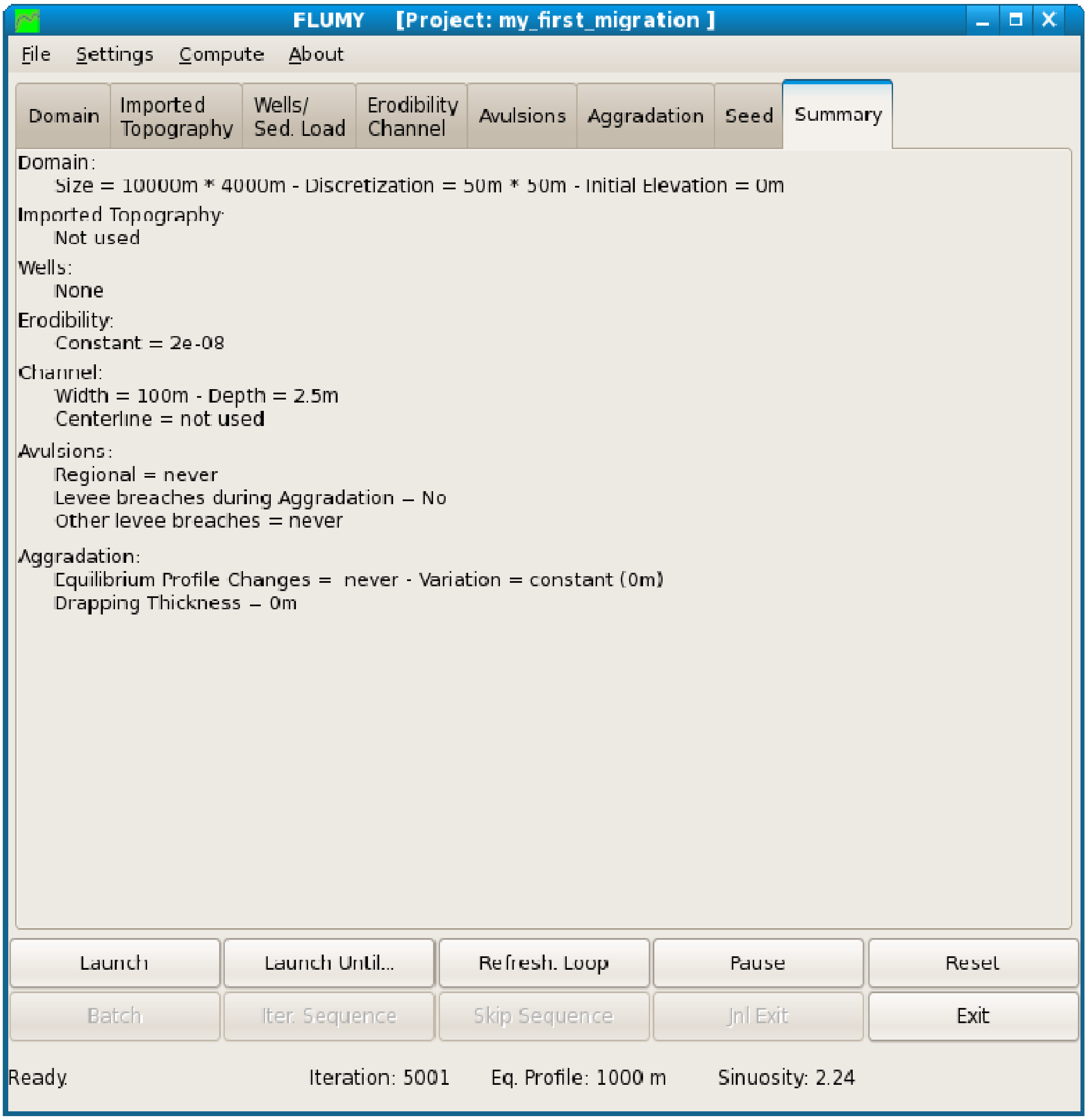
In this section, you will make your first steps with Flumy, by letting a channel migrate and discovering basic utilities.

2.1 Open Flumy, and choose a name for the project

Open Flumy: an interface opens, with “FLUMY” in the title.

When using Flumy, all the information being used, and all the information saved, are written within a “Project”, which is a directory. Give a name to this project by using the menu “File/New Project”, eg “my_first_migration”, and choose where to store this directory. The name of the project then appears in the title of the interface.

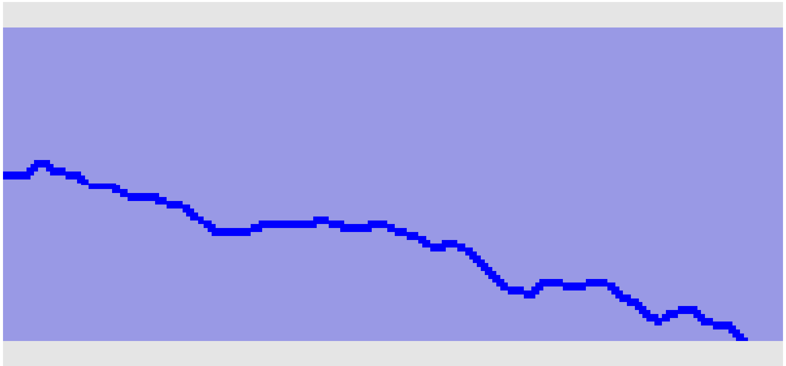
Just under the title, the menu “About/Software” gives the number and the date of the version being used, eg “Version 1.308 - Released on Feb 09, 2009”.



2.2 Define the domain

Define the domain to be modelled in the tab “Domain”. In particular, you can either “Give Grid Size” (Length and Width, eg 10000 m and 4000 m), or “Give Number of Nodes” (NX, NY, eg 201, 81) of the 2D domain. Indeed the domain is discretized into nodes. By default the discretization Lag DX and DY is 50 m.

Then (at bottom of interface) press the buttom “Launch Until…” iteration1. You can see the 2D domain in the graphical window: length in x, width in y, and a channel on it (tossed at random for you, but it will be possible to import one, or to toss another one, see later). The slope, and the flow direction, is towards the right.

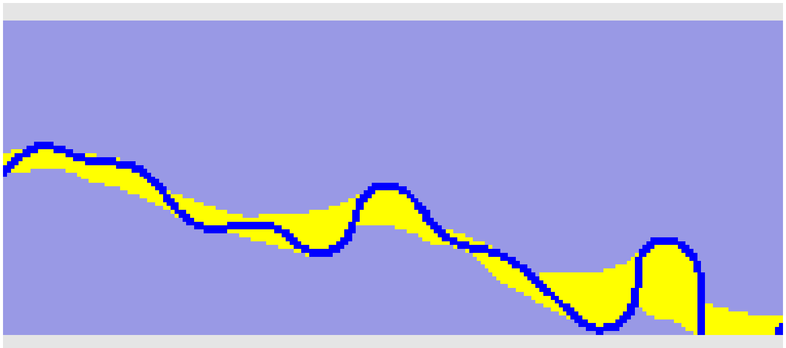


2.3 Choose the channel size

Use tab “Erodibility / Channel” to choose the channel Width and the channel Depth, for instance 100 m and 2.5 m. By default the Width was 100m and the default Mean Depth 3 m (corresponding to a maximal depth of 150% of it, ie 4.5 m, as the channel cross-section is parabolic).

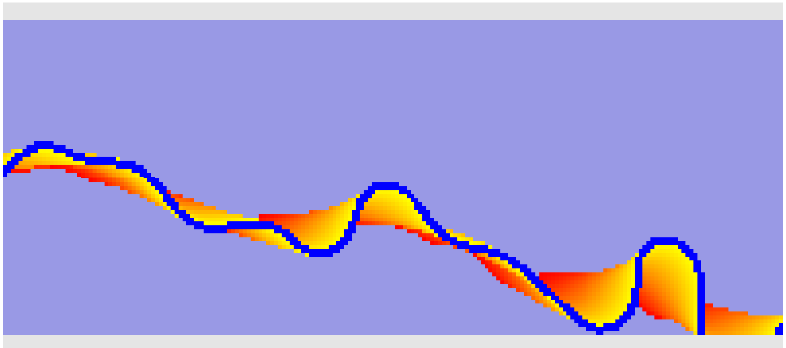
2.4 Migration

Press “Launch”: you can see the channel migrating in time: the outer bank is eroded, and Sand PointBars (in yellow) are deposited in the inner bank. Time is discretized into iterations (typically 1 ite represents 1 year), and the windows are refreshed every 100 iterations (the default Refreshment Period). “Simulating…” and the current iteration are displayed in the Status Bar at the bottom of the interface. Press “Pause” to stop the process after eg 2000 iterations. “Simulating…” is replaced by “Ready”.

