



HAL
open science

From asset to threat: trajectory of sediment on the Rhône River

Joana Guerrin, Emeline Comby, Raphaël Morera

► **To cite this version:**

Joana Guerrin, Emeline Comby, Raphaël Morera. From asset to threat: trajectory of sediment on the Rhône River. *Water History*, 2021, *The Social Life of Sediment*, 13 (1), pp.75-94. 10.1007/s12685-021-00276-6 . halshs-03194110

HAL Id: halshs-03194110

<https://shs.hal.science/halshs-03194110>

Submitted on 3 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Water History

From asset to threat: trajectory of sediment on the Rhône River (France)

--Manuscript Draft--

Manuscript Number:	IWHA-D-20-00002R2	
Full Title:	From asset to threat: trajectory of sediment on the Rhône River (France)	
Article Type:	Original Research	
Keywords:	Sediment; Rhône; Hydropolitics; Perception; Hydrosocial cycle.	
Corresponding Author:	Joana Guerrin, PhD INRAE FRANCE	
Corresponding Author Secondary Information:		
Corresponding Author's Institution:	INRAE	
Corresponding Author's Secondary Institution:		
First Author:	Joana Guerrin, PhD	
First Author Secondary Information:		
Order of Authors:	Joana Guerrin, PhD	
	Comby Emeline	
	Raphaël Morera	
Order of Authors Secondary Information:		
Funding Information:	Agence Nationale de la Recherche (ANR) (FLUIDGOV - ANR-18-EQUI-0001)	Dr Joana Guerrin
	Agence Nationale de la Recherche (ANR) (FluidGov (ANR-18-EQUI-0001))	Dr Raphaël Morera
	Agence Nationale de la Recherche (ANR) (ANR-11-LABX-0010)	Dr Comby Emeline
Abstract:	<p>Sediment is physical matter and, as such, is usually studied in the physical and natural sciences, such as chemistry, geomorphology, or hydraulics and hydrology. However, sediment is also deeply embedded in society and politics. Sediment flows are affected by river transformation and, in turn, affect river management. This article highlights the changing ways in which society has considered sediment in the Rhône River (France). In the early-modern historical period (16e-18e c.) sediment was generally considered a blessing. However, the contemporary evolution of the Rhône's industrialisation, river engineering, and governance has challenged this perspective. Today sediment is more likely to be viewed as a threat. The concept of the hydrosocial cycle is a useful framework within which to describe the variety of ways societies have understood river sediment. The variation is caused by, and in turn affects, the meaning and representation of sediment, the structure of land and water governance, the nature of sedimentary and water resources, and the materiality of sediment and water, mediated by technology. This article aims to open the issue of sediment to the social sciences through a dialogue between history, human geography, and political science.</p>	
Response to Reviewers:	<p>Dear editor, Please find attached the reviewed version of the paper after copyedits. Best,</p>	

History and politics of sediment management on the Rhône River

Authors

Joana GUERRIN

ORCID: 0000-0002-4065-2295

INRAE, UMR GESTE (MA 8101), Strasbourg, France. Joana.guerrin@inrae.fr

University of Strasbourg, Strasbourg, France

Emeline COMBY

ORCID: 0000-0003-4057-3623

University of Lyon, UMR 5600 EVS, University Lumière Lyon 2.

Raphaël MORERA

CNRS

Centre de recherches historiques, EHESS/CNRS, Paris, France.

Biography of authors

Joana Guerrin is researcher at the French National Institute for Research in Agronomics and the Environment (INRAE) in Strasbourg, France. She was trained in Political Science and Policy Analysis. Her research focuses on the government and governance of water-related risks. She has been mainly researching on the role of the State in governing floods on the Rhône River (France) and on drought governance in São Paulo (Brazil). She is the French coordinator of FLUIDGOV Project funded by ANR and focusing on hydrosocial cycle as a framework to analyze flood governance in the Upper Rhône (Switzerland), Rhône Delta (France) and Ganges Delta (India).

Emeline Comby is an Associate Professor in Geography at the University of Lyon Lumière Lyon 2, UMR EVS. Her research interests include water policy, landscape, and stakeholder perception. She has been analysing how European and American riverscapes have changed under the influence of different power relations. She is one of the two coordinators of the Social observation of the river governorship (OSTF) which is part of the Rhône Basin Long-Term Ecosystem Research (LTER, ZABR).

Raphaël Morera is researcher at the French National Center for Scientific Research. He works on water history in Early Modern France, focusing on energy production and wetlands management. He contributes to the FLUIDGOV Project. He is editor in chief of *Études Rurales*, edited by the École des Hautes Études en Sciences Sociales.

Acknowledgements

1
2 This research was generously supported by two research projects funded by the French National
3 Research Agency (ANR): The FluidGov project (Towards ‘fluid’ governance: hydrosocial analysis of
4 flood paradigms and management practices in Rhone and Ganges basins (India, France and
5 Switzerland): ANR-18-EQUI-0001) and the French programme ‘Investissements d’Avenir’ (ANR-11-
6 LABX-0010), managed by the ANR, supported by the OHM Vallée du Rhône and part of a
7 programme of Rhône Basin Long-Term Ecosystem Research (LTER, ZABR). The authors are grateful
8 for insights gleaned at a seminar in Lyon in 2018 (‘Dams, Sediment Discontinuity, and Management
9 Responses in Mediterranean River Basins’) and a workshop in Berkeley in 2019 (‘The Social Life of
10 the Sediment Balance’). The authors would also like to thank the anonymous reviewers for their
11 constructive insights, Carole Barthélémy for her comments on a previous version of this paper, and
12 Fanny Arnaud who collected historical maps.
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

From asset to threat: trajectory of sediment on the Rhône River

Abstract

Sediment is physical matter and, as such, is usually studied in the physical and natural sciences, such as chemistry, geomorphology, or hydraulics and hydrology. However, sediment is also deeply embedded in society and politics. Sediment flows are affected by river transformation and, in turn, affect river management. This article highlights the changing ways in which society has considered sediment in the Rhône River (France). In the early-modern historical period (16e-18e c.) sediment was generally considered a blessing. However, the contemporary evolution of the Rhône's industrialisation, river engineering, and governance has challenged this perspective. Today sediment is more likely to be viewed as a threat. The concept of the hydrosocial cycle is a useful framework within which to describe the variety of ways societies have understood river sediment. The variation is caused by, and in turn affects, the meaning and representation of sediment, the structure of land and water governance, the nature of sedimentary and water resources, and the materiality of sediment and water, mediated by technology. This article aims to open the issue of sediment to the social sciences through a dialogue between history, human geography, and political science.

Keywords: Sediment; Rhône; Hydropolitics; Perception; Hydrosocial cycle.

Introduction

Sediment is an essential part of rivers, and they are also important for the society living near rivers. On the Rhône River (France), if sediment is today rather considered as a threat regarding quality and quantity issues, this was not always the case. This article highlights the changing ways in which society has considered sediment in the Rhône River (France), comparing the early-modern historical period (16e-18e c.) and today.

The Rhône is a major river in France, rising in Switzerland and running towards south-eastern France, ending in the Mediterranean Sea by the Camargue delta (Figure 1). On many French maps the river appears to start at the French border. However, the issue of sediment transport does not stop at political boundaries. The Rhône drains a catchment area of 98,000 km² along its 718 km course through Switzerland and France. In France it has a 512 km main stem, flowing from Lake Geneva to the Mediterranean Sea. Several rivers contribute to the Rhône's considerable flow, including the Saône, Isère, Drôme and Durance. Representing a natural boundary, the river crosses three administrative regions and eleven departments. The Museum of Ancient Arles bears testimony to the rich history of human settlement on the banks of the Rhône and the use of the river for navigation and commercial exchanges in the Gallo-Roman period. The Rhône's particularly high flow played a crucial role in the reconstruction and modernisation of post-war France (Pritchard, 2011). Notoriously dangerous to navigate, the river was tamed through extensive modification over the course of the nineteenth and twentieth centuries, providing flood protection, easier navigation, hydropower and nuclear power. This altered the landscape significantly, as well as profoundly shifting the river's hydrology and sediment dynamics. The riparian inhabitants were also forced to adapt their relationship to the river. Today, the Rhône Valley is a major transit route (railway, motorway and waterway) and industrial axis in France, the riverbanks having been massively artificialised linking cities, industrial sites, and farmland.

Figure 1: Map of the Rhône River valley (Comby, 2020)

The Rhône River is about much more than water, as shown by a rich social science literature. Sara Pritchard's passionate history of the Rhône's post-war development shows how political and economic factors have been presented as 'natural' in terms of how the Rhône should flow. Indeed, 'masking the cultural and political work behind these "natural" changes has helped make their political implications invisible' (Pritchard, 2004, p.798). From a similar perspective of river development, other authors have shown how power relations have contributed historically to the shaping of the Rhône's riverscape (Comby et al., 2019). Political science has shown how floods were related to political factors, the risk being made alternately invisible through the Rhône development strategy and visible through sociopolitical crises (Guerrin, 2014). Sociologists have analysed the drivers and impediments to the implementation of restoration projects on the Rhône River and shown how local protests around

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

crises such as flooding and pollution could hamper or boost socio-natural changes along its banks (Barthélémy and Armani, 2015). Such examples testify to the diversity of socio-natural studies being carried out on the Rhône. Yet few specifically focus on the sediment itself, tending instead to focus on its connection to pollution. For example, Gramaglia and Babut (2014) deconstruct the sociopolitical crises that emerged on the Rhône with chemical pollution stored and dispersed by sediment. Comby et al. (2014) analysed the same crises through the media coverage. In this paper we focus on sediment to show how the idea of sediment and its role has evolved through history.

