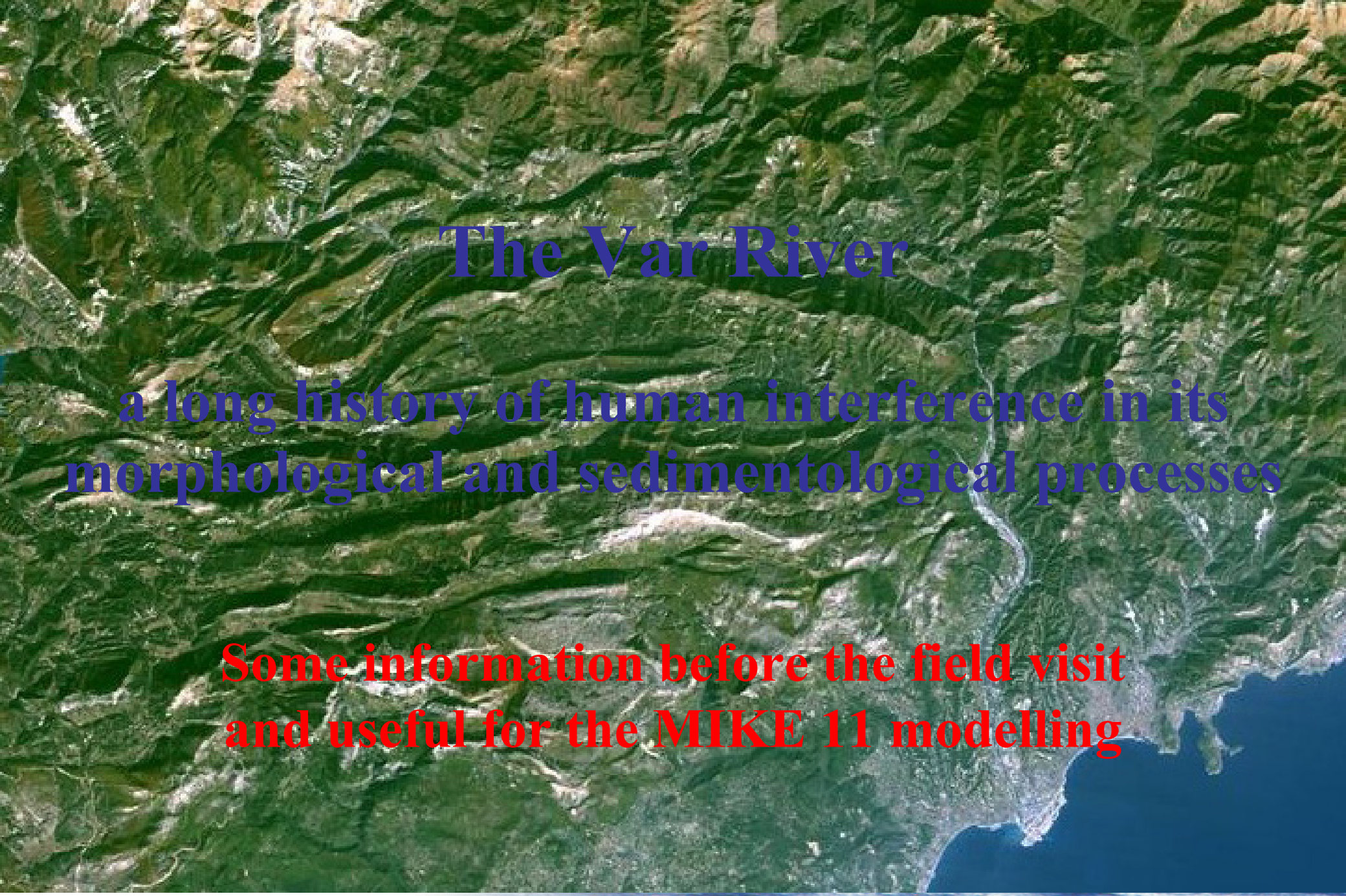


The Var River

a long history of human interference in its morphological and sedimentological processes

Some information before the field visit and useful for the MIKE 11 modelling

Prof. Ir. J.J. Peters | MaRiMorph | Consultant - River specialist

GEO-FLUVIOMORPHOLOGY OF THE LOWER VAR RIVER

- In the Chaudan gorges, the river course is strongly controlled by valley borders, made of very hard rocks
- From there on starts the Lower Var, which was previously running freely between the valey slopes with large gravel bars, very mobile and composed of coarse bed material

Human impacts in lower valley

Over its entire length of the lower valley, the river was canalized, reducing its width from about 1000 m (in average between valley slopes) to 300 m, and even 200 m in the last stretch, close to the sea.