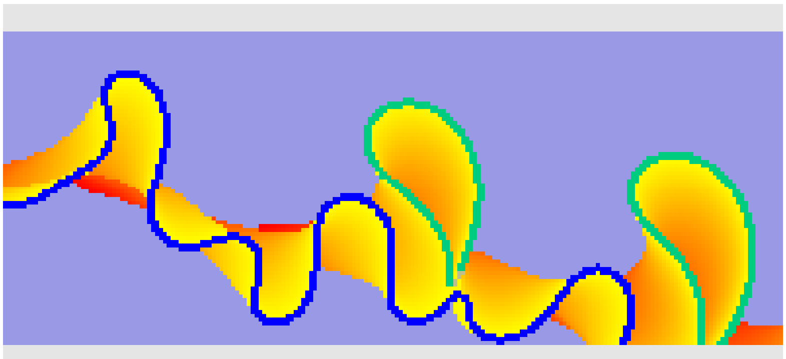


It is possible to display the aerial view as well as x- and y-sections. Type “s” over the graphic window to show or hide the positions of the sections. Then type “a”, “x” and “y”, or equivalently the icons “Aerial View”, “X Section View” and “Y Section View” (at top of graphical window) to choose the type of view. Note that the x-section is from South, on left, to North, on right. Use the arrows of the keyboard to change the positions of the sections.

By typing keys “d” and “f”, or with the icons “Color Coding: Facies” and “Color Coding: Age + Granulometry”, you can choose between the two representations. With the latter one, the older Sand PointBars are in red.



You can repeat different sequences of iterations by pressing “Launch” and “Pause”. The channel develops its loops, increasing its Sinuosity. The sinuosity, the ratio between the channel length and the distance between its extremities, is displayed in the Status Bar at the bottom of the interface. At some time, the channel will present a cutoff, and the abandoned loop is filled in with MudPlug, in green. Cutoffs limit the loops and stabilize the sinuosity.



You can also “Launch until …” a given number of iterations, or press “Refreshment Loop” to run 100 iterations (the default Refreshment Period).

2.5 Save and Exit

When you have made about 5000 iterations, use the menu File/Save Project to save the project, then Exit.

> If you have the curiosity, use a file manager to go into the Project directory. You will see different files. One is a directory "ite_####" where #### is the number of iterations at which you have saved the simulation. This itself contains different files, in particular the results of the simulated deposits stored as "simulation.dat" (do not try to open it) and the final channel centerline "centerline.txt" (points defining a broken line). It will be possible to import such a centerline in another project.

2.6 Reset

If you open again Flumy, you will be by default in the previous project. If you want you can continue the simulation.

Otherwise it is possible to make again the same simulation. Press "Reset" (at bottom of interface): we are back at the beginning. Then press "Iterations sequence" repeatedly. Exactly the same sequences of iterations are made again. The corresponding commands had been automatically recorded in a "Journal File". Do not forget to "Save" the project at the end if you want to have it saved again this time!

"Reset" is also currently used to start again a different simulation. By choosing "jnl Exit" (journal exit), the previously recorded journal file will be ignored.

2.7 Seed

When starting the simulation, change the value in the seed tab. This is a way for the program to generate other values for the random numbers used in the simulation, so to make another simulation which is different but presents a similar aspect (the other parameters being the same). In the present case, the tossed channel will be different.

2.8 Exercises

2.8.1 Refreshment period

Go to “Settings/Refreshment period” at top of the interface, set it to 1 iteration, and look at migration in details.

2.8.2 Lag and channel width

Experiment the combined effect of the domain discretization lag (to be defined at the beginning of the simulation, or after “reset”) and of the channel width by changing values. If the channel width is too small compared to the discretization lag, the channel will appear as a dotted line. Conversely a very fine discretization lag will increase the computing time. In practice the channel width should be at least twice the discretization lag.

By typing keys “c” and “C”, or using icons “Toggle Display of Channel (real)” and “Toggle Display of Channel (discretized)”, compare the pixelized channel to the real one, in sections or aerial view (in this, grey line indicate migration).

2.8.3 Channel width and depth

What is a realistic depth value for a given width value? Or vice versa. Find empirical relation in the Flumy usersguide.

2.8.4 Migration and wavelength

By varying channel width and channel depth, find what rules:

- the migration velocity;
- the wavelength of the meander loops?

(wavelength = twice the average distance between two successive inflexion points of the channel loops)

2.8.5 Meandering loops and slope

Look at the influence of the slope on the meandering loops (“Slope along Flow Direction” under tab “Domain”, to be changed at beginning of simulation or after “reset”). Current values are between 0.001 and 0.016.

Can you see the slope in y-cross-sections? No, even if unrealistically high! In Flumy, the reference plane is represented by a horizontal plane.

2.8.6 Erodibility

Migration is proportional to the “Erodibility Coefficient” under tab “Erodibility / Channel”. Default is 2e-08 (i.e. $2x10^{-8}$) . See what happens when changing it (for instance 1e-08 or 2e-07).

2.8.7 Emap

It is possible to import an Erodibility map, or Emap. Under tab “Erodibility / Channel”, choose “Emap: “, “Loaded from file”, and import “File” from directory mcrc\data\flumy:

- erod_10_4.dat (covering a domain defined by Grid Nodes NX = 201 and NY = 81)
- erod_5_4.dat
- erod_5_4_seismic.dat (both covering a domain defined by Grid Nodes NX = 201 and NY = 81).

Use keys “e” or icon “Color Coding: Erodibility” to visualize the Emap. Observe migration of the channel using the Emap.

Expert! It is also possible to build an Erodibility map from the Centerline, that would represent a channel belt:

> open *File / Export Erodibility map built from Centerline;* the Emap is obtained by locating anisotropic bumps at channel centreline points, making use of the input Extension from channel points (as multiple of channel width) along X and along Y.

and then to import this Emap.

2.8.8 Import centerline

Exercise for expert! In a new project, under tab “Erodibility / Channel”, tick “Import Centerline” and choose the “centerline.txt” file that has been saved in a previous project (*within* a saved simulation directory ite_xxx). If you Launch, Flumy will import the centerline in one iteration and automatically stop. Think to untick “Import Centerline” to continue the simulation.

2.8.9 Longitudinal margin

Want to see what is the “Longitudinal Margin (multiple of channel width)”? find it in Flumy usersguide.

3 Aggradation project

In this section, you will perform aggradation of the system, that is, deposition of sediment over the floodplain represented by the domain, in addition to migration.

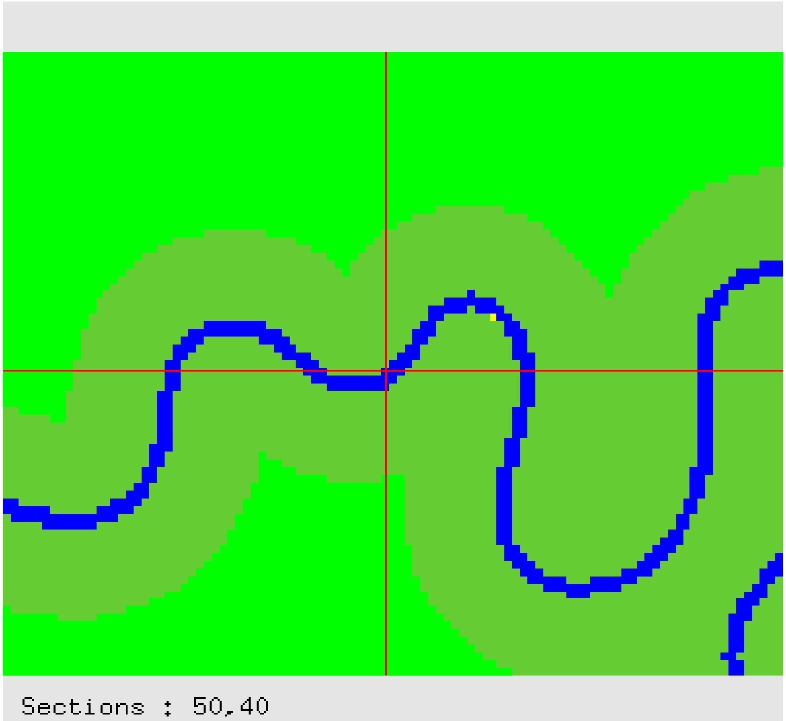
First define a Project eg “aggradation”, with default domain 5000m x 4000m.

