NATURE AND THE EXTEND OF THE IMPACT

The nature and distribution of the impact created in the indirect areas of influence of a dam has important and specific features that should be considered, namely:

The environmental impact and risks associated with changes in fluvial morphodynamic processes

Inter-Celtic colloquium on Hydrology and Management of Water Resources

José Antunes do Carmo

University of Coimbra
Portugal

Guimarães - Portugal, 11-15 July 2005

THE BACKGROUND

Some evidences that justify actions to be carried out, to provide suitable management of the natural systems:

(1) In general, a *quasi*-natural balance established in the past for rivers, estuary environments and along the coastline no longer exist.

(2) Natural needs in the past and present-day needs for coastal protection are not comparable.

(3) What to do ?

THE TOPICS

The following topics will be adressed along my presentation:

(1) Environmental impact and associated risk factors;

(2) The reaction of the fluvial system to alterations in morphodynamic processes; and,

(3) Experimental study on local scour around bridge piers.

THE INSTITUTIONAL FRAMEWORK

Basically, integrated management of water resources involves:

(I) a set of actions that aim to provide multiple and rational use of water resources,

(*i*) serving all purposes and all users satisfactorily in terms of quantity and quality standards,

(*ii*) as well as in terms of the control, conservation, protection and recuperation of these resources,

(*iii*) with an equal distribution of costs amongst users and beneficiaries.

ENVIRONMENTAL IMPACT AND ASSOCIATED RISK FACTORS

Some important environmental impacts occur during the constructional phase of a large hydraulic dam, namely:

(1) The provisional diverting of the river, to enable work to be carried out on the river bed;

(2) Access and transport of materials and equipment to the area where the work is being carried out;

(3) Areas affected by temporary buildings and deposits of essential or excess materials;

(4) Local quarries for the use and/or extraction of inert materials; and,

(5) The cutting down and clearing of vegetation in the area to be flooded.

ENVIRONMENTAL REPERCUSSIONS CAUSED BY THE CONSTRUCTION OF A DAM

The presence and operation of a large dam:

(1) Alters the morphology of the alluvial beds;

(2) Reduces the transporting flow capacity;

(3) Contributes towards increasing the already high levels of sedimentary deficit;

(4) Contributes towards destabilising ecosystems or making them disappear; and,

(5) Creates profound changes in local fauna and flora.

ENVIRONMENTAL REPERCUSSIONS CAUSED BY THE APPEARANCE OF A LARGE RESERVOIR

The presence of a large reservoir:

(1) Increases erosion and instability on the slopes of the banks by the action of winds, waves and currents;

(2) Reduces the daily and annual thermal amplitude;

(3) Causes fog and mist, as well as alterations in local rainfall patterns; and,

(4) Reduces the frequency of frosts.

POTENCIAL HYDROLOGICAL IMPACTS DOWNSTREAM OF DAMS

When the hydrological system of a river is modified by the construction of a dam:

***i*)** alterations downstream are generally caused by the way in which the dam operates,

- both as a consequence of the way it controls and regulates discharges, and
- also due to the reduction/alteration in seasonal variability and heavy discharges.

POTENCIAL HYDROLOGICAL IMPACTS DOWNSTREAM OF DAMS

…the construction of a dam also causes:

***ii*)** modifications to the characteristics of the water and sedimentary effluents generated in the dam, which feed the segment of the river downstream.

The environmental impact may also extend to the alluvial plain, affecting the groundwater hydrological system, since as a consequence of the water discharge there will be alterations to the rate at which the water infiltrates the soil.

THE REACTION OF THE FLUVIAL SYSTEM TO ALTERATIONS IN MORPHODYNAMIC PROCESSES

Dynamic-equilibrium principle:

"At any point in the course of a river, the morphology of the alluvial bed is adjusted according to the amount of sediment in transit and the flow dynamics."

However,

>> throughout the world, the morphology of fluvial systems has been dramatically altered by man's actions.

THE FOLLOWING PROPORTIONAL RELATIONSHIP CAN BE ESTABLISHED (Lane, 1953):

$$Q_s * D_n \propto Q * i$$

in which:

Q_s represents the total solid discharge;

D_n represents the characteristic diameter of the sediment transported (normally $D_n \cong D_{50}$, this being the mean diameter, since 50% of the material is finer);

Q is the water discharge; and,

i represents average slope of the thalweg.