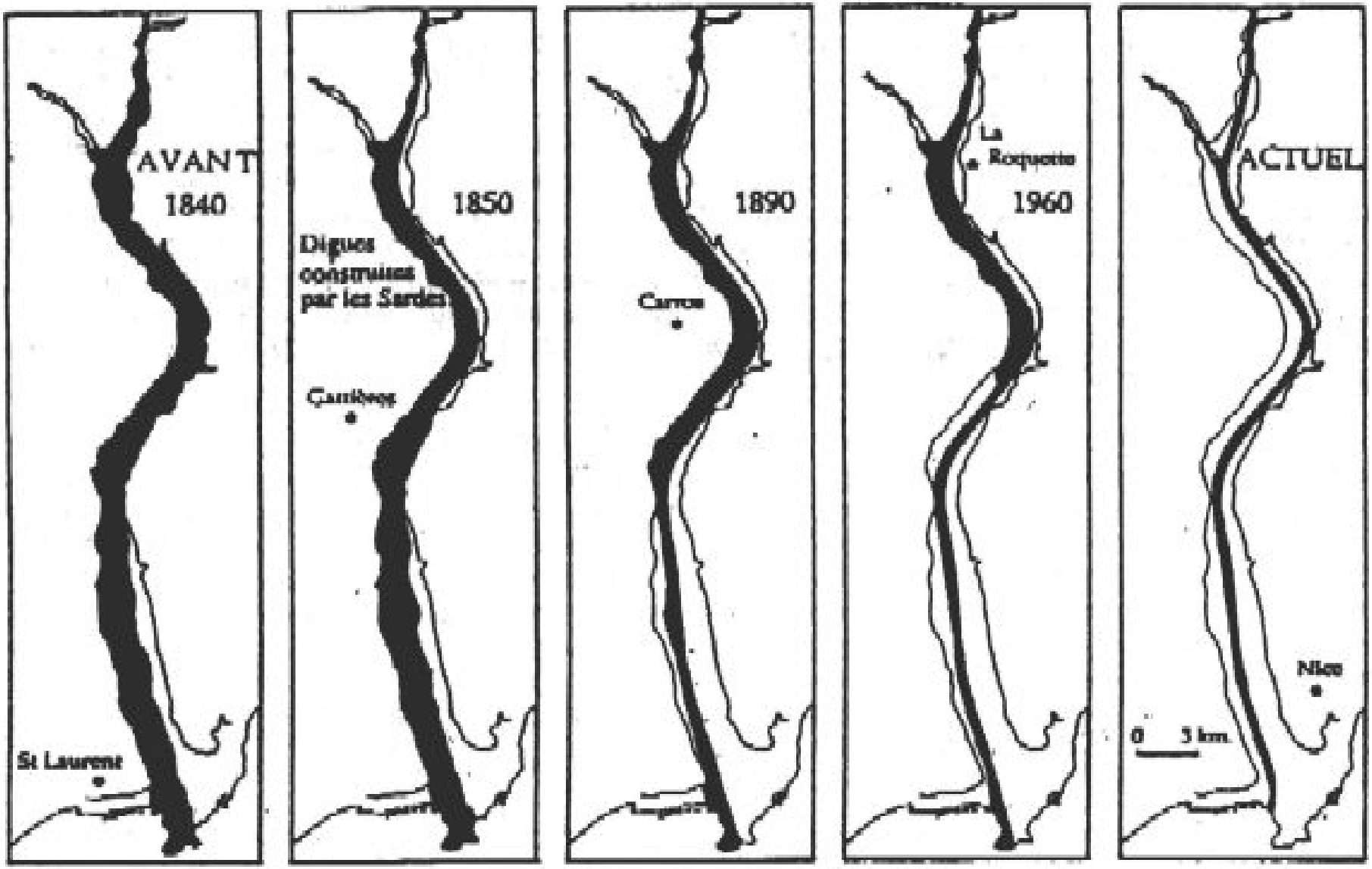
The Esteron river is joining the Var in its lower valley.

