Hydromorphology auditing: a generalized framework at a nation scale to view streams and rivers in their landscape context

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HYDROMORPHOLOGY AUDITING: A GENERALIZED FRAMEWORK AT A NATION SCALE TO VIEW STREAMS AND RIVERS IN THEIR LANDSCAPE CONTEXT

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ABSTRACT

In Europe, there are less than 10 % of total stream and river length that can be considered as relatively free of human pressures. Historical and contemporary human uses of landscape and watershed has produced situations where several cumulative impacts is very common. In that context, it is essential to analyse properly the risks of hydromorphological impairment and its causes, before defining appropriate restoration measures. We propose a multi-scale hierarchical framework named Syrah for “The relational system of water course hydromorphology auditing”. It is based on geomorphology functioning principles. This "top down" approach proposed relies on an assessment of large scale "damage risk": damage to processes (flow and sediment transport in particular) and structures (resulting morphology) are at the heart of the assessment. Fourteen types of hydromorphological damage have been identified. These are the most common types and are most likely to be the cause of impact on the ecological state of water courses. To process them, the audit relies on an evaluation of the layers of geographical data, existing databases, and on cross references between this information and the data required for management, programming, decision-making and assessment of restoration actions. "Land Use and Activities" (urbanization, agriculture, transport, energy) and resulting "Artificial Features and Uses", which are identifiable are quantified. Syrah multi-scale approach has been validated on selected regions, representing a diversity of hydromorphological situations and around 10 % of the France territory.

Keywords: Stream, Rivers, landscape, human pressures, cumulative impacts, geomorphology auditing

THE CURRENT CONTEXT

In order to implement the appropriate measures to achieve the objectives set by the European Water Framework Directive (WFD, 2000/60/EC), an analysis tool for the hydro morphological functions of water courses is required.
A "Good Ecological State", which is the common objective assigned to all water bodies, is based on an assessment of the biological compartments (fish, macro-invertebrates, macrophytes and diatoms) and of chemical parameters. The physical characteristics of the water bodies, only provided to qualify the "Very Good Ecological State", are taken into account indirectly, by their affect on the quality of aquatic biocoenosis, which are in themselves capable of influencing the biological state.

AUDIT PRINCIPLES

The primary determinants on a regional scale (relief, climate, geology) define the hydro morphological control variables (hydrological and sedimentary regimes, width and gradient of valley bottoms). The key factors of ecological status are dependent on these variables, as well as on the structure of the riparian vegetation and the correct state of the water course's lateral and vertical connectivity: physical habitat, aquatic "climate", food webs. To understand and diagnose hydro morphologically driven ecological dysfunctions, we must necessarily take account of this hierarchical and multi-scale organization of the operation of hydro systems.

The "top down" approach proposed in the SYRAH-CE audit system relies on an assessment of large scale "damage risk" which makes it possible to focus analysis work on the lower level if high probabilities of damage are identified. The Audit is analogous in essence to the recent work in Australia [1].
For technical reasons (short turnaround for the performance of the audit) and economic reasons (relatively limited budget), the assessment of the hydro morphological function as a function of the constraints exerted by the primary determinants along water courses has been given precedence over a more conventional approach involving a description of the "state" confined solely to the station level.
Damage to processes (flows and sediment fluxes in particular) and structures (resulting morphology) are at the heart of the assessment:

- they are in fact closely linked to the intensity of anthropogenic pressures in a given geomorphologic context (at the scale of a section of the water course),

- they are clearly at the root of direct and indirect disturbances of aquatic habitats and also of their regeneration processes.

Fourteen types of hydro morphological damage have been identified. These are the most common types and are most likely to be the cause of impact on the ecological state of water courses.

To process them, the audit relies on an evaluation of the layers of geographical data, existing databases, and on cross references between this information and the data required for management, programming, decision-making and assessment of restoration actions.

PRINCIPLE

We direct our first scale of analysis of hydro morphological dysfunctions at the level of a higher compartment called **"Land use and activities"** (urbanization, agriculture, transport, energy). These activities and land use interact, according to their nature, with the operation of water courses at several different spatial, lateral and longitudinal scales (watershed, floodplain, river channel).
They are set out in concrete terms in "**Artificial features and uses**", which are identifiable and often quantifiable objects, with direct and indirect effects on the operation of water courses. These effects translate into "damage to processes" (modification of flow and sediment fluxes, stream erosion processes, hydrodynamic components) and "**structural alterations"** (plane, longitudinal and transversal geometry, morphological units, substrates) of the physical environment (fig. 1).

These different types of damage are in fact modifications (detrimental) of natural forms of water courses and consequently of their habitats.