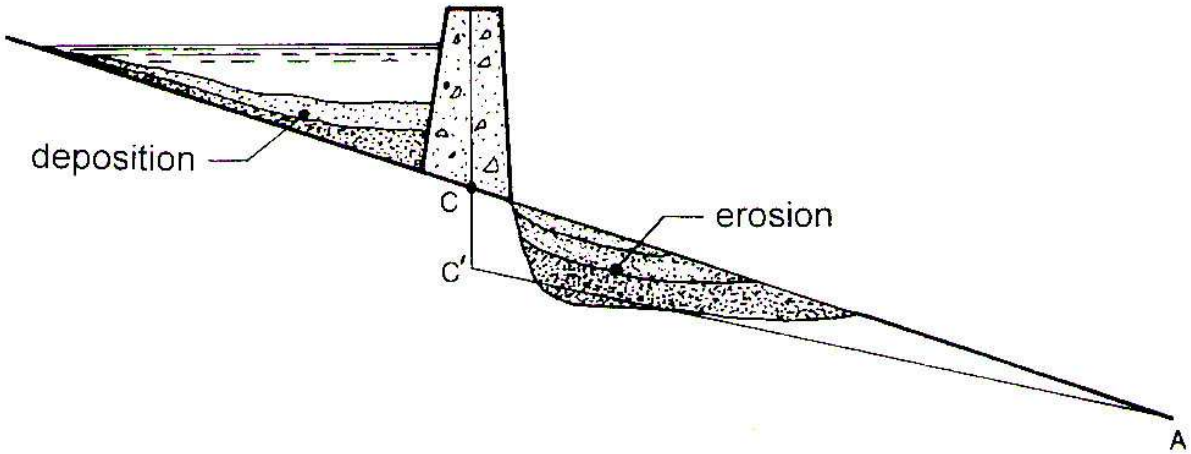
This expression represents the tendency of four variables to establish a natural balance.

POTENCIAL HYDROLOGICAL IMPACTS DOWNSTREAM OF DAMS

Any alteration to any one of these variables implies an imbalance in the system and a new balance will tend to establish itself in time, with the necessary contributions from one (or more) of the remaining variables.

On the basis of this expression we may therefore forecast the qualitative responses of a fluvial system to natural modifications or alterations imposed on the morphodynamic processes.

THE REACTION OF THE ALLUVIAL BED TO THE BUILDING OF A DAM



$$Q_s^{-} * D_n \propto Q * i^{-}$$

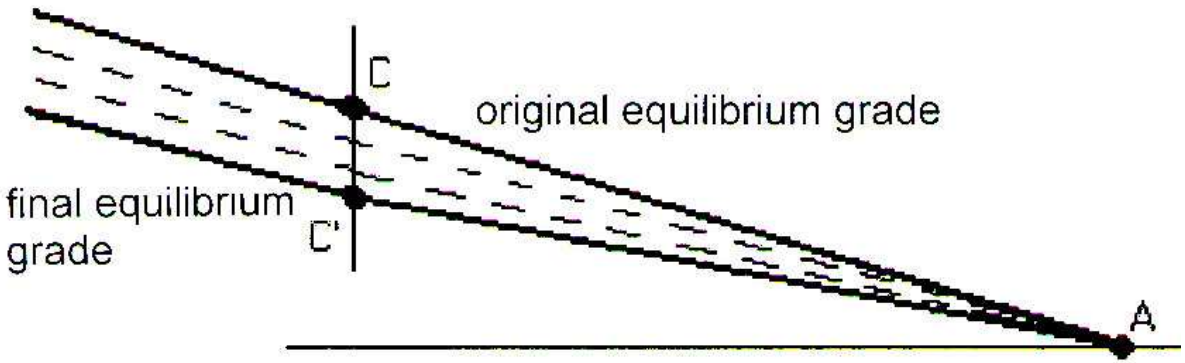
As a consequence of the lowering of the alluvial bed downstream of the dam:

(i) there may be regressive erosion in the tributaries in the area;

(ii) there may be damage to bridges and support walls along the banks due to excavation beneath their foundations; and,

(iii) water collection works in the river may be put out of action.