Sediments from the Estéron are different from those in the Var (more yellowish in Estéron)

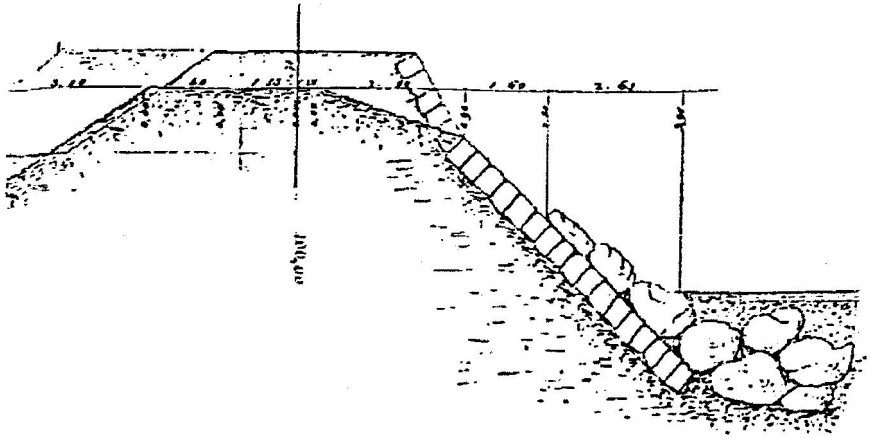
Creating an artificial flood plain

- Originally, agriculture was in the river itself and population lived on the valley slopes
- Over the past two centuries, an artificial floodplain was created by constructing sedimentation tanks in which part of the flood flows were diverted, so that ground level would rise by sedimentation of the fine suspended solids, creating good soils for agriculture

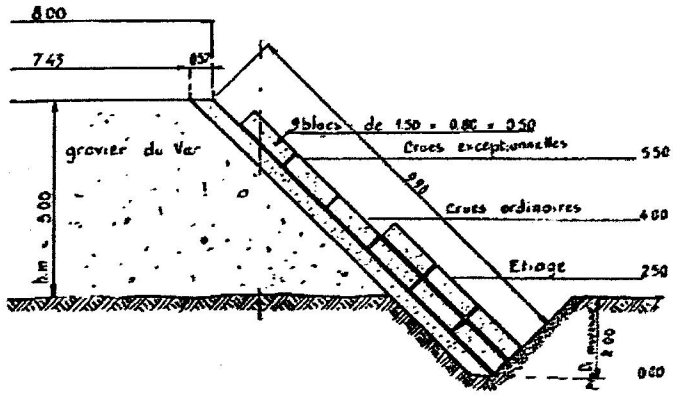
Progressive embankment of Var



Progressive embankment of Var



Digue des Sardes *(1844-1851)*



Digue *(1861-1974)*

Land owners were responsible for protecting their own banks. The Sardes build these protections with rocs, but these protections were often destroyed during flood events.

A century ago, a new efficient system was invented: the “sugars” bricks on a concrete revetment; today, engineers changed it with “riprap” …

Gates at Manda Bridge, which were controlling the flow to artificial floodplain (sedimentation areas, 1960ies)