As Jamie Linton (2010) comprehensively explains, water is a lot more than H₂O. Created by scientific discourse and developed by hydrology, this modern and abstract form has affected how we perceive water today. Linton differentiates H₂O, water as a component we can scientifically know, with other ways of experiencing it, such as through our senses and beliefs. From this perspective, the works on the ‘hydrosocial cycle’ propose reintegrating water’s material nature (expressed by H₂O) with theories, discourses, and representations of water, including the power relations and the role of technology and infrastructure within the construction of water (Linton and Budds, 2014). What has barely been proposed, however, is giving sediment back to water.

Recent works have advocated a reconsideration of one of the ‘foundational binaries’ of geography – ‘that of land and water’ (Lahiri-Dutt, 2014) – and a reintegration of land, and sediment, within the hydrosocial cycle (Lafaye de Micheaux et al., 2018). In the context of riverscapes, water has been separated from land and, therefore, from sediment through regulation and practices inherited from private land ownership and agriculture, as well as colonialism (Lahiri-Dutt, 2014). Interestingly, Lafaye de Micheaux et al. (2018) propose opening the hydrosocial cycle model to sediment through an analysis of: i) meanings and interpretations (including scientific and/or local knowledge) of land and water in so-called ‘muddyscapes’; ii) land and water governance and power relations; iii) resource (water and sediment) use and exchange patterns; and iv) physical and biological processes, partly mediated or affected by technology. This research agenda allows land to be brought back into the picture when looking at water, turning riverscapes into muddyscapes and reminding us that water and land are not so separate.

Sediment cannot be separated from water in riverscapes. It is deeply embedded in society and politics because it is not just physical matter. It has a social life. This paper shows that sediment is part of the Rhône’s hydrosocial cycle when extracted to repair dykes or produce cement, when it overflows (for better or worse), when fish are contaminated by chemical pollutants, or when sediment-charged water kills wildlife after dam flushing. However, sediment’s role has evolved over time. Until the 18th century, in early modern history, its management was part of the daily life of riparian Rhône inhabitants. Used in agriculture and construction, sediment was considered a valuable resource. Throughout the nineteenth and twentieth centuries the development of the river served to separate water from land through infrastructural changes related mainly to the hydropower and nuclear

1 industries. The riverscape was significantly modified, transforming its water and sediment regime.
2 Yet, while sediment tended to be ignored and separated from water, we show that contemporary
3 disputes have put it back on the Rhône's water agenda, albeit now cast in a negative role.
4

5 Society and public policy have been adapting to the evolving definition of sediment. The idea that
6 the same matter can evolve from an asset to a threat – a resource to a hazard – is well documented in
7 the literature of the sociology of risk (for a review of the French literature see Borraz et al., 2007).
8 Risk is always defined in terms of specific social, political, and historical processes. This corresponds
9 to a 'framing process' (Goffman, 1974) or 'schemata of interpretation that enable individuals to locate,
10 perceive, identify and label occurrences within their life space and the world at large' (Snow et al.,
11 1986 p.464). Framing refers to the understanding of issues in terms of specific contexts that can vary
12 over time (e.g. floods can be framed as an environmental or a public security issue). This process is
13 usually analysed through the role of actors (Cobb and Elder, 1972), social movements (Benford and
14 Snow, 2000), or crises and political opportunities that open a 'policy window' (Kingdon, 1984),
15 enabling something to be seen as a problem. Within a long-term perspective sediment in the Rhône
16 has undergone a drastic evolution: framed as an asset in the past, it is now considered a threat. This
17 trajectory is the core of our paper: what are the factors, actors, and effects of such an evolution?
18

19 The paper is organised into three main parts. First, we explore the role of sediment in early modern
20 and modern history when it was seen primarily as a blessing. We then explore the infrastructural
21 change on the Rhône in the nineteenth century, which intensified in the twentieth century, and the
22 impact it had on sediment dynamics. In the third part we focus on the current construction of sediment
23 as a threat through different aspects: pollution, flooding, and dam flush
24

25 26 27 28 29 30 31 32 33 34 35 36 37 1. Sediment as an asset in early modern times 38

39 The history of sediment is inherently linked to that of the Rhône's development. In medieval and
40 early modern times the river largely maintained its natural course, evolving following major floods.
41 Riparian communities used sediment dredged from the river to build dykes and protect themselves
42 from floods. Nevertheless, given the magnitude and frequency of the flooding they could not prevent
43 overflow into human settlements. Due to their agricultural value, however, overflows of water and
44 sediment could be considered a blessing.
45
46
47
48
49

50 The profile of the Rhône River has changed greatly throughout history. Since Roman times,
51 however, the Rhône has been a fundamental axis for inland navigation between Lyon and the
52 Mediterranean Sea, and the river was an essential link within the Roman Empire, remaining so
53 throughout the Middle Ages. In the Middle Ages the lower basin was formed of large wetlands, whose
54 landscape evolved in accordance with the rhythm of the river (Rossiaud, 2007). From at least the
55 twelfth century, cities located along the Rhône built levees both to protect against flooding and to ease
56 navigation (Stouff, 1993). The form of their construction, in earth and wood, is well documented in
57
58
59
60
61
62
63
64
65

1 local archives. The levees in Arles (located at the delta of the Rhône, Figure 1) are the best known.
2 *Levadiers*, city officials with responsibility for dykes, were documented from the mid twelfth century.
3 Paid from landowners' taxes, they had the authority to order landowners to maintain or repair their
4 dykes.
5

6
7 Despite the constant efforts to control it, the Rhône was still free to change its course and would
8 regularly flood the surrounding land. In the fourteenth century, the surveyor Bertrand Boysset gave a
9 detailed description of the lower Rhône area. Boysset's skills were essential to the social equilibrium
10 of Arles (Portet, 2004): with flood after flood, property boundaries became less and less visible. Only
11 the surveyor was able to delineate parcels of land and secure properties by fixing boundaries between
12 land and water. Each flood event changed the waterways and could even create new arable areas due
13 to sedimentation. Hence, medieval records describe the lower Rhône as a rich hunting and fishing area
14 (Roucaute, 2004). The Romans cultivated the entire area, but during the Middle Ages wheat and other
15 cereals were mostly grown in the upper areas, such as the Crau (a vast alluvial plain at the original
16 confluence of the Durance and Rhône, Figure 1).
17
18
19
20
21
22
23

24 Practices had begun to change by the end of the fifteenth century when rural and urban elites
25 invested in new land. Associations were established to oversee land drainage and agriculture, the first
26 being officially registered in 1543 in the delta of the Rhône, the Camargue (Morera, 2016). Their role
27 was to channel communal efforts to overcome the challenge of water management. They also installed
28 hydraulic infrastructure, such as dykes and canals, as flood protection. Yet, as investors worked to
29 separate land and water in order to develop arable land it remained important to maintain a link
30 between the river and the cultivated soil, and at that time the link was fluvial sediment.
31
32
33
34
35

36 At the time, flooding was an ambiguous event. On one hand, a winter or spring flood was a disaster
37 for the crops and promised a hard summer too: the loss of a harvest was terrible for the communities.
38 But on the other hand, floods always enriched the land with sediment. It could wipe out a year's crops
39 but at the same time ensure high yields in subsequent years. In the middle of the sixteenth century the
40 Arles aristocrat Pierre Quiqueran de Beaujeu summarised this complex relationship between a
41 community and its river, comparing the Rhône to the Nile because of sediment:
42
43
44
45
46

47 Then the Rhône returns to its bed, leaving behind very fertile silt similar to that of the
48 Nile, apart from the monstrous animals. They are comparable because the Rhône's silt is
49 also thick and sticky. When this mud settles in the summer not only does it burn those
50 ears of wheat that are still standing, but when the heat dries it out it turns into sterile sand.
51 These floods only occur in those areas of Arles where the fertile land is very low, forcing
52 it to defend itself against this very dangerous river by building dykes, but this makes this
53 area admirable. The flooding that the city of Arles undergoes every two or three years,
54 and sometimes two or even three years in a row, takes with it seeds, the work of men and
55
56
57
58
59
60
61
62
63
64
65

1 oxen and the hopes of fathers. But the year the river does not overflow it provides them
2 with such crops that it repays the damage and removes their fear of the future. (Quiqueran
3 de Beaujeu, 1999 [1551]¹)
4

