

## Looking at half a millennium of co-existence: the Danube in Vienna as a socio-natural site

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**Abstract** Which insights can be gained from a long-term study for river management today? Vienna's layout and city budget are still influenced by interventions undertaken in the 19th century or even earlier. This introduction to a thematic issue on the Viennese Danube's environmental history from 1500 to 1890 offers a short overview of important events in Vienna's and the Danube's intertwined histories as well as an overview of the study's conceptual basis and summarizes the main results, ranging from method development and floodplain evolution reconstruction to the histories of settlement, sewage and regulation. Today, Vienna is a city with almost 2 million inhabitants, the capital of a small, landlocked country. Since the great regulation of the 1870s, the Danube river has flowed straight through it. A second, parallel river bed was designed in the 1970s to build a retention basin big enough to cope even with major floods. The path leading to this arrangement was both long and winding. To understand the complex interaction between urbanites and the river, one must look beyond the water-filled channel and take the entire floodplain into account. To do this, our interdisciplinary group of researchers synthesized results from river morphology and history into a long-term perspective.

**Keywords** Danube · Long-term-socio-ecological research · Vienna · Socio-ecological site · River · Regulation · Environmental history

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There is nothing more difficult than writing a history of the rivers' courses and their changes; in particular that of the Danube, a river always throwing up new islands, digging new beds, and filling up the abandoned with pebble.  
(Alois Groppenberger von Bergenstamm, Vienna 1812, transl. by the authors).

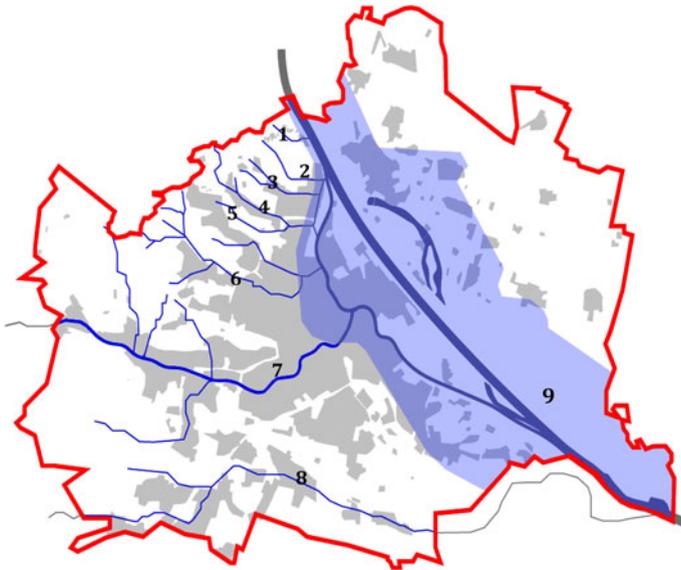
## Introduction

Today, Vienna is a city with almost 2 million inhabitants, the capital of a small, landlocked country. Since the great regulation of the 1870s, the Danube river has flowed straight through it. A second, parallel river bed was designed in the 1970s to build a retention basin big enough to cope with even major floods (cp. Figs. 1 and 2). The path leading to this arrangement was both long and winding. To understand the complex interaction between urbanites and the river, one must look beyond the water-filled channel and take the entire floodplain into account. To do this, our interdisciplinary group of researchers synthesized results from river morphology and history into a long-term perspective, framed within environmental history.

The environmental history of the pre-modern Viennese Danube and its transformation in the 19th century offers a baseline for the evaluation of the river's role in Vienna during the 20th and 21st century, much of which can be better understood through a long-term perspective. Almost a fifth of Vienna's built-up area now lies in the former floodplain, and many of the nearly two million Viennese live in a former riverine landscape, although most of them are probably not aware of their fundamental dependence on control of the river being maintained. Yet vulnerability has not decreased, but rather increased, now that a major part of the Viennese population live in low-lying parts of the floodplain and depend on protective infrastructures (see Fig. 1).



**Fig. 1** Vienna and the Danube today, the extension of the historical floodplain is highlighted with blue shading (graphic design by Friedrich Hauer, based on an orthophoto by the city of Vienna, the former floodplain is taken from the land survey under emperor Joseph II—"Josephinische Landesaufnahme"—from 1773–1781)



**Fig. 2** Vienna and the Danube after 1875. Boundaries are those of Vienna's current territory. The area studied in the project ENVIEDAN, including the course of the Danube and its main tributaries is highlighted with blue shading; the latter (among others 1 Waldbach, 2 Schreiberbach, 3 Nesselbach, 4 Arbesbach, 5 Krottenbach, 6 Als, 7 Wien, 8 Liesing) flow from the hilly regions west of the city, the Vienna Woods (*Wienerwald*) with heights up to 542 m a.s.l., into the Danube; the lowest terrain is in today's *Lobau* (9), a remnant of the former floodplain in the city's southeast, at 151 m a.s.l. Grey shading denotes built-up areas in 1913 (graphic design by Friedrich Hauer, based on a hydrographical map of Magistratsabteilung 45 "Wiener Gewässer", city of Vienna)

Concrete dams, once-wandering channels straitjacketed into navigational routes with stabilised banks, and bridges over and tunnels below the river all foster the urbanites' impression that this landscape has been completely conquered, and stabilised indefinitely. Vienna today has four watercourses called "Danube," remnants of a riverine landscape that once spanned more than 6 km in width. The *Alte Donau* ("Old Danube"), which today is more of a lake than a river, was the main channel until the 1870s, and at that time situated at a distance from the city. Over centuries, ships had come to Vienna on the *Donaukanal*, still marking the southwestern edge of the riverine landscape in historical times. What the Viennese call the "Danube" today, is the riverbed excavated between 1870 and 1875 by a thousand workers under miserable conditions with the aid of French machines brought from the recently finished Suez Canal (Holzer and Limbeck-Lilienau 2005, 68). A century later, further improvements in flood protection resulted in the *Neue Donau* ("New Danube"), a flood bypass finished in 1988; this "New Danube" constitutes the main flood protection for the city today. In the wake of this new regulation, a 21 km-long artificial island, the *Donauinsel* (Danube Island), was created, offering recreational benefits in addition to flood protection.