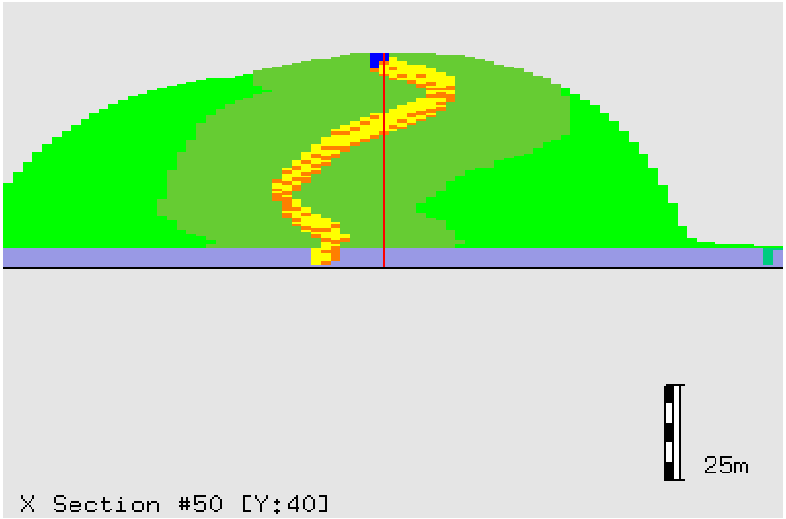
3.1 Drapping

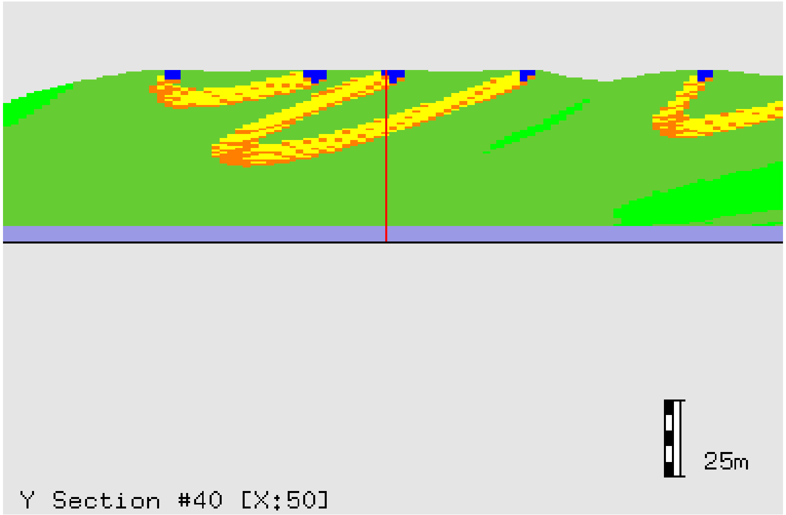
In the previous section the channel was depositing PointBars and Mudplug by migrating onto some reference plane. To avoid deposits lying on nothing, we will start to make a basement. For this, open tab “Aggradation”, and make a deposit with constant thickness by selecting “Drapping” with the desired “Thickness” eg 5 m. Then Launch: Flumy will make the drapping in one iteration and automatically stop. Check the result in a cross-section.

3.2 Overbank floods

Now select “Overbank floods” (unless you have previously imported a channel centreline, a channel will automatically be generated, depending on the seed, and not necessarily within the domain). At the chosen “Occurrence” in time that you will choose (eg “periodic” with Period 100 iterations), there will be an overbank flood, deposition of sediment over the floodplain, and increase of the elevation of the channel. Define “Thickness” (eg constant 1 m, even if this is in reality large compared to a period of 100) to give this increase, which will be also the thickness of the Channel Lag (in orange) deposited at the bottom of channel, and the height of the levee deposited at the bank of the channel (dark green). Ask for “Refreshment loop” a few times to look at the aerial view and cross-sections every 100 iterations (default refreshment period). Note that migration is processed every iteration while aggradation is performed at the chosen occurrences. Then launch until you have made about 5000 iterations.


Sections : 50,40


25m
X Section #50 [Y:40]



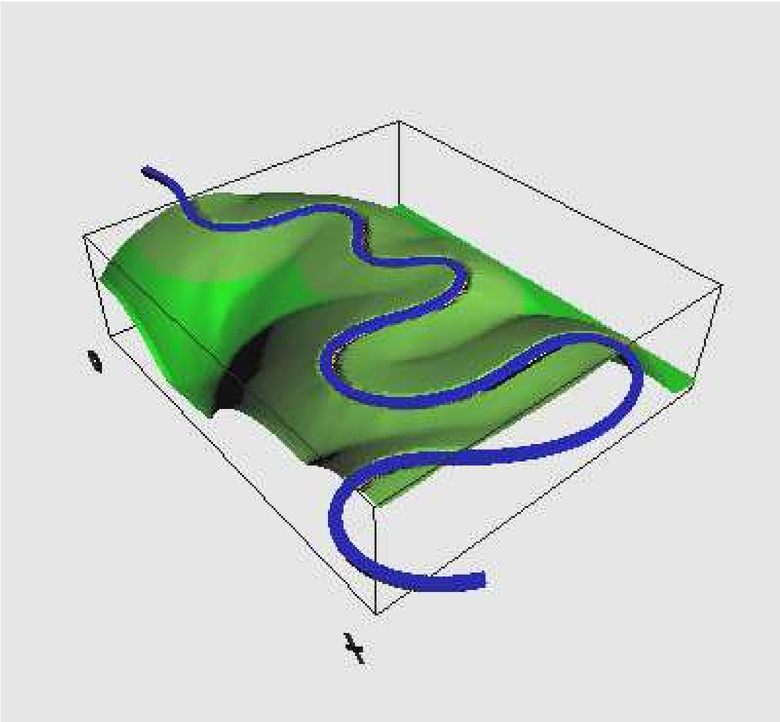
The thickness of the deposited sediment decreases away from the channel, as a negative exponential, controlled by its parameter (in m): “Exp. Decrease : Thickness”, per default 1000 m. The deposited thickness is reduced to 37%, 14% and 5%, at distances equal to 1, 2 and 3 times the parameter. Change the parameter value to 2000 m to see its effect. Note that in Flumy, only individual deposits thicker than 1 cm are considered.

Similarly the grain size decreases according to the parameter “Exp. Decrease : Grainsize” (in m). Look at view and sections using “Color Coding: Age + Granulometry”.

Conventionally sediment is coded as levee facies (dark green) up to a distance from channel equal to “Levee width (multiple of channel width)” (default 6, that is, 6 times the channel width), and coded as overbank sediment facies (light green) beyond this.

Use key “3” or icon “3D View”. Type “v” to “Toggle Display of Cube”. Type “z” and “Z”, or icons “Z-“ and “Z+” to decrease or increase the vertical exaggeration. A problem of the graphical window? Type “r” or icon “Reset”. Want to save the picture? Type “g” or use icon “Snapshot”.

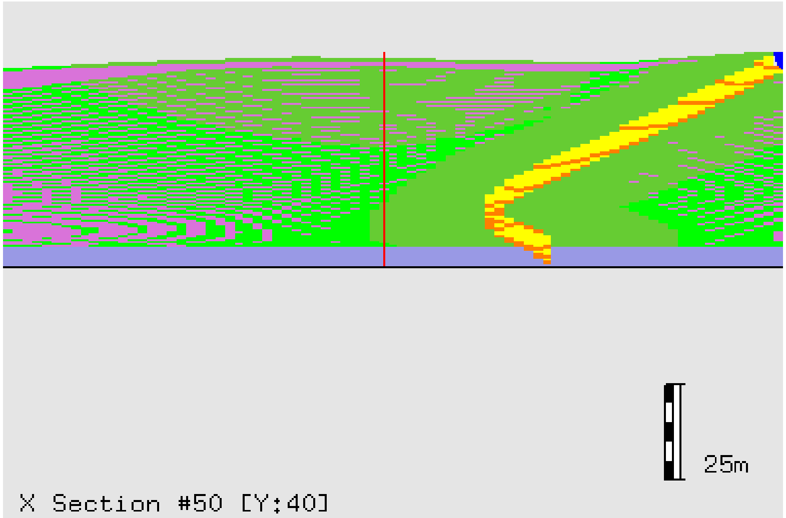
Want several graphical windows at the same time? Use “File/New graphic window”.



3.3 Wetland

Between two overbank floods, peat may accumulate in the lowlands. In Flumy, this accumulation is performed just before the overbank flood, and on the lower parts of the domain defined by "Wetland Proportion (%)", a percentage of the domain area. Default value is 0. Choose positive percentages, eg 70 (%) to deposit peat (in purple).

Restart the aggradation project with this. In the aerial view, wetland will be visible only where it is not covered by the last overbank flood sediments. Better look at a vertical cross-section. Note the compaction of each peat deposit by a factor of 10 at the next overbank flood. Remember than individual deposits lower than 1 cm disappear.



3.4 Exercises

3.4.1 Intermediate drappings

In order to better distinguish each overbank flood deposition in cross-sections (and possibly also peat), introduce drappings (deposits with a thickness constant over the domain, with a contrasted color) between these.

3.4.2 Overbank floods occurence

Explore the different options, in particular “Poisson” which corresponds to random events (the parameter gives the average interval between events, in iterations). Look at the iterations where Overbank Flood occurs in the Messages Window.

3.4.3 Overbank floods thickness

Explore the different options: constant, uniform between chosen min and max, normal or lognormal with chosen mean and standard deviation.

3.4.4 Migration versus aggradation

How to favour migration over aggradation? Aggradation over migration?