5 It is clear that sediment so enriched the arable land that farmers could see the Rhône's floods as
6 blessings. Sediment transport and deposition could offer valuable additional income to the community.
7 At the time the Rhône's profile was not continuous and regular as it is today. Even in its lower part the
8 riverbed was highly complex and shifting. Thanks to the sediment and the irregularities of the riverbed
9 several islands divided the water flow. These offered very fertile land that benefited the community.
10 Such was the case in Arles, where the city authorities leased the larger islands to farmers (Archives
11 municipales d'Arles, DD 57 and 58) and thus obtained regular incomes. It was similar in the city of
12 Avignon, the main part of which was built on islands that had been conceded by the king (Archives
13 municipales d'Avignon, DD 106).
14
15
16
17
18
19
20

21 The relationship between the Rhône's riverside communities and its sediment became more
22 complicated when property-related pressure intensified in the seventeenth century (Morera, 2011). The
23 high level of sedimentation began to be seen as a problem. Draining projects were hampered by
24 sediment build-up in the hydraulic infrastructure due to a lack of maintenance. Several surveys in the
25 1630s described the lower Rhône valley as entirely under the influence of water. Filled in with
26 sediment, canals were further obstructed by reeds and other tall grasses. Whether it came from the
27 Rhône or not, sediment had taken possession of its main riverbed (Archives départementales des
28 Bouches-du-Rhône, 108 E 97).
29
30
31
32
33
34

35 The major drainage projects of the 1640s were focused on the hydraulic infrastructure they had
36 inherited. They were carried out in a relatively short period of time thanks to massive funding and land
37 appropriation by investors in land drainage. The work mainly consisted of cleaning the drainage canals
38 at great depths and removing the sediment and alluvium to ease the flow of water. But again sediment
39 would create arable opportunities. Indeed, land was drained, and farmland was enriched by sediment.
40 The agricultural results were rapid: yields on the newly cultivated land were high, thanks mainly to the
41 richness of the alluvial deposits from the Rhône. The works led to a reoccupation of the land bordering
42 the river. But now the benefits of the floods were less noticeable. Indeed, the risk they posed to
43 infrastructure and crops was clearer than the benefit of sedimentary deposits. Capital expenditure had
44 changed the environment and the relationship between the Rhône and those living alongside it.
45
46
47
48
49
50
51

52 Continuing to cultivate the land despite the challenges of the river meant local residents had to
53 continuously maintain the hydraulic infrastructure, whether landowners or not. This entailed
54 continuous renegotiation between the river and its sediment on one hand and social structures on the
55 other. The eighteenth century was marked by a relative decline in the cultivation of the land in the
56
57
58
59

60 ¹ Authors' translation.
61
62
63
64
65

1 Rhône Delta (Baehrel, 1988). With landowners' absenteeism and a consequent lack of interest in
2 agriculture, the sediment reasserted itself and provoked constant flooding of the whole Lower Rhône
3 with the loss of arable land. In 1733 Gaspard Bernardy, a royal engineer, produced a detailed study of
4 this issue, according to which, from the Durance to Arles, the Rhône Valley was entirely submerged.
5 This study laid the blame on a lack of maintenance and the filling in of canals. To bring the land back
6 into cultivation Bernardy recommended restoring the slope of the canals and that, 'the land resulting
7 from the dredging be used to thicken and raise the dykes to the necessary height to contain the highest
8 waters so they do not overflow into the lowest lands' (Bernardy, 1733). Sediment needed to be taken
9 out of the canals and could then be used to reinforce the existing dykes.

10
11 It was predominantly the towns of the Lower Rhône that had to deal with the issue of sediment
12 accumulation, since that is where the alluvial material ended its journey. Yet, even in this area,
13 society's relationship with the natural process of sedimentation was double-sided. On one hand the
14 river enriched the soil for cultivation, but on the other it relentlessly weakened the infrastructure
15 constructed to protect towns and land. Before being deposited, sediment must be gathered by the
16 water. Communities feared the loss of sediment and the vanishing of profitable land. Moreover, along
17 the Rhône, dykes and levees were made of alluvial sediment and stone (at certain points), and these
18 had to be maintained to contain the river's greed. It was able to give with one hand and take with the
19 other. Engineering surveys of eighteenth-century Avignon depict the erosion of hydraulic
20 infrastructures. An example from 1747 shows a large section of the riverbank having collapsed. Those
21 leading the survey urged the authorities to rebuild the levees of dykes in stone (Archives municipales
22 d'Avignon, DD 105). In the face of this challenge, the city of Avignon, that was under the rule of the
23 papacy, called on a large workforce to bring earth to renew the dykes, called *palières* (Archives
24 municipales d'Avignon, DD 125). The city council allocated a substantial budget each year to prevent
25 sediment loss.

26
27 Avignon's authorities saw the Rhône as a threat from which they needed to be protected. In a letter
28 to the vice legate (the pope's representative) the engineer P. Thibaud defended his project to reinforce
29 the town's hydraulic equipment by arguing that the Rhone was 'imperceptibly carrying away its land'
30 (Archives municipales d'Avignon, DD 106, date unknown). Later, presumably in the late 1750s,
31 another engineer urged the papacy to finance new dykes by stressing that, 'the water is often on the
32 verge of taking land away' (Archives municipales d'Avignon, DD 106, date unknown). Thus, for the
33 city of Avignon, sediment loss threatened the income from land cultivation and taxes.

34
35 Agricultural pressure on valley bottoms gave rise to highly ambiguous relationships with the water
36 and sediment. The communities' interest in these areas arose from the arable value of sedimentation
37 alongside the obstacle it posed to their use due to the risk of flooding from land loss. This
38 contradiction was partly addressed by viewing sediment as raw material for large, technical
39 infrastructure to raise watercourses, in particular building dykes along the Rhône and affluent canals

1 from sediment deposited on the riverbed. However, the fragility of this infrastructure and the
2 unavoidable dyke breaches offered some flexibility to the socio-technical system that had been
3 established. But it was an unstable equilibrium that lasted beyond the French Revolution only to be
4 shaken by the agricultural crisis of the 1840s and state intervention during the Second Empire (Allard
5 and Maurice Corsand, 2004). From the nineteenth century, floods became a public issue in France, and
6 higher dykes were erected around major cities and the Camargue (Guerrin, 2014). Along with the
7 transportation and energy advances of the twentieth century, this infrastructure caused significant
8 change to the river and, consequently, sediment dynamics.
9

14 2. Industrialisation and river engineering from the nineteenth century onwards: 15 affecting sediment quantity and quality 16

17
18
19 Until the nineteenth century, the Rhône was a meandering river with several channels. Sediment
20 was part of the daily life of inhabitants. But in the nineteenth and twentieth centuries, industrial
21 development and river engineering led to significant change in the river's landscape and in sediment
22 dynamics. The creation of high and secure dykes durably separated land from water and limited the
23 sedimentation of land. Sediment flux was reduced by the development of river engineering, as
24 industrialisation created pollution that could reduce the sediment's quality.
25
26

27
28
29 Environmental and social transformations affect sediment flow. In terms of quantity, the amount of
30 sediment flowing along the Rhône was drastically reduced from 18.8 mm³ per year in the late
31 nineteenth century to 6.1 mm³ per year in 2010 (Provansal et al., 2014). Geomorphologists attribute
32 this to climatic conditions, i.e. the natural decrease in the frequency of major floods at the end of the
33 Little Ice Age (Bravard, 2010), as well as to anthropogenic factors (Provansal et al., 2014). Indeed, the
34 nineteenth century saw a change in the flood regime of the Rhône River. Sediment flux was reduced
35 by a combination of a rural exodus associated with a decline in mountain agriculture, catchment
36 reforestation to prevent flood events, and the engineered stabilisation of feeder torrents (Provansal et
37 al., 2014). The century also witnessed two major floods on the Rhône (1840 and 1856). For various
38 sociopolitical reasons, the latter was to inspire France's first flood-protection legislation (Guerrin,
39 2014). Under Napoleon III the state invested in protection measures for the main cities along the
40 Rhône River and the Camargue. Civil engineers from the Ponts et Chaussées corps supervised all
41 dyke-building and maintenance on navigable rivers such as the Rhône. Major levees, termed
42 'unsinkable', were built around Lyon, Avignon and the Camargue to prevent flooding. The resulting
43 decrease in the frequency of major and minor floods meant reduced sediment transfer and fewer
44 sedimentary deposits on riparian forest (Provansal et al., 2014).
45
46
47
48
49
50
51
52
53
54
55

56
57 In the nineteenth century, navigation was the primary means of economic development and had
58 geomorphological and ecological impacts that remain today (Comby, 2015). Sediment was cleared to
59 improve navigation on the Rhône, and the river's fluvial pattern changed between 1860 and 1870
60
61
62
63
64
65

1 when the first levees were built (Bravard, 2010). At this time, structures known as *casiers Girardon*,
2 submersible groynes resembling groyne fields, were built to narrow the Rhône's channel, concentrate
3 its flow and ease navigation (Räpple, 2018). They consisted of a series of submerged dykes,
4 perpendicular to the bank, to encourage sedimentation on the sides while the waterway became
5 consequently deeper in the middle of the riverbed. The channelisation of the Rhône entailed the
6 artificial disconnection of most of its secondary channels (Dépret et al., 2017) and a loss of
7 connectivity between the floodplains and the channel (Vauclin et al., 2019). However, the
8 infrastructure itself attracted sediment. By 1945, 42 per cent of the area it covered had become land,
9 and today only 10 per cent remains aquatic (Thorel et al., 2018). The divisive *casiers Girardon* are
10 now recognised as hosting interesting biodiversity but also as polluted sediment traps or for artificially
11 separating the river from its bed.
12