Another visible difference between pre-industrial and industrial interventions into rivers is represented by the new arrangement of the Viennese Freudenu power plant. Downstream of the power plant, the left bank of the Viennese Danube is part of a national park. This stretch is considered one of the last remaining free-flowing sections of the river. However, the groundwater level is manipulated to extract drinking water for Vienna's

inhabitants. Species composition differs fundamentally from that of earlier days due to the anthropogenically influenced flood dynamic.

Two driving forces dominate the Danube and its continuing transformation today: Power generation and long-distance bulk transport. Interest, and hence perception, practices and arrangements have shifted from the nutrient-carrying abilities of the river and the use of fertile floodplains to the use of its energy in power plants. Banks are steep, secured with stones, while groynes and dikes along the river secure a stabilised difference between land and water. Vienna has become a major harbour, ever larger ships use the river for transportation, and harbours are built with huge concrete landings. Tourism along the river also flourishes. Boats of various sizes travel up and down the river, providing passengers with views of the area between Vienna and Bratislava.

Although it might appear as though the industrial re-creation of the river has erased all former interventions and that conditions are fundamentally different now from those “in the past”, the past is in fact visible in the layout of Vienna and its four ‘Danubes’ and continues to influence urban development.

Figure 2 shows the city of Vienna in 1913 with the river and its tributary network. The old city centre borders the *Donaukanal*, the former *Wiener Arm*. Due to Vienna’s long history as an imperial centre, the source basis for studying the past is extraordinarily rich. In contrast to cities such as Paris or Strasbourg, which were built on an island in a river, Vienna was built next to one arm of a major river, adjacent to its floodplain, the thicket of islands and rivulets serving as part of the fortification of the town. Siltation therefore proved as much of a problem as floods, prompting river engineering measures documented as early as the 14th century (Thiel 1904, 9). Another distinctive feature is its situation on the upper part of a river with a particular alpine dynamic. The city’s inhabitants were able to cope with the river’s characteristics only due to the ability of the city and its rulers to invest heavily into river engineering measures over the centuries.

This study is a contribution to the growing body of environmental histories of rivers (see Mauch and Zeller 2008 for a recent overview). Rivers have figured prominently in the dynamic development of environmental history (Worster 1985, Steinberg 1991; White 1995; Lewis 2005; Saikku 2005), and environmental histories of rivers have evolved from impact-driven degradation or conquest narratives to co-evolutionary histories of society-nature interactions (Tvedt and Jakobsson 2006). Among European rivers, the Rhine has been the focus of major studies (Cioc 2002; Bernhardt 2007; Blackbourn 2006), and comprehensive studies also exist for the Rhône (Rossiaud 2007, Pritchard 2011) and the Dordogne (Cocula-Vaillières 1981), while for other rivers the literature is confined to particular sections or periods (e.g. Althöfer-Westenhoff and Wagner 1997; Herrmann and Kaup 1997). Urban history has produced a rich historiography, and important studies have dealt with city-hinterland relations and urban supply (Campbell et al. 1993; Galloway 2000, Hoffmann 2007; Crow 2012). Whereas both cities and rivers figure prominently in environmental history (Isenberg 2006; Tarr and Dupuy 1988; Cronon 1991; Melosi 1993; Schott 2007; Winiwarter 1998; Bernhardt 2001; Massard-Guilbaud 2007), city-river interaction has received little attention.

Dieter Schott (2007) has programmatically outlined the challenges of the study of rivers as urban environments; his overview surveys the functions that rivers had for the development of European cities. Stephane Castonguay discussed the construction of floods as catastrophes on the St. Francis and Quebec (Castonguay 2007) and Gavin Weightman (2005), in his book on London, has argued that understanding the Thames is a fundamental part of the history of this city, pointing to the tidal nature of the river as an essential element. Jørgensen (2010) has examined responses to river pollution in English towns from

the late 14th to the 16th centuries, and Castonguay and Evenden (2012) assembled case studies on urban interventions on rivers in North America and Europe during the 19th and 20th centuries. A recent review shows that the main themes of urban water (as opposed to river) history are pollution and urban infrastructures, in particular sewage infrastructure. Antiquity seems to be of special interest, although the vast majority of works deal with the 19th and 20th centuries (Katko et al. 2010). Interdisciplinary, long-term studies are still a novelty. Their particular strength lies in the ability to deal with socio-natural dynamics which play out over the long term of centuries. Furthermore, the magnitude and importance of pre-industrial interventions into rivers becomes tangible with such an approach.

### Vienna and the Danube: a short overview of their common history<sup>1</sup>

The history of the Viennese Danube presented in this thematic issue differs in at least two important aspects from previous work. It focuses on the river landscape as a dynamic feature of the environment of the urban population, rather than on pollution and infrastructure, and it tells a long-term story over the course of half a millennium, thereby being able to show long-term trends and discussing important transformations of the interaction between city and river.