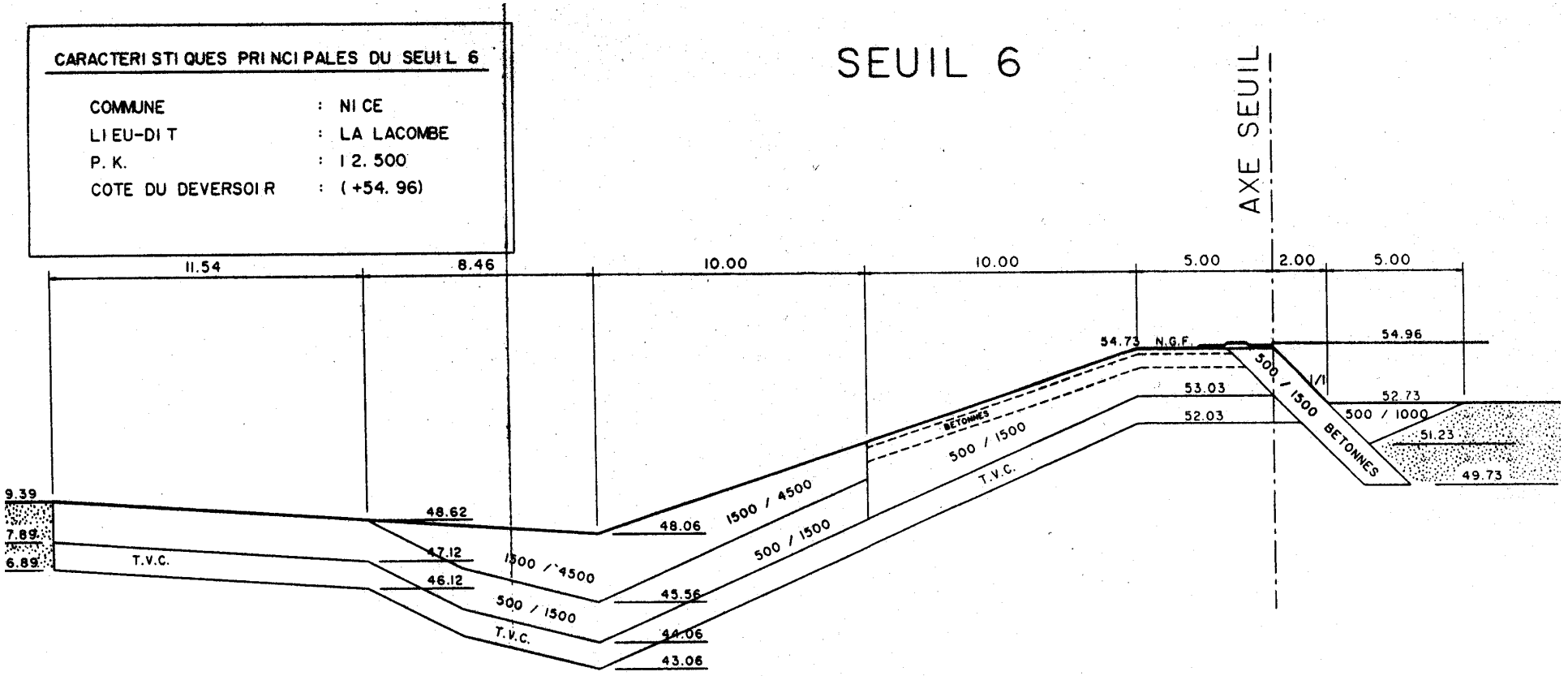
Controlling the slope with sills

- Rapidly increasing demand for building materials after World War II because of quick development of tourism ⇒ mining the river bed (cheap & easy)
- Mining of riverbed material lowered the river, by 6 m in some places
- Groundwater levels dropped, creating difficulties for groundwater use by farmers
- Engineers decided to stop the degradation of the riverbed by building fixed weirs (sills 2 to 16, sill 1 only sheet piles preventing salt seawater penetration)

Controlling the slope with sills

- The basic idea was that the sills would elevate the water surface and make the surface water recharging the groundwater at a higher elevation
- At that time, France started producing low-head hydropower schemes and the Lower Var was an excellent opportunity to “demonstrate” the technology of the bulb turbines (priority to export!, not to the river)
- The weirs (also called ‘sills’ or ‘grade-control structures’) were studied at the hydraulic laboratory at Chatou, however without taking into account sediment

Original design of sill No. 6



Sill No. 8, showing damages at foot and siltation upstream the weir

Morphological impact of the sills

Fine silt deposits changed the river environment: narrow channels bordered with lateral terraces.