13 From the nineteenth century onwards the landscape of the Rhône changed rapidly with Napoleon
14 III dykes and the *casiers Girardon*. A river with braided channels in the eighteenth century, it was
15 transformed into a simple channel, disconnected from its former meanders (Figure 2), as we can see
16 from these two historical maps showing the landscape's evolution between 1832 and 1907.
17

18 *Figure 2: Historical maps and changing riverscape at Pont-Saint-Esprit (Gard department, France)*
19

20 While engineering projects had been affecting the landscape since the nineteenth century, works
21 progressed even more rapidly after World War II, with the construction of nineteen dams and five
22 nuclear power plants. In 1945 the Rhône's riverscapes served the political purpose of reinforcing the
23 authority of the central government over the regions, to promote economic development and to ensure
24 national independence (Pritchard, 2011). In 1933 the Compagnie Nationale du Rhône (National Rhone
25 Company, CNR) was created and was given the concession for managing the Rhône with three
26 objectives: hydropower, navigation, and irrigation. From 1945 to 1986, CNR built 19 hydropower
27 dams along the river (Figure 1), between the Swiss border and the upstream part of the delta,
28 associated with major dykes to channel the river. Press reports of the time compared the CNR's
29 projects to those of the Tennessee Valley Authority in the US (Comby et al., 2019). In the 1970s and
30 1980s five nuclear plants were built near the Rhône (four are still in operation), drawing water from
31 the Rhône to cool their reactors.
32

33 These major infrastructural changes in the landscape of the Rhône had impacts on sediment flux.
34 Dams reduced sediment transport within the river, and, in its catchment, major Alpine dams retain
35 much of the sediment. The large Serre Ponçon dam, for example, was estimated to have been retaining
36 around 200 mm³ of sediment, or 4 mm³ per year since the 1950s (Provansal et al., 2014), creating
37 riverbed incision downstream of the reservoirs. Although CNR hydropower plants (mostly run-of-the-
38 river dams) retain less water and therefore less sediment, some coarser sediment is unable to travel
39
40
41
42
43
44
45
46
47
48
49

1 through the bypassed channel as the usual managed discharge is insufficient. Therefore, much of the
2 sediment is conveyed during large floods (Provansal et al., 2014).

3
4 Gravel mining further reduced sediment transport in the Rhône River. The amount of gravel
5 dredged from the river's main channel between Lyon and Arles was estimated at 13.5 mm³ (0.83
6 mm³/y) between 1970 and 1990 and around 84 mm³ for the entire basin, according to Provansal et al.
7 (2014). Mining also took place in the tributaries, resulting in less available bedload flux and
8 exacerbating riverbed incision (Provansal et al., 2014).
9

10
11
12 The significant transformation of the Rhône's riverscape in the nineteenth and twentieth centuries
13 was illustrated by the use of the term 'river highway' in the national press in reference to the
14 straightening of the river (Comby et al., 2019). In the space of 150 years the river formerly described
15 as a 'furious bull' by the French historian Michelet in 1840 was tamed and transformed into a source
16 of many utilities (nuclear power, hydraulic power, water for irrigation, navigation route), becoming a
17 channelised river between two large banks for the majority of its course, flanked by a motorway and a
18 high-speed railway. The development continued as part of a post-war modernisation project that
19 sought national independence through hydraulic and nuclear power as well as strong trade links
20 through navigation. These strategic goals, along with riparian interests and local authorities looking to
21 develop irrigated agriculture, defined how the Rhône's water and sediment currently flow. According
22 to geomorphologists, the principal threats to large rivers, especially the Rhône, are artificial
23 modifications to their discharge and channel and floodplain morphology (Lamouroux et al., 2015).
24 Indeed, gravel mining, dyke and dam construction and channelisation for navigation have simplified
25 the lateral pattern of the channel and incised and paved the riverbed (Parrot, 2015). This has separated
26 land and water and deeply impacted sediment flux in the Rhône.
27
28
29
30
31
32
33
34
35
36
37

38 In the same period of time industrialisation took hold in the Rhône Valley. A 25 km stretch from
39 Lyon harbour to Loire-sur-Rhône was called 'chemical valley' (Duchêne and Marchand, 2015). In the
40 second half of the nineteenth century various factories were established in the south of Lyon, and for
41 almost a century companies grew up along the Rhône, particularly in connection with Lyon's textile
42 and photographic industries. For example, Rhône-Poulenc produced dyes for the silk industry. Various
43 economic crises led these businesses to be joined by other economic sectors, such as the
44 pharmaceutical industry and petrochemicals, with the installation of a refinery in Feyzin and a pipeline
45 between Fos (France) and Karlsruhe (Germany), which has run along the valley since 1962. The
46 industrialisation extends downstream, beyond Lyon's urban area. Among the companies present in the
47 Rhône Valley, Lafarge operates quarries, notably at Le Teil in Ardèche. In the 1960s and 1970s the
48 Rhône was polluted by industrial and domestic waste, as the press reported: 'The Rhône flows,
49 depending on the day, with nothing but masses of red or blue moss, waste from riverside factories' (*Le*
50 *Monde*, 16 June 1972); 'Upstream from Lyon, the river is practically free of pollution. It is not the
51 same downstream' (*Le Monde*, 14 May 1966). Indeed, the Rhône was considered a convenient sewer.
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 But industrial accidents (e.g. Pierre-Bénite in 1976) highlighted the problem of pollution and had a
2 lasting impact on its perception.

3
4 The pollution of the Rhône was due to the valley's industrialisation and urbanisation, as well as
5 industrialisation around tributaries that increased the contaminated discharge. For example, the current
6 presence of PCBs (polychlorinated biphenyl) in the river is partly linked to industrialisation along its
7 course. PCBs were produced in large quantities from the 1930s, mainly for use in capacitors² and
8 transformers sold in France through the firm General Electrics. The production of PCBs in France was
9 estimated at between 130,000 and 180,000 tons for domestic use (Gramaglia and Babut, 2014). In
10 particular, two industrial sites near Grenoble produced the majority of PCBs used in France from the
11 1950s until 1984 (Gramaglia and Babut, 2014). In Saint-Vulbas, along the Rhône River, a company
12 (Tredi) treats PCB waste (Comby et al., 2014). The pollution arising from such intense
13 industrialisation ultimately affected the quality of sediment.
14
15
16
17
18
19
20

21 Major anthropogenic and technological changes had a huge impact on sediment flux and quality
22 and therefore on the relationships that the Rhône's communities had with the river. There was a
23 significant reduction in sediment import from the upstream catchment and tributaries. Moreover,
24 sediment transported within the river was blocked by the many dams and levees, even creating
25 artificial banks, particularly at the *casiers Girardon*. Today, bed mobility remains very low, and it is
26 mainly fine sediment that is transported (Vázquez-Tarrío et al., 2019). Since 1999 various reaches of
27 the Rhône have been restored as part of a programme to regain lateral connectivity by removing
28 dykes, installing migratory fish passages, increasing minimum flow, and regenerating floodplain
29 channels and habitats that are no longer maintained or created by fluvial processes by dredging
30 alluviums (Riquier et al., 2015). However, the implementation of this programme was hampered by
31 the politicisation of sediment through the issues of flooding and pollution. We will see more closely
32 how sediment came to be pushed into politics.
33
34
35
36
37
38
39
40
41

42 3. The contemporary politics of sediment

43
44 Sediment is subject to politics. It becomes political when policies are devised to address specific
45 problems framed around sediment (i.e. quantity or quality) or when actors use sediment to defend their
46 interests. The concept of politicisation can be defined as the 'requalification of any social activity
47 that comes from an agreement between social agents to question or transgress the existing separation
48 of activities'³ (Lagroye, 2003, pp.360-361). According to Lagroye, politicising an activity or matter
49 would mean changing, or intending to change, the category (social, political) it belonged to. The
50 process of politicisation is not limited to qualifying an activity or matter as political but extends to the
51
52
53
54
55
56
57
58

59 ² A capacitor is an electrical component that stores energy.

60 ³ Authors' translation.
61
62
63
64
65

1 questioning of an institutionalised category. Hence, studying the politicisation of sediment means
2 questioning the apparently natural origin of the existing view of sediment – as a blessing, for example.