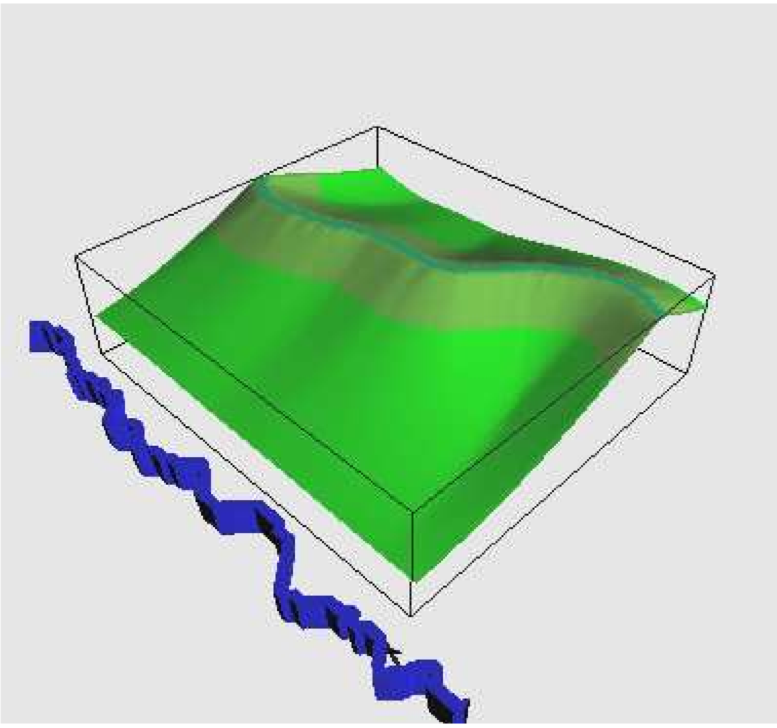
4 Avulsions project

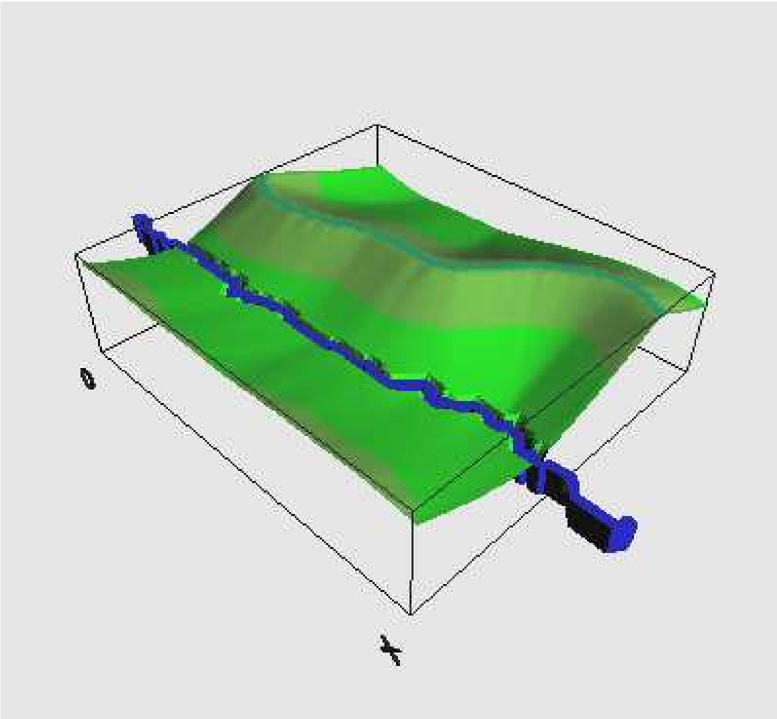
In this section, you will make levee breaches, and enable the channel to take a new path downwards (avulsion).

First define Project "avulsion", choose default domain, default channel. Choose aggradation parameters: overbank floods periodic(100) and thickness 1m.

4.1 Regional avulsions

In tab "Avulsions", introduce occurrences for "Regional" avulsions, eg Periodic(1000): every 1000 iterations you will see the channel changing its path, with a new entry upstream.





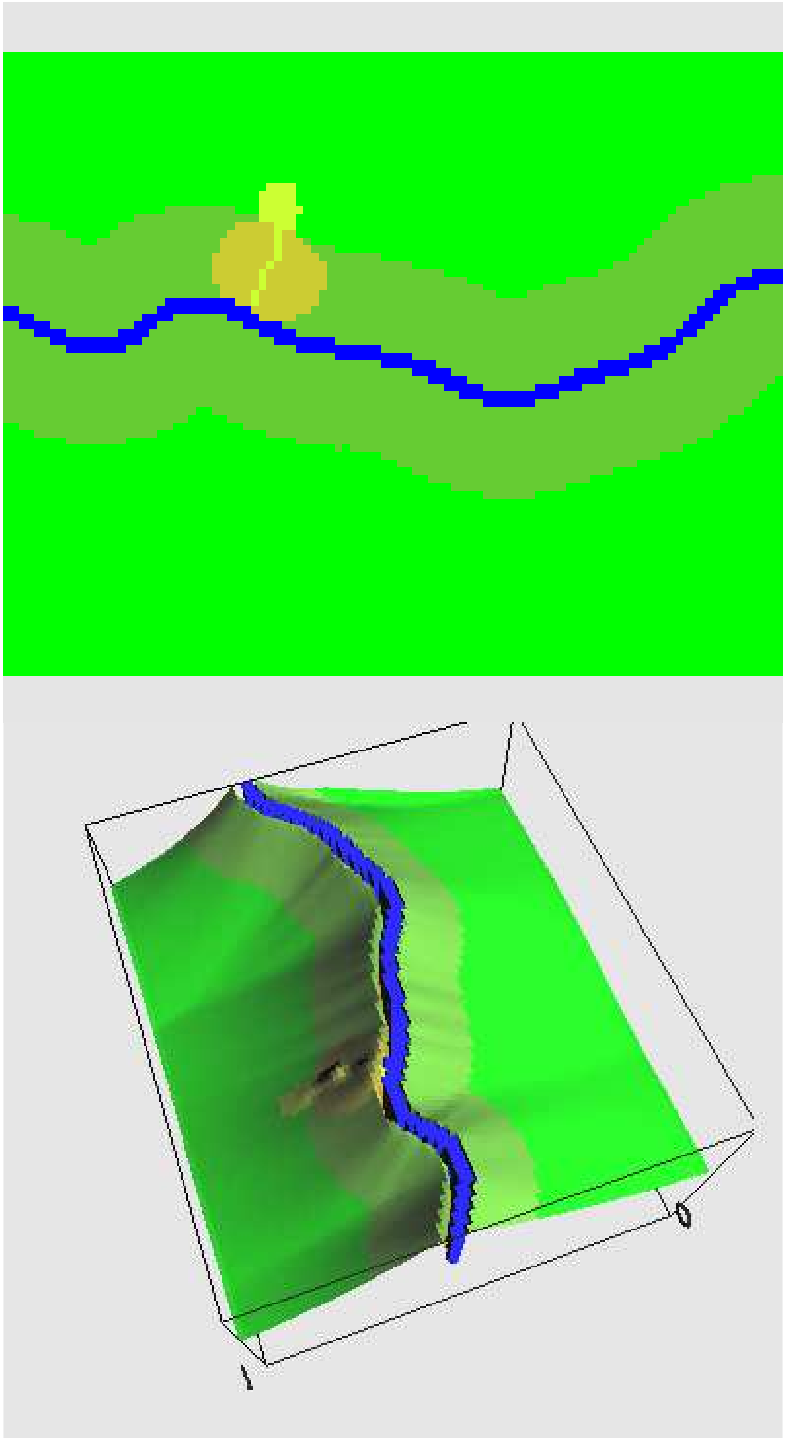
Find the facies deposited in the old channel by opening the “Facies Color Dialog” from “Settings / Change facies colors” at top of the interface.

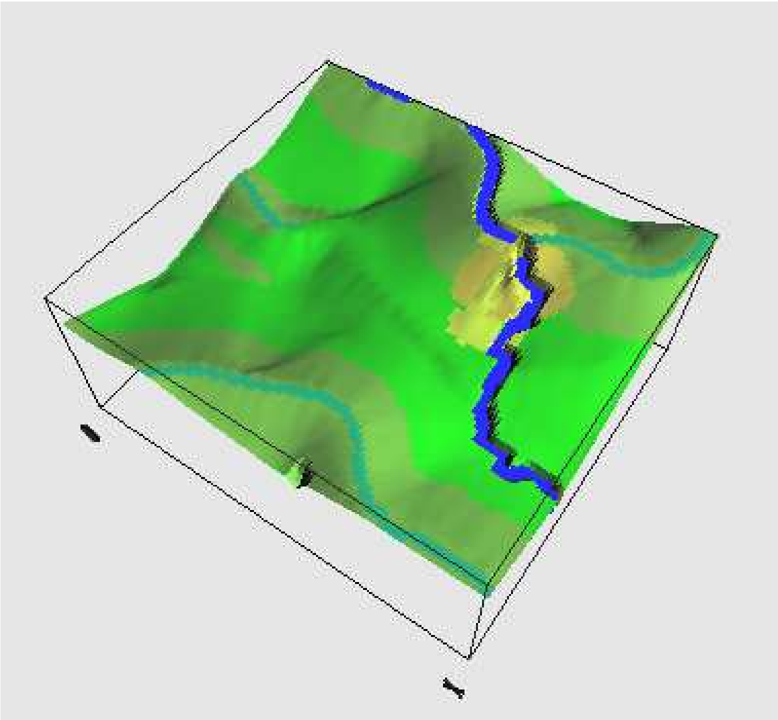
What is the effect of avulsions on the topography? Are new paths always within the domain? Why?