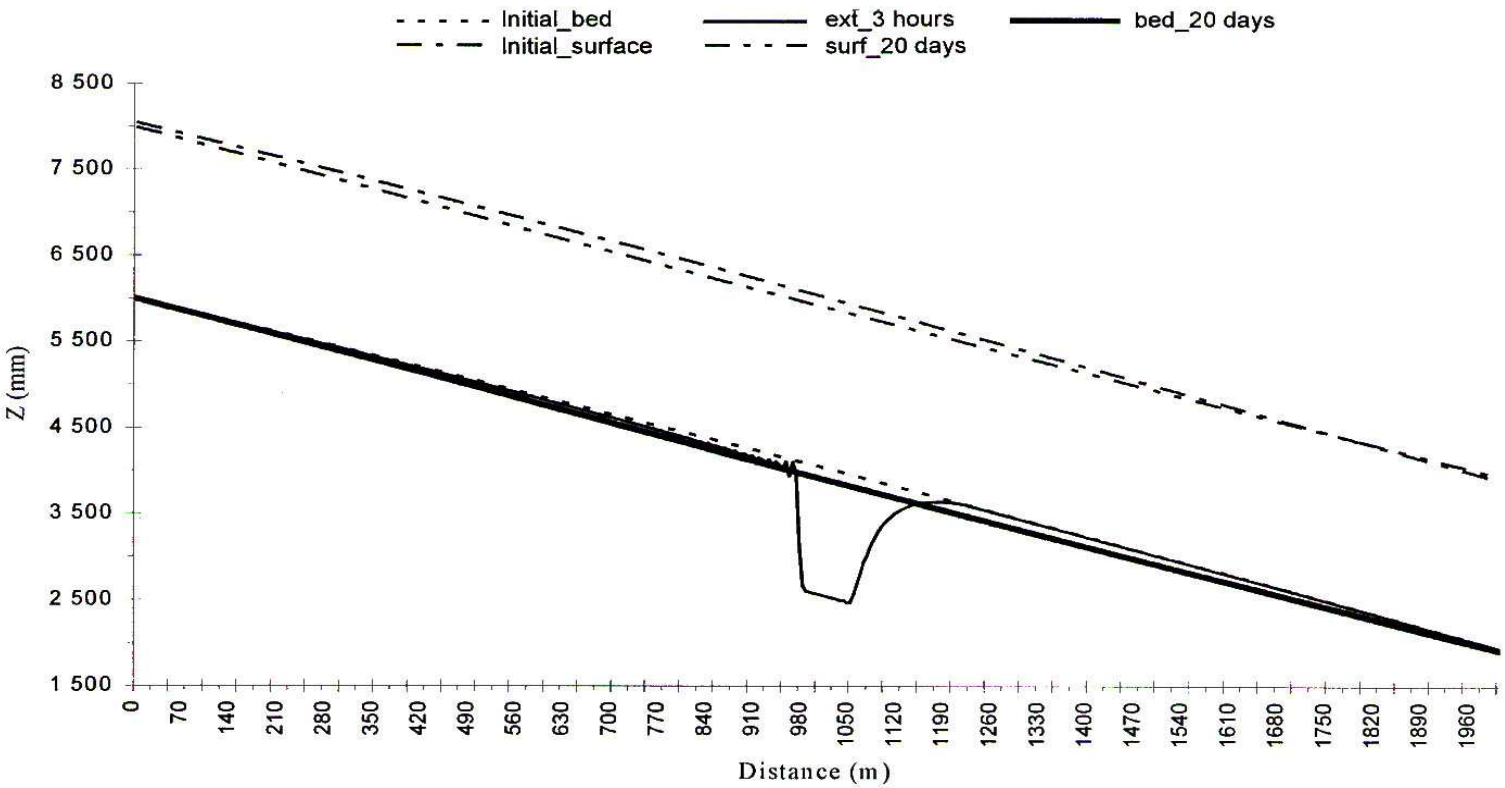
THE REACTION OF THE ALLUVIAL BED TO A REDUCTION IN SOLID DISCHARGE



$$Q_s^{-} * D_n \propto Q * i^{-}$$

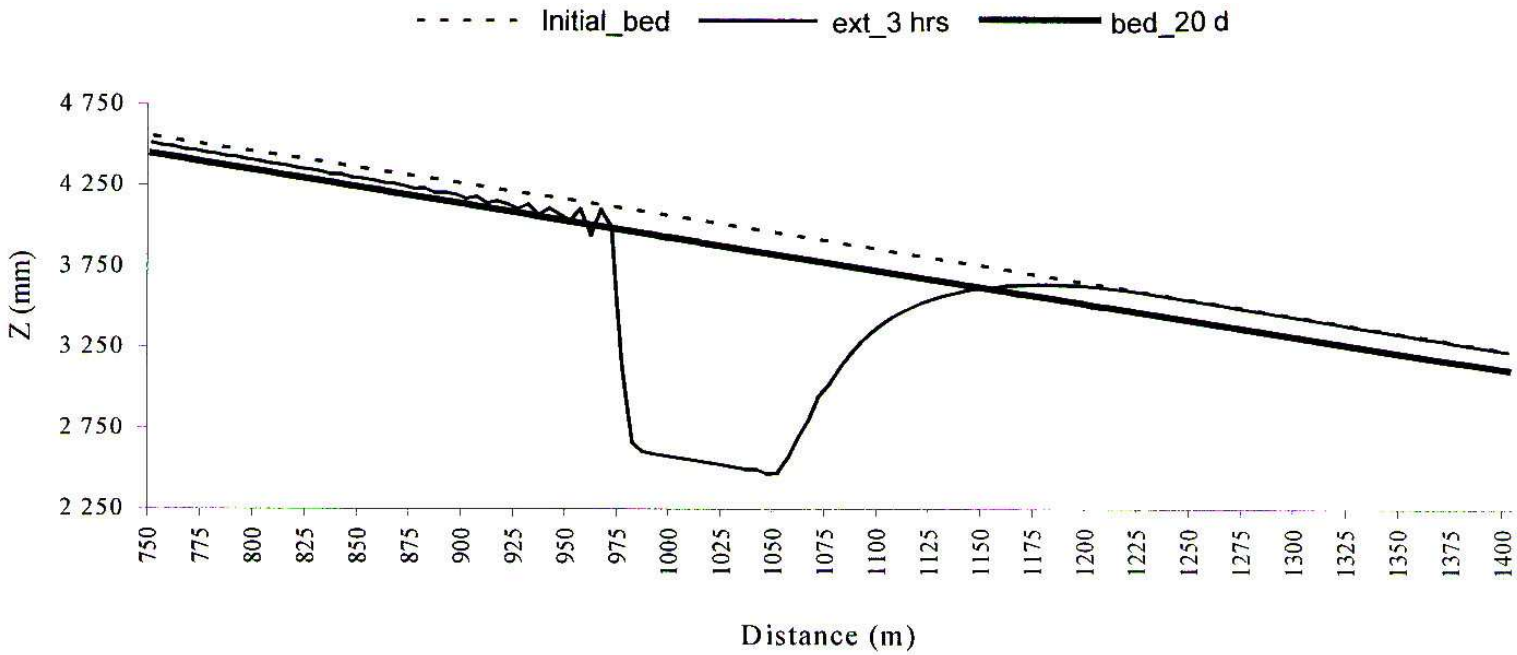
Occurrences of this type may have similar implications to those previously quoted.

THE REACTION OF THE ALLUVIAL BED TO A LOCALISED LOWERING OF DEPTH



Configurations of the initial bed (in a uniform system), 3 hours after extraction of inert material and 20 days after.