3
4 The politicisation of the Rhône’s sediment arose from various sectors, such as professional fishing
5 and flood and dam management, each of which defines the issue in its own way. Having been viewed
6 as a blessing or valuable resource in the past, over time sediment came to be seen as a natural hazard.
7 It can now be considered a threat for reasons of quantity, such as when it is blamed for exacerbating
8 floods or destroying biodiversity during dam flushing, or quality, such as when it contaminates fish
9 and ultimately humans through the bioaccumulation of pollutants or spoils agricultural soil due to its
10 adverse quality. Focusing on the politicisation leads to a questioning of the legitimacy of a particular
11 order. The politics of sediment, which involve new ways of viewing it or making it (in)visible, or even
12 a new framing of the issue, usually arise at times of dispute. Indeed, modifying the existing order
13 implies a transgression of accepted categories, but one that can be legitimised by a specific crisis.
14 Three forms of the politicisation of sediment on the Rhône arose during sociopolitical crises connected
15 to pollution, flooding and dam flushing.
16
17
18
19
20
21
22
23

24 Sediment and pollution

25
26 Rivers receive many different persistent organic pollutants, including PCBs, that are released into
27 the environment by improper disposal, leakage, incineration and volatilisation (Mourier et al., 2014).
28 PCBs attach to sediment, which is ingested by fish that are then unsuitable for human consumption.
29 Indeed, PCBs have an impact on aquatic biota and, ultimately, human health through bioaccumulation
30 (Lopes et al., 2012). The production, use, and sale of PCBs were prohibited in the 1980s; however,
31 river dynamics, such as floods and dam flushes, have been contributing to the dissemination of PCBs
32 in the environment (Mourier et al., 2014).
33
34
35
36
37

38 In the 1980s local scientists and NGOs highlighted the issue of the Rhône’s fish being
39 contaminated with chemicals such as PCBs, but the authorities did not allow the warnings to reach the
40 public. With two European Directives, in 1976 and 1985, the use of PCBs was prohibited in France in
41 1987, giving the impression that the problem had been dealt with (Gramaglia and Babut, 2014). In
42 1996 the Council of the European Union planned PCB decontamination in several countries, but by
43 2002 France was criticised for having done too little too late to confront the issue (Comby et al. 2014).
44 As a result, the problem came to light again in 2005 locally in the Lyon urban area, in 2007 along the
45 Rhône Valley and then nationally through sediment. In 2005, in order to reassure his clients of the
46 safety of Rhône fish, a professional angler submitted two sample breams to the local veterinary
47 services for analysis. A high concentration of PCBs was discovered in them. As a result, the prefect of
48 the Rhône department imposed a ban on the sale and consumption of fish from the area where the first
49 two had been caught (Meunier, 2008). Following the initial discoveries, several surveys were
50 conducted within the valley, at certain points along the Rhône River up to the delta. These led to
51 further department-wide bans on fish from almost every point on the river. This raised the issue of
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 public authority jurisdictions with regard to rivers. The ban on fish consumption was imposed by the
2 prefect, meaning the measure was taken at the departmental level. As the Rhône marks the boundary
3 between departments, a fish could not be eaten on the left bank (the Prefecture of Rhône and Isère
4 prohibited the sale and consumption of fish in February 2007), yet the same ban did not come into
5 force until several months later, in June 2007, in the Loire Department on the right bank. Many
6 anglers criticised these measures, pointing out that fish and sediment do not recognise departmental
7 boundaries.
8
9

10
11 The pollution crisis made sediment a political object, notably through the actions of a few local
12 elected representatives upstream of Lyon where the first two contaminated breams had been fished.
13 They maintained pressure on the authorities to act on the problem and helped to frame the issue as
14 affecting the entire river rather than just their local area, thereby highlighting the disseminating role of
15 sediment (Vionnet, 2011). Prior to 2007 the main stakeholders had been the prefects, a few mayors
16 and an environmental NGO, but by the end of 2007 the role of the state and the presidential majority
17 had become prominent (Comby et al., 2014). Thus, on 10 October 2007 the Minister of Ecology
18 Nathalie Koscisuko-Morizet appeared beside the Rhône River to announce a national response (a
19 commission and research programme) to the pollution of French rivers by PCBs. A National
20 Assembly commission ordered a parliamentary report, which was produced in 2008, entitled ‘The
21 Rhône and PCBs: long-term pollution’ (Meunier, 2008). The member of parliament responsible for the
22 report belonged to the same party as the president and represented the area where the first two
23 contaminated breams had been caught. At the same time the association of professional anglers on the
24 Rhône filed a complaint, demonstrating the degree of concern from those in the private sector who
25 were dependent upon fish production (Meunier, 2008). Similarly, environmental NGOs highlighted
26 the unwitting actions of the dam operators (EDF and CNR) during river dredging that would be
27 spreading contaminated sediment (Vionnet, 2011). The local and national media broadcast alarming
28 information about the dangerous nature of PCBs and the fact that a public health crisis had been
29 allowed to happen despite the authorities having been aware of the dangers twenty years earlier. The
30 term ‘French Chernobyl’ was used several times by bloggers and NGOs (Meunier, 2008).
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45

46 The broadening of the PCB debate to the full length of the river had the effect of widening the
47 administrative responsibility from the prefect of the Rhône Department to the river basin prefect in
48 2007 (Gramaglia and Babut, 2014) and then to the national level. As a result of this local crisis, a
49 national action plan was adopted in 2008 to improve scientific knowledge on the dissemination of
50 PCBs through sediment and to introduce the widespread monitoring of fish intended for human
51 consumption (Gramaglia and Babut, 2014). From 2005 to 2007 studies concentrated primarily on
52 sediment and fish. Since 2008, however, in addition to examining more and more species of fish and
53 types of sediment, researchers have also examined invertebrates and sediment cores (Comby et al.,
54 2014). Scientists are working to establish the broader role of sediment pollution throughout the
55
56
57
58
59
60
61
62
63
64
65

1 hydrologic cycle. According to scientists, it will be at least another decade before PCB concentrations
2 meet the regulatory level for fish consumption (Mourier et al., 2014). Fluvial dynamics mean that PCB
3 concentrations in sediment increase exponentially in a downstream direction, and that they are
4 unlikely to diminish in the short term (Mourier et al., 2014). The significance of contaminated
5 sediment to local actors was illustrated by the nexus that was discovered between floods, dam flushes,
6 and contaminated sediment. Since 2007, however, the Plan Rhône (a development contract linking
7 riverbasin stakeholders, the state, and the EU) brought local actors into river management,
8 encouraging studies on PCBs and the tackling of the issue at the basin level. Sediment spread PCBs,
9 and PCBs in turn framed sediment as a threat, due to its contamination, via the human consumption of
10 fish. This pollution crisis impacted the treatment of another major public concern along the Rhône:
11 flood risk.
12

13 The nexus of sediment and flood

14 Subsequent events were to reactivate the issues of sediment quantity and quality, including floods
15 and the restoration of the Rhône's meanders. Sediment was placed on the political agenda by flooding
16 on the Rhône and its tributaries between 1990 and 2003. Severe events occurred in 1993, 1994, 2002
17 and 2003, around the Rhône and/or its tributaries that caused extreme damage. In 1993 dyke breaches
18 caused severe damage in the delta; the events of 1994 claimed 10 lives; in 2002 flooding on Rhône
19 tributaries caused 23 deaths in the Gard department; and in 2003 the Rhône and its tributaries flooded
20 a large area, causing 1 billion euros of damage (Guerrin, 2014).
21

22 Sediment was accused of aggravating the impact of flooding by lowering river margins and
23 narrowing riverbeds. Dredging the river and removing sediment, in particular from the meanders of
24 the 'former Rhône', became a regular demand from flood victim associations and local representatives
25 in order to improve flood protection (Barthélémy and Souchon, 2009; Guerrin, 2014). Debates
26 organised after a flood on the Rhône River in 2003 revealed that those affected by the flooding who
27 were in attendance tended to believe that the river was becoming filled up with sediment and that the
28 answer, therefore, was to dredge the river. According to Barthélémy and Souchon (2009), these
29 impressions are based on what locals can see, such as bridge piers and *casiers Girardon* filled with
30 sediment. Others suggest that such observations would be reinforced by a sceptical view of the CNR,
31 whose programme of river containment had been understood by locals to include levees that would
32 protect them from flooding (Guerrin, 2014). Indeed, they had been encouraged in this view by the
33 CNR's communication strategy while developing hydropower. Following the floods of the 1990s and
34 2000s the CNR, along with the state, was regularly held responsible for what was seen as the failure of
35 the levee and dam system. As a consequence, the CNR was also blamed for the issue of sediment,
36 which was seen as having been exacerbated by dams (Guerrin, 2014).
37

38 The demand for sediment to be removed from the river was then incorporated into the ecological
39 agenda of environmentalists calling for the restoration of the Girardon infrastructure and the meanders
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 of the former Rhône. In 1999, when the environmentalist Dominique Voynet entered government, a
2 10-year programme for the Rhône was launched. It aimed to restore a ‘fast and flowing river’. State
3 authorities and scientists understood this as increased river flows to benefit specific migratory fishes,
4 but for urban planners and riverside municipalities it meant more life in former meanders, more
5 amenable landscapes and more space for water during flooding (Barthélémy and Souchon, 2009).
6 They requested that sediment be excavated in order to store floodwater and reduce damage. However,
7 the PCB crisis raised concerns over the practice of putting sediment back into the water (Bouleau et
8 al., 2018), and the project to remove the *casiers Girardon* was blocked from 2005 to 2010 (Thorel et
9 al., 2018).