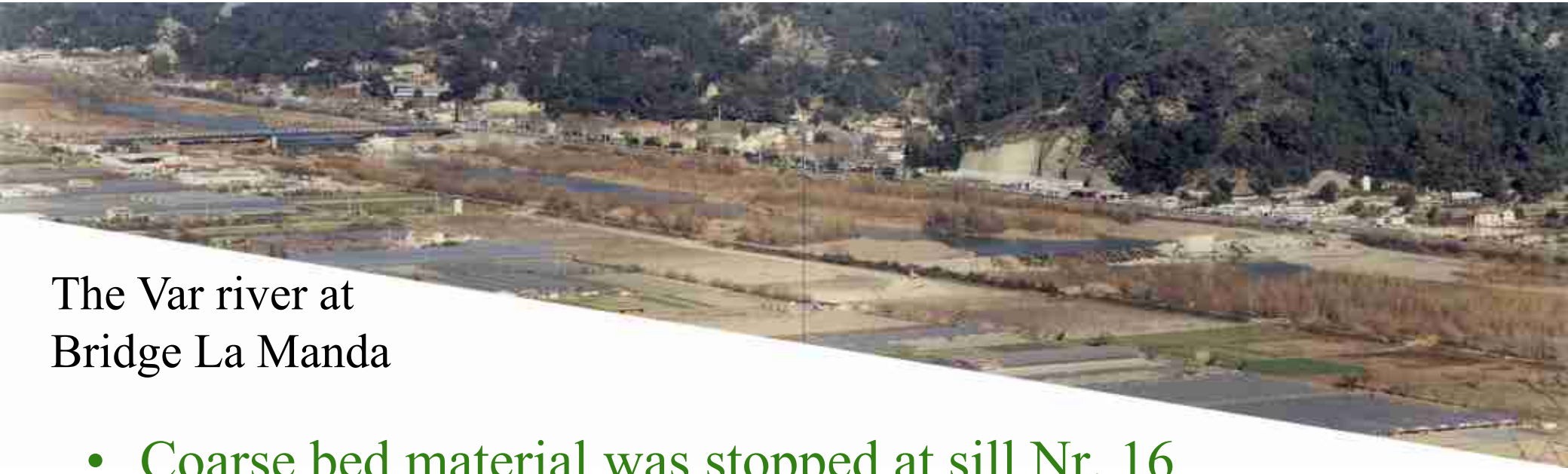
Dense vegetation grew on these terraces in between the sills, changing the flow resistance.

Morphological impact of the sills

Sills / weirs, for what?

- To control the water levels (official reason)
- To demonstrate low-head hydropower and generate electricity (economic reason)
- Negative impacts were not anticipated (nobody concerned…)