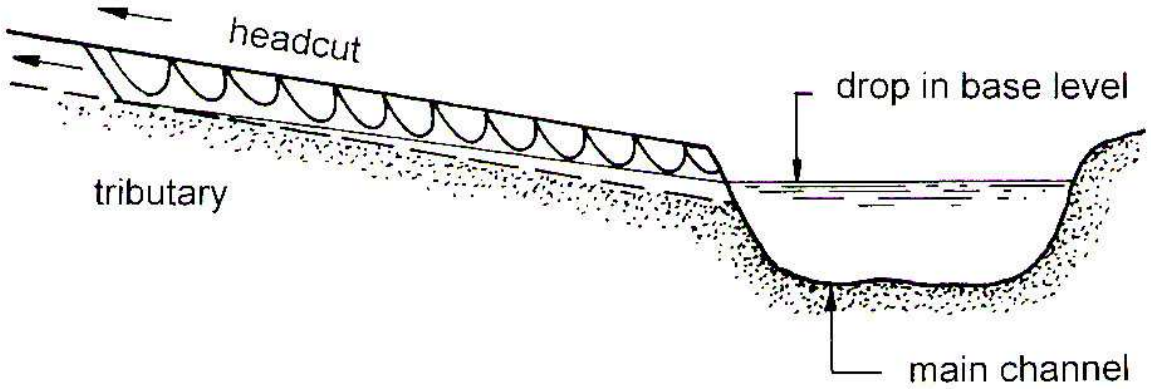
THE REACTION OF THE ALLUVIAL BED TO A LOCALISED LOWERING OF DEPTH



Increase in section at between 750 m and 1400 m

As expected, there is general erosion both upstream and downstream, of the affected area.

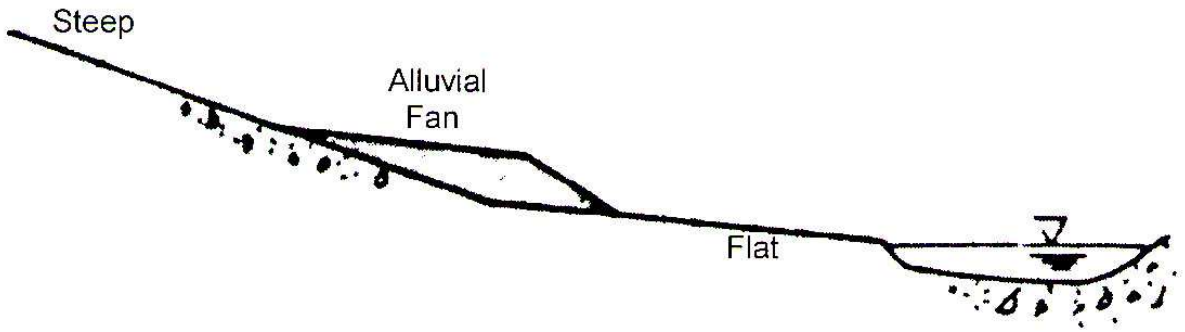
THE REACTION OF THE FLUVIAL SYSTEM TO A LOWERING OF THE BASE LEVEL OF THE FREE SURFACE OF THE MAIN WATER COURSE



Effect on tributary caused by the raising of the base level of the free surface of the main water course.

This situation may occur as a result of any of the previous situations, giving rise to general erosion and creating a lowering of the base levels of the tributaries