4.2 Local avulsions

Previous regional avulsions correspond to levee breaches upstream of the domain resulting in new channel paths. By contrast local avulsions correspond to levee breaches within the domain.

Tick “Levee Breaches : during aggradation”. Launch Flumy so that you stop just after the aggradation (eg ask Refresh. Loop of 100 iterations, with overbank floods every 100 iterations). Scrutinize the result.





Flumy may make one or several Levee Breaches with deposition of a “Crevasse Splay Type I” (incisive and elongated, in brown) as echoed in the Message Window. This itself may be covered by a “Crevasse Splay Type II” (light brown), with possible small Crevasse Channels (greenish) on it (check colors on the “Facies Color Dialog”). Finally this may lead to a “Local Avulsion - New path downstream” or to a “Local Avulsion - Path joining current channel”.

If the new path joining the current channel is short, a “Local Avulsion - Chute cutoff” appears, without deposition of crevasse splay.

4.3 Exercises

4.3.1 Other levee breaches

Levee breaches preferentially occur during overbank floods. But it is also possible to ask for “Levee Breaches : Others” by choosing their occurrence.

4.3.2 Crevasse Splays Probabilities

The passage from CSI to CSII is ruled by “Probability for Transition from CSI to CSII”. Change its value to test it.

Small crevasse channels can be added successively on CSII. Test the effect of “Probability for adding a new CS channel” by changing its value.

4.3.3 Slice view

Make a simulation using aggradation and avulsions. Type “$” or use icon “Z Slice” to view slices. Select the vertical position of the slice and press “Apply”. Slices are parallel to the reference plane. The vertical coordinates are consistent with the elevation of the origin in tab “Domain”.

4.3.4 Vertical Proportion Curve

Compute the VPC of a simulation from “Compute/Vertical proportion Curve” using default options. This gives the proportion of each facies per horizontal level, from the lowest deposit to the highest one.

You can also choose the “number of levels”, the “thickness” of these levels, and/or “use elevation limits”. Within the “Vertical proportion Curve” window, the menu “Graphics” makes it possible to show/mask the undefined or unavailable facies, and to remove/concatenate different facies (eg those corresponding to sand).

In the same window, the menu “File/Save” save the results in a text file. If you have chosen a “number of levels” equal to 1, you will then get the global proportions of facies between the limits used, in particular the proportion of sand (N/G).

4.3.5 Forecasting tools

It is not easy to know which will be the proportion of sand of a simulation defined by its parameters. Run at least one iteration with these parameters, a forecast sand proportion will be displayed in the Status Bar at bottom of the interface. Run the simulation a long time, and compare the forecast to the sand proportion computed from the VPC.

Also compute the effective aggradation rate (by dividing the total deposited thickness by the number of iterations), and compare to the displayed “Forecast : Aggradation Rate”.

4.3.6 Export topography

It is possible to export the topography of the simulation at any iteration. Use “File/Export_Topography”. This will be used in a further exercise.

4.3.7 Export well

The column of sediments deposited at any 2D grid point can be exported as a pseudo vertical well. For this, go to the first graphical window that was opened, if several graphical windows are opened. Use the aerial view, type “s”, and choose the x- and y-sections intersecting at the desired 2D grid point. Then export the corresponding well data by “File/Export Well”.

By editing the text file of the well, you will see the format that will be needed to conversely import vertical well data into Flumy.

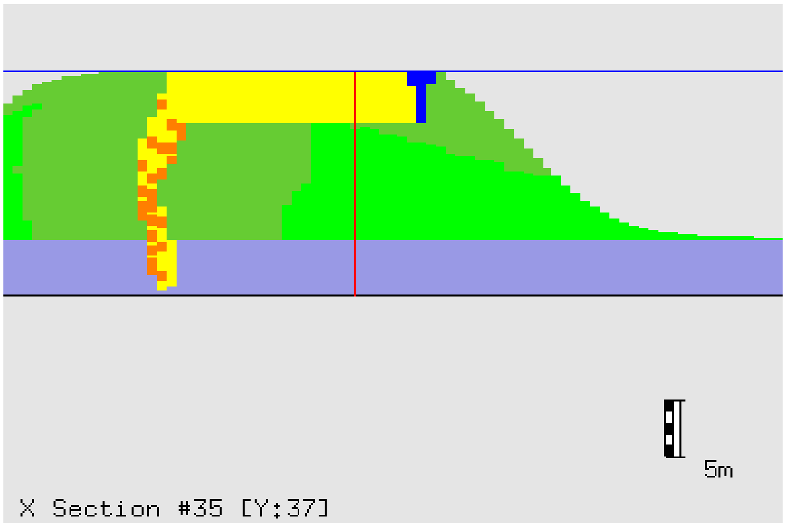
5 Equilibrium Profile project

In this section, you will make use of the Equilibrium Profile (EP). This allows limiting aggradation in time, as well as making incision.

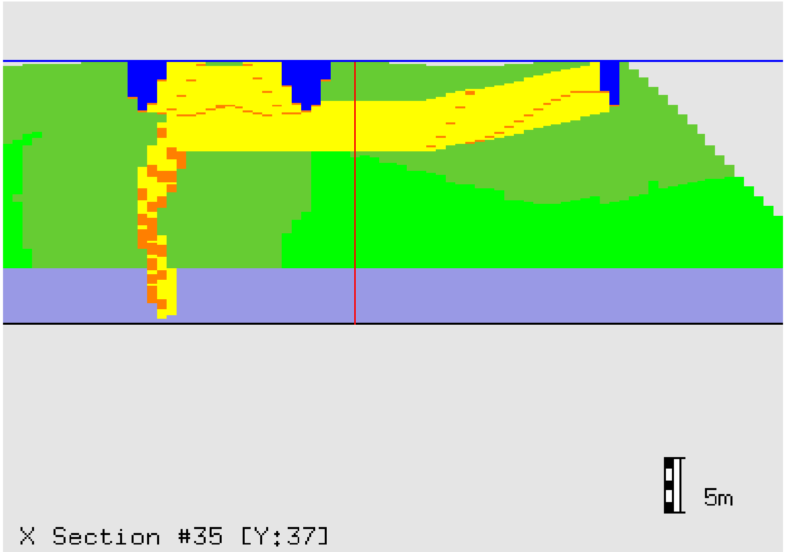
5.1 Aggradation

The equilibrium profile corresponds to a plane parallel to the reference plane. By default its elevation is 1000 m, that is, very high above the default elevation of the origin of the domain (0 m). Then it has no influence on the system, which is free.

At the beginning of the simulation, set the EP elevation to eg 20 m in tab "Aggradation", and choose aggradation and avulsion parameters. In a cross section, type "p" or icon "Toggle Display of Equilibrium Profile" to visualize the EP, and observe the evolution of the system when aggrading. When the flood plain reaches the EP, the channel migrates without aggrading any more, depositing a lot of sand.

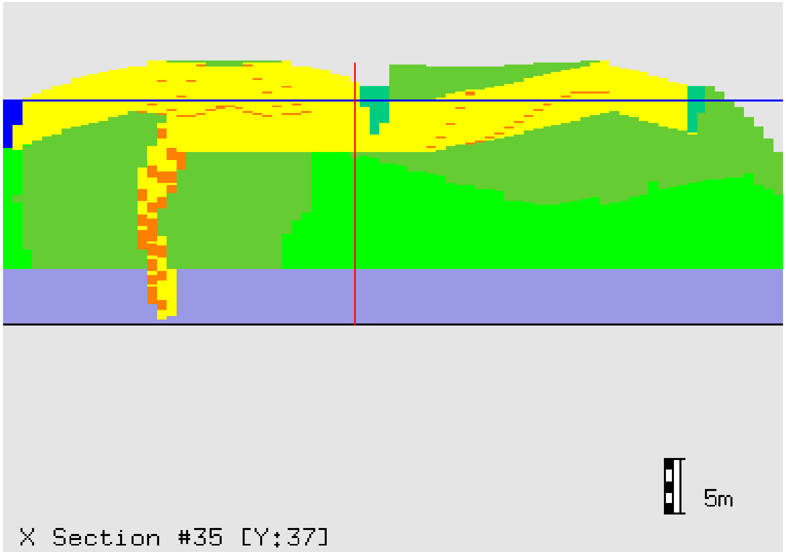


Then let the EP elevation increase with time by choosing the occurrence for "Elevation Changes" and its "Variation". Choose values that make the EP increase slowly compared to the free aggradation, and see the evolution of the aggradation when constrained by the EP. Compute the final VPC.