Impact on transit of sediment



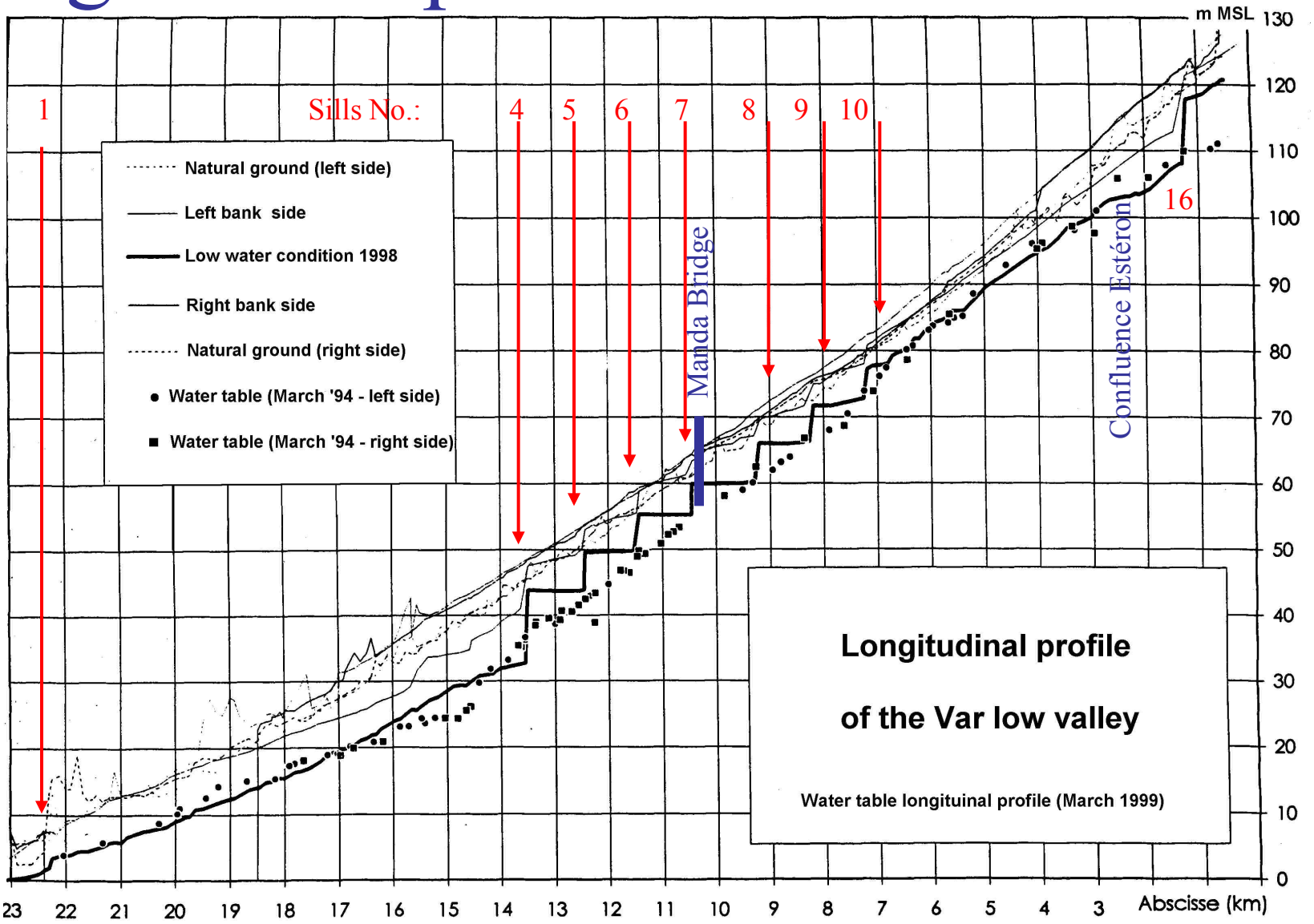
The Var river at
Bridge La Manda

- Coarse bed material was stopped at sill Nr. 16
- Only fine material passed the sills after these were constructed
- Sediment deficit (Lane Balance) created scouring downstream of lowest sill (Nr. 2), which head (difference in water elevation over the weir) passed from 6 to 12 m (!), destabilising the structure that was designed for a head of 6 m

Impact on transit of sediment

The sills were built between 1970 and 1986. In 1980 already (see fotograph), the degradation of the riverbed between sill 2 and the sea was clearly visible, but the authorities did not realize the danger of collapse during a flood to come … (the 1994 catastrophe could have been avoided!)

Longitudinal profile 1998



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The collapse of sills 2 & 3

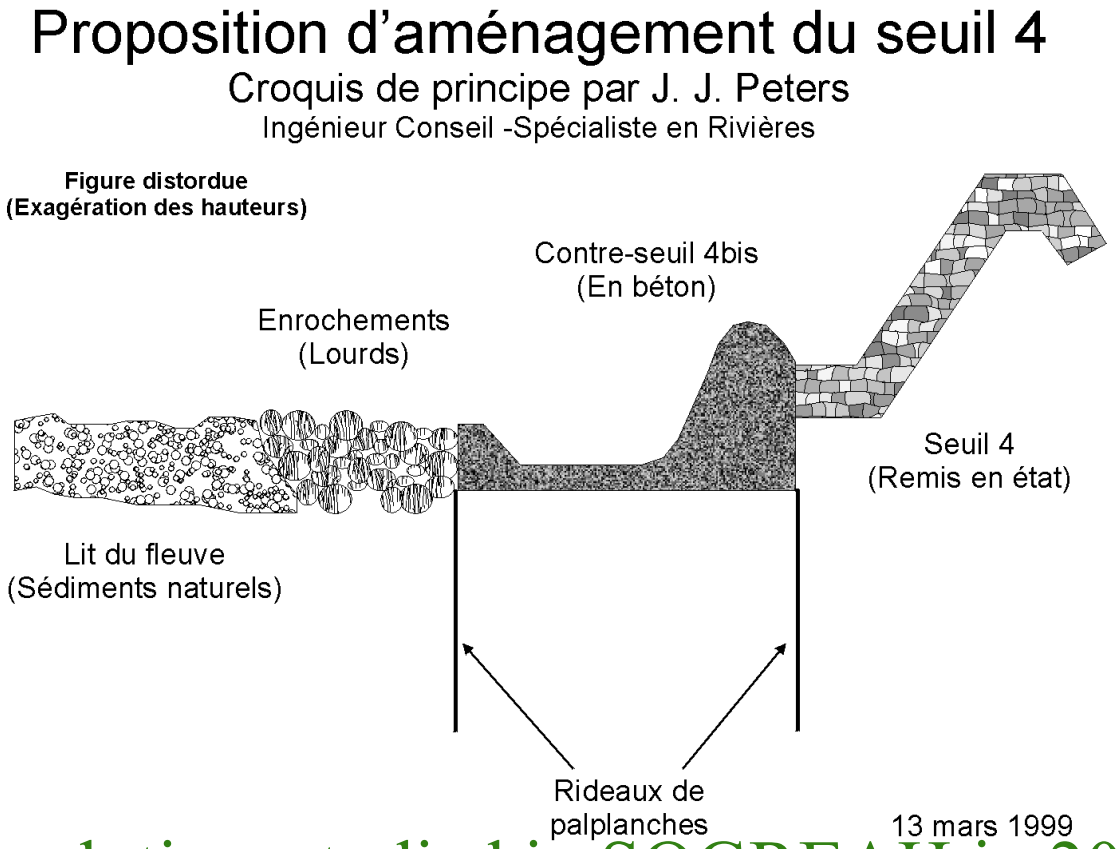
During the flood event of 5/11/94, sills 2 & 3 collapsed and the flood wave inundated part of the city and the airport.