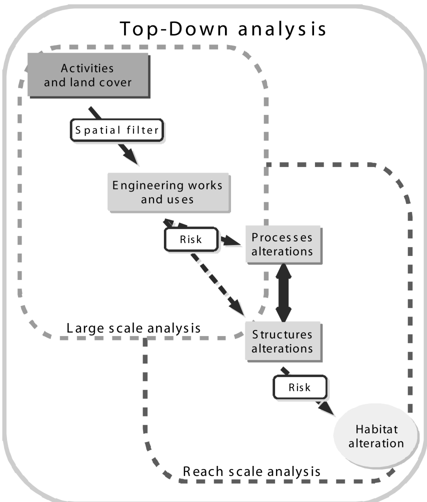


Figure 1. SYRAH-CE conceptual framework

TYPES OF DAMAGE: DISTURBANCE OF PHYSICAL FUNCTIONING AND STRUCTURES

The main aim of the audit is to detect hydro morphological damage of a "non-natural origin" which can be clearly linked to deterioration of the "Ecological state", particularly through a **deterioration of aquatic and riparian habitats.**

Structural damage (morphological in the main) is generally translated by a modification of the "fluvial forms" (main channel and secondary branches, succession of morphological units, river channel geometry, substrate). This necessitates descriptions or measurements taken by direct observation in the field.

As regards damage to **processes** (flow and sediment fluxes), we must factor in a notion of time, which requires the use of time series.

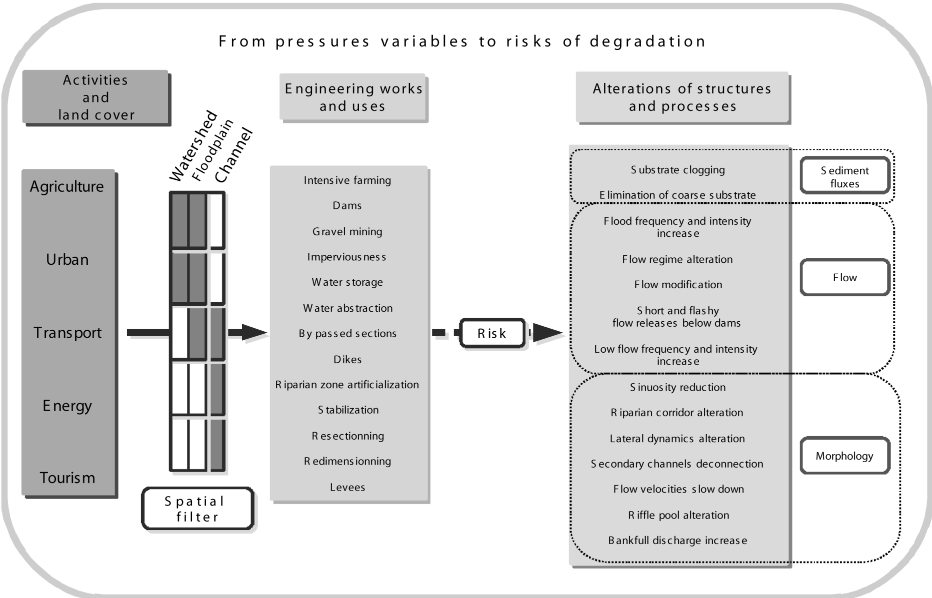


Figure 2. Pressure and physical damage risk variables

It is difficult to assess the damage directly, especially in terms of structural damage (it is necessary to carry out measurements in the field on the entire river system), and perhaps even impossible (complicated and voluminous systems to be set up and kept up to date). It has therefore been necessary to propose an indirect assessment method.

ARTIFICIAL FEATURES AND USES

The final aim of the audit is to foster the implementation of measures designed to correct dysfunctions, if possible from the outset. It seemed to us to be appropriate to propose audit methods starting "upstream" in the causal chain, and thus at the level of

"Artificial features and Uses" (fig. 2). A list of developments and uses likely to cause hydro morphological damage has been drawn up, taking account of the various spatial scales involved: watershed (agriculture, urban area), floodplain (agriculture, urban area, transport), river channel (transport, energy, perhaps tourism). It is possible to analyze all these features and uses identified as being on a large scale using nationally available geographical databases.