5.2 Incision

Now give a negative value for the “Variation”. Observe the decrease of the EP, and the incision of the system (at iterations corresponding to overbank floods).

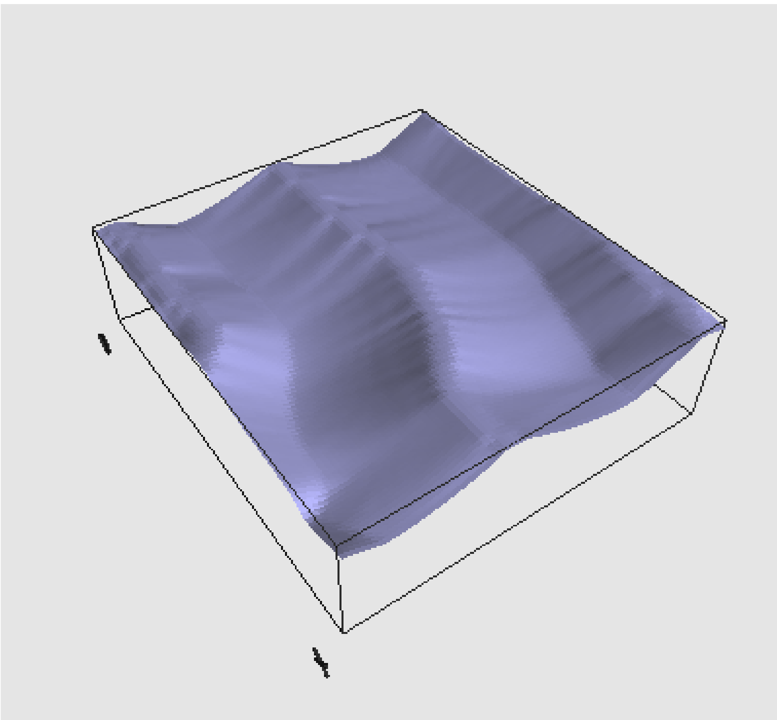


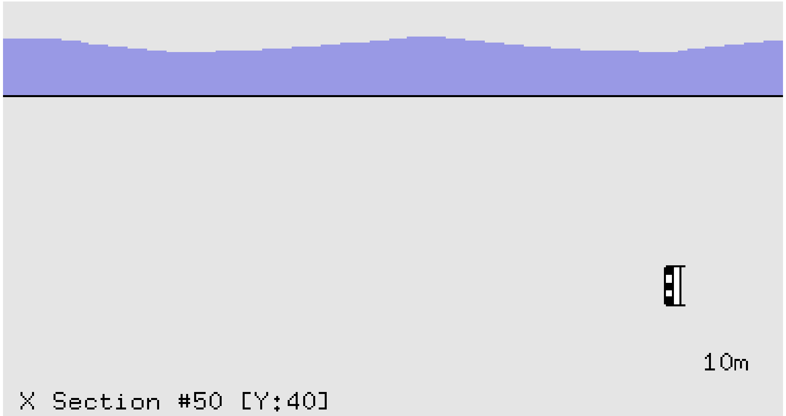
6 Topography project

In this section, you will see how to import a topography into Flumy and what can be done with it. To import a topography, see tab "Imported Topography", tick "Imported Topography" and choose between an imported topography which is flat and defined by its "Constant Elevation", or a topography "File".

6.1 Replace current topography

Per default, the topography at the beginning of the simulation is a flat plane at elevation 0. It is possible to replace this by an imported topography. Then choose "Replace [current topo] by Imported Topography". Possible gaps in between will be filled in with the chosen "Filling Facies". Then Launch: Flumy will make the replacement in one iteration and automatically stop.

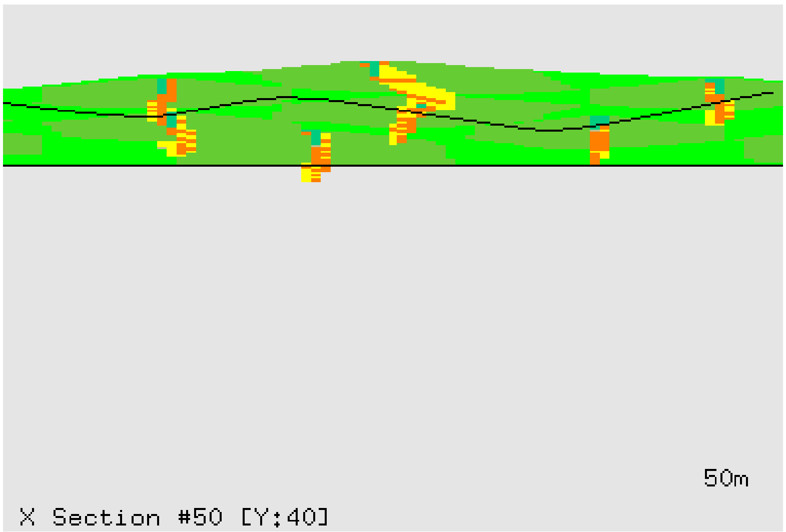




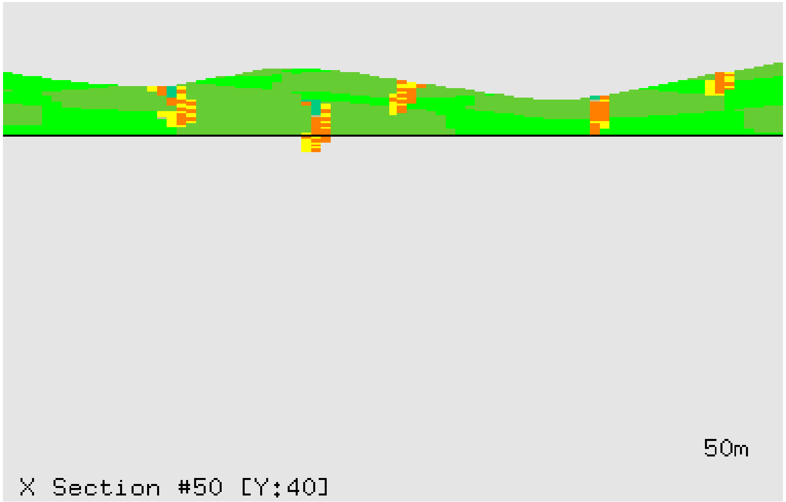
Untick "Imported Topography" to continue the simulation.

6.2 *Importing a topography representing a future erosional surface*

The imported topography can also be introduced as an upper limit, representing either a future erosional surface, or a surface to be reached approximately by the simulation. In both cases, choose "Stop when Imported Topography Exceeded", and in the first case you can directly launch the simulation. In the graphical window, key "u" will display the upper limit in black in a cross-section, while in the aerial view toggling key "u" allows visualizing the whole simulation or letting in white the parts where the simulation is still lower than the upper limit (possibly the whole domain). The percentage of area above the upper limit is displayed in the Status Bar at the bottom of the interface. The simulation will automatically stop when the imported topography is exceeded everywhere.