10
11
12
13
14
15 Sediment quality was also used as political leverage to oppose a floodplain restoration project on
16 the downstream Rhône. The 1990s saw changes to state flood policy in France, and more broadly in
17 Europe and the United States (Guerrin and Bouleau, 2014). The public savings ideology proponents
18 questioned the public expense of dyke building and flood damage compensation, and Western
19 governments became less and less willing to fund them. This new approach opened an avenue for
20 environmentalists who had long criticised the impact of dykes on freshwater ecosystems. They
21 successfully claimed that flooding was beneficial for the managing of sediment, land fertility, and
22 groundwater recharge, and thereby gained public support for the restoration of the Rhône (Bouleau et
23 al., 2018).

24
25
26
27
28
29
30
31 However, not everyone was ready to celebrate the benefit of sediment brought by flooding. The
32 mayors of two municipalities located on the downstream Rhône, Piolenc and Mornas, overcame their
33 former political rivalry and came together to oppose the project that had earmarked their areas for
34 floodplain restoration (Guerrin, 2015). To counter the environmentalist narrative of the benefits of
35 sediment, these elected officials drew the public’s attention to the pollution of the Rhône’s sediment
36 (particularly with PCBs) and its potential effect on agriculture and drinking water. They pointed out
37 that contaminated sediment would be transferred, and contrasted this with the high quality of the land
38 along the river thanks to the long-standing separation of agricultural land from (contaminated) water
39 by the CNR dykes. Indeed, the dispersal of PCBs is exacerbated by sediment flushing operations and
40 flooding, since floods cause bank erosion, which results in ‘inputs of less-contaminated sediment in
41 some cases, or in inputs of more contaminated sediment in others’ (Mourier et al., 2014). The
42 politicisation of Rhône pollution was expressed by the media with a familiar dramatic reference:
43 ‘Chernobyl risk in Provence’ (*La Provence*, 6 July 2008). Alongside other concerns and obstacles, the
44 opposition led by Piolenc and Mornas saw the cancellation of the floodplain restoration project
45 (Guerrin, 2014).

46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

1 identified for potential restoration to store floodwater again, sediment came back as an issue but with
2 regard to its *quality*, in terms of pollution. Land and water had been separate for so long that people
3 were no longer used to living with floods. Rather, they had come to see the Rhône as polluted due to
4 the contamination of sediment with PCBs. Those who opposed the floodplain restoration programme
5 used the new evidence and the media coverage generated by the PCB crisis to support their cause.
6 They even recycled the image of Chernobyl that had been used locally during the initial crisis. A plan
7 to store water within a former floodplain, framed as an issue of water quantity, came to be reframed as
8 one of quality by its opponents. Hence, the Rhône's hydrosocial cycle created a link between flooding
9 and the quantity and quality of sediment that was to prevent state action. The question of dam flushes
10 further highlighted the controversial nature of the river's sediment.

17 Sediment becomes transnational through the issue of dam flushing

18 Dams control the flow of sediment in the Rhône. Over time, sediment accumulates behind dams,
19 lowering their water storage capacity and hence their power production. Flushing operations are
20 carried out to mitigate this phenomenon. On the Rhône, dam flushing is managed by the Verbois dam
21 in Switzerland, which has a large reservoir, produces electricity, and prevents flooding in the Geneva
22 urban area. However, it also traps solid material which it must regularly discharge in a process taking
23 place about every three years. Between World War II and 2016, 22 flushing operations were carried
24 out on the Rhône. A flushing event is a temporary and planned disruption of the functioning of water
25 and sediment flows. This dam-water-sediment interaction affects ecosystems and potential uses of the
26 river. Flushing on the Rhône necessitates international cooperation between Switzerland and France,
27 and sees collaboration between the Swiss dam operator (SIG – Geneva Industrial Services) and the
28 CNR in France.

29 From the 1950s to the 1970s French mayors believed that flushing was an effective way to remove
30 pollutants. Yet, in the 1970s the procedure became a political issue as fishers raised objections locally.
31 Initially these concerned the flushing itself, which visibly changed the water by suddenly filling it with
32 sediment. At the time, dam operators carried out the operations in summer, when the water level is
33 low and electricity production less profitable. However, the low water level made the impact of the
34 flushing more obvious (by the sight and smell), potentially affecting tourism and leisure activities (e.g.
35 fishing). Therefore, from the mid-1970s flushing operations were moved from July or August to May
36 to appease the locals.

37 Since 1976 the hydrobiology laboratory at the University of Lyon 1 has been studying the impact
38 of dams on invertebrate fauna. In 1978 a technical company conducted a survey in Brégnier-Cordon
39 (Ain department, Figure 1) and observed that massive amounts of fish would die during flushing due
40 to the anoxic flow (Bravard, 1987). The findings drew the attention of anglers, environmental NGOs
41 and scientists. Indeed, it turned out that the flushing operation of 1978 had been an ecological disaster.
42 The decline in river flow at the Chancy-Pougny dam caused a high concentration of coarse and fine
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 material downstream, notably at the Génissiat dam. Fish mortality was very high up to 100 km
2 downstream of the dam. The event shed light on the flow of suspended material, emphasising the roles
3 of geomorphology and physical geography in understanding the hydrosystem. In June 1978 an
4 association of anglers filed a complaint in court. Environmentalists, anglers and scientists called for
5 new bilateral management between Switzerland and France of flushing operations and the sediment
6 issue. The CNR adopted specific measures, for example monitoring the minimum flow and
7 sedimentary material during the operation and the creation of a nature reserve. Further, as a result of
8 this issue a specific quantity of suspended material was established with regard to any financial
9 compensation (Comby, 2015). Regulatory standards were set that the French and Swiss dam operators
10 could use to negotiate and establish agreements. While the immediate controversy waned, stakeholders
11 continued to pay greater attention to the issue of sediment.
12
13
14
15
16
17
18

19 Although flushing is usually carried out every three years on the Rhône, none took place between
20 2003 and 2012, in part due to a public inquiry that required bilateral authorisation for each operation
21 (Bréthaut and Pflieger, 2013). The delay was also affected by protests mounted by anglers in
22 Switzerland in 2006 and France in 2010. All were calling for greater transparency in terms of sediment
23 flow through dams, and this created many challenges for flood management in the Geneva area,
24 questioning a usually technical subject: ‘The anglers have played a decisive role. It was unimaginable
25 to question Verbois flushing,’ stated Robert Cramer, a councillor in the canton of Geneva (*Le Progrès*,
26 19 June 2006). The protestors focused not only on the quantity of suspended material but also on flow
27 rates and river ecology. During the French public inquiry organised across 47 communes, mayors
28 expressed concern about, or even openly opposed, flushing. In an interview with a regional
29 newspaper, the mayor of Aoste explained: ‘We are going to see our Rhône loaded with mud and many
30 other things. We have been Switzerland’s dump for years and it is still going on’ (*Le Progrès*, 27 May
31 2012). In the same article the mayor of Creys-Mépieu said, ‘we voted against the operation because of
32 the nature reserve. It is a scandal for flora and fauna to flush at this time of year. The results are less
33 harsh in winter’. An environmental group declared they ‘would prefer that flushing operations take
34 place in autumn because of breeding periods. It could be done another way; for example, by removing
35 the sediment more gradually. Yet one must understand that the Swiss do as they want. They have the
36 Lake Geneva tap that allows them to work on the river’. The Swiss stakeholders are perceived to be
37 more powerful because they generate the Rhône’s flow by controlling Lake Geneva. The issue of
38 flushing, therefore, embodies the unbalanced relationship between upstream and downstream
39 stretches. Because of local resistance on the Swiss and French sides, the dam operators had to
40 postpone the operation that was scheduled for spring 2010.
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55

56 The flushing operation eventually took place in June 2012 and garnered huge media coverage. The
57 level of the Chancy-Pougny dam was lower than expected. There was a lot of rain. Facing very high
58 concentrations of suspended material, the Swiss dam operator decided to stop the flushing operation
59
60
61
62
63
64
65

1 before it was complete. A few months later the Swiss operator explained that it had not been 2.6 mm³
2 of sediment that had transited from Switzerland to France as expected but 4.3 mm³ (*Le Progrès*, 5
3 March 2013). An environmental group suspected that the SIG had done it on purpose. Rumours
4 fuelled the tension. The events had economic as well as ecological consequences: the CNR announced
5 an 8 million-euro loss due to the pause in hydroelectric production, having to pay staff in the field to
6 ensure people's safety, save fish, and monitor the flushing operation, and running an awareness
7 campaign to forewarn river users. The object of people's anger was thus twofold, namely the
8 ecological and economic impact of having failed to comply with the legal level of suspended material,
9 which had been central to the balance of the system of actors since the event of 1978.
10