Many major cities were built on the lower reaches of rivers, close to river mouths in estuarine landscapes. Seldom do we find major cities on the headwaters or within the upper reaches of rivers. Vienna is situated on the Upper Danube; this is consequential in at least four respects:

(1) The Danube in Vienna is a mountain river. Its slope is steep, c. 40 cm km<sup>-1</sup> (1.3 feet km<sup>-1</sup>), ten times the slope of the lower Danube. This high amount of kinetic energy is both a challenge and an opportunity for the urban population. (2) The Upper Danube is an Alpine river, with a highly variable flow regime spanning more than an order of magnitude, with a mean flow of c. 1,900 m<sup>3</sup> s<sup>-1</sup> today. Floods are characteristic for the system in all seasons. Thaw floods occur in spring, floods after heavy rainfalls in the upper catchment during summer and autumn, and ice jam floods were once typical in winter. (3) The river transported huge quantities of material from the mountain regions and carried high loads of coarse bed material prior to torrent regulation and slope stabilisation in the mountains. (4) The Danube flows through alluvial plains and gorges in its upper stretch. Vienna is situated downstream of a gorge (*Wiener Pforte*) between Bisamberg and Leopoldsberg (cp. Fig. 4), in the foothills of the Alps. The city is situated on an alluvial stretch, which allows the river to shift its course across a floodplain stretching over approximately 6 kilometres. The Danube has at least four important tributaries in the area that is urbanised today, such as the Wien river (*Wienfluss*), with small watersheds and highly dynamic fluvial regimes as they tumble down from the hilly woodland landscape (*Wienerwald*) to the north and west of the city with its sandstone substrate. The situation of the city is depicted in Fig. 1.

The first evidence of settlement predates our study period. Vindobona, a military outpost of the Roman Empire on its northern border, was created in the first century CE on the Pleistocene terrace above the river. It served as the seat of the Danube fleet which travelled from there as far downstream as the river mouth.

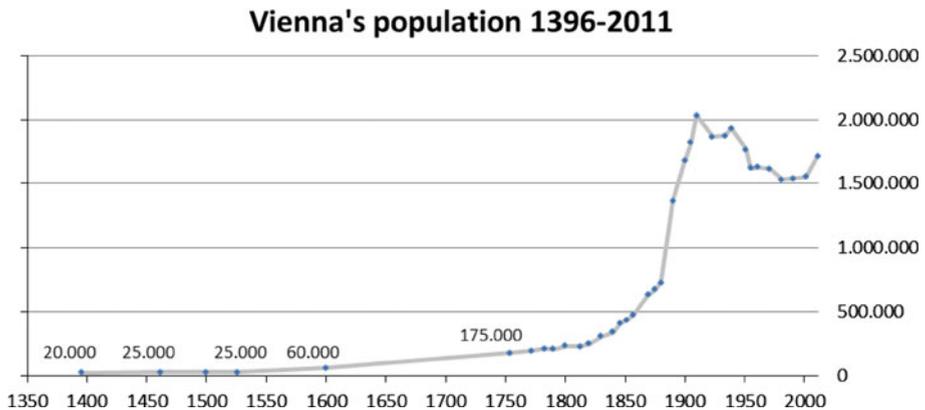
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<sup>1</sup> The complex history of Vienna has brought forth a plethora of studies, although no comprehensive history exists in English. The sketch given here outlines the basic historical context for the study of the Viennese Danube. It does not attempt to do justice to Vienna's multi-faceted past. The main reference text is a history of Vienna in three volumes (Csendes and Opll 2000, 2003, 2006).

The settlement regained prominence from the middle of the 12th century onwards, when Vienna became one of the residences of the ruling Babenberg dukes. Vienna was a political centre, situated at the margins of the Christian world. The Habsburg princes laid claim to lands to the east and southeast on the middle and lower Danube, which were under Ottoman control. This led to continued war with the Ottoman Empire. After the first Ottoman siege in 1529, Vienna became the stable residence of the Habsburgs and thus the seat of important authorities. The Habsburg dynasty had at that time achieved the status of one of the main players in Europe. They held the crown of the Holy Roman Empire almost continuously and acquired more and more territories, among them parts of Hungary and Bohemia, which were finally incorporated into the empire in several steps in the course of the 16<sup>th</sup> and 17<sup>th</sup> centuries. Not least due to constant bloody conflicts between Habsburg and the Ottomans, the Danube was a theatre of war for centuries.

Until the second half of the 19th century, the Vienna floodplain consisted of several fluvial branches forming numerous small and some larger vegetated islands in an ample plain. According to the typology of river morphologists, the Viennese Danube is a “gravel-dominated, laterally active anabranching river associated with a medium-energy, primarily non-cohesive floodplain” (Hohensinner et al. 2013a, in this issue). In short, anyone living close to the Danube in Vienna prior to channelization would have experienced sudden channel changes, ongoing erosion and sedimentation, an amphibious landscape in which land was replaced by water and vice versa incessantly.

At the time of the 1529 siege, Vienna had less than 30,000 inhabitants and was still fortified by its medieval ring wall. To prepare for the next siege, the city was transformed into an Italian style fortress from the 1540s onwards. The Danube plain was part of the defence system and served as a strategically important resource reservoir for supplies. The Ottoman siege in 1683 found Vienna a growing city that would reach a total population of 180,000 inhabitants by 1754. The rate of population growth increased further in the subsequent century. Vienna contained a quarter of a million inhabitants by around 1800, and reached over ten times that figure during the next century through industrialisation (cp. Fig. 3).



**Fig. 3** Vienna's population from the late Middle Ages to the present; note that the boundaries of the city changed substantially from medieval to present times (until 1754, the population within the city wall is counted, from the middle of the 18th century onwards, the population within the *Linienwall* fortification; for the 19th and 20th century cp. Gierlinger et al. 2013, in this issue). The data, plus a detailed study of Vienna's demographic transition and evaluation of data quality in particular before 1750 can be found in Weigl 2000, 50–55

Over the entire study period, the most important function of the river for the city was transportation, using the kinetic energy provided by the swift flow. Another way of harnessing the energy of the water involved ship mills in the Danube upstream of Vienna, and stationary mills along an artificial channel parallel to the major tributary river, the *Wienfluss* (cp. Fig. 5 (Angielini, 1566–1574 in Sonnlechner et al. 2013, in this issue). As grain was milled on-site, these mills were a major component of the food supply system of Vienna. The Danube was important for the provision of food in another way, too. We know through a series of legal acts how important the fish market (*Hoher Markt*, today in Vienna's first district) was from at least 1400 onwards. Hunting in the alluvial forests was an exclusive right of the nobility, being important for social as much as for material reasons. Land use patterns in the riverine landscape echoed the degree of stability of islands and banks. Settlements on the more stable islands are documented at least from the 13th century onwards; orchards, pastures and firewood collection in the alluvial forests and on the islands are evident from the 16th century onwards. Flood protection would later become a major concern in the settled areas. The Danube was least important for fresh water supply. A total of 600–800 wells in the city and water pipes from the hilly regions to the west of the city are documented from around 1500 onwards. However, the river was also the main discharge channel for waste and wastewater. As late as 1879, four years after the great Danube regulation had been completed, considerable amounts of night soil were still thrown into the river downstream of the city (Meissl 2001).