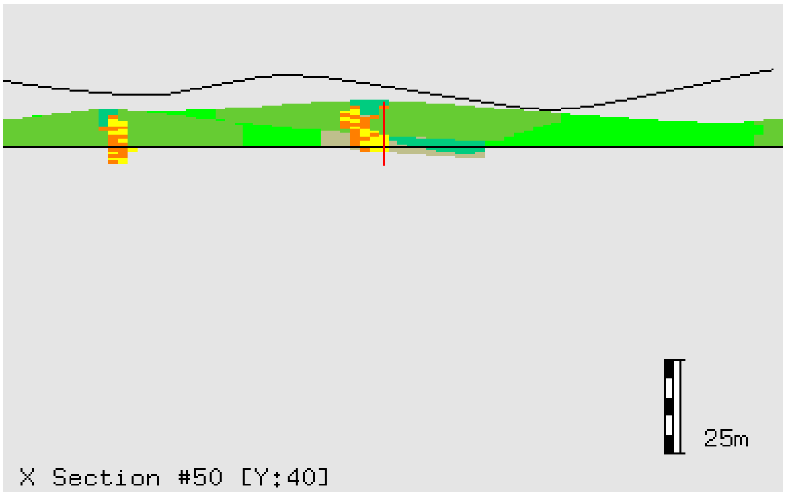


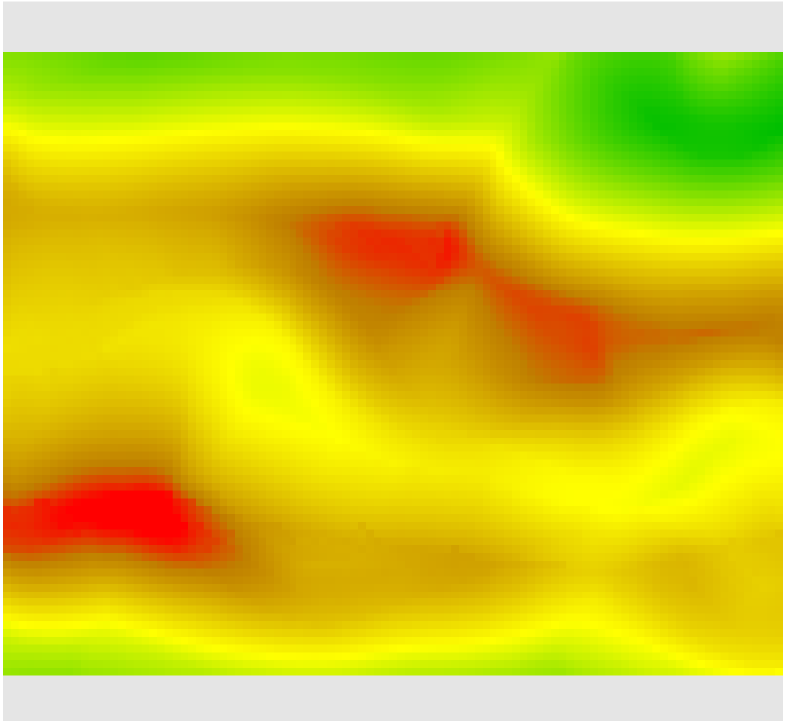
If the imported surface represents an erosional surface, then by choosing “Replace [current topo] by Imported Topography”, Flumy will erode the simulation down to this.

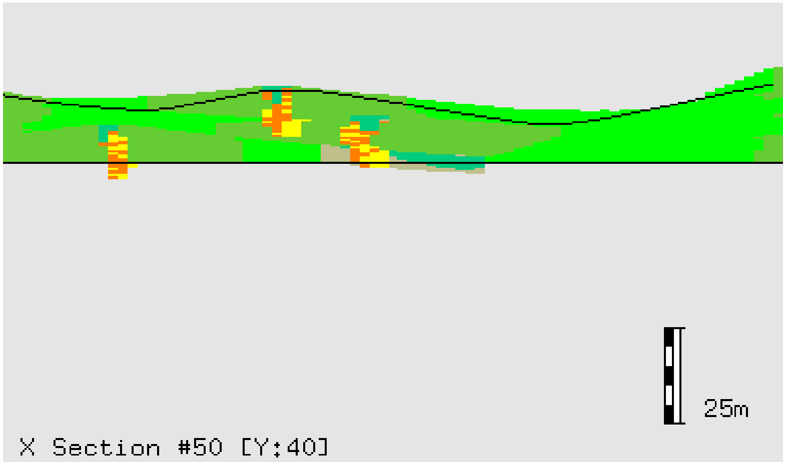


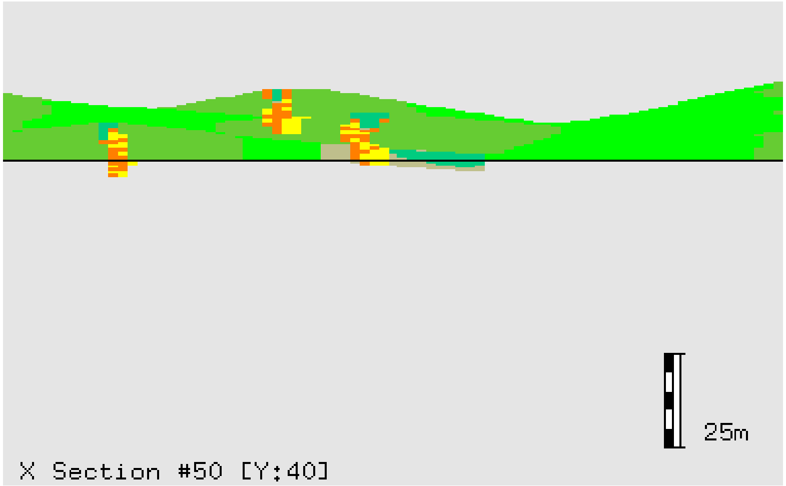
6.3 Importing a topography representing a surface to be reached

In the case the imported topography represents an upper limit to be approximately reached by the sedimentation, an Emap “Built from actual to imported topography” is to be used during the simulation, that favours at any time new location of channel and so deposition preferentially where imported topography to be reached is the highest above the actual topography.






25m
X Section #50 [Y:40]


25m
X Section #50 [Y:40]

7 Wells project

In this section, you will introduce well data in Flumy, and perform simulations conditional on these data. Wetland, Equilibrium profile and incision are not considered when making conditional simulations.

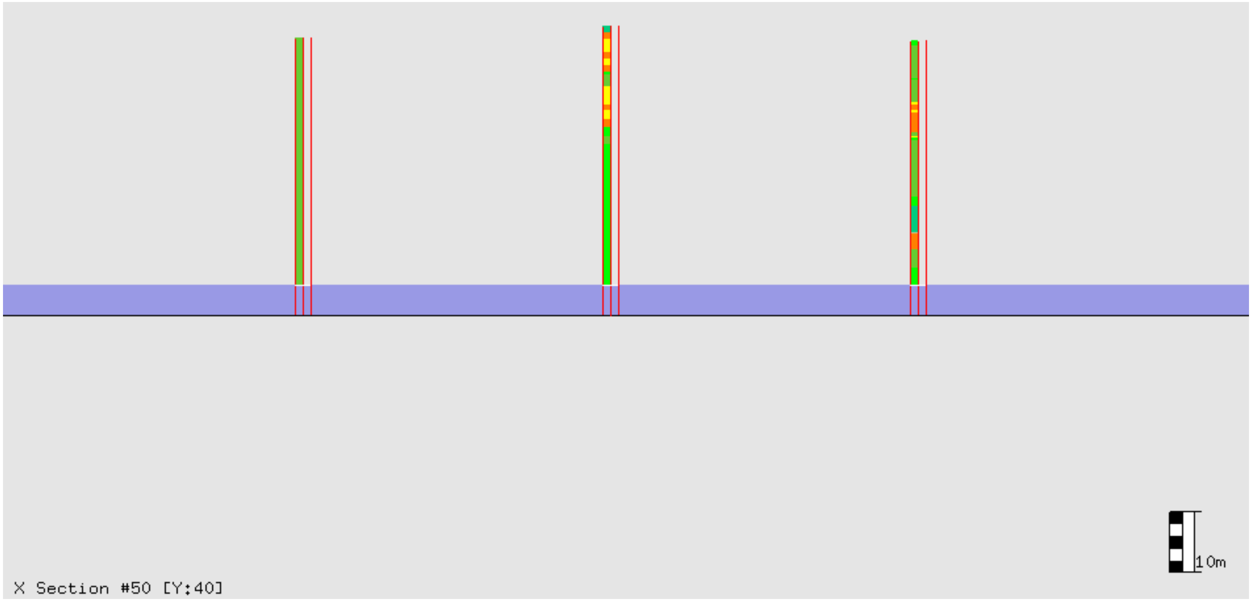
7.1 Import wells

At the beginning of the simulation, under tab "Wells/ Sed. Load", select "Wells" and "Add" the wells in the "List" of wells.

7.2 Visualize imported wells

Check the 2D location of the imported wells in the aerial view. They are represented by a red cross.

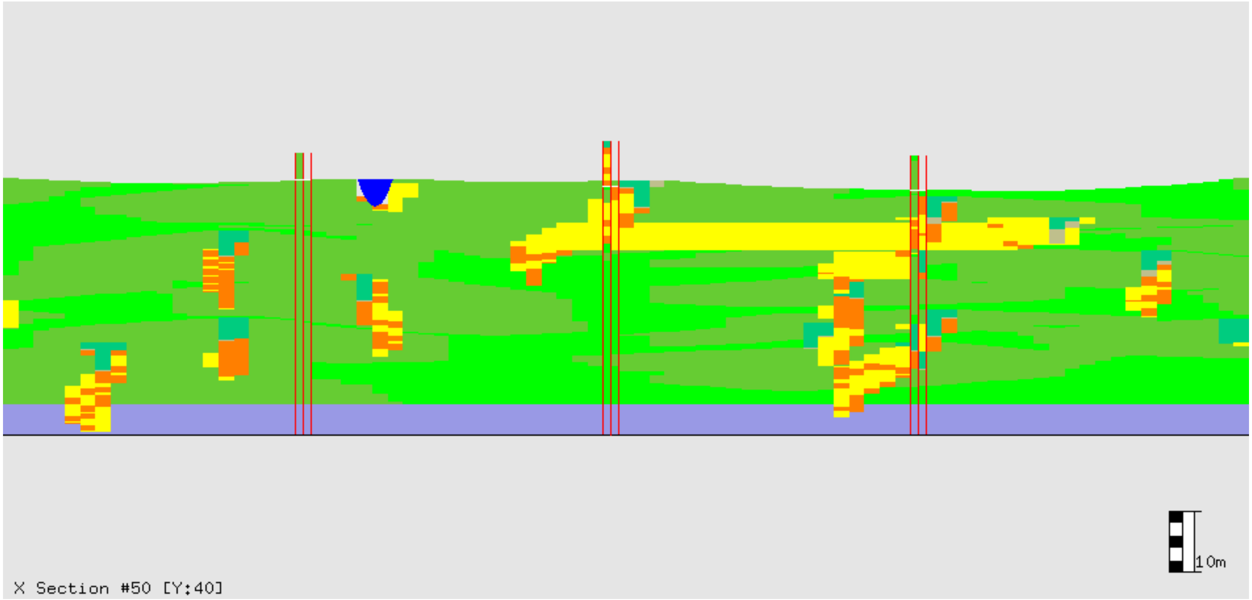
Select a x- or y-section going through a well. You can see two adjacent columns. The column at left represents the imported well data. The column at right will be filled by the values of the simulation. Ideally these would be identical (except that point bar, channel lag and sand plug are considered equivalent; and levee, crevasse splays and crevasse channel are also considered as equivalent). In practice there will be differences. The white line across the well represents the level, under which the data are considered as honored or validated during the simulation.