Sill 4 was also in danger of collapsing because of high head

Downstream: Sill 4 was in great danger

How to avoid collapse of Sill 4?

The proposal made in 1999 (exactly 10 years ago) was not considered by the authorities (guess the reason why …)



A different solution, studied in SOGREAH in 2006 was implemented in 2009 … (10 years of potential catastrophe!)

Sill 4 in 2006: vegetation; active width?

Formula for flow over the sills?

- Which formula to apply in the numerical models?
- How about the conditions to apply one or anther formula?
- What about the active width to consider for the flow over the sill?

Sediment deficit and role of the sills?

- Experts claimed that the deficit in 1995 represented 300 years of natural sediment supply (thus they supported the need to reconstruct the sills 2 and 3 …)

- There were no data about sediment transport (aspect still neglected today, despite a very limited study)

- With a student, we could show that an adaptation of the sills (lowering) would restore the original (natural) river bed in a few decades only

Upstream: Sill No 10 in 2002

Sediment passing sill No 10 in 1997

Which bank protections needed?

- Experts claimed that the flow is parallel to the banks during the flood events

- In 1983, there was a breach in the right bank in the Carros Industrial Zone (where are located chemical industries handling dangerous products)

- We pretend that the most active flow is not distrinuted over the entire width, rather in a narrow but very strong meandering flow, dangerous for bank attack

Which bank protections needed?

- The ‘sugar’ bank protection was developed by the locals by trial and error; it was very effective when the locals were in charge with their maintenance

- Replacing the ‘sugars’ by loose blocs (riprap) is the present solution, interesting for whom?

- The “Conseil Général” (regional government) is today in charge with the maintenance of the river and technical solutions decided by engineers and modellers not aware of the reality of the Var River …

Still sediment deficit below sill 4

Bank protection:
Concrete blocs on concrete revetment
“old” method or “local knowledge”?

Issues and questions for the field visit

- During the stop at the airport, look at the bridge openings and think about this question:
  - ✓ **Which effect had the narrowing of the riverbed (from 300m down to 200m) on the flood risk?**
  - ✓ **Why is the effect of this narrowing worse here than more upstream?**
- Compare elevation of the riverbed and level of the road (build on the dike):
  - ✓ **Why is this different in the various parts of the Lower Var?**
- Look at the sediments in the riverbed:
  - ✓ **Do the sediment sizes change and where?**
  - ✓ **Can you find an explanation why?**

Issues and questions for the field visit

- The Estéron river valley has very steep slopes:
  - ✓ **What could have been the effect of a landslide of the steep valley slope because of the heavy rains preceding the 5/11/1994 event?**
  - ✓ **Which effect can be expected from coïnciding flood peaks in the Var and Estéron rivers?**
  - ✓ **What can be the influence of narrowing the 2 rivers just upstream of the confluence (mainly narrowing the Estéron)**
- The morphology of the Var riverbed changed:
  - ✓ **How would you describe it and why is the flow attacking the banks in many places?**
- About the weirs (sills):
  - ✓ **How would you describe their functioning and hydraulic efficiency?**
  - ✓ **Which adaptations to the sills could be helping and with which effects?**

Var – Estéron confluence (2006)

Recommandations for the visit

- Be on time at the bus!
- Wear warm clothes and shoes for bad terrains
- Do not forget your sandwiches and drinks **(lunch will be taken in a nice old village in the mountain with beautiful view on the Var, but there are no shops!)**
- Take profit from the field visit to understand as much as possible about the physical functioning of the river, it will help you quite a lot during your second week!!!