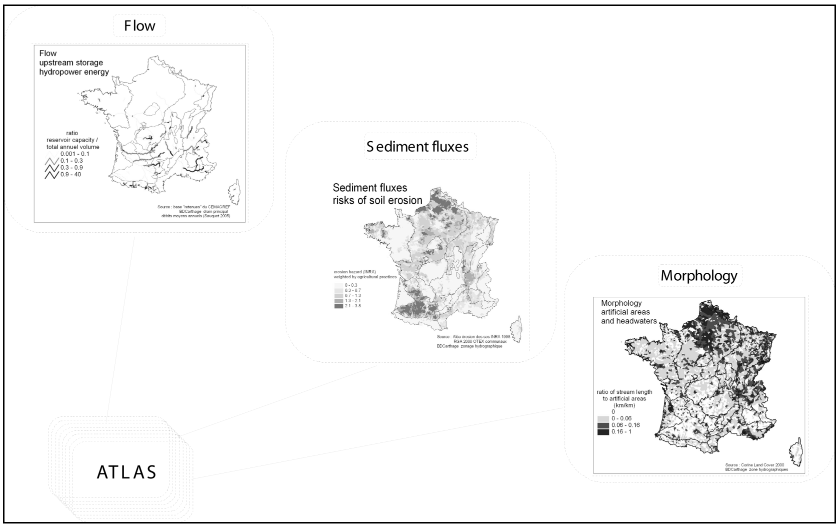
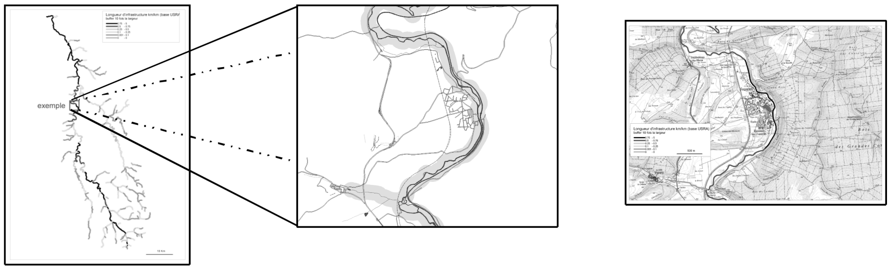


Figure 3. Examples of maps taken from the analysis of large-scale developments and uses

The resulting maps (fig. 3) can be used for management and programming purposes but their precision is limited, particularly regarding "local" morphological aspects. This scale of analysis is therefore inadequate to enable a precise diagnosis of the dysfunctions and to design restoration measures, but does nevertheless provide us with an overview of a large area.

The analysis at the scale of geomorphologic sub-sections provides a description of these "features and uses" to a level of precision compatible with the search for causes of deterioration of the observable ecological state. This level of precision in the analysis is made possible by the existence of precise geographical databases such as BDTOPO IGN® (fig. 4).



Example of results : Roads in floodplain

BdTopo IGN® anlysis in floodplain

Selected elements on a topographic map

Figure 4. Example of an analysis at the scale of a section using BDTOPO IGN®: communication infrastructures in floodplain

RESULTS

We test the methodology on 6 watersheds, chosen as representative of a large diversity of geographical situations. The total area of the test zones is around 10 % of the total France metropolitan area. We compare data and associated probability to encounter physical impairment from the filter process on maps and thematic national databases with observed situations on field. A qualitative assessment has been built for each of the component of the methodology (see Appendix). There is a good to very good agreement between the two sets of information. The 2 levels of screening are complementary. Some components like dams, dikes, levees and weirs are closed dependent from the quality of databases. Some observed components are more widespread than expected: siltation and embeddedness are also encountered in zones where the land use was not intensive agriculture and due for example to the presence of numerous ponds in the watershed (1 case on 2); this is also the case of the stream straightening, which is also frequent, due to historical anthropogenic use, and only visible at small scale (1 case to 5). The general screening process is now validated.

We obtain gross indicator values for the identified "features and uses" of each analytical unit (geomorphologic sub-section). These results can be stored in geo-referenced mapped databases (fig. 5). A further step will be necessary to reinterpret these results according to the geomorphologic characteristics of the section in which they were collected. For example, an identical density of thresholds does not have the same consequences in a fast-flowing mountain torrent as in a mature river with a gentle slope. Another example: infrastructures in the floodplain immediately next to the river channel will only have really negative consequences on geodynamically active rivers.