11
12
13
14
15 As has been seen, flushing can fuel a negative perception of sediment due to the change in the
16 colour of the water during the operation, the size of the sediment (Le Lay et al., 2013), the quantity of
17 dead fish, and the issue of pollutants. The event of 2012 led some environmental groups to blame
18 sediment, even calling it 'shit' (*Le Progrès*, 5 March 2013). Flushing operations disturb riverscapes.
19 They remind inhabitants and users that the river is made of water and sediment. Views of sediment are
20 built both from residents' experiences of it and detailed scientific monitoring by geomorphologists,
21 hydrologists, and ecologists. One feature of the Rhône River is the transnational character of its
22 flushing operations, where sediment flows from Switzerland to France, and the multilevel governance
23 of this flow has been crucial in minimising disputes.
24
25
26
27
28
29
30

31 Conclusion

32
33
34 Sediment has a social and political life. Once welcomed as a valuable resource, sediment has come
35 to be criticised for its quality by impacting biodiversity and also fishing and its quantity, being blamed
36 for exacerbating flood damage. Sediment is subject to evolving interpretations, meanings, uses, and
37 means of knowledge production, depending on historical, socio-natural and technical factors. The
38 changing governance structure within which the Rhône falls has also affected whether sediment has
39 been viewed as a blessing or a curse. Indeed, the state engineers' monopoly of expertise and the
40 modernist approach to the Rhône's development nullified the role of sediment, which only came back
41 onto the agenda thanks to local residents and elected representatives through sociopolitical crises,
42 conflicts and disputes, which altered the pre-existing power relations. The Rhône's sediment, once a
43 blessing, is now seen largely as a threat, hampering any state action to remove it and implement
44 floodplain restoration projects.
45
46
47
48
49
50
51
52

53 The Rhône is indeed about more than water. As historical and contemporaneous politics remind us,
54 sediment is part of water, and their combination affects sociopolitical processes that have a dialectical
55 impact on biological and physical sediment dynamics. Indeed, sediment is deeply embedded within
56 the Rhône's hydrosocial cycle. The management of the Rhône's water as a resource affected sediment
57 dynamics, highlighting the fact that water is not only about H₂O but also about sediment transport.
58
59
60
61
62
63
64
65

1 Sediment dynamics on the Rhône were deeply affected by technological developments in terms of
2 their quantity and quality. Today, technology is in turn affected by the social and political life of
3 sediment, when dam flushing is the subject of dispute and local opposition. The Rhône may not look
4 like a muddyscape, since water and land seem clearly separated, but conceptually it is. Sediment – a
5 natural feature – now confronts hydraulic infrastructure, and the societies it supports, head on. The
6 mud that engineers had hoped to hide has dramatically re-emerged as a critical issue.
7
8
9

10 Sediment is involved in socio-natural processes and is, therefore, an object of natural as well as
11 social science. In 2009 the Rhône Sediment Observatory (OSR) was established. Its research teams,
12 spread along the river, gather data on the quantity and quality of sediment, as well as the levels of
13 contamination. There are currently no social scientists at the OSR. Yet it has enormous potential as a
14 forum for the comprehensive exchange of ideas between those in the social and natural sciences about
15 socio-natural sediment dynamics. The social sciences have a role to play in highlighting the effects of
16 sediment dynamics on societies and of social dynamics on sediment.
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Reference list

1
2 Allard P, Maurice Corsand L (2004) La gestion des espaces humides, d'un mode à l'autre :
3 changement et continuité dans le bas Rhône. In: Burnouf J, Leveau P (ed) Fleuves et marais, une
4 histoire au croisement de la nature et de la culture. CTHS, Paris, pp 355-364.
5
6

7
8 Baehrel R (1988) Une croissance. La Basse Provence rurale de la fin du XVI^e siècle à 1789.
9 EHESS, Paris.
10

11
12 Barthélémy C, Armani G (2015) A Comparison of Social Processes at Three Sites of the French
13 Rhône River Subjected to Ecological Restoration. *Freshwater Biology* 60 (6): 1208-20.
14

15
16 Barthélémy C, Souchon Y (2009) La restauration écologique du fleuve Rhône sous le double
17 regard du sociologue et de l'écologue. *Natures Sciences Sociétés* 17 (2): 113-21.
18

19
20 Benford R, Snow D (2000) Framing Processes and Social Movements: An Overview and
21 Assessment. *Annual Review of Sociology* 26 (2000): 611-39.
22

23
24 Bernardy (1733) Rapport du Sieur Bernardy, Bibliothèque municipale d'Arles, Ms. 893, Arles.
25

26
27 Borraz O, Gilbert C, Joly PB (2007) Risk Studies: The French Contribution. *Journal of Risk*
28 *Research* 10 (7): 941-57.
29

30
31 Bouleau G, Barthélemy C, Comby E, Guerrin J (2018) The social life of solid load in the Rhône
32 River: friends and enemies of sediments. Dams, Sediment Discontinuity, and Management Responses
33 in Mediterranean River Basins Seminar; Lyon, France, 5 of October.
34

35
36 Bravard JP (1987) Le Rhône. Du Léman à Lyon. La Manufacture, Lyon.
37

38
39 Bravard JP (2010) Discontinuities in braided patterns: The River Rhône from Geneva to the
40 Camargue delta before river training. *Geomorphology* 117: 219-33.
41

42
43 Bréthaut C, Pflieger G (2013) The shifting territorialities of the Rhone River's transboundary
44 governance: a historical analysis of the evolution of the functions, uses and spatiality of river basin
45 governance. *Regional Environmental Change* 15 (3): 549-58.
46

47
48 Cobb R, Elder C (1972) Participation in American Politics: The Dynamics of Agenda-Building.
49 Allyn and Bacon, Boston, MA.
50

51
52 Comby E (2015) Pour qui l'eau ? Les contrastes spatio-temporels des discours sur le Rhône
53 (France) et le Sacramento (Etats-Unis). Dissertation, Université Jean Moulin Lyon 3
54

55
56 Comby E, Le Lay Y-F, Piégay H (2014) How chemical pollution becomes a social problem. Risk
57 communication and assessment through regional newspapers during the management of PCB
58 pollutions of the Rhône River (France). *Science of the Total Environment* 482: 100-115.
59
60
61
62
63
64
65

1 Comby E, Le Lay Y-F, Piégay H (2019) Power and Changing Riverscapes: The Socioecological
2 Fix and Newspaper Discourse Concerning the Rhône River (France) Since 1945. *Annals of the*
3 *American Association of Geographers* 109:1671–1690.

4
5 Dépret T, Riquier J, Piégay H (2017) Evolution of abandoned channels: Insights on controlling
6 factors in a multi-pressure river system. *Geomorphology* 294: 99–118.

7
8
9 Duchêne F, Marchand L (2015) *Lyon, vallée de la chimie. Traversée d'un paysage industriel,*
10 Editions Libel, Lyon.

11
12
13 Goffman E (1974) *Frame analysis: An essay on the organization of experience.* Harvard University
14 Press.

15
16
17 Gramaglia C, Babut M (2014) L'expertise à l'épreuve d'une controverse environnementale et
18 sanitaire: la production des savoirs et des ignorances à propos des PCB du Rhône (France). *VertigO* 14
19 (2).

20
21
22 Guerrin J (2014) *Une inondation négociée? Politisation d'un risque naturel sur le Rhône.*
23 Dissertation, Université Montpellier I.

24
25
26 Guerrin J (2015) A Floodplain Restoration Project on the River Rhône (France): Analyzing
27 Challenges to Its Implementation. *Regional Environmental Change* 15 (3): 559-68.

28
29
30 Guerrin J, Bouleau G (2014) Remparts ou menaces ? Trajectoires politiques de l'endiguement en
31 France, aux Pays Bas et aux Etats Unis. *Revue Internationale de Politique Comparée* 21 (1): 89-109.

32
33
34 Kingdon J (1984) *Agendas, alternatives and Public Policies.* Little Brown, Boston.

35
36
37 Lafaye de Micheaux F, Mukherjee J, Kull CA (2018) When hydrosociality encounters sediments:
38 Transformed lives and livelihoods in the lower basin of the Ganges River. *Environment and Planning*
39 *E: Nature and Space* 1 (4): 641-63.

40
41
42 Lagroye J (2003) Les processus de politisation. In Lagroye J (ed) *La politisation.* Belin, Paris,
43 pp. 359-372.

44
45
46 Lahiri-Dut K (2014) Beyond the water-land binary in geography: Water/lands of Bengal re-
47 visioning hybridity. *ACME: An International Journal for Critical Geographies*, 13(3): 505-529.

48
49
50 Lamouroux N, Gore JA, Lepori F, Statzner B (2015) The ecological restoration of large rivers
51 needs science-based, predictive tools meeting public expectations: an overview of the Rhône project.
52 *Freshwater Biology* 60:1069–1084.

53
54
55
56 *La Provence*, 6 July 2008, "Les dangers d'une crue maîtrisée"

57
58
59 Le Lay YF, Piégay H, Rivière-Honegger A (2013) Perception of braided river landscapes:
60 implications for public participation and sustainable management. *J Environ Manage* 119: 1–12.