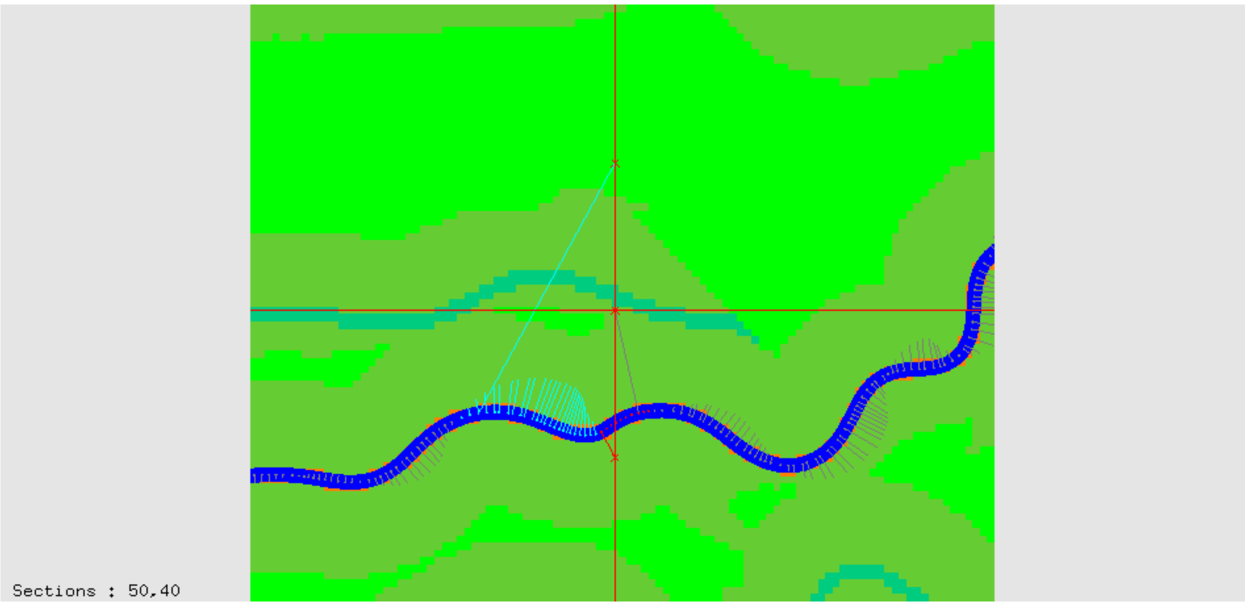


7.3 Run conditional simulation

When you have chosen the parameters of the processes, run the simulation and observe the results. Flumy will try to keep the channel away from data points with fine sediments, not to deposit sand at these locations. On the contrary, Flumy will try to attract the channel at data points where sand is desired, at least when the channel is getting too high. Then it will block aggradation if “Relaxation” under “Wells” tab is set to 0%, but block it less frequently with a higher relaxation. A compromise is to be found, between depositing sand at every data point where data is sand, without depositing too much sand in the simulation.

Observe the attraction (blue arrows) or repulsion (red arrows) of the channel in aerial view with the non pixelized channel. In 3D, type “t” toggle between actual topography and the modified topography used to toss avulsions toward sand data.





7.4 Conditioning statistics

The statistics comparing data and simulation at wells can be obtained under Tab: Compute “conditioning statistics”.

8 Management project

In this section, you will learn more on the use of projects and journal files.

8.1 Save project

When a project has been saved, it is possible to Exit and then to "Open Project" again to continue the simulation. But "Save Project" offers more possibilities. It is possible to "Save Project" at different iterations, and then to "Project Navigate Backward" and "Project Navigate Forward" between the different saved simulations. Note that it is possible to run again the simulation (eg changing parameters) from the simulation as saved at a given iteration, but then simulations that could have been saved at higher iterations will be lost by a new "Save Project".

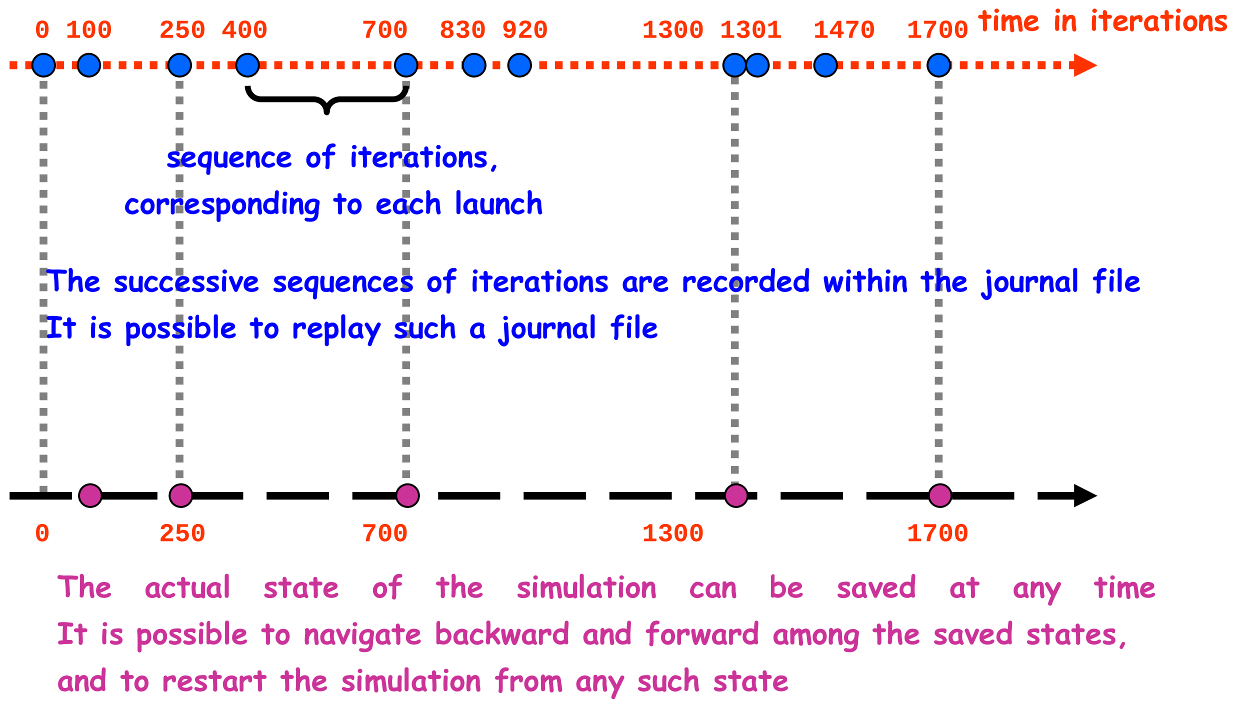
8.2 Project files

The project is a directory that includes files and other directories. All imported files (centreline, wells, topography, erodibility) are stored automatically in the directories with the corresponding name. (Export files are stored by the user where he wants). "Save Project" saves the simulation in a directory with a name "iter_xxxx" indexed by the number of iterations. Files with extension ".jnl" are the journal files of the project and of the saved simulations.

8.3 Journal file

Flumy automatically records the commands for the sequences of iterations in a journal file. Conversely, it is possible to run again a previously recorded journal file (in particular the just previously recorded journal file when making a "Reset"). Such a journal file can be run sequence by sequence, or as a whole by "Batch". But it is possible to "Skip Sequence" or "Jnl Exit" (exit from journal), or on the contrary to make additional launches between the sequences of the journal.

Question for the (near) expert: relation between the sequences of iterations in the journal file and the different saved simulations?


0 100 250 400 700 830 920 1300 1301 1470 1700
time in iterations
sequence of iterations,
corresponding to each launch
The successive sequences of iterations are recorded within the journal file
It is possible to replay such a journal file
0 250 700 1300 1700
The actual state of the simulation can be saved at any time
It is possible to navigate backward and forward among the saved states,
and to restart the simulation from any such state