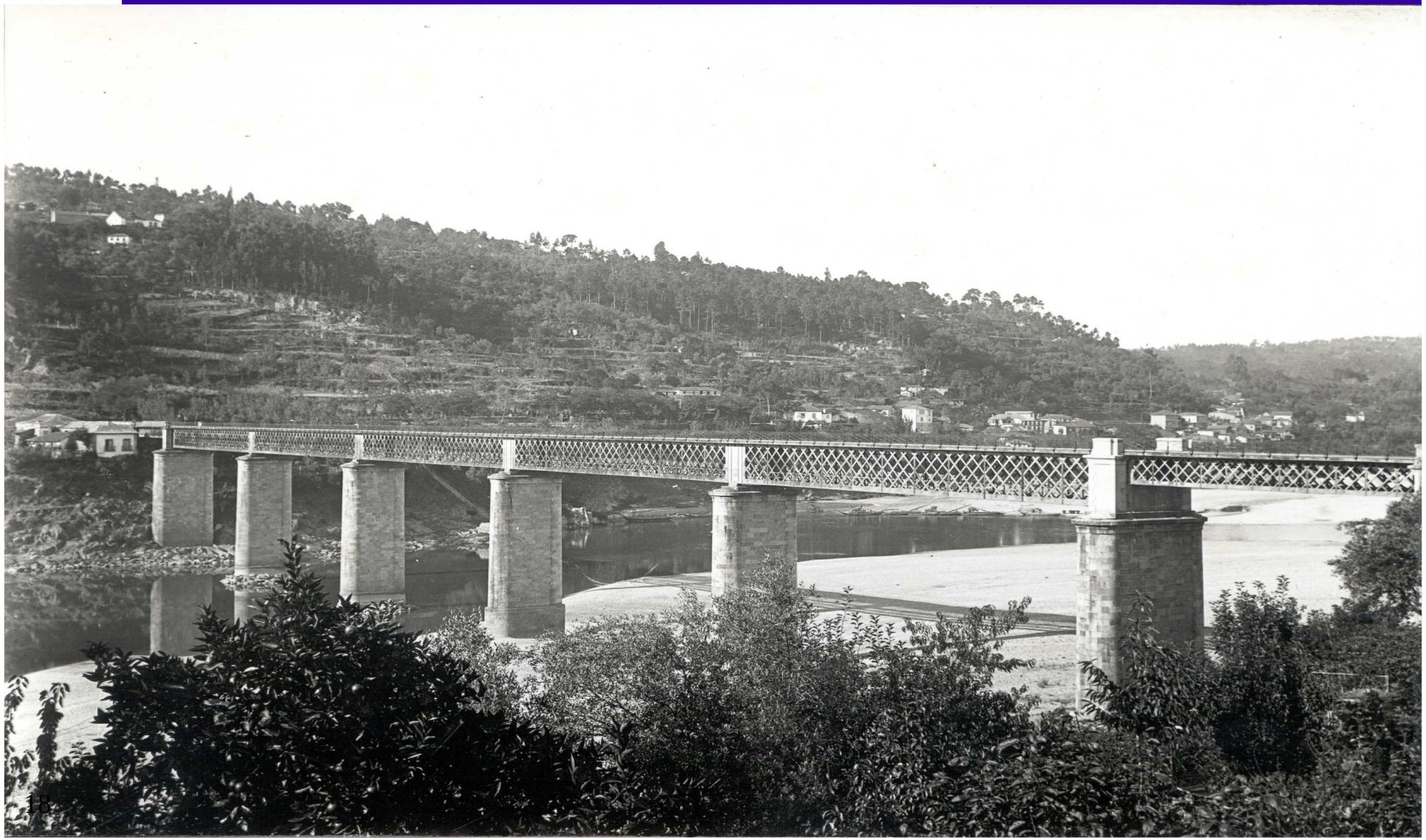
THE REACTION OF THE FLUVIAL SYSTEM TO TO THE RAISING OF THE BASE LEVEL OF THE FREE SURFACE OF THE MAIN WATER COURSE



Effect on a tributary caused by the lowering of the base level of the free surface of the main water course.

This may occur as a result of the two first situations, giving rise to generalised deposits that cause create elevations in the base levels of tributaries and reduce their ability to transport, thus creating generally undesirable flood conditions.

Experimental study on local scour around bridge piers in rivers



Scour mechanism

Scour protection

The following expression seems to provide a good representation of the scour (maximum equilibrium depth):

$$h_s = 0.24 * \left(Q/\sqrt{d_{50}}\right)^{1/3} - h_0$$

where

Q is the flow;
d_{50} is the mean sand grain size;
h_0 is the undisturbed approach flow depth.

Based on our data and other studies and comparisons, the following functional relationship for the minimum critical stone size is proposed:

$$d_{50} = 0.3 * K_D K_S K_\alpha K_\gamma F^{1.2} * h_0$$

CONCLUSIONS

The balance between the resulting types of environmental impact and the risk factors associated with a possible dam break due to an exceptional event, such as an earthquake or part of the reservoir bank collapsing, may or may not justify the venture.

Scour in the vicinity of structures may occur as a result of natural changes of flow in the channel, as part of longer-term morphological changes to the river, or through man's activities, such as building structures in the channel or dredging material from the bed.

Activities in natural systems should be drastically reduced and heavily controled.