The beginning of the 19th century saw Europe in the grip of the Napoleonic wars. In 1804 the Holy Roman Empire ceased to exist and in 1806 Vienna became the political centre of the newly established Austrian monarchy. Following nationalist conflict, which had been a major problem for over 100 years, the Austrian empire was transformed into the Austro-Hungarian dual monarchy in 1867 with Budapest as a second centre on the Danube's banks. Conflicts had led to a new fortification effort in the early 1700s. Vienna's new line of defence (*Linienwall*) would shape urban development in the decades to come, serving taxation rather than military purposes. In the spring of 1809, Napoleon's army became entangled on the Danube islands, leading to its only defeat during the war, although Napoleon prevailed soon thereafter. After the end of the Napoleonic war, the 1815 Congress of Vienna not only set out the new political order of Europe but also designated the first international river, the Rhine, which was to be controlled by a commission and serve international trade.

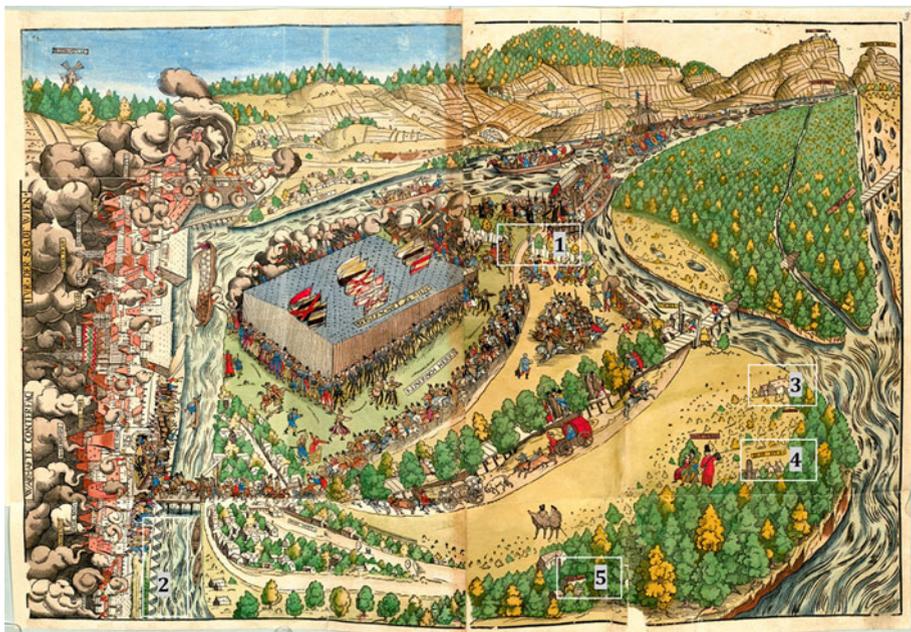
The Danube was in turn created as an international river in 1856, with a commission to safeguard its role as an international trade route focusing on the Danube delta, although this had little bearing on the Viennese stretch of the river. The end of seigniorial control of lands in the aftermath of the 1848 revolution would gradually lead to changes in land use and occupation with ensuing ecological consequences. Under neo-absolutist Habsburg rule, military barracks were built, and the presence of armed forces in Vienna increased. Military activity in the city, which had been important for so many centuries, continued. Nationalist tensions grew within Europe, and in 1914 the onset of WWI only precipitated what had been brewing for decades: the dissolution of the Habsburg monarchy. At that time, Vienna had more than 2 million inhabitants. The end of the Danube monarchy in 1918/19 left the city as the oversized capital of a small, landlocked country, the first Republic of Austria.

### Approaching the Danube conceptually

Richard White's *The Organic Machine: The Remaking of the Columbia River* (1995) examines "the ways in which humans and nature act together to create new, intermingled

forms and processes” (White 1995, 22). We wish to pursue this interpretative approach by looking at the co-evolutionary transformation of practices and arrangements on and in the riverscape over almost 500 years (Winiwarter et al. 2012). White distinguishes between nature and humans. Rather than investigating the ‘natural’ and the ‘cultural’ and their interaction, we suggest investigating ‘practices’ and ‘arrangements’, both understood as socio-natural hybrids (Fischer-Kowalski and Weisz 1999). A plethora of concepts and theories to approach nature-culture or nature-society hybrids and interactions exist, such as ‘ecotechnological’ systems (Hughes 2005), actor-networks (Latour 2005, Callon 1987), the ‘envirotechnical’ (Pritchard 2012) or ‘hybrid causation’ (LeCain 2009). Others suggest ‘assemblages’ (Kelly 2008), ‘social nature’ (Castree 2001), or the consciously hyphenated nature-culture (Haraway 1991). While all these concepts are useful tools, our concept of socio-natural sites as nexus of practices and arrangements permits to investigate interactions without reproducing an ontological difference between nature and culture – a difference that does not exist in the world of hybrids we study.

How can we investigate Vienna as a socio-natural site and its changes through changing practices over time? Maps and topographic views constitute an important part of our sources. They allow us to analyse the practices Vienna’s inhabitants undertook in the dynamic riverscape at specific points in time. It is important to note that not all practices are directly aimed at the procurement of resources; arrangements are equally part of the display of power and thus of the reproduction of social structure. In Fig. 4, the Danube floodplain is utilised as a theatre of display by the newly crowned Emperor Maximilian II.