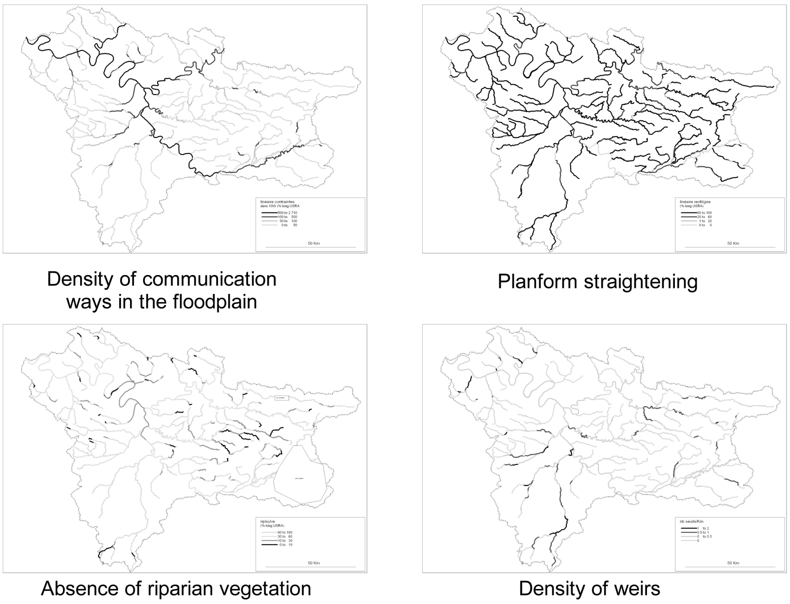


Figure 5. Examples of results of the analysis of features and uses (Malavoi, 2007).

POTENTIAL USES OF THE AUDIT

Apart from mapping the risks of hydromorphological deteriorations undergone by rivers, the SYRAH-CE audit provides aid for management decision and functional restoration. The raw results of the audit allow an easy identification of the parts of the river network that are undergoing limited pressure. This information, combined with the knowledge of the chemical quality of the water, is necessary to delineate the sectors likely to be classified in "High status" according to the WFD, which are thus a priority for conservation. The method used allows the rivers analysed to be considered in a more general context, and focuses the analysis on the hydromorphological functioning, considered on a scale that exceeds the site of investigation. Mapping the indicators that represent the pressures causing geomorphological dysfunction allows to identify the most prevailing ones; the problems can be located, and even categorized in a ranking order.

An analysis of this set of information could provide support for the establishment of management plans to be considered on several scales, with an easier identification of desirable restoration actions, and help for the decision-makers.

Acknowledgments

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REFERENCES

[1] Norris R. H., Linke S. , Prosser I., Young W.J., Liston P., Bauer N., Sloane N., Dyer F., Thoms M., “Very-broad-scale assessment of human impacts on river condition." *Freshwater Biology*, Vol. 52, No. 5, (2007), pp. 959-976.

[2] Chandesris A., Malavoi J.R., Souchon Y., Wasson J.G. and Mengin N., « Le système relationnel d'audit de l'hydromorphologie des cours d'eau (SYRAH CE): un outil multi-échelles d'aide à la décision pour la gestion des cours d'eau ». *Ingénieries - Eau Agriculture & Territoires*, No. 50, (2007), pp. 77-80.

APPENDIX

Field observation versus “aerial” view and national databases

	Engineering works and uses	**Watershed and Riparian Scale**
SEDIMENT FLUXES	**Intensive agriculture**	At risk situations: 100 % true No large scale risk identified: 50 % with siltation by fine sediment (different origins: ponds, reservoirs, …)
	Dams	Difficult to verify by spot field observations – *Great dependency on data quality of the national dam database*
	Sediment mining	True to the expected pattern at this scale of investigation
FLOW	**Impervious area**	True to the expected pattern at this scale of investigation
	Reservoir water storage	Difficult to verify by spot field observations – *Great dependency on data quality of the national dam database*
	Water abstraction	Effective variable – *often at a wider range than expected*
	Minimum flow (by pass section)	
MORPHOLOGY	**Dikes and levees**	
	Riparian area removal	Efficient for the floodplain vegetation, lees for the detail of the corridor
	Stabilization	Efficient for the large scale constraints
	Straightening	At risk situations: 100 % true No large scale risk identified: 20 % with observed straightening

	Channnelization	Good identification in areas at risk. Other impacted situations still exist.
	Weirs	*Great dependency on data quality of the national dam database*
		Reach Scale
SEDIMENT FLUXES	**Intensive agriculture**	
	Dams	
	Sediment	True to the expected pattern
FLOW	**Impervious area**	
	Reservoir water storage	
	Water abstraction	
	Minimum flow (by pass section)	***Methodology and relevant variable to calibrate***
MORPHOLOGY	**Dikes and levees**	*Heterogeneous data, qualitative information.*
	Riparian area removal	True to the expected pattern at this scale of investigation (riparian and channel vegetation in the floodplain)
	Stabilization	True to the expected pattern at this scale of investigation
	Straightening	True to the expected pattern at this scale of investigation. Sensitivity function of the typology of streams
	Channelization	
	Weirs	*Great dependency on data quality of the national dam database*