61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Le Monde, 14 May 1966, "En amont de Lyon le Rhône est exempt de solution"

Le Monde, 16 June 1972 : Henri Briot, "L'Hallali des rats"

Le Progrès, 19 June 2006, Annick Stevenson, "Le Rhône soumis à l'examen : à l'origine, quelques pêcheurs", p. 8

Le Progrès, 27 May 2012, Michel Thomas, "La vidange du barrage suisse de Verbois inquiète les élus", p. 17

Le Progrès, 5 March 2013, Olivier Leroy, "Chasses du Rhône : les Suisses ne veulent pas parler d'argent", p. 9

Linton J (2010) *What Is Water ? The History of a Modern Abstraction*. UBC Press, Vancouver.

Linton J, Budds J (2014) The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum* 57: 170-80.

Lopes C, Persat H, Babut M (2012) Transfer of PCBs from bottom sediment to freshwater river fish: A food-web modelling approach in the Rhône River (France) in support of sediment management ». *Ecotoxicology and environmental safety* 81: 17-26.

Meunier P (2008) *Le Rhône et les PCB : une pollution au long cours*. Rapport pour la Commission des affaires économiques, de l'environnement et du territoire, Assemblée nationale, Paris.

Morera R (2011) *L'assèchement des marais en France au XVIIIe siècle*, Presses universitaires de Rennes, Rennes.

Morera R (2016) *Mise en valeur des zones humides et associations de gestion. Naissance et affirmation de nouveaux pouvoirs territoriaux (France, XVI^e-XVIII^e siècles)*. *Siècles - Cahiers du Centre d'histoire Espaces et Cultures* 42.

Mourier B , Desmet M, Van Metre PC, Mahler BJ, Perrodin Y, Roux G, Bedel JP, Lefèvre I, Babut M (2014) Historical records, sources, and spatial trends of PCBs along the Rhône River (France). *Science of the Total Environment* 476: 568-76.

Parrot E (2015) *Analyse spatio-temporelle de la morphologie du chenal du Rhône du Léman à la Méditerranée*. Dissertation, Université Jean Moulin Lyon 3.

Portet P (2004) *Bertrand Boysset, la vie et les œuvres techniques d'un arpenteur médiéval (1355-1416)*. Éditions le Manuscrit, Paris.

Pritchard SB (2004) Reconstructing the Rhône: The Cultural Politics of Nature and Nation in Contemporary France, 1945-1997. *French Historical Studies* 27 (4): 765-99.

Pritchard SB (2011) *Confluence. The Nature of Technology and the Remaking of the Rhône*. Harvard University Press, Cambridge.

1 Provansal M, Dufour S, Sabatier F, Anthony EJ, Raccasi G, Robresco S (2014) The geomorphic
2 evolution and sediment balance of the lower Rhône River (southern France) over the last 130 years:
3 Hydropower dams versus other control factors. *Geomorphology* 219: 27-41.
4

5 Quiqueran de Beaujeu P (1999) *Louée soit la Provence* [French translation by Véronique
6 Autheman *De laudibus Provinciae*, Lambert Dodu, Paris, 1551]. Actes Sud, Arles.
7
8

9 Râpple B (2018) *Patrons de sédimentation et caractéristiques de la ripisylve dans les casiers*
10 *Girardon du Rhône : approche comparative pour une analyse des facteurs de contrôle et une évaluation*
11 *des potentialités écologiques*. Dissertation, Université de Lyon.
12
13

14 Riquier J, Piégay H, Šulc Michalková M (2015) Hydromorphological conditions in eighteen
15 restored floodplain channels of a large river: linking patterns to processes. *Freshw Biol* 60:1085–1103.
16
17

18 Rossiaud J (2007) *Le Rhône au Moyen Âge*, Aubier, Paris.
19
20

21 Roucaute E (2004) Gestion et exploitation des marais arlésien au Moyen Âge. In: Burnouf J,
22 Leveau P (ed) *Fleuves et marais, une histoire au croisement de la nature et de la culture*, CTHS, Paris,
23 pp. 245-252.
24
25

26 Snow DA, Rochford Jr EB, Worden SK, Benford RD (1986) Frame alignment processes,
27 micromobilization, and movement participation. *American sociological review* 51: 464-481.
28
29

30 Stoff L (1993) La lutte contre les eaux dans les pays du bas Rhône XIIe – XVe siècle. L'exemple
31 du pays d'Arles. *Méditerranée* 78: 57-68.
32
33

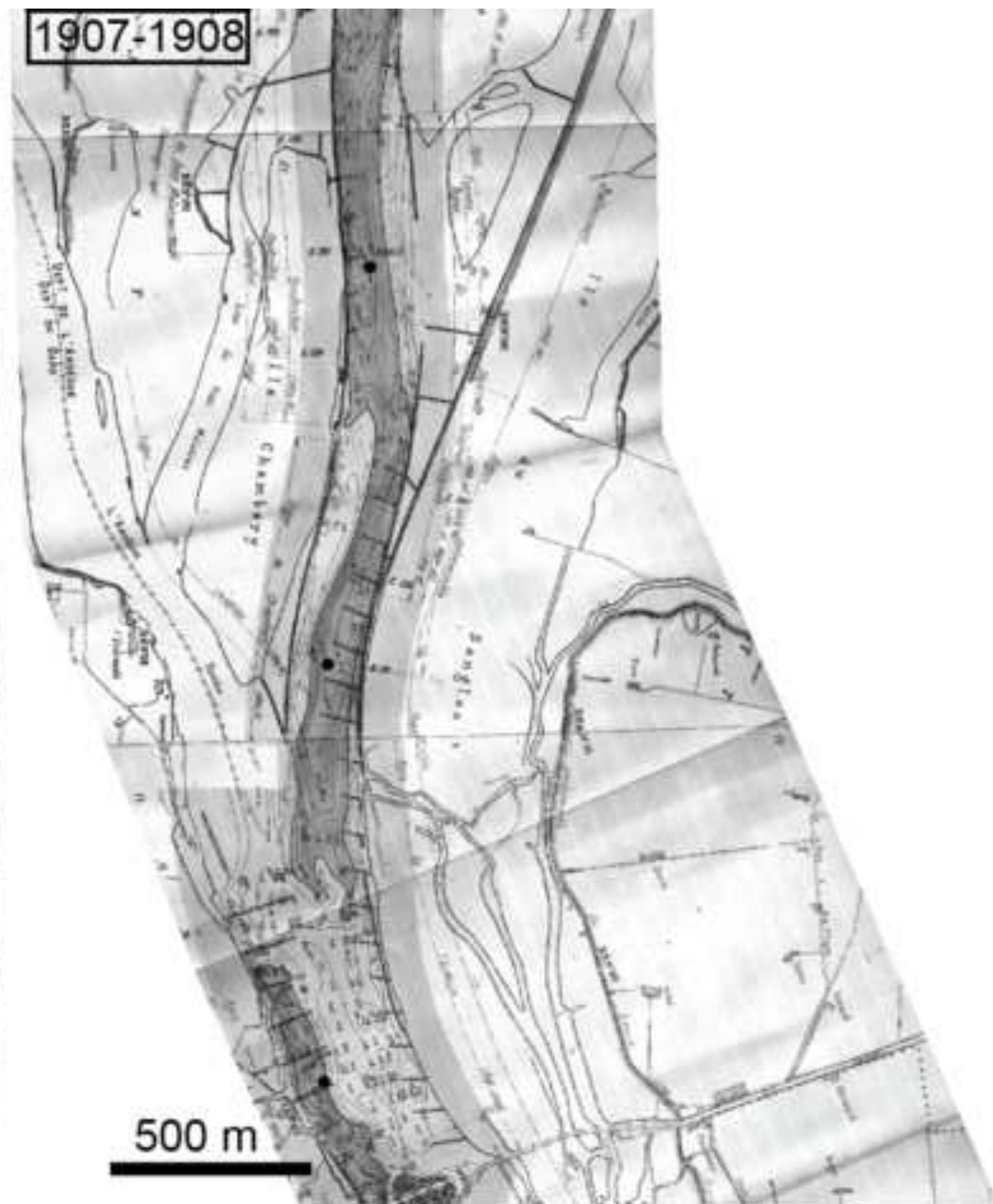
34 Thorel M et al. (2018) Socio-Environmental Implications of Process-Based Restoration Strategies
35 in Large Rivers: Should We Remove Novel Ecosystems along the Rhône (France)? *Regional*
36 *Environmental Change* 18 (7): 2019-31.
37
38

39 Vauclin S, Mourier B, Tena A, Piégay H, Winiarski T (2019) Effects of river infrastructures on the
40 floodplain sedimentary environment in the Rhône River. *J Soils Sediments* : 1-12.
41
42

43 Vázquez-Tarrío D, Tal M, Camenen B, Piégay H (2019) Effects of continuous embankments and
44 successive run-of-the-river dams on bedload transport capacities along the Rhône River, France.
45 *Science of the Total Environment* 658:1375–1389.
46
47
48

49 Vionnet A (2011) *La pollution du Rhône aux PCB : la mise à l'agenda d'un problème public et sa*
50 *gestion à travers une politique publique environnementale partenariale*. Dissertation, Université
51 *Lumière Lyon 2*.
52
53
54
55
56
57
58
59
60
61
62
63
64
65





**Cadastre napoléonien
(Archives départementales du Vaucluse)**

**Bathymetric chart
(Compagnie nationale du Rhône)**