1 gate (*Porta*), 2 bank protection, 3 ice hut (*Eis grub*), 4 glass kiln (*Glas hut*), 5 hunting lodge (*leger haus*)

**Fig. 4** Ceremonies to welcome Emperor Maximilian II in Vienna in 1563 (from Stainhofer 1566)

On 16 March 1563, he returned to Vienna from his coronation ceremony in Frankfurt. Caspar Stainhofer published an illustrated description of these celebrations (Stainhofer 1566). The picture is mainly devoted to the river Danube, its islands and waters forming the scenery for a grandiose orchestration of triumphant return. The emperor debarks at the upper end of a large island, the *Unterer Werd*. Close to his landing place, right in the middle of the riverscape, the first of several triumphal arches can be seen, a splendid gate (“ain herrlichs tor”, “porta”), daintily decorated with gold, with oranges and other southern fruit. Verses on the arch let the river itself (“der Wasserfluss”) attest with joy his and everybody’s happiness about the emperor’s return. The riverscape serves as an arrangement for the manifestation of social order, whereby the powerful demonstrate their control over nature, be it by mitigating obstacles for navigation or—as in this case—with trees bearing exotic fruit in early spring.

The perceivable, combined change of social as well as of biophysical phenomena, the change of everything that relates to humans in this world, can be described as a transformation of socio-natural sites. Socio-natural sites are nexuses of arrangements and practices. Practices are impossible without material objects and human beings create, via their practices, arrangements from the material world. The arrangements are shaped by practices, being the material precipitates of these.

Even a tree may be an arrangement, if its existence and shape owes anything to human intervention, but more commonly the term refers to e.g., dams, reservoirs, trains and their rails, and the myriad other objects shaped by human practices. If one is interested in the nexus of practices and arrangements, i.e. the socio-natural site, then physical human interaction with the material world becomes a key issue. Work (in its physical sense, as also used by White, 1995, see also Ayres and Warr, 2005) is the sole possibility of material interaction, although it is based on perception, representation and programmes. Work, which is bounded by both practices and arrangements (e.g. a taboo governing the felling of trees on Sundays, and an axe), is an intervention into material arrangements; it changes these arrangements, which leads to changes in practices, which in turn has an impact on where and how work can be done. Building a bridge facilitates the crossing of a river, but the same bridge may also become an obstacle for shipping transport.

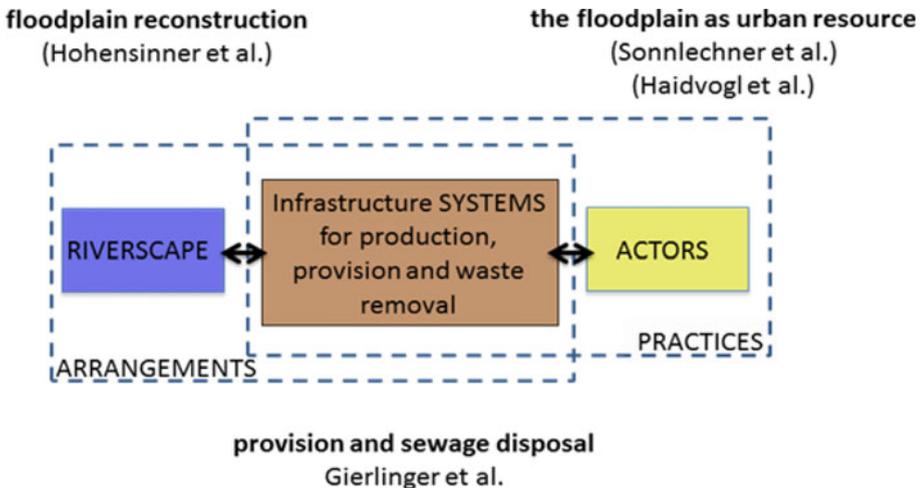
But what is a practice? A ‘practice’ is a routinised type of behaviour which consists of several elements that are interconnected: forms of bodily activities, forms of mental activities, ‘things’ and their use, background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge (Reckwitz 2002). Individuals are not only carriers of patterns of bodily behaviour, but also of certain routinised ways of understanding, knowing how and desiring. These conventionalised ‘mental’ activities are necessary elements and qualities of a practice in which the single individual participates, not qualities of the individual. The practice is a ‘nexus of doings and sayings’ (Schatzki 2003). Practices and arrangements are transformative with regard to each other; if one changes, the other changes too, and the socio-natural site transforms.

Closer observation of the image in Fig. 3 shows several of the more mundane practices tied to the river landscape. An ice hut (“Eis grub”) and a glass kiln (“Glas hut”) can be seen towards the right bank of the island, to the left of them, within a terrain depicted as forested, a hunting lodge (“Ieger haus”) is visible. The banks of the city opposite the island are protected, both as part of the military fortification and as a necessary measure to maintain the stability of landing places. The ice-hut, glass kiln and protected river banks are some of many arrangements visible in the picture. Each of these arrangements is the material precipitate of a practice in the sense described above. Each of these arrangements is also a prerequisite for specific practices, and their co-evolution shapes the landscape as much as it shapes society.

Glass-making, hunting, ice-making and the transportation of goods on the river are all practices shaping the river and its floodplain. Practices can be conflicting, such as glass-making depending on the forest for potash production and fuelwood being in clear conflict with riparian forest hunting. Many of them have important side-effects. If the river's energy is kept at bay in one place by embankments, it will erode other spaces with more force, necessitating additional fortifications and other regulation efforts.

Practices using and affecting the river are undertaken by various actors, among them powerful landlords, engineers and, later on, commissions for the regulation of the river. These actors' actions are based on their respective perceptions of the riverscape, expressed in particular forms of representation which have to be taken into account when analysing the various written and pictorial sources that form the basis of our reconstruction and investigations (Andraschek-Holzer and Schmid 2011; Forget and Bravard 2011).

The riverscape's change over time is—on the one hand—a function of morphological characteristics such as discharge, bedload, in-stream structures such as gravel bars and islands, but also of ecological characteristics such as floodplain vegetation and fauna, and the amount of woody debris and ice travelling down the river. All these factors are involved in changes of the longitudinal and cross-profile of the river over time. Some of them are the results of human intervention in the immediate area or in the catchment, while others are not influenced by humans. Likewise, infrastructures such as weirs, dams, groynes, hythes, harbours, bridges, but also uses of riparian areas such as brickyards, glass-kilns, shipmills and others influence the riverscape and its evolution, as do sewers and artificial channels. All these are the work of humans, i.e., various actors from local fishermen to military ship-builders and landlords, who have to react to the effects and side-effects of their interventions, thereby creating the hybrid space we call a socio-natural site, composed of practices and their material precipitates, the arrangements. This basic concept is depicted in Fig. 5.



**Fig. 5** Conceptual model of the main elements of the Viennese Danube as a socio-natural site. The nexus between arrangements and practices is in infrastructure systems. The case studies of this issue concentrate on floodplain reconstruction (Hohensinner et al. 2013a and 2013b, in this issue), the floodplain as a spatial resource for urban growth (Haidvogel et al. 2013, in this issue) and as a site for the procurement of material resources for the city (Sonnlechner et al. 2013, in this issue) and on material supply and sewage disposal (Gierlinger et al. 2013, in this issue)

## Vienna and the Danube: a socio-natural site in transformation

The articles in this volume all deal with the Viennese Danube conceptualised as a socio-natural site. They either focus on specific periods (e.g. Sonnlechner et al. 2013, in this issue, on the 16th century), areas (Haidvoogl et al. 2013, in this issue, on the relatively stable Danube island *Unterer Werd*), or on important topics of an integrated environmental history of a river and a city (e.g. Gierlinger et al. 2013, in this issue, with an urban metabolic approach).

Taken together, the four detailed studies offer a comprehensive view of several centuries of interaction between city and river, in other words, of the changing socio-natural site of riverine Vienna. It becomes clear that even in the pre-industrial history of Vienna, the Danube played a much more important role as both obstacle and opportunity than has hitherto been acknowledged.

The methodology used to reconstruct the riverscape in our study (the “regressive-iterative approach”) has never been described before and is explained in this issue (Hohensinner et al. 2013a, in this issue). Based on a multitude of different historical sources interpreted by an interdisciplinary team, it combines GIS methods, analysis of fluvial processes, and knowledge about the changing historical techniques of hydraulic engineering measures. This method moves from the known present state stepwise back in time, but each completed reconstruction of an earlier state is used to revise the younger state again, and with each such iteration the margin of error becomes smaller. This meticulous method allows for an unprecedented degree of detail in the reconstruction. Environmental histories are place-specific, and this detailed reconstruction allows including the riverine landscape into the historical narrative on a site-specific, local level.

The numerous historical sources providing spatial information were used by Hohensinner et al. (2013b, in this issue) to reconstruct the riverine landscape as a socio-natural site that underwent fundamental changes from the 16th century onwards. Since the 1500s, the Danube approached the city centre at times, and at times retracted from it due to river morphological dynamics (including meander evolution, channel straightening and channel migration). The reconstruction of the Viennese riverscape from 1529 onwards allows these important changes in the arrangements to be traced.

Changes in the riverine arrangements have been the subject of numerous place-based histories of Vienna. Two fundamental aspects have been highlighted in the historical literature on the Viennese Danube: the retreat of the Danube from the historical city centre to the north since Roman times, envisaged as a more or less linear process (“the later the date, the farther away from the city”); and the extensive effort that has gone into securing navigation in the side arm between the main Danube arm and the city, today called the *Donaukanal* (also *Wiener Arm* in early modern times). Hitherto, the so-called “Great Regulation” that took place between 1870 and 1875 has been the main focus of historical studies (Thiel 1906; Michlmayr 1994; Mohilla and Michlmayr 1996; Holzer and Limbeck-Lilienau 2005).

By then, as has become clear during our investigations, Viennese authorities had already struggled for centuries to keep the *Donaukanal* navigable. Until 1565, its upper course was, in fact, the main Danube arm and not a side channel. Regulation efforts in the 16th and early 17th century pursued a much more ambitious goal than merely regulating a side arm: they intended to deflect the main Danube arm into its former bed closer to the city, in an effort to counteract the full power of the Danube. The location of the *Donaukanal* was by far the most important feature of the riverscape for the Viennese population. Similar to the main arm, it would eventually be domesticated and channeled and stripped of its past identity as the Danube proper.

Prior to the early 19<sup>th</sup> century, large parts of the Viennese riverscape were not directly affected by regulation measures. But thereafter, the growing and industrialising metropolis needed a stable riverscape for new settlements (cp. Haidvogel et al. 2013, in this issue) and to protect infrastructure in the floodplain, such as bridges, roads and railways. Though large parts of the riverscape had already been stabilised in 1849 and therefore opened to the expanding city, the flood threat remained. The systematic transformation of large parts of the Viennese riverscape into settlement areas was finally accomplished by the great Danube regulation of 1870–1875. This would predetermine urban expansion, transportation routes, and sanitation—but also remaining natural floodplain zones and urban open space—for the decades to come. Regulation was undertaken on a river that had been substantially changed in preceding centuries, not only by the measures implemented but also by their side-effects (Hohensinner et al. 2013b, in this issue).

This fundamental transformation can be understood by looking at the long-term history of interventions. Hotspots of activity in the 16th century lay towards the north, at *Nußdorf* where the *Donaukanal* branched off the main arm, and on the ephemeral islands of the floodplain. Imperial authorities and landowners were important actors with specific motives for using, stabilising and changing parts of the riverscape in the 1500s. Transport on ships and over land required certain arrangements which changed the socio-natural site: bridges were erected and had to be rebuilt and maintained after each flood. The same applied to bridgeheads, paths, catwalks, streets and toll stations.

The analysis of the role of the Danube for Vienna would be incomprehensible without paying adequate attention to the area adjoining the river. For parts of this floodplain, infrastructure maintenance meant increasing settlement and strategic importance. Due to military practices, the perception of the floodplain, and the floodplain itself, changed. The city's riverbanks were fortified. Stone edifices and the arsenal were erected right beside the river, but at a cost, since water undermined these structures. Expensive water engineering measures were carried out by professionals, not only at *Nußdorf* to keep the river in town, but also at the bridgeheads and for flood protection at the islands. Weirs, dams and embankments were established (Sonnlechner et al. 2013, in this issue).

Fortification led to a new interest in the floodplain for the provision of resources. This had ecological consequences. Vienna's transformation into a "Danube fortress" in the course of the 16th and 17th century led to intensive timber harvesting, especially driven by coppicing. The dynamic of the floodplain changed the forested area and caused legal problems that amplified as the resources increased in value. Water engineering works aimed at stabilising the floodplain for settlement, transport and resource use—especially timber production. A stable floodplain would exhibit stable borders, a prerequisite for settling legal claims (Sonnlechner et al. 2013, in this issue).

Settlement was and continues to be a major driver for land use change in the riverscape. The relation between urban development and the Viennese Danube changed markedly between the late 17th and the early 20th century. The integration of the riverine landscape into urban space progressed in several distinct phases. Urban sprawl into the floodplains started on the large island next to the city centre, the *Unterer Werd*, because of its relative stability. The river's dynamics affected the island only at its fringes (Haidvogel et al. 2013, in this issue).

In the 14th century, the hydromorphological dynamics of the Danube had limited urban development on the islands close to the city center. By the late 17th century, these islands had coalesced to form one large tract of land (*Unterer Werd*) situated between two major Danube channels. Settlements on this large island were initially limited to places along the

main navigation channel opposite the city centre and along the roads crossing the island and adjacent Danube channels in a northerly direction. Although local constructions fixing the river banks and flood protection structures had been erected by the 18th century, the main practices of flood protection were passive. Risk was mitigated, e.g. by erecting expensive infrastructure and buildings mainly at low-risk sites. This approach changed in the 19th century, when practices to gain control over the arrangements' dynamics began to dominate. From the 1830s onwards, the city expanded towards the north and northwest of the island.

By the 1850s, this part of the Danube floodplain had attained importance as a land resource for the growing and industrialising city. New regulation technologies changed the relation between urban space and the river fundamentally. From the 1850s onwards, growth on the island outrivaled other urban districts. By the end of WWI, the districts on this former island were by far the most populous in the city. This process, initiated and organised by the municipal authorities in cooperation with the Danube Regulation Commission (DRC), preceded the great Danube channelization of 1870–1875, but its speed accelerated after the great regulation. The last decades of the 19th century mark a turning point in urban development. From then on, large urban areas would depend on a reliable and comprehensive flood protection system (Haidvogel et al. 2013, in this issue).

During the industrial transformation in the 19th and early 20th centuries, the role of the urban waterscape for the provision of materials and the disposal of waste in Vienna changed fundamentally. Urban metabolism and with it the river-city relationship were transformed due to the transition from a solar-based energy system to the large-scale use of coal. Statistical records on the transport of goods along the Danube allow the amount of material (food, feed, fuel wood, coal, and construction material) brought to the city between 1830 and 1910 to be quantified. The changing significance of different means of transport becomes visible. Another method for investigating these changes involves looking at the amount of nitrogen discharged into the urban waterscape. This can be done by using population and livestock numbers, information on excrement production, and the disposal system (Gierlinger et al. 2013, in this issue).

Before the transition, the kinetic energy of the river was used for the transportation of material into the city and for the disposal of urban excreta. Thereafter, its function for the disposal of waste became more important. The proportion of goods transported to the city by water declined, whereas the amount of nitrogen contained in wastewater discharged into the Danube rose by a factor of seven. Meanwhile, the urban waterscape itself was fundamentally transformed. Parallel to the great Danube regulation in the 1870s, the city began to integrate almost all of the Danube's small tributaries into the sewer system. The actors involved considered sewerage and regulation as closely intertwined. Prevention of epidemics was a major driver in this respect.

From 1849 to 1851 the first DRC (Danube Regulation Commission) considered regulating the *Donaukanal* and stopping the direct discharge of sewage as equally important to the regulation of the main arm. The second commission delivered its final report in 1868, by which point regulation focus had shifted. Vienna was intended to become a commercial centre with regulated water courses, stockyards, landings for ships, a winter harbour and other infrastructure. Regulating the *Donaukanal* and ending the direct discharge of sewage into the water were no longer of major concern. In stark contrast to contemporaries' expectations, the Danube's role as a line of supply for the city decreased. Railways now brought coal from northern parts of the monarchy to the capital.

## Vienna—and the larger environmental history of the Danube

The combined reconstruction of past riverine landscapes, ecosystems, palaeo-meanders and human intervention allows us to appreciate the complex, intertwined history of effects turning into causes and vice versa, and the long-term legacies of prior interventions limiting the degree of freedom for human action in due course.

Vienna and the Danube shared a dynamic co-evolution over the more than four centuries we studied. But just how typical or exceptional is this intertwined development? Vienna is situated on the upper reach of the river with its particularly intense flood dynamic, and it was an imperial capital, a military centre and a fast-growing population agglomeration. All these factors make it a specific, unique case.

Yet, similarities to other stretches of the river exist. Some parts of Vienna's story are, in fact typical for the Danube at large. The late absolutist state placed importance on rivers as prime means to boost the economy and to achieve territorial integration via trade, military and communication networks. Three vignettes aim to show the kind of interventions undertaken to foster the plan. In the early 1770s, Maria Theresia, head of the house of Habsburg, established a new authority, the "Imperial Navigation Directorate" to improve navigability of waterways in her monarchy. This new authority was responsible for about 1,000 km of the Danube extending from Engelhartzell, at that time the border between Austria and Bavaria, and Zemun, now a municipality of the Serbian capital of Belgrade, which during Maria Theresia's time was the last Habsburg outpost at the border with the Ottoman Empire (Andraschek-Holzer and Schmid 2011).

In the late 18<sup>th</sup> century, Bavarian sections of the Danube were channelized and the *Donaumoos*, once the largest bog in southern Germany, was drained between 1790 and 1795 for land reclamation upon order of the Prince of Bavaria, Karl Theodor. He set up a commission, which in turn set up a court to manage the transformation. The drainage provides an illustrative case for the long-term effects of large-scale interventions into riverine ecosystems (Aretin 1795). Today, the level of the *Donaumoos* is three metres lower than it was in 1790; after heavy rainfall, large parts of the Moos are flooded.

Between the 1820s and the early 1900s, the Danube Regulation Commission, a panel of experts and stakeholders, was entrusted with the systematic regulation of the river, along almost its entire Austrian stretch. Channels were rectified and deepened for navigation through dredging and blasting; by-channels were closed; meanders were cut off, banks were stabilised and flood protection dykes erected all along the Danube (Lóczy 2007).

The Viennese Danube exhibits nearly all the ingredients of this broader history of human interaction with the river from the late 18th century onwards. In Vienna, the Danube was manipulated earlier and on a larger scale than has hitherto been documented for any place along the river. In Vienna, city authorities attempted to regulate the riverine landscape as early as the 14th century. It remains largely unknown if similar interventions were undertaken at other sites along the river. However, topographical sources from Bavaria reveal comparable interventions for this upper river section by the 16th century (Leidel and Franz 1998).

This swift-flowing, gravel-bed alpine river at whose outer floodplain terraces humans had settled for millennia was converted into a part of the city mainly during the demographic transition of the long 19th century. The city expanded towards the river floodplain, creating new vulnerabilities for urbanites. Sewage, transportation, settlement, hygiene—any crisis that the rapid development of the city brought forth demanded that the city authorities engaged in transforming the Danube into a stable part of urban infrastructure.

We are bound to the maintenance of our arrangements; legacies of earlier interventions have a profound impact on our practices and those of our descendants, especially with regard to perception. The most recent transformation has rendered the kinetic energy of the river and the various smaller watercourses feeding into the river as invisible as the wastewater produced by Vienna's population and industry. Following in the footsteps of absolutist monarchs and their visions in the 18<sup>th</sup> century, the Danube Vienna city authorities now perceive the Danube as cleaned up, improved, cultivated and civilised. The dynamics of an alpine river, climate variability, geopolitics and the energy transition from solar to fossil energy have all played their part in the transformation of the Danube and of Vienna from 1500 onwards, shaping the changes of the more recent past. One lesson to be learned from this integrated history of a river and a city is that there will never be an end to regulation, as the river's energy cannot be fully controlled. Because of the long lasting and self-binding legacies of human interventions into such fluvial socio-natural sites, regulation of a river is inevitably coupled with a regulation of society itself.

### **Afterword: how was this analysis possible?**

An environmental history of the kind we aimed to write requires two quite different sets of skills. One set comprises the historian's craft. The historian works at making sense of sources, constructing a compelling narrative from chaotic facts, tracing human appreciation of the Danube, human uses of the Danube, and human interventions into the Danube such as dams, spurs, embankments, bridges, weirs, fishtraps, ship mills and, later on, power plants. Without knowing the perceptions of historical actors, as the basis for their actions, the narrative remains incomplete. The skills of natural and social scientists such as landscape ecologists, hydrologists, historical geographers and geomorphologists make up the second set. Reconstructions of past riverine landscapes, ecosystems, and palaeo-meanders have to be combined with a thorough understanding of human interventions to enable the study of such interventions and their environmental reverberations as they unfold in space and time.

An interdisciplinary team was brought together for the project "Environmental History of the Viennese Danube (ENVIEDAN)". Efforts went into securing intensive communication among the team. The understanding of notions and terms differs between disciplines, as do methods, theories, and forms of presentations. The disciplines represent different scholarly cultures; joint work therefore is a type of intercultural experience. Project-based research in addition faces severe time constraints. While some team members had previous experience of participating in joint projects, the team as such had never worked together before. To facilitate interdisciplinary cooperation, a scholar and experienced counsellor (Gert Dressel) assisted the team by designing and facilitating the project workshops. His conceptual approach was based on the premise that differences can only be successfully overcome if they are first made visible. Methods employed comprised the joint discussion of sources (maps and topographical views) that each project team member had chosen to share at the beginning of the project, the inductive construction of visual aids to understand how the parts of the project interlocked (which formed the basis of Fig. 4 of this Introduction), and a series of reflective communicative exercises ('feedback') during all project meetings to increase trust and thus facilitate joint work. One important factor for coalescence of the project group was the shared study area, Vienna. Most members of the team had previous experience of working together and based their joint work on functional rather than hierarchical differentiation. Intensive discussion of cases was conducted

between the natural scientist and the historians, those with expertise in both fields often acting as ‘translators’. This fostered the joint understanding of aims and ways to achieve them. Guided by the facilitator, the team considered its work as a joint learning journey. This journey resulted in a unique contribution to the environmental history of rivers, because we could combine a detailed and source-critical, long-term reconstruction of geomorphological changes of the fluvial landscape with the detailed study of actors, their interests and their interventions into its ever-changing shape.

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